Disposal of Low Activity Radioactive Waste

Proceedings of an International Symposium, Córdoba, Spain, 13–17 December 2004

IAEA
International Atomic Energy Agency

Organized by the
International Atomic Energy Agency

hosted by the Government of Spain through the
Empresa Nacional de Residuos Radiactivos, S.A. and the
Consejo de Seguridad Nuclear

in co-sponsorship with the
Agence nationale pour la gestion des déchets radioactifs and

in cooperation with the
OECD Nuclear Energy Agency

DISPOSAL OF LOW ACTIVITY RADIOACTIVE WASTE

Printed by the IAEA in Austria
June 2005
STI/PUB/1224

PROCEEDINGS SERIES

DISPOSAL OF LOW ACTIVITY RADIOACTIVE WASTE

PROCEEDINGS OF AN INTERNATIONAL SYMPOSIUM ON
DISPOSAL OF LOW ACTIVITY RADIOACTIVE WASTE
ORGANIZED BY THE
INTERNATIONAL ATOMIC ENERGY AGENCY
AND HOSTED BY THE GOVERNMENT OF SPAIN
THROUGH THE EMPRESA NACIONAL
DE RESIDUOS RADIACTIVOS, S.A.
AND THE CONSEJO DE SEGURIDAD NUCLEAR
IN CO-SPONSORSHIP WITH
THE AGENCE NATIONALE POUR LA GESTION
DES DÉCHETS RADIOACTIFS
AND IN COOPERATION WITH THE
OECD NUCLEAR ENERGY AGENCY,
AND HELD IN CÓRDOBA, SPAIN, 13–17 DECEMBER 2004

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2005

COPYRIGHT NOTICE

Sales and Promotion Unit, Publishing Section
International Atomic Energy Agency
Wagramer Strasse 5
P.O. Box 100
A-1400 Vienna
Austria
fax: +43 1 2600 29302
tel.: +43 1 2600 22417
http://www.iaea.org/books

IAEA Library Cataloguing in Publication Data

International Symposium on Disposal of Low Activity Radioactive Waste (2004 : Córdoba, Spain)

Disposal of low activity radioactive waste : proceedings of an International Symposium on Disposal of Low Activity Radioactive Waste / organized by the International Atomic Energy Agency and hosted by the Government of Spain through the Empresa Nacional de Residuos Radiactivos, S.A. … [et al.], and held in Córdoba, 13–17 December 2004. — Vienna : The Agency, 2005.

p. ; 24 cm + 1 CD-ROM — (Proceedings series, ISSN 0074–1884)
STI/PUB/1224
ISBN 92–0–102905–5
Includes bibliographical references.

1. Radioactive waste disposal — Congresses. 2. Hazardous wastes — Management — Congresses. I. International Atomic Energy Agency. II. Empresa Nacional de Residuos Radiactivos (Spain) III. Series: Proceedings series (International Atomic Energy Agency).

IAEAL 05–00403

FOREWORD

The largest part, by mass and volume, of the radioactive waste created in the operation and decommissioning of nuclear power plants, in the production of nuclear fuel, in the use of radionuclides in medicine, industry and research and as a by-product of various industrial processes, is of low activity. Management solutions exist for some, but not all, of the waste types that can be described as low activity. A new urgency exists in many countries to develop or extend existing arrangements for low activity waste management and disposal because of the ongoing or imminent decommissioning phase of their commercial nuclear power plants. In other countries, the problems associated with the management of the low activity radioactive waste from non-nuclear industries, for example, waste including naturally occurring radioactive material (NORM), is becoming more recognized. The subject of low activity radioactive waste management raises several issues of both a philosophical and a technical nature, such as the question of when a waste is to be considered radioactive from a regulatory perspective, the issue of guiding suitable management strategies for waste that is both long lived and present in large volumes and of finding suitable disposal routes for new types of low activity waste.

The IAEA organized this international symposium to provide an opportunity for the exchange of information on the subject among its Member States and to look for common approaches to the problems so identified. The symposium explored the subject through five topical sessions: policies and strategies for low activity radioactive waste management and disposal; very low activity waste; low activity radioactive waste from decommissioning; long lived low activity radioactive waste and unique low activity waste. This publication, which constitutes the record of the symposium, includes the opening and closing speeches, the invited papers, the summaries of the discussions during the sessions and during the panel sessions and an executive summary of the symposium. A CD-ROM containing the unedited contributed papers to the symposium can be found at the back of this book.

The IAEA gratefully acknowledges the support and generous hospitality of the Government of Spain through its Empresa Nacional de Residuos Radiactivos, S.A. (ENRESA) and its Consejo de Seguridad Nuclear (CSN). It also acknowledges the support of the French Agence nationale pour la gestion des déchets radioactifs (ANDRA) and of the OECD Nuclear Energy Agency.

EDITORIAL NOTE

CONTENTS

Panel

VERY LOW LEVEL RADIOACTIVE WASTE (VLLW) (SESSION 2)

Panel

LOW ACTIVITY RADIOACTIVE WASTE FROM DECOMMISSIONING (SESSION 3)

Panel

LONG LIVED LOW ACTIVITY RADIOACTIVE WASTE/ OTHER MATERIALS (SESSION 4)

Panel

UNIQUE LOW ACTIVITY WASTE (SESSION 5)

Panel

CLOSING SESSION

EXECUTIVE SUMMARY

1. BACKGROUND

The arrangements for managing many types of low activity radioactive waste are quite mature. The waste generated during the operations of nuclear power plants and from the use of radionuclides in medicine, industry and research is managed routinely and disposed of, usually, in near surface disposal facilities. However, there are some exceptions to this, especially in relation to the large volumes of low activity long lived radioactive waste from the mining and milling of uranium and thorium, from the production of fertilizers, from the oil and gas industry and from the cleanup of land surface areas contaminated by industries which operated in the early to mid-twentieth century. For these waste types, the management methods being used are not coherent from country to country and there is, similarly, a lack of consistency in the way that they are regulated.

As increasing numbers of nuclear power plants reach the end of their useful lives and are decommissioned, the need to make additional arrangements for the management and disposal of the associated waste is being recognized both in terms of creating extra disposal capacity and of developing new types of disposal facilities. Some of the types of radioactive waste from decommissioning are unique in form and in the potential radiological problems they present, for example, the graphite from gas cooled nuclear reactors; they therefore need special consideration in the context of disposal.

Since much of the waste from decommissioning is inactive or contaminated to very low levels, there is a pressing need to have well-established criteria for determining which waste can be freely released from regulatory control and which needs to be treated as radioactive waste.

The problems of disposal in relation to disused sealed radioactive sources from medical and industrial origins are becoming well known. Millions of such sources exist and they are widely spread around the world. For most countries, with no prospect of developing a geological repository, there is no safe and affordable solution in sight. While proposals are being put forward to meet the needs of these countries they are not yet well enough developed.

For these and other reasons it was timely to hold an international symposium on the disposal of low activity radioactive waste, to provide an opportunity for the exchange of views and experiences between IAEA Member States and to seek common solutions to the problems so revealed.

2. THE CURRENT SITUATION

Speakers from several countries described the existing and planned arrangements for managing low activity waste in their countries. It is evident that most countries with nuclear power plants have operating disposal facilities, mainly of the near surface type, and that they also have the capability to extend the existing arrangements to manage the expected waste from decommissioning.

In some countries there are problems with public acceptance of proposed new repositories for low level radioactive waste. However, some success stories were described in which the potentially affected public had been given a strong role in decision making about the construction and siting of the repository.

In some non-nuclear countries there are inadequate institutional structures in place to facilitate the safe management of radioactive waste and there is evidence of foreign companies taking advantage of this weakness in operations involving radioactive sources. The lack of funds to implement internationally recommended safety requirements and to establish facilities for managing radioactive waste is also a common problem for these countries. The potential of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (Joint Convention) to help resolve some of the difficulties relating to establishing adequate national infrastructures and to resolving disputes between countries on radioactive waste management matters was highlighted.

3. WASTE CATEGORIZATION

Current radioactive waste categorization schemes give insufficient attention to certain types of low activity waste. The increasing interest of nuclear power countries in developing national strategies for managing the waste from decommissioning has prompted proposals for new waste categories and, in particular, a category of very low level waste. The current international waste category scheme was determined mainly on the basis of the suitability of waste types for disposal in different surface or underground locations. The rationale for the newly proposed very low level waste category is that such waste can be disposed of in simple facilities with fewer barriers than in normal near surface repositories but, because of its very low activity, without any reduction in facility safety. Several countries are actively exploring the scheme, which brings clear economic benefits, and one country has already adopted it. For countries operating a clearance policy, in which materials with activity concentrations below clearance levels can be released from regulatory control for recycle or disposal in normal waste facilities, the lower bound of the activity concentration of the material for disposal in very low level waste repositories would be at the clearance level.

The recent international agreement on clearance levels, as documented in the IAEA's Safety Guide RS-G-1.7, has greatly helped national policy development in this area. However, it was evident from the discussions at the Symposium that there is a need for further guidance on procedures for verifying compliance with clearance levels and for elaboration of the so-called 'graded approach' to regulation.

Other waste types are not explicitly considered in the current international waste categorization scheme, examples are: disused sealed sources, uranium mining and milling waste and waste containing naturally occurring radioactive materials (NORM) from non-nuclear industries.

In summary, the international categorization scheme for radioactive waste is useful since it provides a scientific and technical rationale for separating waste types, but it needs to be elaborated to include other important waste types and their potential disposal routes.

4. LONG LIVED LOW ACTIVITY RADIOACTIVE WASTE

This waste type arises from several sources: as a by-product from several industrial processes, for example, the uranium processing industry, the phosphate industry, the gas and oil industry and from the cleanup of historic sites contaminated with radium. This waste usually contains low levels of naturally occurring radionuclide contaminants but the radionuclides are long lived and the waste is present in large volumes. Normal near surface disposal facilities are not usually appropriate for this waste type because of its long lived nature and its large volumes. Deep disposal is usually considered to be too costly. National regulatory approaches to the management of the waste vary; in some countries it is regulated as a radioactive waste, in others as a chemical waste and in others it is not regulated. Very often the chemical or heavy metal content of the waste presents a greater hazard than the radioactive content. Similarly, the disposal practices being adopted vary considerably.

Discussions at the Symposium revealed a sense of frustration among national regulators and operators at the inconsistencies and variations from country to country and at the lack of international direction. A strong desire was expressed for international guidance towards establishing a coherent and internationally consistent treatment of the problem. Proposals were made for a systematic risk based approach which balances concern for safety of the affected public with economic realities.

5. DISUSED SEALED SOURCES

Although not strictly low active radioactive waste, this waste type was included within the scope of the Symposium because it is currently seen as a major radioactive waste disposal problem by most Member States.

The topic has been on the international agenda for several years and it has become generally recognized that there is a need for safe but affordable national disposal solutions for the small volumes of disused sealed sources that exist in every country. For this reason, the ongoing international work to develop the borehole concept, as a cheap but safe disposal system, capable of being implemented in every country, was strongly endorsed by the Symposium.

Furthermore, the international organizations were encouraged to develop and promote other practically useful technological initiatives and to provide advice that is specific to particular problems rather than giving only general recommendations.

6. OTHER ISSUES

The problems of unfavourable economics of scale that small countries face in implementing solutions for managing radioactive waste were highlighted. For example, it was pointed out that most countries will never have a geological disposal facility because of the small amounts of high level waste that they generate and because of the associated costs and difficulties. The most obvious approach to these problems is through bilateral or multilateral action — the sharing of the various types of waste management facilities between countries. Evidence was presented of the recent progress made in this direction and the role of the international organizations and of the Joint Convention in facilitating such action was discussed.

7. THE FUTURE

It was evident from this Symposium that the field of low activity radioactive waste management is still developing. Solutions are being sought and tried out for managing several of the various waste types. Progress is being made and it will be valuable to review that progress in a few years time.

OPENING SESSION

Chairperson

A. BEICEIRO
Spain

OPENING ADDRESS

Y.A. Sokolov
Deputy Director General,
Department of Nuclear Energy,
International Atomic Energy Agency,
Vienna

On behalf of the Director General of the IAEA, it is my pleasure and privilege to welcome you to this International Symposium on Disposal of Low Activity Radioactive Waste. I would like to offer my sincere thanks to the two Spanish organizations, the Empresa Nacional de Residuos Radiactivos (ENRESA), and the Consejo de Seguridad Nuclear (CSN), for hosting the Symposium on behalf of the Government of Spain, in this magnificent and historic city of Córdoba. Let me also thank the French Radioactive Waste Management Agency, ANDRA, for co-sponsoring the Symposium and the OECD Nuclear Energy Agency for cooperating in its organization. I would also like to thank you all, the 250 or so registered delegates from around the world, for participating in this Symposium. I trust that you will have a fruitful and enjoyable week.

This Symposium builds on the accomplishments of several related major international conferences, while sharpening the focus on low and very low level waste management issues. I should note, in particular, the Conference on Safety of Radioactive Waste Management, held here in Córdoba in March 2000, the Symposium on Management of Radioactive Waste from Non-Power Applications — Sharing the Experience, held in Malta in November 2001, and the Conference on Issues and Trends in Radioactive Waste Management, held in Vienna in December 2002. The outcomes of these international conferences, organized by the International Atomic Energy Agency, have heightened awareness that the management of low activity radioactive waste is a recurring and emerging issue in many Member States and have prompted the initiative to organize this Symposium.

Low and intermediate level radioactive waste (LILW), containing both short and long lived radionuclides, is produced in the nuclear industry from activities such as uranium enrichment, fuel fabrication, reactor operations, decommissioning of nuclear facilities and fuel reprocessing, as well as in research laboratories, universities, hospitals and industries. The safe management of radioactive waste, and specifically, the need to protect humans and the environment now and in the future from its possible harmful impacts, has received attention both internationally and in Member States, especially those having well established nuclear energy programmes. This issue is also of concern in many other Member States that are using radioactive materials only for medical, industrial or research purposes, as well as in those generating radioactive waste only from non-nuclear industrial activities.

The largest volumes of radioactive waste currently generated in Member States fall into the category of LILW. During the past few decades, much of this waste has been placed in near surface repositories. Consequently, methods and technologies for the disposal of LILW have developed and evolved considerably. Several tens of surface and near surface disposal facilities have been built worldwide, and more are under development. These facilities are designed primarily to receive short lived LILW containing limited amounts of long lived radionuclides. With the establishment of specific international safety standards for this type of facility, safety reviews are regularly taking place in Member States and, in some cases, repository upgrading is taking place in States with repositories built to earlier standards.

An issue of current interest in many countries is the management of large volumes of very low activity waste, mostly generated as a result of the decommissioning of nuclear installations, but also arising from research laboratories, research reactors and nuclear power plants. Decommissioning and radioactive waste management are interrelated activities that must be properly coordinated; they need careful strategic planning if decommissioning projects are to be taken forward successfully. In this context, it is generally recognized that the lack of suitable disposable routes for all waste types generated during the dismantling of nuclear installations may hinder decommissioning plans.

Although many surface and near surface repositories have been licensed worldwide for the disposal of low level radioactive waste, the level of safety provided by this type of disposal facility is not really commensurate with the comparatively small radiological hazards presented by very low level waste. Therefore, several countries, such as, Japan, Sweden, France, and in the near future, Spain, have opted for simple and cost effective surface or near surface repositories with minimum engineering, which will be dedicated to receiving the largest part, by volume, of the decommissioning waste. Other countries may be interested in following their example.

Complementary to the option of disposing of radioactive waste in the ground, the application of the clearance concept can avoid unnecessary disposal expenses by removing materials containing very low levels of radionuclides from the regulatory control regime. Such materials, once cleared, can be treated as ordinary industrial waste or, in some cases, reused or recycled. The IAEA has recently published a Safety Guide on this subject to provide guidance to national authorities on the application of the concepts of exclusion, exemption and clearance. This publication contains specific levels of activity concentration for both radionuclides of natural origin and those of artificial origin which may be used to determine the levels at which bulk amounts of material may be released from regulatory control. It also elaborates on how these concepts may be used in a variety of situations.

Several types of low activity radioactive waste, primarily those containing long lived radionuclides, require special consideration in selecting appropriate disposal options. Examples are: the technologically enhanced naturally occurring radioactive materials derived from industrial activities outside the nuclear sector, irradiated graphite waste from gas cooled reactors, waste containing depleted uranium and long lived radioactively contaminated chemically or biologically toxic waste. A unique feature of these types of waste is that, even though the radioactivity levels are low, the long half-lives of the radionuclides may render them unsuitable for disposal in a typical near surface disposal facility. Hence, alternative disposal options need to be explored and hopefully, this Symposium can contribute to progress towards an acceptable solution.

Residues and waste containing naturally occurring radioactive materials (NORM) have increasingly attracted attention due to their unclear regulatory status in most Member States and due to the technical and logistic difficulties in adequately handling their disposal. The main concerns are the extremely large volumes (e.g. of mining residues) and the long lived radionuclides that they contain. The safety implications of possible future intrusion into the waste and unauthorized reuse of the materials pose particular challenges in selecting appropriate disposal methods. In making decisions on the most suitable disposal options for these waste types, not only radiological and conventional safety aspects must be considered, but also socioeconomic and sociopolitical factors. The IAEA has reviewed the current situation in a recent Technical Report Series document and is currently developing guidance on the safe management of these waste types.

Sealed radioactive sources are used extensively in most countries around the world. The management of disused sealed sources is of particular importance, especially in light of heightened security concerns with such sources, and because they can present serious health hazards if they are not kept under control. Because of their high specific activities they are not usually accepted at normal near surface repositories. Currently, there is a great deal of interest in exploring other potential disposal options with the aim of making their long term management more safe and secure. A particularly attractive and cost effective solution that is presently being investigated is the borehole disposal concept, which seems to be especially suitable for high activity sources and those containing long lived radionuclides. A borehole disposal project, sponsored by the IAEA, is under development within the African region, targeting geologies at depths of thirty to fifty metres and utilizing straightforward and robust technology, which could be cost effectively deployed in any country. The management of sealed radioactive sources is presently one of the IAEA's high priority areas.

Member States with nuclear power have, thanks to the economic strength of the power sector, set up adequate infrastructures to deal with the radioactive waste from nuclear power generation. For these Member States, the management of non-power radioactive waste does not pose major problems as these waste types are, or can be, assimilated by the existing infrastructures and the waste management programmes for the nuclear power sector waste. This is, unfortunately, not the case in developing Member States with only non-power applications. Indeed, many of them still face the problem of setting up proper infrastructures and of acquiring the technologies that serve the purpose. For these countries, shared solutions for the disposal of their limited amounts of waste would make sense. Similar solutions may also be relevant to countries with limited nuclear power or with only research reactors and several of these countries have already displayed interest in finding shared solutions for the disposal of their spent fuel and radioactive waste. The IAEA has recently published a technical document elaborating a framework dealing with institutional and other aspects of such multinational initiatives.

At the beginning, I mentioned a number of important recent international meetings. I should also note the first Review Meeting of the Contracting Parties to the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, which took place in November 2003, and which identified several issues related to topics of this Symposium. The Joint Convention is generally recognized as an effective means for Contracting Parties to enhance their safety performance levels, by systemically reviewing all national activities in the field of spent fuel and radioactive waste management, and by comparing their practices with others at the Joint Convention review meetings. In that respect, I would strongly encourage more IAEA Member States to ratify the Convention, thereby demonstrating their full commitment to safety in managing spent fuel and radioactive waste.

Because the topics to be discussed at the Symposium are so diverse, you have a very full programme ahead of you. I hope that your deliberations this week will be fruitful and that they will contribute to making progress towards the resolution of some complex radioactive waste disposal issues. I look forward to hearing your findings.

I would like now to declare the Symposium open on behalf of the Director General of the IAEA and give the floor to your Symposium President, M.-T. Estevan Bolea, Chairperson of the Consejo de Seguridad Nuclear.

OPENING ADDRESS

M.-T. Estevan Bolea
President
Consejo de Seguridad Nuclear (CSN),
Madrid, Spain

During this week, we will be dealing with important and relevant issues of safety as applied to the final disposal of low activity radioactive waste. I hope that, jointly, we will be able to make progress and go deeper into the relevant science and into the technical aspects involved in these activities. And, of course, I expect that this symposium will contribute to the development of a common understanding of this topic.

During the last few years, significant progress has been made in the safe management of radioactive waste, both domestically and in the international arena.

In Spain, we have developed a system which can serve as a model for the safe management of low activity waste, thus guaranteeing compliance with the basic principles published by the IAEA for the safe management of this type of waste. ENRESA, the Spanish company in charge of radioactive waste management, has the knowledge, the qualified personnel and the resources that have allowed it to design and establish a national programme that has gained the highest international recognition. A proof of the excellence of its work is the El Cabril facility, which you will be visiting next Wednesday. The Nuclear Safety Council, over which I preside, has started to apply all of the necessary mechanisms in order to verify and control, throughout the process of low activity radioactive waste management, compliance with the local and the European regulations, as well as with the most demanding standards and recommendations from international institutions, such as the International Commission on Radiological Protection and the IAEA.

In the international arena, the OECD Nuclear Energy Agency and the IAEA have established the scientific and technical grounds for the safe management of radioactive waste by developing appropriate standards, safety assessment criteria, methods and technologies. Great progress has been made with the help of these agencies, which have even proposed innovative concepts, such as the one designed by the IAEA for the final deep well disposal of orphaned sealed radioactive sources.

I cannot but mention the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management as the most valuable instrument available to the international community, aimed at promoting the most demanding international safety standards for the management of radioactive material and, in the context of this symposium, aimed at attaining worldwide harmonization of safety approaches for the final disposal of low activity radioactive waste. In my opinion, this is the international instrument that deserves our confidence and to which we should devote our efforts. Spain has always supported the Convention and has repeatedly stated this before the IAEA's Board of Governors. The institution I represent, the Nuclear Safety Council, along with our government and ENRESA, are perfectly integrated and involved in the work being performed for this Convention.

Nevertheless, certain important technological and regulatory issues are still to be understood more thoroughly. The problems raised by orphaned radioactive sources need further consideration, since they can introduce heterogeneities into the final disposal system that might affect the long-term safety of a facility. Currently, the large volumes of waste with a low radioactive content from several different origins constitute a challenge. The final disposal systems for this waste type must provide a balance between radiological protection — and consequently the protection of the population and of the environment — and the economic costs involved in the system itself. Low activity waste has appeared during the last few decades from directions, which, initially, had not been contemplated in the design of low activity waste management systems, such as, from accidents involving radioactive materials. In Spain, everybody remembers the Acerinox case, which, while it did not result in any radiological consequences for the population, generated significant amounts of low activity radioactive waste and prompted us to introduce changes in our radioactive waste management strategy and system. In this context, I can also mention the recent war conflicts in which depleted uranium was used as part of the military armament, generating significant amounts of waste material and contaminating parts of the biosphere. Another clear example of an emerging activity that involves the production of large amounts of low activity radioactive waste in Spain is the decommissioning of nuclear facilities. All of these issues will be discussed during this symposium.

I would like to finish by emphasizing the importance of the IAEA's International Conference on the Safe Management of Radioactive Wastes, which was held here, at this location, in the year 2000. That event brought about a qualitative change in the international standing of this problem. The conference produced very concrete conclusions that were submitted to the IAEA's General Conference for approval. The General Conference approved a plan for international actions that is currently being used as a framework to address, from the technical and regulatory viewpoints, the final disposal of radioactive waste and, particularly, in the context of this symposium, of low activity waste.

I encourage you to engage actively in your work and discussions this week, so that this symposium can also result in a great contribution towards safety in the management of radioactive waste and, at the same time, I suggest that you do not miss the opportunity of being here in Córdoba and of enjoying this lovely city.

KEYNOTE ADDRESS

J.M. Grávalos
Director of Operations,
Empresa Nacional de Residuos Radiactivos,
Madrid, Spain

I should first like to welcome you on behalf of the Spanish Radioactive Waste Management Agency, Empresa Nacional de Residuos Radiactivos, S.A. (ENRESA), to the city of Córdoba and to this opening ceremony of the International Symposium on the Management of Low Activity Radioactive Waste, which will be held throughout this week. I should also like to thank the IAEA and all the organizations that have collaborated in organizing this event, and most especially the Programme Committee for giving me the honour of being able to address you today.

As has become traditional in recent years, this historical and monumental city of Cordoba once more has the honour of hosting an important international event. As you may remember, the International Seminar on Regulation for the Long term Safety of Final Radioactive Waste Disposal, organized in 1997 by the OECD Nuclear Energy Agency, was held here, as was the International Conference on the Safety of Radioactive Waste Management, organized by the IAEA in 2000. This is no coincidence, but rather, in my opinion, a result of the fact that Córdoba is the Spanish province most sensitive to issues relating to radioactive waste management.

As you are aware, the Empresa Nacional de Residuos Radiactivos, S.A. (ENRESA) is the public company that, since 1985, the year in which it was created, has been responsible for the management of all types of radioactive waste and for the dismantling of nuclear facilities in this country. The company is independent of the waste producers and it has been provided with a sound financial base. The national scheme within which the company exists includes the involvement, in their respective realms of competence, of the State Administration, the Nuclear Safety Council (CSN), the waste producers and ENRESA itself.

As regards the management of low and intermediate level radioactive waste, Spain possesses an integrated management system covering the entire range of activities, from waste collection and transport to final disposal. Within this system, the nuclear facilities have the capacity to treat and condition waste in accordance with ENRESA acceptance specifications, approved by the Nuclear Safety Council. In other cases, the producers deliver their waste to

ENRESA in an agreed manner and ENRESA carries out the necessary conditioning tasks.

The El Cabril low and intermediate level radioactive waste (LILW) disposal facility is an essential part of the national system and, in fact, constitutes its central axis. Although the main purpose of the installation is the final disposal of this type of waste in a solid form, it also possesses various technological capabilities, including facilities for waste treatment and conditioning and laboratories for waste characterisation and verification.

Over the years, the national system has demonstrated its operability and flexibility, having adapted to the needs that have arisen, such as, the management of radioactive waste from the dismantling of the Vandellós I Nuclear Power Plant and of the waste arising from the occurrence of industrial incidents not regulated by the nuclear system. In turn, these events have allowed new principles and criteria to be established for the optimization of the system.

The main directions in which the system is being optimized are shaped by the ongoing need to minimize waste production and waste volumes, and the need to plan for the management of the expected large volumes of very low level waste arising from the dismantling of nuclear power plants and of waste generated as a result of potential incidents — mainly in the metal industry.

The coordinated efforts of the last few years have led to the reduction in the LILW generated at the nuclear power plants to less than one third and the policy of collaboration with the producers in projects for waste volume reduction, decontamination and the characterization of materials for recycling will continue.

In order to be able to address the large volumes of very low level radioactive waste and the waste generated in possible incidents, a project is under way for the development of a complementary disposal facility for very low level waste at the El Cabril site. This project is currently being reviewed by the Nuclear Safety Council.

Finally, I should not like to conclude without underlining the importance for the national system of the signing and implementation, in late 1999, of a Protocol for collaboration in the radiological surveillance of metallic materials, which includes the involvement of the various Ministries having responsibilities in this area, the Nuclear Safety Council, various metallurgical associations, the iron and steel production and recycling industries and ENRESA. The initiative for establishing this Protocol was taken by the National Authorities as a result of an incident at a steelyard in which a high activity source of ^{137}Cs was smelted due to its having been included in a batch of metallic scrap used in the industrial process. The incident did not have any appreciable effect for people or the environment, but did cause operational disturbances and high costs for the factory involved.

Since the implementation of the Protocol, there have been a significant number of radioactive material detections and three further incidents, but with smaller impact than the initial one, all of which points, in my opinion, to the need to coordinate action at the international level.

The presentations and debates that will take place throughout this week at the Symposium, on different aspects relating to low level radioactive waste, will undoubtedly contribute to providing us with a better understanding of the problems and will lead to the improvement of our management systems.

KEYNOTE ADDRESS

J.C. Lentijo
Director of Radiation Protection,
Consejo Seguridad Nuclear,
Madrid, Spain

I should like to express thanks, on behalf of CSN, to the IAEA and to all the other organizations that have collaborated in organizing the Symposium along with the CSN. The efforts of those who have participated in organizing this event undoubtedly warrant our recognition and deserve to be rewarded with a series of excellent results, which I am sure will be the case.

One of the functions of the CSN, as the regulatory authority responsible for nuclear safety and radiation protection, is the performance of studies, assessments and inspections of all plans, programmes and projects relating to the different phases of radioactive waste management, from production to final disposal.

Radioactive waste management is one of the most important challenges facing the nuclear regulatory organizations of the world. In this respect these organizations have to undertake a wide variety of tasks covering activities such as the development of standards, the control of the management of the waste generated at authorized facilities, as well as the waste arising from non-regulated activities, the establishment of criteria for the declassification of waste materials, the control of the management of waste from the dismantling of installations and, obviously, the licensing of facilities for the temporary storage and the final disposal of waste, as well as supervision of their operation.

The CSN is aware of the importance and difficulty of these tasks and it sets aside significant resources to address them and actively participates in international fora in which issues relating to the management and disposal of radioactive waste are debated, with the objective of exchanging information to help in resolving common problems.

The development of general criteria for the dismantling and decommissioning of nuclear and other facilities which, as you are aware, give rise to large volumes of low activity waste, is a priority issue in Spain. Our aim is to completely or partially release the sites of such facilities for other future uses. In this same context, it is necessary to develop criteria for the declassification of waste materials arising from the dismantling of these installations. Because of the low radiological risk associated with such materials, many of them can be treated via conventional routes. The availability of this option contributes to the optimization of the strategic processes of radioactive waste management.

In the same context, mention should be made of the importance of having a solid materials declassification process for use during the operating phase of the facilities. This naturally contributes to reducing the waste to be managed in decommissioning and to optimizing overall radioactive waste management.

In relation to declassification, a large number of activities have been carried out or are currently under way in Spain, among which I shall mention, as examples, the systematic approach to the licensing of various common projects for the declassification of materials at nuclear power plants, such as those applied to metallic scrap, spent resins, activated carbon and wood. Also noteworthy is the recent adoption of a general standard for the declassification of materials at medical, research and industrial facilities; this includes general criteria and specific activity values for the radionuclides usually used at such installations. All of the above mentioned declassification initiatives have taken full account of the recommendations of the IAEA.

To date, one nuclear power plant has been dismantled in Spain, and although the site has not yet been formally released, this is an aspect that is currently being reviewed in the final stage of the licensing process. The dismantling of a second nuclear plant is foreseen after the year 2006. A number of nuclear production facilities have been decommissioned and various uranium mine restoration projects have been carried out.

In keeping with the lines mapped out in the Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management, Spain possesses an administrative structure, a regulatory framework, an assignment of responsibilities and a financing system that provide assurance that the management of spent fuel and radioactive waste will be carried out safely.

Although, to date, no generic regulations have been developed governing the long term management of radioactive waste, the regulatory authorities have defined and approved, upon request, specific criteria applicable to the licensing of individual facilities.

Nevertheless, because we are aware that the very nature of the safe management of radioactive waste and spent fuel, particularly in the long term, involves regulatory and social dimensions different from those applicable to operating facilities, certain initiatives have been undertaken to develop and complete the legal and regulatory framework, taking into account the various elements of international consensus in this area. As a result, the new Strategic Plan soon to be published by the CSN includes a number of objectives and actions relating to these issues.

The areas in which work is currently being performed are the development of standards relating to safety in the management of low and intermediate level radioactive waste, the development and implementation of radioactive waste management plans at the sites of waste production and actions aimed at improving the general capacity to respond to radiological emergencies in which significant amounts of low activity radioactive waste might be generated.

Likewise, several initiatives have been launched for the adoption of general criteria applicable to the release of sites; this includes requirements for institutional surveillance when the sites cannot be released without restrictions. Of special interest is the problem of the management of the long lived low activity waste associated with uranium mining and milling activities, on which the Symposium will include a specific session.

I should especially like to mention the problems involved in managing TENORM waste arising from the processing of materials contaminated by isotopes of natural origin, which is very much a major issue in Spain at present. In this respect, as in the previous cases, the bringing into harmony of practices at international level is of great importance.

Mention should be made of the fact that in licensing the new complementary facility at El Cabril for the disposal of very low activity waste, work has been carried out jointly with ENRESA during the preparatory phases for the definition of applicable safety and radiation protection criteria.

Following this example, I would like to express my conviction that in order to guarantee adequate protection for workers, the public and the environment, and to respond with rigour to the current social demands relating to radioactive waste management, very close collaboration is required between all those involved; this includes the regulatory authorities, the waste producers and, obviously, those responsible for the actual management. International collaboration in this area is also considered to be a priority issue, as regards both the bringing of practices into harmony and the development of international standards of reference. In this respect I should like to endorse the work carried out by institutions such as the IAEA through its standards development committees, especially the one dealing with radioactive waste, WASSC, the OECD Nuclear Energy Agency through its various specialist groups and the WENRA through its radioactive waste and dismantling liaison group.

The symposium that we are opening today is very much a part of the aforementioned initiatives and constitutes a valuable forum for debate and the presentation of problems and solutions. I wish you great success in the work to be undertaken over the next few days and hope that you find time to enjoy the many attractive features that this historic city of Córdoba has to offer.

KEYNOTE ADDRESS

F. Jacq
Chief Executive Officer,
Agence nationale pour la gestion des déchets radioactifs,
Châtenay-Malabry, France

Radioactive waste management, especially in the case of low and intermediate level waste, is an important issue in all countries, irrespective of their national energy policies or their stance on nuclear energy. In that respect, I am very happy to endorse the initiative of the International Atomic Energy Agency in organizing this symposiun and to welcome here all the representatives of the countries and organizations involved for the discussion of such a crucial matter and for the sharing of valuable experiences with colleagues and counterparts. Radioactive waste management is definitely a field where an added value may be gained through international cooperation.

It is important to define very clearly the nature of the potential international cooperation to be implemented. It is obviously desirable that common principles be formulated and shared by the different actors. On such major themes as waste conditioning or environmental protection, general rules may prove beneficial to all. However, the bases for international cooperation must remain very clear at all times. Waste management is essentially a matter of national jurisdiction. The approach to radioactive waste management is specific to each country, it may be influenced by the historical background of the waste management activities in the country, by the specific technical designs developed to ensure safe manag ement, by the nature of geological formations (if underground disposal is sought), by the industrial infrastructuure, by the corporate framework, by the national arrangements for safety regulation, etc. Similarly, cooperation and the definition of common principles must not lead to wrong impressions. There is no single way to manage radioactive waste and national specificities must be taken into account. Furthermore, waste management is not only a scientific and technical issue, but also a social and political one. The implementation of a management system also implies the careful forging of a suitable framework for the system to work efficiently. In summary, one must recognize that, for many countries, globalizing the industrial management of radioactive waste is not on their current agendas and would upset their populations if it were.

A quick overview shows that industrial solutions exist or are emerging for most types of low and intermediate level waste. It is therefore possible and desirable to obtain some feedback from the experience gained, even after only a few decades of practice. Such feedback is a useful element in orienting future approaches and for promoting continuous industrial progress. During the past decades, the specialists involved in radioactive waste disposal have demonstrated their ability to develop new techniques and to bring more and more rigour to their waste management methods. Disposing of low and intermediate level waste in surface facilities now represents a sound and proven industrial practice. In such a context, and in the interests of making continuous progress, research must continue in practical directions towards managing adequately any future changes within the installations.

A major interest of this symposium is in the opportunity it offers to make comparisons between different approaches. There are already many aspects where existing practices may be put into perspective. If I only had one example to quote, I would choose a non-technical one, that is, the disposal costs for low and intermediate level waste. However, the purpose of such comparisons should not be to establish preferred approaches or to select a single solution. On the contrary, the goal should be, not only to highlight the differences, but also to understand and to explain why they may lead to equivalently satisfactory and safe solutions.

A common objective for all countries is to have the availability of solutions for the entire set of waste categories. In the current context, the solutions for some categories appear to be less developed than for others. One may think more particularly of radium-bearing waste resulting from historical practices initiated as early as the beginning of the 20th century. Others may mention graphite waste originating from the former gas–graphite reactor system. France, for example, is currently confronted with finding solutions for both of these waste categories, and she is far from being alone in that position. Consequently, I believe that special attention should be given to the subject, since it constitutes a significant barrier towards progress.

The waste package is a key element in the waste management mechanism. It constitutes the basis of the safety approach. The care with which the specifications of the package are first defined, then controlled, through rigorous quality assurance procedures, is essential. Often enough, waste management incidents which are reported in the media are concerned with waste packages. The credibility of sound management is often determined by such matters.

The safe management of radioactive waste is achieved primarily through the reliability of the managers and of all the actors involved in waste disposal in carrying out their long term responsibilities. In order to properly implement their missions, they must be associated, at an early stage, with any new waste management practices. Ultimately, it may be desirable that new practices for managing a waste type become applicable only after an assessment study involving the future manager. It would not be appropriate for any manager to be required to assume responsibility for situations over which he has no real control or margin of flexibility. In fact, it is in the waste producers' interest to associate management organizations, as early as possible, in any new procedure. It is the best way to estimate requirements, to assess innovative solutions and to adapt to any new constraints resulting from the regulations. It is desirable, therefore, for the waste manager not to remain a simple actor intervening only at the end of the line, but rather to be one who contributes actively and concretely to the overall management process.

The history of low and intermediate level waste management now spans several decades. As we all know, history implies memory, and memory sometimes involves forgetfulness. One of the key challenges during the years ahead will be to manage acquired knowledge, to preserve memory and to maintain the required skills. Part of the feedback already obtained gives reason to reflect on future strategies, such as, the feedback from disposal facilities that have already entered, or are ready to enter, into their monitoring phase. I strongly believe that we must carefully reflect on the experience already obtained and to continue to preserve knowledge, not only to prevent the repetition of past errors, but also to maintain the safe control over the activities that were launched a few decades ago.

The management solutions that we develop are not only useful to ourselves but also to other users, and especially to the public at large when we are dealing with the waste resulting from nuclear medicine. The public often has mixed feelings, not only about radioactive waste, but also about associated management methods. Doubts are sometimes cast on the managers' rigour or truthfulness concerning reported data, while other concerns are expressed about our capability to accept the responsibility for the waste. It is therefore imperative that our citizens learn about what we are doing, if only to ensure that they understand better the issues at stake and that we, in turn, are in better position to take their expectations into account.

Hence, this symposium has several objectives. Looking rapidly at the agenda, I notice that a broad diversity of view will be presented throughout the different sessions and should lead to a top quality and fruitful debate. Let us be thankful for such a wonderful opportunity to meet here and to advance together towards a safer and more effective management of radioactive waste.

KEYNOTE ADDRESS

L. Echávarri
Director General
OECD Nuclear Energy Agency,
Paris

We are grateful that the IAEA has created this opportunity to discuss the disposal of low activity radioactive waste, and the NEA is gladly cooperating in the organization of this symposium.

While the public and political debate about waste management is focusing on high level waste and spent nuclear fuel, it is often forgotten that by far the greatest volumes of radioactive waste are generated in the very low level and low level waste categories. Outside the nuclear power programmes, materials with similar levels of radioactivity are also generated in large amounts. Given the volumes that are involved, it is important that a review of current management perspectives be made in order to understand and address concerns that may be warranted from both a safety and an economical point of view.

The NEA has been engaged for over twenty years now in helping its member countries to find long term sustainable solutions for the management and disposal of radioactive waste. Its standing Committee on Radioactive Waste Management (RWMC) works on issues related to policy and governance in long term waste management, stakeholder confidence issues, the long term safety of deep disposal, and the development of scientific information and databases. RWMC is also active in the development of frameworks for the safe and efficient decommissioning of nuclear facilities and for managing the attending materials.

1. THERE ARE MANY EXAMPLES OF SUCCESSFUL IMPLEMENTATION OF FINAL REPOSITORIES FOR SHORT LIVED LOW AND INTERMEDIATE LEVEL WASTE

Activities for ensuring the safe management of short lived low and intermediate level waste have been ongoing for many years now. More than 80 near surface disposal facilities have been built worldwide and more are under development. Regulatory frameworks and specific international safety standards are also in place through the work of the IAEA.

Short lived low and intermediate level waste is also successfully being disposed of at intermediate depth in geological repositories operating in Finland and Sweden.

The capacity of the existing disposal facilities usually covers well the needs of the operational phase of the nuclear installations that they serve. One of the reasons for this is that, nowadays, the nuclear installations generate less low and intermediate level waste than previously, due to better operating procedures and improved housekeeping.

2. SOLUTIONS, BUT ALSO CHALLENGES, IN DISPOSING OF LONG LIVED LOW AND INTERMEDIATE LEVEL WASTE

One option for the management of long lived low and intermediate level waste is to build deep underground repositories that are ultimately closed and sealed. This option is being widely investigated and developed worldwide to protect humans and the environment both now and in the future.

Long lived low and intermediate level waste is being disposed of in the Waste Isolation Pilot Plant (WIPP) geological repository in the USA. A geological repository for both short and long lived non-heat emitting waste has also been licensed for operation in Germany (the Konrad mine), although it is not yet operative. Efforts are under way in other countries.

Other options than building repositories are also being considered, e.g. borehole disposal in some small programmes. A specific technical challenge, in some countries, is to find 'ad hoc' long term solutions for waste with special properties, such as, mixed waste and graphite waste. In the meantime, the safe storage of all these waste types has to be maintained.

3. WASTE MANAGEMENT CHALLENGES ALSO ARISE FROM THE DECOMMISSIONING OF OBSOLETE INSTALLATIONS

A new range of challenges is opening up as modern nuclear power programmes mature and large commercial nuclear power plants approach the end of their useful lives for reason of age, economics or changes of policy on the use of nuclear power. The scale of such challenges may be judged from the fact that over 500 nuclear power plants have now been constructed and operated worldwide As of October 2004, 440 were in operation and 84 had been phased out. OECD/NEA member countries account for more than 80 % of the total number of plants and most of these will need to be decommissioned in the next few decades. When all of these nuclear installations are being decommissioned, relative large volumes of very low activity waste will be generated. This, in turn, will place demands on repository space. Current planning indicates that decommissioning activities will peak around the year 2015.

The volumes of the decommissioning waste generated depend on many different parameters, such as, clearance levels set by national authorities, the possibility of recycling materials, the availability of repositories (geological or surface based) and the costs of disposal. Solutions already exist to deal with very low level wastes, for instance, the Morvilliers facility in France has just started operation and a new facility is expected to be opened at El Cabril, Spain, but further discussions and developments are warranted to arrive at a stabilized approach to these issues worldwide. The NEA perspective on the decommissioning waste volumes will be presented in Session 3 of the symposium.

In the context of very low level waste it must be observed that radioactive products, by-products and 'waste' arise from practices other than nuclear power generation. In particular, more than 280 million tonnes of slightly radioactive coal ash are produced annually worldwide. It is notable that different management standards are being applied for nuclear and non-nuclear industry waste.

4. THERE IS WIDE INTERNATIONAL AGREEMENT ON THE BASIC PRINCIPLES ON WHICH SOLUTIONS MUST BE FOUNDED

There is international agreement, now formalized in the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management that solutions are required that do not result in undue burdens on future generations and whose reasonably predictable impacts are not greater than those permitted for the current generation. In the spirit of the "The Rio Declaration", the international community, and certainly the OECD countries, are adhering to the principle that those who generate the waste — as well as those who benefit from the primary sources — should also provide for the appropriate management means. Amongst these means there is, at the national level, the provision of appropriate policy and regulatory frameworks and relevant institutions. The NEA committees are working on the regulatory aspects. One identified important item, is the provision of regulatory frameworks that do not require new permits on each occasion when different parts of the plants are dismantled. Progress in amending regulations is taking place in countries, such as Germany, France and the United States of America.

5. SOCIETAL CHANGES REQUIRE THE ADAPTATION OF APPROACHES

Long term radioactive waste management is being shaped by the rapid changes that are occurring in modern society. These include new forms of governance for dealing with hazardous activities, including decision making processes that involve a large number of stakeholders and, therefore, new forms of dialogue. The new dynamics of dialogue and decision making process have been characterized as a shift from a more traditional "decide, announce and defend" model, focused on technical assurance, to one of "engage, interact and cooperate", for which both technical assurance and quality of the decision making process are of comparable importance. Consequently, the scientific and engineering aspects of waste management safety are no longer of exclusive importance. I call your attention to two publications of the NEA in this context, Society and Nuclear Energy and Learning and Adopting to Societal Requirements for Radioactive Waste Management.

In general, the decision making process for a repository for short lived low level waste is not expected to be as difficult as the process for implementing repositories for high level waste and long lived waste. However, in the present context, it is clear that:

- any significant decisions regarding the management of radioactive waste will be accompanied by a comprehensive public review with the involvement of a diverse range of stakeholders;
- the public, and especially the local public, are not willing to commit themselves to technical choices on which they have insufficient familiarity and understanding.

Recent progress in Belgium and Canada in the management of low level radioactive waste provides good examples of such new approaches.

In Belgium, 76 inhabitants of the municipality of Dessel have worked for four and a half years in a partnership with the national waste agency NIRAS/ONDRAF, and have just proposed to the municipal council an integrated disposal project. The NEA is happy to have provided an opportunity — last year — for an international review of the Belgian partnership concept. It is expected that, similar to the Dessel partnership, two more local partnerships — involving the municipalities of Mol, Fleurus, and Farcienne — will each issue a report on a repository project in their communities.

In Canada, a solution to the disposal of the historic low level waste in the Port Hope community has been found — with the active involvement of the community. Also in Canada, through the joint efforts of the industry and the municipalities around the Bruce nuclear power station, progress is being made in the long term management of low and intermediate level waste at the Western Waste Management Facility located on the Bruce site. Technical work was carried out over a period of two years and a hosting agreement was signed on October 13, 2004 by the Kincardine Municipality on principles leading to a geological disposal facility. The agreement mirrors the one signed in Port Hope between that municipality and the Federal Government.

The NEA is giving great attention to the issue of decision making and to concepts in which the public, and especially the most affected local public, are involved in the planning process. The NEA Forum on Stakeholder Confidence is a focal point for developments in these areas.

6. WHAT ARE THE FUTURE CHALLENGES RELEVANT TO THIS SYMPOSIUM?

Radioactive waste disposal is a long term technical and social project. Management challenges arise from the historic waste, from the expected relatively large volumes of lower activity waste that will be generated from decommissioning, from the specificity of some waste streams, and from having to obtain public support for the associated long term solutions.

Planning and implementation of long term projects is definitely a challenge in the present climate of public opinion. A further challenge, in this context, is maintaining institutional control over timeframes of hundreds of years. However, many examples of successful projects exist and the problems we are facing are not insurmountable.

Although the procedures and methods adopted will be nation or programme specific, they will be influenced by developments elsewhere. International cooperation becomes, more and more, co-operation between neighbours. The development of procedures and methods, the training of staff and the progress in disposal system development will be aided through the development of international contacts and the exchange of experiences and viewpoints. International fora, allowing dialogue between the involved parties, and cooperative projects are, therefore, likely to continue to play an important role. This symposium is one example of such a dialogue providing an opportunity for further development and experience exchange.

I would like to again thank IAEA for arranging this Symposium, and also ENRESA and CSN, the national hosts. I would also like to thank all the speakers that have accepted to share their views and experiences with us.

POLICIES AND STRATEGIES FOR LOW ACTIVITY RADIOACTIVE WASTE MANAGEMENT AND DISPOSAL

(Session 1)

Chairperson

P. CARBONERAS
Spain

THE MANAGEMENT OF LOW ACTIVITY RADIOACTIVE WASTE: IAEA GUIDANCE AND PERSPECTIVES

D. LOUVAT, J.H. ROWAT, J.-M. POTIER
International Atomic Energy Agency,
Vienna
Email: D.Louvat@iaea.org

Abstract

This paper describes the safety standards and reports of the International Atomic Energy Agency (IAEA) applicable to the management and disposal of low activity radioactive waste and provides some historical perspective on their development. Some of the most important current issues in the area of low activity radioactive waste management are discussed in the context of related ongoing IAEA activities. At the end of the paper, a number of issues and questions are raised for consideration and discussion at this symposium.

1. INTRODUCTION

It is interesting to look back at the proceedings of the last symposium sponsored by the IAEA on disposal of low activity radioactive waste, which took place in Vienna in June of 1996 [1]. At that meeting, the focus was on operational waste from nuclear power plants, and on safety assessment for near surface disposal facilities. To pick just two examples, the startup of the El Cabril facility and the results of the IAEA NSARS programme for safety assessment of near surface disposal facilities were reported at the 1996 meeting. Eight years later, the focus has shifted towards waste from decommissioning and NORM waste.

The International Conference on Issues and Trends in Radioactive Waste Management [2] organized by the IAEA in cooperation with the European Commission and the OECD Nuclear Energy Agency in December 2002 in Vienna, marked a turning point in the international discussions on the management of low activity radioactive waste. Following this conference, the IAEA Action Plan on the Safety of Radioactive Waste Management was revised and the list of actions was updated and increased to nine actions. Three are of particular relevance for the management of Low Activity Radioactive Waste (LARW); they are: (1) to develop a common framework for the management and disposal of different types of radioactive waste, paying particular attention to large volumes of waste containing long lived naturally occurring radionuclides, (2) to develop an internationally accepted and harmonized approach for controlling the removal of materials and sites from regulatory control, and (3) to explore international mechanisms for facilitating the management of spent sealed radioactive sources and, in particular, for the disposal of such sources.

This paper describes how the IAEA is extending existing guidance, developing new guidance and applying its guidance in providing assistance to its Member States — all in relation to the three actions of the Action Plan on the Safety of Radioactive Waste Management. The International Symposium on Disposal of Low Activity Radioactive Waste will contribute to the implementation of these three actions as it provides a forum to discuss open questions, some of which are included in this paper.

2. CLASSIFICATION OF RADIOACTIVE WASTE: AN EVOLVING TOOL

Classification is a primary tool for simplifying the management of radioactive waste. Since 1970, the IAEA has published three documents on radioactive waste classification.

The main purpose of the first IAEA document on waste classification, Technical Reports Series No. 101, was to document the experience of the few countries that were concerned with managing radioactive waste from the back end of the nuclear fuel cycle [3]. The TRS-101 classification scheme was based on the radioactive content of the waste types and, in some cases, based on the ratio of maximum permissible concentrations determined from radiological protection considerations. This document makes explicit mention of very low radioactive waste but does not elaborate upon the concept.

Ten years later, TRS-101 was superseded by IAEA Safety Series No. 54 [4]. In this document, a classification scheme was proposed that assigned waste to one of five “categories” based on the disposal endpoint; decisive parameters for categorization were radioactive content, half-life and waste conditioning. This document was the first safety standard to formalize the use of the terms low, intermediate and high level waste.

In 1994, Safety Series No. 111-G-1.1, Classification of Radioactive Waste [5] superseded Safety Series No. 54, and provided a system of waste classification that was consistent with existing IAEA guidance on exemption of materials from regulatory control. The document proposed a method for deriving a classification system, and it provided a general system of waste classification with quantitative boundaries. The system provides a clear linkage to safety. The distinction between low and intermediate level waste was considered of secondary importance in the context of radiation protection compared with distinction between the short to long lived radionuclides contained in the waste. Waste containing long lived natural radionuclides was for the first time included in the Safety Guide as a form requiring an individual regulatory approach.

Since the 1994 guide was issued, waste produced as a result of the termination of nuclear activities, such as, facility decommissioning and site remediation, and waste from uranium mining and milling and from non-nuclear activities, such as the use of sealed radioactive sources, have broadened the types of radioactive waste that need to be brought into the classification system. In 2005, the IAEA will review the 1994 Safety Guide on classification of radioactive waste to take into account a broader spectrum of radioactive waste and, perhaps, a broader spectrum of concerns (e.g. security). It is expected that the IAEA's initiative on 'the common framework', which is intended to explore the management options for this broad range of radioactive waste types, will be linked closely with any revised waste classification system.

3. THE MANAGEMENT OF LARW: A WORLDWIDE ISSUE

In addition to low activity radioactive waste generated by operation of NPPs, which were the main concern of the 1996 IAEA Symposium, there are a range of other activities that also generate types and quantities of LARW that require safe management. LARW arising from the decommissioning of nuclear fuel cycle facilities, research laboratories and industrial facilities has been increasing from year to year. In recent years, more attention has been given to the wide range of industries using raw materials that generate waste containing naturally occurring radioactive material (NORM). The volumes of waste generated by these activities are often very large.

Many countries with little or no nuclear fuel cycle activities have only small amounts of low and intermediate radioactive waste to manage, and their strategies and options for managing their waste differ appreciably from those employed in countries with nuclear power plants.

International mechanisms and standards already exist to safely manage LARW, but they may not address all existing situations, in particular, situations where the quantity of waste is comparatively small and where there are very limited financial resources.

3.1. The Joint Convention

The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management [6] is an international agreement among countries to achieve and maintain a high level of safety in managing spent fuel and all categories of radioactive waste. It was derived from the IAEA 1995 Safety Fundamentals publication, “The Principles of Radioactive Waste Management” [7]. The nine principles contained in this document have also served as the foundation for the RADWASS series of safety standards. The Joint Convention envelops all of the issues related to the management of LARW and is relevant to every country in the world because every country has at least some LARW to manage. An overview of the Joint Convention, as it applies to LARW, is described elsewhere in these proceedings.

3.2. Storage

Storage is assuming an increasing role in the management of LARW. In 2003, the IAEA published a “position paper of international experts” that examined the safety and sustainability of long term storage for high level waste and waste containing higher concentrations of long lived radionuclides [8]. The IAEA is beginning to examine the safety and sustainability, and, in turn, the strategic implications of long term storage of LARW. In fact, the distinction between long term storage and disposal is becoming less distinct. Recognizing this, some countries now prefer to talk about the long term management of radioactive waste.

Of particular relevance and importance is the application of safety assessment to the storage of radioactive waste. The IAEA’s project, “Safety Assessment Driving Radioactive Waste Management Solutions” (SADRWMS) is an international programme of work to examine international approaches to safety assessment in aspects of predisposal radioactive waste management, including waste conditioning and storage. In comparing international approaches to safety assessment in these areas, it is anticipated that a body of safety assessment methodology will be developed which will be acknowledged as international best practice in these areas. The SADRWMS project is intended to encompass a broad range of waste types, including operational waste and spent fuel, legacy and decommissioning waste, and NORM residues. Security concerns expressed over long term surface storage were evident during the various SADRWMS discussions and again the need was emphasized to address physical security threats within the overall safety assessment process.

3.3. Disposal

It has been 5 years since the IAEA published its Safety Requirements for near surface disposal of radioactive waste [9]. Feedback at conferences and IAEA meetings indicate that the Safety Requirements provide a sound and practical basis for safe near surface disposal of radioactive waste. To support the Safety Requirements, a Safety Guide on the safety assessment of near surface disposal was published at the same time as the Safety Requirements document [10] and, recently, the IAEA published a Safety Report on surveillance and monitoring of near surface disposal facilities [11]. From the experience of IAEA-sponsored programmes for near surface disposal safety, it appears that there is a need for more comprehensive guidance related to near surface disposal to complement the Safety Requirements for near surface disposal, for example, in the area of safety in the design and operation of such facilities. In response to this need, development will begin, in 2005, of a new Safety Guide for the design and operation of near surface disposal facilities.

To promote safety assessment methodologies, the IAEA launched, in 1997, a project on Improving Long Term Safety Assessment Methodologies for Near Surface Radioactive Waste Disposal Facilities (ISAM). The main outcome of the project, which was completed in 2000, was the establishment of a harmonized methodology for carrying out post-closure safety assessment of near surface disposal facilities. The methodology has found widespread acceptance and the results of the project have been published in a series of reports dealing with scenario development, modelling and confidence building, together with three documented test cases [12].

To investigate the application of the ISAM methodology to a range of practical issues, the IAEA has started a new and complementary project on Application of Safety Assessment Methodologies for Near Surface Radioactive Waste Disposal Facilities (ASAM). It builds on the experience gained with the ISAM programme, with special emphasis on application of the ISAM methodology to practical problems of near surface disposal, such as development of design concepts, safety reassessment and upgrading of existing facilities. The emphasis of the ASAM project is on evaluating the post-closure safety of radioactive waste disposal facilities.

4. THE IMPORTANCE OF CLEARANCE IN MANAGING LARW

In most countries, clearance is part of the management strategy for LARW. The radiological protection principles for exempting sources from regulatory control were first published in 1988 in IAEA Safety Series No. 89

[13]. The IAEA published Safety Series No. 111-P–1.1 in 1992 to facilitate the application exemption principles, primarily by providing practical measurable quantities expressed in terms of mass activity and surface activity concentrations [14]. The Basic Safety Standards (BSS) [15], published in 1996, contain exemption levels that apply only to moderate amounts of radioactive material (less than one tonne); for larger amounts of material additional guidance was needed.

To provide this additional guidance, an international effort was then started to derive specific values of activity concentration for both radionuclides of natural origin and those of artificial origin. With the publication in 2004 of the Safety Guide entitled "Application of the Concepts of Exclusion, Exemption and Clearance", there is now an internationally endorsed set of levels for clearance that apply to bulk amounts of radioactive material [16].

LARW envelopes a broad range of waste types, and hence there are many strategies for its management. Like waste classification systems, strategies for LARW management are to a large extent determined by the disposal endpoint. The following disposal endpoints imply a range of possible strategies:

— VLLW[1]disposal + LLW disposal with no clearance;
— VLLW disposal + LLW disposal + clearance;
— LLW disposal + clearance;
— Geological disposal of all radioactive waste + extensive use of clearance.

Moving down the list there is an increasing reliance upon clearance. Strategies that employ only limited use of clearance will result in larger volumes of waste but with radionuclide concentrations that are lower, on average, compared with strategies that make extensive use of clearance. When the availability of disposal facilities and costs are taken into consideration, the development of a comprehensive and appropriate strategy can be a complex task.

The present suite of IAEA safety standards (including those under development) will address the safety aspects of the activities needed to implement strategies for LARW management.

---

[1] Some Member States define a very low level waste (or VLLW) category for radioactive waste (see paper by M. Dutzer in these proceedings).

5. LARW FROM DECOMMISSIONING

Waste management and decommissioning strategies are always interdependent and should not be formulated in isolation. The amounts and types of radioactive waste and the timing of when these wastes are generated are important issues for planning. The Safety Fundamentals [7] (under "interdependencies"), the Safety Requirements [9] and the Joint Convention [6] address this issue by requiring lifecycle planning for radioactive wastes, from the time a facility is designed until final disposal of the waste generated by its operation and decommissioning.

Large volumes of material are produced during the decommissioning of nuclear facilities. Part of this material has to be managed as radioactive waste. The volumes of this radioactive waste are variable depending on the facility type and the available options for processing and management. The waste may not always have been anticipated in national plans for radioactive waste disposal. Some of the waste may require special predisposal arrangements in the absence of suitable disposal facilities. The nature of the waste (e.g. volume, radionuclide content, chemical form and dispersible) may justify the development of specific processing and disposal strategies. The IAEA Action Plan on Decommissioning of Nuclear Facilities includes the specific task of reviewing the options for the management and disposal of radioactive waste from decommissioning activities.

The Action Plan also includes the development of an internationally agreed approach for assessing the safety of decommissioning operations. The IAEA project on Evaluation and Demonstration of the Safety of Decommissioning of Nuclear Facilities (DESA) aims to develop a harmonized methodology for evaluating and demonstrating safety during decommissioning and to produce model safety assessments for selected nuclear facilities by applying this methodology.

6. LONG LIVED LARW MANAGEMENT

A wide range of industries process raw materials containing naturally occurring radioactive material (NORM), mainly from the U and Th decay series. The radioactive materials from NORM often become concentrated in the associated waste streams — typically large volume waste streams that contain low levels of long lived radionuclides. Industries that produce significant NORM waste include uranium mining and milling, mineral sand mining, oil and gas recovery and phosphate fertilizer production.

The issue of NORM and, in particular, of NORM waste, is complex from a regulatory point of view because the national nuclear regulatory authority is often not responsible for the regulation of these types of materials or of the industries that generate them. The national organizations responsible for their regulation may have different regulatory philosophies from those of the nuclear regulator. Additionally, NORM is often regarded as a non-radiological concern. As a consequence, some NORM waste may simply be disposed of as industrial refuse or may be re-used and recycled to provide raw material for other industrial sectors.

The IAEA has started work on approaches for the management of NORM. IAEA Safety Standards Series No. WS-G-1.2 [17] is concerned with the management of radioactive waste from the mining and milling of ores (including U/Th ores), and Safety Reports Series No. 27 [18] provides guidance on the monitoring and surveillance of residues from the mining and milling of uranium and thorium. The extent of environmental contamination by NORM and the technological options for its mitigation are touched upon in Technical Reports Series No. 419 [19].

Achieving the long term safety of long lived radioactive waste raises several questions: Can institutional controls provide for long term safety? What factors distinguish long term storage and disposal strategies for LARW? Is there a sound basis for the differences in the way LARW and NORM are technically managed and controlled?

7. UNIQUE LOW ACTIVITY WASTE

The optimum disposal routes for some diverse types of low activity radioactive waste have yet to be generally established (e.g. irradiated graphite, radium bearing wastes, disused sealed sources, depleted uranium). Furthermore, it is not apparent how many of these should be categorized within the IAEA's present system of waste classification [5]. The waste types that fall into the 'unique' category are often the types of waste of most concern for countries without nuclear power programmes, that is, those countries without large nuclear infrastructures.

Rather than developing generic safety guidance for the entire spectrum of LARW management, recent programmes within the IAEA have led to guidance that is sector specific. For example, IAEA Safety Standards Series No. RS-G-1.6 [20] provides guidance on occupational radiation protection in the mining and processing of raw materials, and Safety Reports Series No. 34 [21] is dedicated to the radiation protection and the management of radioactive waste in the oil and gas industry.

In some countries, LARW can include relatively highly concentrated radioactive materials, such as disused sealed sources. In the past decade the IAEA has focused considerable effort on the safety and security of disused sealed sources and has issued a number of documents that provide guidance for their safe and secure management. These include the Code of Conduct on the Safety and Security of Radioactive Sources, and a Technical Document on the categorization of disused sealed sources [22, 23]. The IAEA is investigating the borehole disposal concept as a safe solution for the disposal of disused sealed sources (i.e., sources that cannot be returned to the country of origin). A Safety Guide and a Safety Report to support this initiative are in preparation.

The IAEA is also developing general guidelines for the safety and security of radioactive waste to address all of the waste types that can pose significant safety and security threats.

8. CONCLUSION

In the past, the types of LARW that have received most consideration for disposal are those arising from nuclear power plant operations, and from medical, industrial and research applications. These waste types are generated continuously, day after day, and so require prompt attention. There are a variety of reasons why other types of LARW have not received as much attention. For example, waste from decommissioning and waste from industries not associated with the nuclear fuel cycle tend to be generated, or dealt with, only after facility operations have ceased. A second example concerns the management of disused sealed sources, for which interim storage is an expedient solution because the waste volumes are small. At this symposium all types of LARW are being considered, including those for which appropriate waste management solutions have yet to be found.

Some clarification of issues related to the management of LARW may come from a better classification system for waste and from a common framework that establishes appropriate management options for all types of LARW.

In organizing the 2004 Córdoba Symposium, the IAEA aimed to gather and solicit advice on several questions as a means of assisting in the development of the common framework and the development and revision of safety standards. In this context, it is considered that the questions for panel discussions, namely,

— How can radioactive waste management strategies be developed to better address the needs of countries with limited resources?

- Clearance and VLLW disposal: competing or complementary approaches?
- Radioactive waste disposal routes — a bottleneck for decommissioning?
- Do we have adequate solutions for disposal of long lived low activity radioactive waste?
- Remaining gaps and issues related to the disposal of low activity radioactive waste?

are timely and relevant to helping the development of international guidance for safe LARW management.

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, International Experience in the Planning and Operation of Low Level Waste Disposal Facilities, Vienna, 17–21 June 1996, (1997)

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Issues and Trends in Radioactive Waste Management, Proceedings of an International Conference, Vienna, 9–13 December 2002, (2003).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Standardization of Radioactive Waste Categories, Technical Reports Series No. 101. IAEA, Vienna (1970).

[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Underground Disposal of Radioactive Wastes, Basic Guidance, Safety Series No. 54, IAEA, Vienna (1981).

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Classification of Radioactive Waste, Safety Series No. 111-G-1.1, IAEA, Vienna (1994).

[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, INFCIRC/546 (1997).

[7] INTERNATIONAL ATOMIC ENERGY AGENCY, The Principles of Radioactive Waste Management, IAEA Safety Series No. 111-F (1995).

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, The Long Term Storage of Radioactive Waste: Safety and Sustainability, A Position Paper of International Experts, Report No. IAEA-LTS/RW, Vienna (2003).

[9] INTERNATIONAL ATOMIC ENERGY AGENCY, Near Surface Disposal of Radioactive Waste, IAEA Safety Standards Series No. WS-R-1 (1999).

[10] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Assessment for Near Surface Disposal of Radioactive Waste, IAEA Safety Standards Series No. WS-G-1.1 (1999).

[11] INTERNATIONAL ATOMIC ENERGY AGENCY, Surveillance and Monitoring of Near Surface Disposal Facilities for Radioactive Waste, Safety Reports Series No. 35 (2004)

[12] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Assessment Methodologies for Near Surface Disposal Facilities, Vol. 1, Review and enhancement of safety assessment approaches and tools, Vol. 2, Test Cases, Vienna (2004).

[13] INTERNATIONAL ATOMIC ENERGY AGENCY, Principles for the Exemption of Radiation Sources and Practices from Regulatory Control, Safety Series No. 89, IAEA, Vienna (1988).

[14] INTERNATIONAL ATOMIC ENERGY AGENCY, Application of Exemption Principles to the Recycle and Reuse of Materials from Nuclear Facilities, Safety Series No. 111-P-1.1, IAEA, Vienna (1992).

[15] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).

[16] INTERNATIONAL ATOMIC ENERGY AGENCY, Application of the Concepts of Exclusion, Exemption and Clearance, Safety Standards Series No. RS-G-1.7, IAEA, Vienna (2004).

[17] INTERNATIONAL ATOMIC ENERGY AGENCY, Management of Radioactive Waste from the Mining and Milling of Ores, Safety Standards Series No. WS-G-1.2, IAEA, Vienna (2002).

[18] INTERNATIONAL ATOMIC ENERGY AGENCY, Monitoring and Surveillance of Residues from the Mining and Milling of Uranium and Thorium, Safety Reports Series No. 27, IAEA, Vienna (2002).

[19] INTERNATIONAL ATOMIC ENERGY AGENCY, Extent of Environmental Contamination by Naturally Occurring Radioactive Material (NORM) and Technological Options for Mitigation, Technical Reports Series No. 419, Vienna, (2003).

[20] INTERNATIONAL ATOMIC ENERGY AGENCY, Occupational Radiation Protection in the Mining and Processing of Raw Materials Safety Guide, Safety Standards Series No. RS-G-1.6, Vienna, (2004).

[21] INTERNATIONAL ATOMIC ENERGY AGENCY, Radiation Protection and the Management of Radioactive Waste in the Oil and Gas Industry, Safety Reports Series No. 34, IAEA, Vienna (2003).

[22] INTERNATIONAL ATOMIC ENERGY AGENCY, Code of Conduct on the Safety and Security of Radioactive Sources, IAEA Report No. IAEA/CODEOC/2004, Vienna (2004).

[23] INTERNATIONAL ATOMIC ENERGY AGENCY, Categorization of Radioactive Sources, IAEA TECDOC Series No. 1344 (2003).

POLICIES AND STRATEGY FOR LOW ACTIVITY RADIOACTIVE WASTE MANAGEMENT IN SPAIN

J.M. REDONDO GARCÍA
Ministry of Industry, Tourism and Trade,
Madrid, Spain
Email: JMRedondo@mineco.es

Abstract

Electric power generation is the main potential source of radioactive waste in Spain. There are nine power reactors in operation with an output of 7.8 GW(e) and one nuclear power plant is being decommissioned. Other radioactive waste comes from nuclear fuel fabrication facilities, the use of radioisotopes in medicine, education, industry and research (minor producers) and incidents involving radioactive materials. An accumulated volume of 170 000 m^3 from all origins, including the decommissioning of the existing nuclear facilities, is assumed for planning purposes in the next decades. The Spanish Government, through the Ministry of Industry, Tourism and Trade (MITC), establishes the radioactive waste management policy, which is issued in a document entitled the General Radioactive Waste Plan (GRWP). Other important actors are the Nuclear Safety Council (CSN) and the Ministry of Environment. ENRESA was created in 1984 with the role of managing the radioactive waste in Spain. It has a broad scope of responsibilities in this field. These include the management of low, intermediate and high level radioactive waste and their final disposal, decommissioning of nuclear power plants and other redundant facilities, and, when so required by the MITC, the rehabilitation of other type of facilities. Low activity radioactive waste (LAW) management in Spain can be described as an integrated system; control is exercised the production of radioactive waste untill its final disposal. Major producers are responsible for waste treatment and conditioning; they follow ENRESA's specifications, which are approved by the MITC after prior approval by the CSN. From a nuclear safety and radiological protection point of view, the CSN controls the different actors in all steps of the process. The MITC establishes the management policy and surveys the economical and financial needs to support the plan. A key element in the management of LAW in Spain is the El Cabril disposal facility. The main objective of the El Cabril facility is the isolation of the low and intermediate level waste (LILW) by means of a multibarrier system. In addition, it provides the required capabilities for treatment and conditioning (supercompaction, incineration, immobilization, etc), characterization and verification of waste packages, interim storage, and fabrication of concrete overpacks. The site was originally used for uranium mining. From 1961 it was used as a storage facility. The disposal facility was licensed during the period 1988–1992 and began its operations in October 1992. The main aspects of LAW management are providing a continuing safe and reliable operation of the

arrangements for treatment and conditioning, acceptance, transport and disposal; it includes the minimization of waste generation, including the provisions for clearance of materials not considered as a radioactive waste and a proposal for the licensing of a specific installation for very low activity radioactive waste as part of the El Cabril disposal facility. Research and development to support and improve the overall system are also under way. In addition, government and industry are making efforts to enhance the control of materials so as to prevent potential incidents outside the nuclear regulated field.

1. ORGANIZATION

The Ministry of Industry, Tourism and Trade (MITC) is responsible for proposing the radioactive waste management policy to the Government. This policy is mainly set out in a document called the General Radioactive Waste Plan (GRWP), which is approved by the Government and notified to the Parliament. Both technical and economic aspects of the radioactive waste management strategies and activities are included in the GRWP. The MITC is also responsible for granting the required construction and operation licences for all nuclear installations, including radioactive waste management facilities. Prior to each of these licences being issued, it is required that a report on the installation or proposed activity is provided by the Nuclear Safety Council (CSN) and its contents taken into account in the licence. The CSN is independent of the Government, reports to the Parliament and is the sole competent authority for nuclear safety and radiological protection. The construction licences also need a positive Environmental Impact Statement from the Ministry of the Environment (MIMA).The Spanish Government set up a public corporation to implement solutions for the management of radioactive waste. ENRESA is the Spanish organization responsible for the management of radioactive waste, including low and intermediate level waste, spent fuel and high level waste. Its responsibilities include the siting, construction and operation of facilities for the treatment, interim storage and final disposal of the waste, as well as the decommissioning of nuclear installations and, when so required, the rehabilitation of other installations,. It has a limited liability company status, the shareholders being two state organisms: CIEMAT (Centre for Energy Related, Environmental and Technological Research), responsible to the Ministry of Education and Science, and SEPI (State Industrial Holding), responsible to the Ministry of Economy and Finance. A scheme of the institutional framework is shown in Fig. 1.

The most important source of low and intermediate level waste (LILW) in Spain is nuclear power generation. The main nuclear fuel cycle facilities in

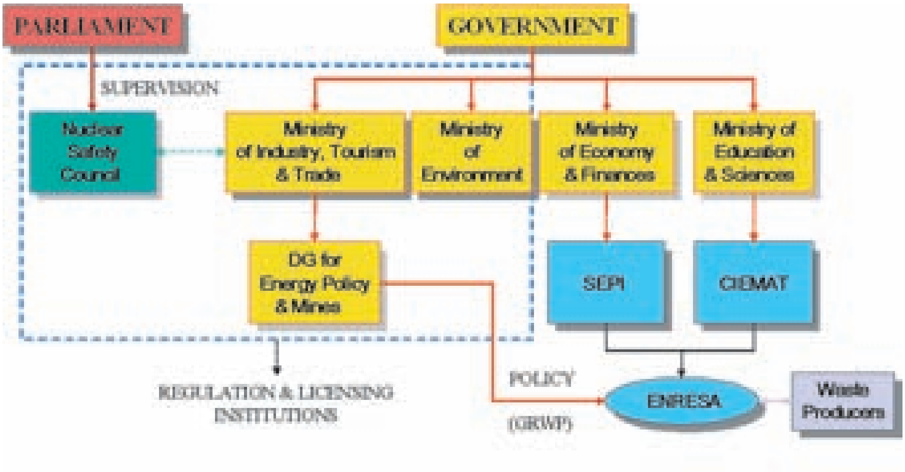

FIG. 1. Institutional framework.

Spain are nine operating power reactors, with a total power of 7800 MW(e), one nuclear power plant being decommissioned by ENRESA and a fuel assembly fabrication plant operated by ENUSA (Empressa Nacionale del Uranio Sociedad Anonima).

2. LEGISLATIVE AND REGULATORY ASPECTS

The licensing of installations related to the management of radioactive waste is regulated by the Nuclear Energy Law of 1964, the law which created the Nuclear Safety Council of 1980, and the specific regulations on Nuclear and Radioactive Installations, revised in December 1999, and on Radiological Protection, of July 2001. The Legislative Decree of 1986 on Environmental Impact Assessment, modified by the Law of 2000, and the Regulation on Environmental Impact of 1988 set out procedures for environmental impact assessment. The Electricity Sector Law of 1997 contains the definition of radioactive waste. The Law on Public Fees and Prices for Services Rendered by CSN (1999) contains provisions for a public taxing mechanism to provide for the activities of CSN. Other regulations dealing with financial and organizational aspects of radioactive waste management are the decrees of 1984 authorizing the creation of ENRESA, modified in 1996 and in 2003. According to this decree, ENRESA must submit a draft of the Radioactive Waste General Plan (GRWP) to the Directorate General for Energy Policy and Mines (DGPEM) every four years or when so required. ENRESA has also to submit annually a budget for developing the activities foreseen in the GRWP to the DGPEM.

3. EL CABRIL DISPOSAL FACILITY

A key element in the management of low activity radioactive waste in Spain is the El Cabril facility (Fig. 2). The main purpose of this facility is the final disposal of all low and intermediate level waste (LILW) produced in Spain. Additionally, it provides the means for the treatment of waste from small producers and for some other waste streams from nuclear installations (e.g. compactable waste or contaminated oil). A waste characterization laboratory has also been constructed as a part of this facility to support the waste acceptance and verification processes. In addition, there is a fabrication plant for manufacturing the reinforced concrete overpacks, used to prepare the final packages used for disposal. Interim waste storage buildings, together with the ancillary systems and buildings, needed for operation and maintenance, complete the facility.

El Cabril is located in the province of Córdoba, some 400 km south of Madrid. Its construction started in January 1990 and it was commissioned in October 1992.

FIG. 2. El Cabril facility — general view.

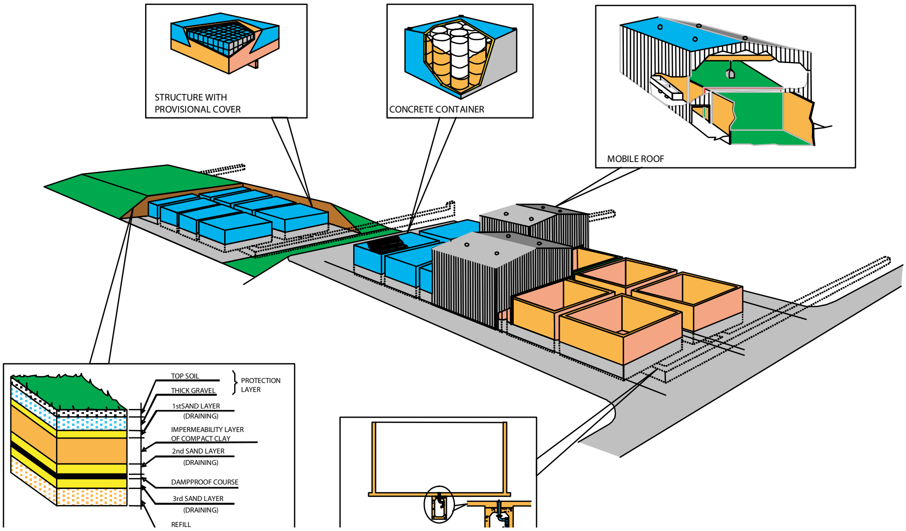

FIG. 3. El Cabril disposal scheme.

3.1. Disposal system

The main design objectives for a near surface disposal facility can be summarized as follows: to protect man and environment from present and future risks; and to allow for the clearance (or release) of the site after a surveillance period of reasonable length (three hundred years).

To reach these objectives two main criteria are stressed: the isolation of the waste from the main vectors of radioactivity release (human and water), and the limitation of the amount of activity being disposed of.

The disposal concept is illustrated in Fig. 3; primary waste packages containing immobilized waste, or pellets arising from the supercompaction process, are reconditioned in concrete overpacks thus forming the final packages for disposal. The gaps among the primary packages are filled by injecting a backfilling grout. Other types of final packages may be used upon approval of the CSN. The final packages are placed inside reinforced concrete disposal vaults. Once a vault is completely filled, it is closed with a reinforced concrete closing slab. The vault is then protected with a provisional cover. While the disposal vault is in operation it is protected from the weather by a shelter. Beneath the disposal vaults there is an inspection gallery, containing the drainage systems.

Twenty-eight vaults have been constructed with a total internal volume of 100 000 m^3, providing room for nearly 50 000 m^3 of primary waste packages.

3.2. Auxiliary buildings

3.2.1. Conditioning building

The waste conditioning building provides for the treatment of small producers' waste and of some waste from nuclear power and fuel cycle installations. It contains an incinerator, a 1200 t compactor, unloading bays for solidified waste drums, facilities for the grout backfilling of concrete overpacks (also used to condition liquid waste from small producers) and systems for the treatment of contaminated smelting ashes.

The conditioning building also has rooms for the storage of sealed sources (sources with half-lives longer than that of ^{60}Co are not currently disposed of) and for liquid waste storage prior to treatment.

3.2.2. Characterization laboratory

Waste characterization is an important stage in waste management, since it allows the quality of the waste forms to be verified and the activity of the packages to be determined, by means of appropriate tests and measurements. In order to provide support for the acceptance and characterization activities, as well as for the technical verification of the waste packages, the El Cabril facility has a verification laboratory arranged in two buildings (active and inactive).

The main element in the active building is the sample preparation cell, with means for drilling out cores from waste packages and for cutting them to standard size specimens, performing mechanical tests, and cutting off the metallic skin of the drums. In addition, this building has an operations room, a leaching test room, a spectrometry assay room, and a radiochemical laboratory.

3.2.3. Other buildings

The facility has four interim storage buildings in operation. It also has buildings for security, maintenance, administration and general services (medical service, radiological protection laboratory and laundry); there is also a concrete containers factory, and an information centre.

3.3. Public information

With the objective of improving the general trust of the public the surrounding population is kept well informed about the activities of the facility.

Some 4000 people from the neighbouring towns visit the information centre and the facility every year.

3.4. Safety and licensing aspects

For this category of nuclear installation, the major licensing steps are the Construction Permit and the Operations Permit. Both permits were granted by the Ministry of Industry after a report from CSN. The Construction Permit involved a public information procedure and an Environmental Impact Statement with an additional public information process. The Construction Permit was supported by a Preliminary Safety Study, while the Operating Permit was supported by a Final Safety Study. The Construction Permit was granted in 1989 and the Operating Permit was obtained in October 1992, and renewed in 1996 and 2001. The 2001 authorization is valid until the 28 existing disposal vaults are filled.

Additionally, the Spanish Law requires, for any construction, including nuclear facilities, a municipal urban planning licence granted by the municipal town council, which has to be obtained independently of the main permit. For El Cabril, located in a rural area, this local permit needed a report from the Provincial Commission on Land and Urban Planning.

3.5. Future trends

One of the requirements of the current Operating Permit is the performance of a safety review every ten years. This review includes an updating of the long term safety assessment and of the analysis of the facility characteristics relevant for long term safety.

ENRESA applied in May 2003 for the authorizations needed to build an extension specifically designed for the disposal of very low activity waste, that would provide an additional disposal capacity of about 120 000 m^3. This licensing process is based on general criteria previously prepared by ENRESA and approved by the CSN. The facility for the disposal of very low activity waste will be the subject of a presentation in Session 2.

4. OTHER MANAGEMENT ASPECTS

ENRESA's responsibilities for waste management vary depending on the origin of the waste. Nuclear power reactors and other fuel cycle facilities (classed as nuclear installations) generally deliver their waste to El Cabril already conditioned, in accordance with the technical specification issued by

ENRESA. In contrast, waste from small producers is collected in a raw form and treated at the El Cabril facility. From the financial perspective there is also a difference between the electricity generating installations and the other installations producing radioactive waste. For the former, funds are generated in advance, throughout the operating lifetime of the nuclear power plants and collected by applying a percentage fee on supplied electricity. For other waste producers, the financing system is based on payment for the services rendered, by way of established tariffs. The prices are established in accordance with criteria set out in a Type Contract approved by the MITC.

4.1. Trends in national waste production

An important activity aimed at optimizing waste management is to obtain a good knowledge of the existing waste at the storage facilities of the waste producers and of expected future waste production at these facilities. According to the 5th Radioactive Waste General Plan currently in force, the total expected volume of LAW is 193 000 m^3, although there is a trend towards the reduction of the generation of waste, as a result of a joint effort made by the waste producers and ENRESA in this field, strongly encouraged by the authorities. The waste generation in the Spanish Nuclear Power Plants has actually decreased from about 6000 0.22 m^3 drums per year in the period 1989–1992 to 3000 drums per year in the period 1997–1999, and to a current production of 2000 drums per year.

4.2. Waste acceptance and verification

ENRESA has established a set of waste acceptance criteria, based on a safety assessment for operational and post-closure phases, and approved by MITC following advice from CSN. It has also set up characterization and acceptance procedures, which include the performance by ENRESA of tests in support of the acceptance of the different waste types. Additionally, ENRESA carries out inspections at the NPPs to check that the waste conditioning is carried out in accordance with the established specifications; it also makes tests, on a random basis, on packages received at El Cabril.

4.3. Transport

Transport of radioactive waste is the responsibility of ENRESA, and is accomplished using either the company's own resources, as is the case for the removal of waste generated at the small producers' sites, or through subcontracting the services of specialist companies. Prior to their removal, the LILW are temporarily stored in installations authorized for the purpose at the producers' sites.

4.4. Institutional waste and other waste

In the case of small producers, the producers and ENRESA sign contracts based on a generic type of contract approved by MITC and, in general, deliver to ENRESA unconditioned waste for treatment and conditioning.

Outside the contractual framework described above, there are a series of waste types, such as decommissioned radioactive lightning rods, radioactive smoke detectors, and other sources that, because of their characteristics, require special management. Also, there is the waste from contaminated scrap metal and from the decontamination of non-regulated industries after incidents. In the case of lightning rods, the strategy was to send them abroad for recycling. Their removal and shipping was concluded at the end of 1996.

From 1998 a number of radiological incidents occurred in the smelting industry which led to the need for the management (delivery to ENRESA for interim storage and disposal after treatment) of significant volumes of radioactive waste, and to the establishment of a protocol, signed by the authorities concerned, the trade unions, the associations of smelters and scrap recyclers and ENRESA, to minimize the risk of such incidents and specifying the actions to be taken in the event of future occurrence.

4.5. Clearance

An aspect of vital importance for achieving optimization of the waste management system is the clearance of materials with extremely low levels of activity, and, in particular, of some of the materials arising from dismantling. The clearance system consists of an administrative authorization, preceded by a process of characterization and checking against agreed radiological criteria, for release of materials without further radiological restrictions.

4.6. Research

Although the management of LAW is well established such that it can be described as being at the level of in an industrial process, research and development to optimize the whole system must not be forgotten and are included in the research programme of ENRESA with the important participation of CIEMAT and CSIC (Scientific Research Council). The main topics in this area are: development of new treatment systems focussed on volume reduction, development of characterization techniques for different matrices, improvement of activity measurement methodology, clearance of materials with an extremely low level of activity and behaviour of barrier materials under disposal conditions.

5. CONCLUSIONS

An overall LILW management system exists in Spain that allows the waste generators to dispose of their waste in an efficient manner, and, at the same time, it provides safety for society and the environment.

Nevertheless, in order to maintain the system and to keep it running in an appropriate way, there cannot be any relaxation and, in addition, the growing social and regulatory requirements must be answered as they arise.

DISCUSSION

P. METCALF (IAEA): In Spain there are clearance mechanisms in place and plans for the development of a facility for the disposal of very low activity waste. What exactly is the waste that will be disposed of at that facility? Will it be waste with activities above clearance levels?

J.M. REDONDO GARCÍA (Spain): As I said in my presentation, there are no general clearance criteria. Clearance is on a case-by-case basis subject to approval by the Nuclear Safety Council.

P. CARBONERAS (Spain — Chairperson): I understand Mr. Metcalf's question to be about whether the 'clearance levels' defined in Spain relate at all to the installations now being developed for the management of very low activity waste at El Cabril.

Any material that is 'cleared' will not go to the disposal facility for very low activity waste. So the 'clearance level values', as approved by the regulatory authorities, will be well below the activity level values accepted for disposal at the very low activity waste facility.

MANAGEMENT AND DISPOSAL STRATEGIES FOR LOW ACTIVITY WASTE IN THE UNITED STATES OF AMERICA

M.V. FEDERLINE
Nuclear Regulatory Commission,
Washington, D.C., United States of America
Email: mvf@nrc.gov

Abstract

The United States of America has no official legal definition for the term 'low activity waste' (LAW). Nevertheless, the management and disposal of radioactive waste that presents less of a radiation hazard than spent fuel, high level waste and the high end of the "low level waste" category is receiving increasing attention in the USA. Safe, practical and cost-effective methods for the disposal of LAW are being studied and developed in response to a national need. This paper will describe the sources and amounts of this waste type in the USA, the US policies and laws that apply to it, factors that affect the amount of LAW that needs to be managed, and the current efforts to expand the options for its management and disposal.

1. INTRODUCTION

Over the last 15 years, the cleanup of government and commercial sites previously contaminated with radioactive materials has received significantly increased attention. These remediation efforts often generate large amounts of radioactive waste, typically contaminated soil and building debris, whose specific activity is well below much of the waste produced during the operations of nuclear facilities, such as power plants. Certain production processes, such as mining or mineral extraction, may also generate large amounts of these materials. Some of this low activity waste can be safely managed or disposed of outside of the conventional shallow land disposal facilities that were originally developed for operational wastes generated in the nuclear fuel cycle. For example, hazardous waste facilities designed to contain chemical waste, or even municipal solid waste facilities, when the concentrations of radioactivity in the waste are very low, may be viable and safe alternatives. LAW may also be managed or disposed of onsite using engineered facilities, institutional controls, or some combination of the two. This paper will address the kinds and amounts of low activity waste, the programmes in which it originates, the existing US laws and regulations that apply to it, factors that affect whether radioactive materials become LAW, and innovative approaches for its management and disposal.

2. DEFINITION OF 'LOW ACTIVITY WASTE'

Although the United States of America has no official legal definition for the term low activity waste, it is a term that is frequently used by organizations involved in radioactive waste management. A recently issued report of the National Research Council (NRC) of the National Academies defined it as including all types of conventional low level radioactive waste produced by generators in the nuclear fuel cycle, discrete sources, slightly contaminated solid materials, uranium and thorium ore processing waste, and waste containing technologically enhanced naturally occurring radioactive materials (TENORM) [1]. The US Environmental Protection Agency (EPA) has been considering the promulgation of a rule that would permit the disposal of certain types of low activity waste in the hazardous waste facilities that it regulates [2]. In connection with this effort, EPA discussed LAW in the broad context of radioactive waste that may contain radionuclides in small enough concentrations to allow them to be managed in ways that do not require all of the radiation protection measures necessary for the management of higher activity materials. This paper will focus on waste types generally consistent with the waste streams that the EPA has defined for its potential rulemaking on this topic, with special attention given to those that are frequently generated by the site remediation programmes that are underway in the USA. Readers interested in obtaining information on all waste included within a broader definition of this term are referred to the above mentioned NRC study [1], and the US National Report for the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management [3].

3. BACKGROUND

The USA has a very large and mature nuclear programme, which has been evolving since its inception in the early 1940s. At that time, the US government created the Manhattan Project to develop the first atomic bombs. With the end of the Second World War, the manufacturing and research complex from the war effort was further expanded in order to compete with the Soviet Union in the arms race of the Cold War. Substantial amounts of radioactive waste from the nuclear fuel cycle were created by the processes used to provide plutonium and enriched uranium for weapons production. When the Cold War ended, the US Department of Energy (USDOE), and the country, turned their attention to the environmental legacy from years of production of nuclear materials. In 1989, the USDOE established an environmental remediation programme for cleaning up over 3000 facilities located on 114 geographical sites. Today, the programme's annual budget is $6 billion, and it is estimated that the programme will eventually cost more than $200 billion [4]. The production of new nuclear weapons materials has largely stopped.

In addition to these USDOE sites, other contaminated sites from the Manhattan Project are managed under the Formerly Utilized Sites Remedial Action Program (FUSRAP), which is currently administered by the US Army Corps of Engineers. These sites were largely commercial and not government owned. This programme was established in 1974 to identify, investigate, and clean up contamination at sites that had been used to process and store uranium and thorium ores for the nuclear weapons programme. It was first administered by the former Atomic Energy Commission, and later by the USDOE, before being transferred to the Army Corps of Engineers in 1997. Since the inception of the programme, 29 sites have been remediated, and 21 sites are currently being remediated. Seven other sites are potentially eligible for inclusion in the programme and are undergoing preliminary assessments and/or site inspections to determine if they should be added [5]. The sites in this programme frequently contain large amounts of LAW from the processing and storage of uranium and thorium ores.

Although the US commercial nuclear programme is robust and the use of nuclear materials and generation of electricity from nuclear power continues, there has also been much increased attention given to the cleanup of other (non-defence related) contaminated commercial sites, and the management of associated low activity waste. The commercial nuclear programme began in 1954, with the passage of the Atomic Energy Act, in which the US Congress encouraged the use of atomic energy for peaceful purposes. Today 103 nuclear power reactors are operating in the US and there are nearly 22 000 users of radioactive materials licensed under the Atomic Energy Act. While the production of energy continues and accounts for approximately 20% of the nation's electrical power, 28 reactors have been shut down, most of them in the last ten years. Many of them are smaller, uneconomical plants that were built in the early days of commercial nuclear power. Six later generation units (greater than 1000 MW(th)), are currently being decommissioned, however, and the associated building debris, rubble, and contaminated soil also contribute to this new class of radioactive waste known as low activity waste.

As with USDOE's defence related programme, the commercial programme is also facing remediation of previously contaminated sites. In the early 1990s, Congress directed that the US Nuclear Regulatory Commission (NRC) review its previously terminated licences to determine where additional cleanup was required in light of the country's increased awareness of potential environmental problems from past practices. The NRC reviewed approximately 37 000 licences that had been terminated, mostly users of by-product and source materials from the nuclear fuel cycle, and determined that 39 had contamination above the regulatory limits. The NRC also established, at that time, a programme directed specifically at overseeing the cleanup of the most complex of these sites. These sites often contain large amounts of slightly contaminated soil and/or building debris and require extensive funds for their cleanup (often in excess of the funds available). The sites require extensive site characterization and dose modelling to determine safe cleanup levels. The number of sites in this programme has varied over the years, but has ranged from approximately 25 to 40 sites. The programme has evolved to include all complex sites, including nuclear power reactors undergoing decommissioning. This programme has also become a source of large quantities of low activity waste.

In addition to the increased attention given to radioactive materials within the USDOE and NRC programmes, beginning in the 1970s, the USA began to focus on past practices for disposal of chemicals. In 1976, Congress passed the Resource Conservation and Recovery Act (RCRA) aimed at protecting human health and the environment from operating facilities, including those with existing contamination. RCRA provides the framework to regulate chemically hazardous wastes from the point of generation to final disposal, but does not cover nuclear fuel cycle radioactive materials. In 1980, Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act, (CERCLA) to provide a means to clean up sites contaminated sites with hazardous materials, including radioactive materials, and hold potentially responsible parties accountable for cleanup costs. CERCLA established a $1.6 billion trust fund, known as "Superfund," which was later supplemented with $8.5 billion. CERCLA and RCRA are both administered by the EPA.

Superfund's National Priorities List (NPL) contains 1523 sites that are generally considered to be among the nation's most contaminated. Most contain chemicals, but according to the EPA's NPL data base, the Comprehensive Environmental Compensation and Liability Information System, or CERCLIS, 77 of these have radioactive contamination (9 of these are USDOE sites) [6]. The sites include manufacturing plants that used radium, landfills, and chemical companies that also processed radioactive materials. Some of the sites are contaminated with technologically enhanced naturally occurring radioactive materials (TENORM), principally radium, but also consisting of uranium and thorium.

Another important source of low activity waste in the USA is the variety of production processes that generate TENORM. It comes from mining and mineral processing (ore residues from copper, zircon, aluminium, titanium, rare earths, and phosphates), oil and gas production, drinking water and waste water treatment, and coal combustion, among others. Unlike nuclear fuel cycle material, most TENORM waste is not regulated at the Federal level; disposal decisions are made by States.. Thus, there is no one programme that addresses TENORM, unlike the programmes that the USDOE, the EPA, and the NRC administer [7].

Decision makers involved in these programmes consider a variety of factors in developing safe, efficient and economical solutions for managing LAW. Commercial low level radioactive waste disposal capacity is limited in the USA, and, beginning in 2008, most US LLW generators may only have access to one facility licensed to accept the lowest class of radioactive waste in the NRC classification scheme (Class A, which includes, but is not limited to, LAW)[1]. Cleanup costs, and costs of disposal in particular, can be extremely large, often costing tens of millions of dollars or more for commercial sites, and, as noted earlier, several hundred billion dollars for the USDOE cleanup programme. For commercial sites with limited funds for cleanup, finding a safe and economical disposal alternative can mean the difference between cleaning up a site and releasing it for unrestricted use, or leaving the waste in place and storing it until another cleanup alternative or programme can be put in place. Transportation of large amounts of low activity wastes is another issue that decision makers need to consider. The mode of transportation and distance between a cleanup site and disposal site not only affects costs, but may also affect overall risk when transportation accidents are considered, especially non-radiological risks.

[1] The State of Texas is currently reviewing a licence application it received for a proposed facility in west Texas in August 2004. The facility, if built, would serve the Texas Compact, which also includes the State of Vermont. LLW generators in 14 other States would continue to have access to the Barnwell and Hanford LLW disposal facilities after 2008.

4. LEGAL FRAMEWORK FOR LOW ACTIVITY WASTE

Each of these cleanup programmes was developed at a particular time to solve a specific waste management issue. Thus, each has its own system of laws and regulations for ensuring the protection of public health and safety and the environment. This legal framework is primarily implemented by three Federal agencies (USDOE, EPA and the NRC) and by the States. For nuclear waste, the EPA has the authority to set generally applicable standards for radioactivity in the environment. The NRC, as an independent agency responsible for implementing these standards through regulations, enforces the regulations to ensure safe commercial applications of radioactive materials. The USDOE's overarching mission is to advance the national, economic and energy security of the USA; to promote scientific and technological innovation in support of that mission: and to ensure the environmental cleanup of the national nuclear weapons complex. Low level waste resulting from its research, development, and production activities is regulated by USDOE internal directives and regulations, consistent with the EPA's generally applicable standards and, to the extent practical and appropriate, similar to NRC standards. Some USDOE waste disposal is regulated by the EPA (e.g. the management of certain cleanup wastes) and by NRC (e.g. uranium mill tailings sites).

The following is a summary of the major laws that may apply to the management and disposal of LAW from the nuclear fuel cycle, i.e. from the activities of the USDOE and from commercial facilities licensed by the NRC and States acting under agreement with the NRC ("Agreement States"):

- The Atomic Energy Act of 1954 established the Atomic Energy Commission (AEC, predecessor of the USDOE and the NRC) with Federal responsibility for regulating commercial use of nuclear materials and regulation of civilian nuclear reactors. It also provides the AEC with the authority for safety and health oversight responsibilities for its own activities, including LAW management and disposal.
- The National Environmental Policy Act of 1969 (NEPA) requires Federal agencies to consider environmental factors in decision making. NEPA applies to all Federal programmes and provides a uniform framework for agencies to assess the overall environmental impacts of their proposed actions.
- The Energy Reorganization Act of 1974 established the Energy Research and Development Administration (ERDA) and NRC. The ERDA, which later became the USDOE, assumed the nuclear technology responsibilities of the AEC, and the NRC assumed the regulatory responsibilities for the commercial nuclear business.

- The Low Level Radioactive Waste Policy Act of 1980, amended in 1985, granted States (and not the Federal Government) responsibility for disposal of commercial LLW. The Act encouraged States to enter into regional Compacts and to create facilities to assure adequate disposal capacity for their wastes. It also provided States and regional Compacts with the authority to regulate the import and export of radioactive waste from the Compacts.
- The Uranium Mill Tailings Radiation Control Act of 1978, as amended, vested the EPA with overall responsibility for establishing health and environmental cleanup standards for uranium milling sites and contaminated properties in the vicinity of uranium mills. The NRC was given responsibility for licensing and regulating uranium production and related activities, including decommissioning and the USDOE with responsibility for long term monitoring of the decommissioned sites.
- The Resource Conservation and Recovery Act (RCRA) of 1976. RCRA is designed to protect human health and the environment from hazardous and solid waste, for facilities currently in operation. The EPA has promulgated implementing regulations for RCRA that apply to solid and hazardous waste disposal facilities. RCRA applies in some cases to USDOE facilities undergoing remediation.
- The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) provides a means to remediate contaminated sites, and recover costs from potentially responsible parties for the contamination. CERCLA applies to both chemicals and radioactive materials. Some USDOE sites are remediated under CERCLA, and the LAW generated by these remediations is subject to this law. Some NRC sites may also be remediated under CERCLA, for example, when there are insufficient licensee funds to complete the remediation or there is significant chemical contamination and the site has been placed on the EPA's National Priorities List.

TENORM, another major source of LAW, is subject to laws that are mostly different from those applicable to nuclear fuel cycle waste.[2] The EPA has the authority to regulate TENORM under several statutes, including the Clean Air Act, the Toxic Substances Control Act, and the Resource Conservation and Recovery Act [8]. States have general regulatory authority to protect the health and safety of their populations and TENORM is one area in which States have asserted such authority. The Conference of Radiation Control Program Directors (CRCPD), a non-profit professional organization whose primary membership is made up of individuals in State and local government who regulate the use of radiation sources, developed the Suggested State Regulation, "Regulation and Licensing of Technologically Enhanced Naturally Occurring Radioactive Materials"[9]. This establishes radiation protection standards for TENORM, including the possession, use, processing, manufacture, distribution, transfer, and disposal of TENORM and of products with TENORM. Even though many States consider TENORM to be regulated by their general rules on radiation protection, eleven States have regulations specifically for TENORM. TENORM contaminated sites have sometimes been addressed under CERCLA.

Occasionally, legislation creates overlapping authorities among the agencies that must be clarified or that require the development of interagency agreements. For example, in 2002, the NRC and the EPA developed a memorandum of understanding (MOU) that establishes a basic framework for the relationship between the NRC and the EPA in the radiological decommissioning and decontamination of NRC licensed sites. The MOU defines a process by which the two agencies will coordinate on cleanup levels and decision making at sites. In 1997, the NRC published, after extensive consultation with the EPA, a staff technical position that defines a process whereby certain emission control dusts from electric arc furnaces may be disposed of in facilities regulated under the EPA's Resource Conservation and Recovery Act. The dusts contain both radioactive and hazardous waste and are subject to both EPA and NRC regulations. The technical position defines a viable process, where one did not previously exist, for disposing of these materials under the

[2] It should be noted that NRC regulates some radioactive materials that are not from the nuclear fuel cycle. NRC has jurisdiction over source material, i.e. (1) uranium or thorium or any combination thereof, or (2) ores which contain by weight 0.05% or more of (i) uranium, (ii) thorium, or (3) any combination thereof. Source material of less than 0.05% by weight is exempt from licensing, although this threshold is not health based. In some cases, an industrial process, such as mineral extraction, will concentrate source material to greater than 0.05%. The material, even though not produced in the nuclear fuel cycle, is then subject to regulation by NRC.

authorities of the two Federal agencies. Similarly, in 2001, the EPA promulgated a rulemaking for mixed radioactive and hazardous waste that permits the disposal of certain of these materials in NRC and Agreement State regulated disposal facilities, and exempts these materials from regulation under the EPA's Resource Conservation and Recovery Act authority.

While these overlapping authorities often require coordination to ensure that there is no unnecessary duplication, they also contribute to cross fertilization of ideas for managing risks associated with LAW. One example is the US increased use of RCRA hazardous waste facilities for the disposal of low activity waste generated under the Atomic Energy Act, as noted above and as will be discussed in more detail later in this paper.

5. AMOUNTS OF LAW

One of the primary reasons that LAW has become a focus of attention is the unusually large volumes that have to be managed in comparison to conventional LLW from the ongoing operations of nuclear facilities. In the USDOE's cleanup programme, 75 million cubic metres of soil are contaminated, and, of the nearly 20 000 buildings and structures, many are contaminated and at least half are no longer used [10]. At the USDOE Fernald site in Ohio alone, the USDOE has shipped 123 trainloads of waste to a disposal facility in Utah. For TENORM, the NRC reports that more than a billion metric tonnes of TENORM waste are produced each year, or the equivalent of approximately 1.5 million cubic metres per year [1]. While some of this waste contains very low levels of radioactivity and may not need special attention, other TENORM waste streams require the implementation of measures to manage their risks. Although no precise numbers are available for NRC's decommissioning and site cleanup programme or the EPA's Superfund Programme, both programmes contain a number of sites that have large (greater than 10 000 m^3) of contaminated soil and debris. The radioactivity concentrations in these materials can range from just above soil background levels [7.4–155 Bq/kg (0.2–4.2 pCi/g)] for uranium, thorium, and radium in soil) to, for the broadest definition of LAW which would include all non-HLW and TRU materials and isotopes, approximately 10^{10} Bq/kg (10^{9} pCi/g) for the high end of low level radioactive waste produced by nuclear power plants. Some typical examples of LAW that is present in very large quantities include fly ash from coal combustion [74–359 Bq/kg (2–9.7 pCi/g)] and scale and sludge from oil and natural gas production (background to approximately 10^{6} Bq/kg (10^5 pCi/g)). Many of the sites undergoing cleanup have concentrations in the range of a few hundred to several thousand becquerels per kilogram of long lived radionuclides of uranium, thorium, and/or radium.

6. INNOVATIVE APPROACHES AFFECTING MANAGEMENT AND DISPOSAL OF LAW

Each programme in the USA was developed based on a need to address a specific issue as it arose, often using different methods for managing risks. In the last ten years, the need to find safe and cost effective means of managing LAW has led to some cross-fertilization between programmes and disposal facilities and/or risk management approaches of one programme are adopted in others.

Conventional LLW, i.e., the waste that results from the operation of nuclear plants and the use of radioactive materials in industry, medicine, and research, has typically been disposed of in one type of facility, namely, shallow land disposal facilities licensed under Agreement State regulations compatible with the NRC's regulations in 10 CFR Part 61. Part 61 is a performance based regulation that relies on a system composed of the waste form, engineered barriers, and natural site characteristics to meet overall performance objectives. One of these is an overall annual dose limit to a member of the public of 0.25 mSv/a (25 mrem/a) (whole body) from radioactive material that may be released to the general environment.[3] Complex modelling of site and engineered features is carried out to demonstrate compliance with the performance standard in the regulations. The USDOE LLW sites also utilized shallow land disposal and are generally similar to those used for commercial disposal. Although conventional LLW disposal facilities are capable of safely isolating LAW, the limited number of these facilities, coupled with the large volumes of LAW, and, in some instances the costs, which can range as high as $1625 per cubic foot [10], has forced the examination of other alternatives.

6.1. Hazardous waste facilities and municipal landfills

Both hazardous waste facilities and municipal or industrial solid waste landfills are now being used to a degree by US generators for LAW disposal. Both types of facility are regulated under the Resource Conservation and Recovery Act, which is implemented by the EPA and States authorized by

[3] NRC policy is to interpret the 0.25 mSv/a (25 mrem/a) whole body limit as 0.25 mSv/a (25 mrem/a) effective dose equivalent.

EPA in the case of hazardous waste, and by States alone in the case of solid waste. Neither type of facility was originally designated for radioactive waste. Nevertheless, the same containment and isolation technology that is used in their design for hazardous and municipal solid waste can also be relied upon, in certain cases, for radioactive waste.

On November 18, 2003, the EPA published an Advance Notice of Proposed Rulemaking (ANPR) for the use of RCRA Subtitle C hazardous waste facilities for the disposal of radioactive waste [2]. The purpose of the ANPR was to solicit the public's views on this issue. The EPA recognizes that RCRA and the Atomic Energy Act employ different regulatory philosophies for the isolation of waste. RCRA defines specific engineering and construction criteria for landfills to minimize contact between waste and water and therefore ensures that releases to the environment are eliminated or are within acceptable limits. RCRA regulations require, among other things, that a disposal facility should have a cap on the disposal cell that minimizes the infiltration of liquids, promotes drainage, minimizes erosion, accommodates settling and subsidence and has a permeability no greater than that of the disposal cell liner system or of natural subsoils. A liner system, constructed of materials of specified thickness, hydraulic conductivity, physical strength, and chemical resistance, is required beneath the disposal cell. In addition, the regulations require a leachate collection and removal system capable of limiting leachate depth above the liner to 30 cm. RCRA also requires that waste be treated before disposal. This treatment can reduce the concentration of hazardous constituents in the waste, change the physical form of the waste, and reduce the likelihood of releasing hazardous constituents from the waste. The EPA is considering public comments on the ANPR and has not yet made a decision on whether to proceed with a rule making or some other action.

In the meantime, LAW generators in the USA are using RCRA hazardous waste facilities for the disposal of some waste containing residual radioactive material, as authorized by the permitting agencies in the States in which the facilities are located. There are approximately 20 such facilities in the USA, far more than the number of commercial LLW disposal sites. While some of the facilities have been accepting TENORM waste, waste from the nuclear fuel cycle is being increasingly being disposed of at these facilities. Facilities in Texas and Idaho currently accept low activity waste from the nuclear fuel cycle. Disposal of this waste is authorized in their permits, and has been analysed by the operators and regulators, often on a waste specific basis, to ensure that the risk management approaches in the disposal facilities will ensure protection of the public health and safety and the environment.

To a limited degree, municipal solid waste landfills are also used for disposal of some radioactive waste that contains very low levels of radioactivity.

For example, the NRC, in collaboration with the State of Michigan, recently permitted certain very low activity wastes from the decommissioning of the Big Rock Point nuclear power plant to be sent to a RCRA Subtitle D (solid waste) landfill. Other States, such as Texas, have also determined that these landfills may offer sufficient protection for certain types of radioactive material, such as material with very short half-lives, and have included provisions in their State regulations that define the kinds and amounts of radioactive waste that may be disposed of in these facilities. Similarly, at a number of USDOE sites, on a case-by-case basis, the USDOE, in coordination with the State regulators, has approved authorized limits for waste disposal at specific solid waste landfills. The authorized limits are established so as to ensure that no special regulatory requirements beyond those already in place for the landfill are necessary.

6.2. Uranium mill tailings impoundments

Uranium mill tailings impoundments in the USA can also potentially be used for the disposal of some low activity materials. These facilities are currently regulated under the NRC's regulations in 10 CFR Part 40, which are based, in part, on the EPA's RCRA hazardous waste standards. The mill tailings regulations include specific provisions for, among other things, radiation protection, radon mitigation, and long term care and ownership by the USDOE or the State in which the facility is located, with NRC oversight of long term care provisions. Despite these additional protective measures, which are above and beyond those specified for hazardous waste facilities, only uranium mill tailings have been disposed of in the facilities to date. Several issues have posed obstacles to the disposal of radioactive waste other than mill tailings in these impoundments. For example, under certain circumstances, the USDOE is authorized to accept responsibility for the long term management of uranium mill tailings sites. If other nuclear fuel cycle waste types were to be disposed of, the USDOE would have to be consulted to ensure that it would accept the responsibility and that it has the authority, under law, to accept these materials for long term care. Other issues affecting direct disposal are the need to obtain LLW Regional Compact approval, and, for the disposal of TENORM and mixed hazardous and radioactive waste, the introduction of another regulatory organization with oversight of the impoundment, or dual regulation. The NRC and Agreement States only have authority over the mill tailings in the impoundment, and do not have regulatory jurisdiction over TENORM or hazardous waste.

Some cleanup waste has been disposed of in mill tailings impoundments through a process called 'alternate feed' material. Since there are certain issues associated with direct disposal of waste in these impoundments, some

LAW generators have sent their uranium bearing waste to mills for processing to remove the residual uranium. Instead of using uranium ore as feed material for the milling process, waste containing uranium is processed in the mill in a manner similar to that for natural ore. The tailings resulting from this processing meet the definition of by-product material, and can legally be disposed of in the tailings impoundment. Through this process, some uranium is recovered and used, and a disposal pathway, not normally available for such materials, becomes viable. A regulatory approval is necessary before such material can be processed at the uranium mill.

6.3. Disposition of solid materials

Closely related to the disposal of radioactive materials in a municipal waste landfill is the 'disposition of solid materials'. The NRC currently has guidance that allows for the release of radioactive material from licensees, on a case-by-case basis and at a level consistent with radiation doses to a critical group of up to a few tens of microsieverts per year, as well as a case-by-case regulatory approach for alternative disposal. Currently, the NRC is conducting an enhanced participatory rulemaking process on disposition of solid materials to determine whether a dose based regulation is appropriate. The NRC conducted an information gathering exercise as part of this effort; it included eight meetings with stakeholders and the receipt of nearly 4000 letters and emails from stakeholders. A diverse spectrum of views has been collected, including the concern of the metals and cement industries about economic impact, citizens groups concern about health impacts, and licensee groups views that there are negligible health impacts associated with releases at the low dose levels under consideration. The US National Academies, provided a report to the NRC with nine recommendations; including that, while the NRC's current approach is sufficiently protective of public health, the NRC should move ahead to evaluate alternatives [11]. The NRC's current approach, they believed, while protective of public health and safety, is inefficient in that it lacks an overall risk basis, consistency, up-to-date measurement basis, and regulatory finality.

The NRC is continuing to analyse rulemaking approaches with regard to alternatives that would result in (a) retention of the current approach by allowing unrestricted use through measurement based guidelines or (b) modification of its regulations to: (i) restrict release to only certain authorized paths such as restricting material to disposal in EPA regulated landfills, conditionally using material (e.g. roadbeds, reuse of tools), and allowing case-by-case requests; (ii) allow release to only licensed low level waste disposal facilities (‘prohibition’); or (iii) allow release of material with no limitation on pathways if a radiation survey verifies that levels are acceptable (‘clearance’).

It is planned to send the rulemaking package, which includes a draft Generic Environmental Impact Statement (GEIS), to the Commission of the NRC in March 2005. It is anticipated that the rulemaking package will then be issued for public comment during mid-2005 to solicit comments on the proposed rule and the alternatives and approaches presented in the draft GEIS. In preparing the GEIS, the NRC staff is taking into consideration stakeholder comments, and is considering a number of release and control alternatives that include dose based approaches including international and national consensus standards, restricted release, and disposal only. Consideration is being given to implementing the nuclide concentrations contained in the International Atomic Energy Agency (IAEA) Safety Guide No. RS-G-1.7, “Application of the Concepts of Exclusion, Exemption, and Clearance” since its use promotes consistency among nations, and would tend to minimize any interference with international commerce. However, no decision on its use has been made at this time.

6.4. Restricted release of contaminated sites

LAW from remediation of sites and decommissioning is also affected by risk management decisions regarding the release of sites. LAW from contaminated sites may be allowed to remain onsite under certain circumstances, and often after the more highly radioactive materials have been removed. The USDOE plans to leave in place certain radioactive materials at more than 100 sites; in this context, it will require long term management (institutional controls) to ensure that uses of the land by humans are safe and that residual radioactivity and barriers are functioning as intended. At many USDOE sites, much of the waste from cleanups will be disposed of on site in CERCLA disposal cells that are likely to require perpetual control. The NRC’s licence termination rule allows for a ‘restricted use’ option, although unrestricted release is the NRC’s preferred option. For the restricted use option, some residual radioactivity may be left on site after the termination of licences, provided that institutional controls are put into place, and that the radiation dose, assuming the controls fail, would be no more than 1.0 mSv/a (100 mrem/a). Finally, the Superfund Program administered by EPA has a long history of permitting residual materials, both chemical and radioactive, to remain on site provided that a reliable system of institutional controls is established. CERCLA requires a review every 5 years to ensure that the controls are continuing to function.

The NRC's criteria for termination of a licence and release of a site allow for some residual radioactivity to remain at the site. The rule allows for unrestricted release of a site if residual radioactivity, after termination of a NRC licence, is present in amounts that would cause no more than a 0.25 mSv/a (25 mrem/a) radiation exposure to an average member of the critical group. The rule also allows for restricted release of the site provided that there are institutional controls in place to limit potential exposure to 0.25 mSv/a (25 mrem/a). For restricted release sites, the rule also requires that radiation doses would be no more than 1.0 mSv/a (100 mrem/a) if institutional controls were to fail. A limit of up to 5 mSv/a (500 mrem/a) can be approved in rare cases. Recently, the NRC developed a new policy involving the use of a long term control licence as the institutional control and enforcement mechanism for use in some cases. In any case, the baseline radiation exposure criteria are used to establish a floor below which material left on site is considered to be 'residual radioactivity', and not LAW that would require, for example, offsite disposal

6.5. Use of more realistic scenarios in dose modelling

Another factor that affects the amount of LAW generated during site cleanups or decommissioning of facilities are the scenarios used to analyse exposures of humans to radioactive materials. In the past, for example, the NRC has used the "resident farmer" as the default scenario in screening analyses for termination of licences, although site specific analyses allowed other scenarios to be used if justified. Recently the NRC clarified its policy; more realistic scenarios should be used, based on a reasonably foreseeable future land uses at sites (e.g. the next few decades to possibly 100 years), and considering advice from land use planners and stakeholders.

One recent case in which the NRC utilized more realistic scenarios involved a former US Army site (the Watertown General Services Administration site in Massachusetts) that handled depleted uranium fragments from munitions. To establish a suite of credible future land use scenarios, a panel of government officials and local stakeholders was convened. This panel included representatives of the Army, the State Department of Health, the State Department of Environmental Protection, the local township development authority, and the town itself. The panel concluded that the most credible future uses for the site fall within the broad categories of public or recreational uses. The panel specifically concluded that the following scenarios were to be considered in assessing radiation exposures — construction worker, occupational worker, recreational facility user, and community gardener. The panel considered other scenarios, such as full time residency or exclusive use of the site for farming, to be either not consistent with the location of the property in a high-population density area, or with the future development plans of the town. Because compliance with the 0.25 mSv/a (25 mrem/a) dose criterion was possible with the selected scenarios, NRC released the site for unrestricted use. No removal of contaminated soil, i.e. low activity waste, was necessary.

7. SUMMARY

Based on economic, safety, and environmental concerns, interest in LAW management in the USA is high. The USA has developed several alternative methods for management and disposal that differ from those methods that are used for conventional LLW resulting from the operation of nuclear facilities. Extensive cleanup of facilities, especially in the USDOE complex still remains to be completed, and in the decades ahead, US nuclear power plants will also need to be decommissioned. The USA will continue to explore safe, effective, and efficient methods for the management and disposal of LAW.

REFERENCES

[1] NATIONAL RESEARCH COUNCIL OF THE NATIONAL ACADEMIES, Improving the Regulation and Management of Low Activity Radioactive Waste. Washington DC (2003). National Academy Press.

[2] U.S. ENVIRONMENTAL PROTECTION AGENCY, Approaches to an Integrated Framework for Management and Disposal of Low Activity Radioactive Waste, Advance Notice of Proposed Rulemaking. U.S. Federal Register Notice, November 18, 2003, Volume 68, No. 222. pp 65120-65151.

[3] U.S. DEPARTMENT OF ENERGY, United States of America National Report: Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. DOE/EM-0654. May 2003.

[4] U.S. DEPARTMENT OF ENERGY, Testimony of Jessie Roberson, Assistant Secretary for Environmental Management, before the Committee on Energy and Natural Resources, U.S. Senate, June 17, 2004.

[5] U.S. ARMY CORPS OF ENGINEERS, History of Formerly Utilized Sites Remedial Action Program. Available at http://hq.environmental.usace.army.mil/programs/fusrap/fusrap.html.

[6] U.S. ENVIRONMENTAL PROTECTION AGENCY. Comprehensive Environmental Compensation and Liability Information System. Available at http://www.epa.gov/enviro/html/cerclis/.

[7] NATIONAL RESEARCH COUNCIL, Evaluation of Guidelines for Exposures to Technologically Enhanced Naturally Occurring Radioactive Materials, Washington DC 1999. National Academy Press. Pp 106-182.
[8] *Ibid,* pp 111-112
[9] CONFERENCE OF RADIATION CONTROL PROGRAM DIRECTORS, Suggested State Regulation: Regulation and Licensing of Technologically Enhanced Naturally Occurring Radioactive Materials. March 31, 2004.
[10] RESOURCES FOR THE FUTURE, Cleaning Up the Nuclear Weapons Complex: Does Anybody Care? Katherine N. Probst and Adam Lowe. January 2000.
[11] NATIONAL RESEARCH COUNCIL, The Disposition Dilemma: Controlling the Release of Solid Materials from Nuclear Regulatory Commission-Licensed Facilities," 2002. National Academy Press

THE MANAGEMENT OF LOW LEVEL WASTE IN FRANCE

F. JACQ
Agence nationale pour la gestion des déchets radioactifs,
Châtenay-Malabry, France
Email: francois.jacq@andra.fr

Abstract

Historically speaking, industrial disposal systems for radioactive waste disposal were first developed for low level radioactive waste. In this field, France already has more than 35 years of experience in the surface disposal of low and intermediate level short lived waste (LL/IL–SLW). That experience allows us to take stock of the situation and to look to the future. After presenting an overview of the different waste categories and showing how important it is to implement a specific management system for each of them, this paper will focus on low and intermediate level waste (LL/ILW). It will address how waste management methods were initiated in French surface disposal facilities, namely through the experience gained at the Centre de la Manche, and the knowledge acquired concerning the transition to the post-closure monitoring phase of that facility. It will also describe the new generation of surface disposal facilities for LL/ILW, as represented by the Centre de l'Aube. After more than 10 years of operation, a first status report is presented on the nature and amount of waste present on the site, the associated waste acceptance criteria, the operation of the facility, the environmental monitoring programme and the costs. In conclusion, the system is shown to be a robust system for ensuring the safe disposal of LL/ILW. The facility will be maintained in service for several decades. It is expected that there will continue to be considerable flexibility in waste management approaches at the facility consistent with safety requirements, in order to take account of new types of waste packages.

1. RADIOACTIVE WASTE CLASSIFICATION AND MANAGEMENT SYSTEMS

France applies its own classification for radioactive waste, based on the activities and radioactive half-lives involved. Table I shows the different waste categories in the French waste classification as well as the current status of existing or investigated management solutions in each case.

The classification is particularly helpful in order to ensure that an appropriate management system, commensurate with the characteristics of the waste, is implemented for every waste category. Although it is possible to

TABLE 1. WASTE CLASSIFICATION AND MANAGEMENT SYSTEM IN FRANCE

Half-life Activity	Short lived < 30 years	Long lived > 30 years
VLL Very low level	VLLW Disposal Facility	
LL Low level	Centre de la Manche Disposal Facility Centre de l'Aube	Disposal project for radium bearing and graphite waste
IL Intermediate level	LL/ILW Disposal Facility	
HL High level	Research on deep geological disposal carried out in accordance with the Law of 30 December 1991	

determine the orders of magnitude of the relative activity of the waste in each category, limits do not only involve numerical values, but also radiological or chemical properties specific to each category. Therefore, a detailed examination is carried out for each category with a view to ensuring the relevancy of the management system involved.

The following paragraphs describe a few basic features of the major waste categories:

— the activity concentration of very low level waste (VLLW) is close to natural background levels. Most VLLW result from the dismantling of nuclear facilities, but may also be generated by industries using naturally occurring radioactive substances. An industrial solution has existed for VLLW since 2003 in the form of a specific VLLW disposal facility, located in the village of Morvilliers, Aube Department, near the LL/ILW disposal facility. It should be noted that tailings originating from the exploration of uranium mines are also considered as VLLW. Those tailings amount to more than 50 million tonnes and have been kept on their original sites where special areas have been designed to ensure their safe disposal;

— low and intermediate level short lived waste, LL/IL–SLW results in part from the operation of nuclear power plants and their associated industrial facilities. It normally includes items such as gloves, coats, etc., or technological waste contaminated with radioactivity. It may also result from nuclear medicine or from research or industrial laboratories using radioactive substances in support of their work. A specific management system has been implemented for this waste category in the form of a surface disposal facility in the village of Soulaines, Aube Department;

— low level long lived waste (LL–LLW) results mainly from two sources: the use of naturally occurring radioactive raw materials, illustrated notably by the use of radium before the Second World War and the graphite waste generated by the first generation of gas–graphite reactors (GGR). No final industrial solution exists today for this waste category, but ANDRA is carrying out investigations in order to determine appropriate disposal solutions;
— high level and intermediate level long lived waste (HL/IL–LLW) is produced by the reprocessing of spent nuclear fuel after its removal from nuclear power plants (NPPs). It comprises two types of waste: high level waste (HLW), in which most of the radioactivity of the fuel is concentrated (fission products and minor actinides), and intermediate level long lived waste (IL–LLW) which includes the technological residues resulting from reprocessing or research activities. The HLW is conditioned in a glass matrix. No final management solution exists for this waste category, but the Law of 30 December 1991 prescribed a 5-year research programme whose results will be considered in a parliamentary debate in 2006 on the management solutions to be selected.

This paper focuses primarily on the management of LL/IL–SLW by describing the relevant facilities and the procedures set in place for that purpose.

Several observations, however, may already be made at this stage:

— the purpose of management systems already in place or under investigation is to provide technical solutions against the risks associated with the different waste categories. That principle mainly determines the definition of the specifications for the various disposal facilities. Thus, the feasibility study for a repository for HL–LLW is focusing on deep geological formations at a typical depth of several hundreds of metres below the surface. Such a depth appears necessary in order to isolate the waste from human beings and the environment, with due account taken of the necessary facility lifetime required and the long term phenomena relating to climatic and geomorphological changes. On the other hand, in the case of LL/IL–SLW, surface disposal seems to ensure a sufficient isolation and protection level consistent with safety standards. The same conclusion applies to VLLW. Between both solutions, shallow disposal at depths exceeding 15 metres seems appropriate for the disposal of low level long lived waste (LL–LLW), since it would protect the waste from intrusion and erosion over a few centuries. The French policy has been to proceed with a detailed examination of the nature of each type of waste and a comprehensive assessment before finalizing any specific management system;

— disposal facilities constitute essential tools for waste management. However, they involve a series of prior measures to be implemented by the waste producers themselves: sorting, characterization and definition of conditioning methods. To the extent possible, the development of these predisposal measures must be made in close relationship with the proposed development of the disposal facility. Although this aspect is very important and would deserve to be described at length, it is sufficient, within the scope of this paper, to explain how the waste manager defines his waste package specifications and controls their implementation. In addition, it is important to distinguish large producers (i.e., those generating nuclear power) from occasional producers. The waste generated by the latter often consists of small quantities of low level waste of the order of approximately 100 m^3 per year and may create potential risks, if it is not conditioned properly, dispersed or neglected due, for example, to the often limited technical means of its owners. It is therefore for the benefit of these owners that collection and support mechanisms have been introduced in the early stages of the waste management procedure to provide a standardized service and to comply with the strict safety and quality assurance rules;

— radioactive waste exists in a wide variety of types and categories. In order to have an overall view of the situation, public authorities have requested suitable support to ensure comprehensive and safe management. To that end, the Law of 30 December 1991 established the independence of the French National Radioactive Waste Management Agency (Agence pour la gestion des déchets radioactifs – ANDRA) from waste producers. ANDRA is the organization responsible for the long term management of radioactive waste in France. Through its expertise and experience, the Agency supports the government’s policy on the management of radioactive waste by means of three closely related missions: research, industrial management and public information. The activities described in this paper all pertain to ANDRA’s industrial mission.

2. FIRST EXPERIENCE IN SURFACE DISPOSAL: THE CENTRE DE LA MANCHE

The development of radioactive waste management strategies was initiated very early and the first management systems were launched during the

1960s and 1970s. In many countries, radioactive waste was still being dumped in deep oceanic trenches throughout the 1960s. In France, that practice was abandoned in the second half of that decade and replaced by a reference strategy that has been maintained since then and consists in disposing LL/ILW in surface disposal facilities.

In 1969, the Centre de la Manche was commissioned as the first French surface disposal facility for radioactive waste. It is located on the shores of the English Channel, in the Cotentin Peninsula, close to the La Hague spent fuel processing plant. The facility was built and managed first by the French Atomic Energy Commission (Commissariat à l'énergie atomique – CEA), but was taken over some years later by ANDRA.

The facility constituted the first industrial achievement in the field of waste disposal. It was in operation from 1969 and 1994 and accommodated a total of 527 000 m^3 of waste packages.

The following examples illustrate this early experience and will be mentioned again in the context of the development of Centre de l'Aube in order to show how it was taken into account:

— requirements concerning waste packages and their nature were only developed gradually, which means that a non-negligible quantity of chemical compounds (e.g. lead) or long lived radioelements was accepted in the early years. In addition, the strict monitoring of waste package inventories only started in 1980. At that time, such practices were considered as conventional for managing LL/ILW, but it was shown that they needed to be improved, since waste packages represent a key element of the disposal system;
— at first, the waste was deposited directly into open ground trenches without any protective system against rainwater and without any collection network for potentially contaminated waters. In 1976, a serious incident occurred when a significant contamination by tritium was detected in the neighbouring environment. The problem was resolved by creating a collection system for any water seepage coming in contact with the waste disposal structures. Later, the collection system solution was implemented fully and systematically at the Centre de l'Aube;
— certain waste packages were conditioned in metal containers which corroded rapidly after the closure of the facility with the risk of causing subsidence in the cover.

The design of the LL/ILW Disposal Facility commissioned at the Centre de l'Aube in 1992, benefited from the experience gained at the Centre de la

Manche not only with regard to the technical design of the disposal structures, but also in relation to the monitoring of the accepted waste packages.

At the end of the operating period of the Centre de la Manche facility, a cover, consisting of an extensible waterproof membrane and of several layers of soil, was installed over the waste area. The purpose of the cover was to protect the disposal facility and to isolate the waste from the environment in the long term. The Centre de la Manche facility has entered into a monitoring phase which will last for several centuries. Monitoring activities include a series of multiple controls for the purpose of ensuring the integrity of the cover and the sound operation of the installations.

It should be noted that the transition into the monitoring phase was examined from a regulatory standpoint as early as the beginning of the 1990s. The French government created an independent committee chaired by Mr Michel Turpin with the mandate to analyse the status of the facility, including a detailed re-evaluation of its waste package inventory, an overall safety assessment of the site, observations on the possibility of recovering the waste and the description of suitable measures to be applied during the monitoring phase.

In its conclusions, the Committee highlighted the fact that the facility did not pose any risk for the environment. It also recommended new measures during the following three monitoring subphases: very active monitoring for approximately 10 years, active monitoring during a few decades and passive monitoring up to the 300 year term. It also felt that a full derestriction of the site at the end of the monitoring period was not possible. Lastly, it recommended that the performance of the cover be checked, with the possibility of modifying the cover if required. The recommended measures for the very active monitoring of the environment and of the installations were implemented immediately. After various public inquiries, the facility officially entered into its monitoring phase in January 2003. The associated decree prescribed ANDRA’s obligations in relation to it.

Monitoring activities at Centre de la Manche comprise more than 10 000 radiological and chemical measurements carried out every year on samples of water, sediments, air and the food chain. Those measurements allow for the permanent control of the environment and of the waste isolation systems. They show that the impact of the facility on its environment is very low and that the regulatory limits on radioactivity levels are not exceeded. The performance of the cover is also monitored and major installations (including the underground water collection system) are carefully maintained in order to determine the need for any corrective actions.

The implementation of long term records is an important issue for the safety of any disposal facility. In the case of the Centre de la Manche, such an endeavour was considered to be an essential part of the preparations for the institutional control period. Data were selected in order to maintain a good knowledge of the facility, to understand the evolution of technical or environmental monitoring results and to perform any corrective actions, as required. A summary document was also issued to maintain a memory of the main features of the disposal facility. Long term records are also important to help build public confidence in the monitoring procedure. Since documents will be used by future generations for a few centuries, hard copies were made on high quality paper called 'permanent paper'. The experience with long term documents at the Centre de la Manche facility shows that the data must be collected promptly at the time of operational activities. Adequate procedures have therefore been established for both facilities at the Centre de l'Aube.

Hence, the Centre de la Manche constitutes a very useful technical tool, because it is now possible for the first time to have experience of the monitoring programme of a full scale disposal facility and to learn fruitful lessons from the experience. Finally, it illustrates the continuing improvement approach based on experience with regard to the safety and design of industrial facilities.

3. A NEW GENERATION OF DISPOSAL FACILITIES

While the Centre de la Manche was reaching its waste capacity limit at the end of the 1980s, a project was launched to create a new disposal facility. The new LL/ILW disposal facility was implemented in the village of Soulaines-Dhuys, Aube Department, and gradually started to take over from the Centre de la Manche facility (Fig. 1).

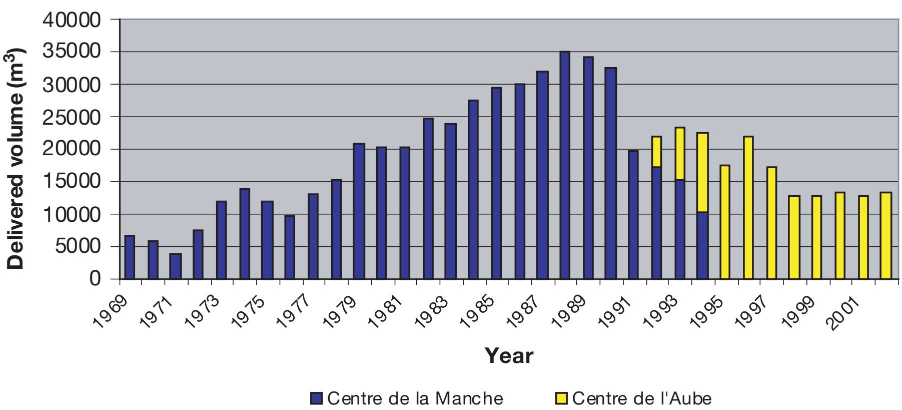

FIG. 1. Waste package deliveries to the Centre de la Manche and the Centre de l'Aube facilities.

3.1. Safety principles

The French surface disposal concept for LL/IL–SLW relies on a multi-barrier system to isolate radioactivity from the public and the environment, as follows:

- — the first waste isolation system is the physical form of the waste itself. It must be solid and encapsulated or immobilized in the waste package;
- — the second barrier is consists of suitable engineered structures to prevent any contact between water and radioactive substances;
- — the third barrier is the disposal site itself. In case of degradation of the first two barriers, it must limit the impact of any radioactive release to an acceptable level.

The disposal facility and its surrounding environment must be monitored for as long as the waste poses a potential hazard. Accordingly, the life cycle of the facility is divided into three periods:

- — an operating period during which waste disposal operations take place;
- — a post-closure institutional monitoring period, lasting as long as the release of disposed materials may cause significant radiological impacts, but not exceeding 300 years;
- — a post-institutional monitoring period starting when it is assumed that the integrity of artificial barriers (packages, engineered structures) cannot be guaranteed. Safety therefore relies on the natural barrier (disposal site) and on the management of the radioactive inventory of the disposal facility in order to ensure that any residual activity is sufficiently low for any potential impact to be harmless.

3.2. Nature of waste packages

In France, most LL/ILW is generated by the different activities of the nuclear industry. The waste may contain a relatively small amount of long lived emitters. More precisely, the mean specific activity for alpha emitters in a surface repository must not exceed 0.37 GBq/t (0.01 Ci/t).

NPPs represent the major source (50%) of the deliveries, although their input has considerably decreased, by a factor of 3.5, over the last 15 years. The other main contributors are:

- — fuel cycle waste, including tailings from the conversion and enrichment of uranium and from the fabrication of fuel assemblies;

— waste from reprocessing plants, consisting mainly of technological residues;
— waste arising from research in the nuclear field, conducted by the CEA.

Small producers (i.e., hospitals, research and non-nuclear industries) located on approximately 1000 sites also generate a small waste stream (2%). ANDRA collects the waste and for this purpose it has set up a specific support organization to characterize and to condition the waste into a suitable form for disposal. Part of the waste generated by NPPs, reprocessing plants, research centres and small producers is incinerated or melted in the dedicated ‘Centraco’ facility located near Marcoule (Rhône Valley). All waste treated in that facility is also sent to the Centre de l’Aube.

Twelve different standard types of disposal packages are commonly used by waste producers to condition their waste: metal drums (100, 200, 450 and 870 L), metal boxes (5 and 10 m^3), concrete drums (0.66, 1.2 and 2 m^3) and concrete boxes (3.7 and 5 m^3). With such a variety of packages, it is easy to adapt the packaging to the size and activity level of the waste. However, consideration is also given to non-standard waste forms.

3.3. General design of the facility

The site was selected because of its very simple geology for safety purposes: a layer of sand above a layer of impermeable clay. The groundwater outlet in the sand layer is well identified: it consists of a small river flowing through the facility and provides for an accurate monitoring of the site. The facility is built on the sand layer. The nuclear site has a surface of 60 ha, exactly half of which is dedicated to the disposal area which has a total capacity of 1 000 000 m^3 of waste packages.

The design of the facility took into account the lessons learnt from the Centre de la Manche. The waste is deposited in large concrete structures under which is built an underground drainage network consisting of channels designed to collect any water seepage through the disposal structures. So far, hardly any water has been collected from the sealed structures. Regular controls are made to check if the collected water is contaminated and retention tanks have been installed for that purpose, but no contamination has been detected so far.

The waste packages are protected by large metal covers while being placed in the disposal structures, in order to prevent any contact with rainwater and, consequently, any potential release to the environment. The lessons learnt from the Centre de la Manche have contributed to the development of this strategy.

The waste packages may be of two types. They may be conditioned in concrete containers in order to ensure their mechanical stability over extended periods of time. In this case, they are disposed of directly into concrete disposal cells, and any voids between them is filled with gravel. They may also be placed in corrodible metal containers, in which case, each waste layer is grouted in the disposal cell in order to ensure the overall stability. Hence, precautions have been taken to prevent any risk of subsequent settlement within the disposal facility.

The design of the second generation of disposal facilities demonstrates an evolutionary approach providing control over the ongoing disposal procedure and ensuring future safety.

3.4. Waste package acceptance procedure

According to the 1989 Order constituting the Centre de l'Aube, ANDRA shall certify all package types prior to delivery. The certification implies that ANDRA must confirm that all packages comply with the waste acceptance criteria of the disposal facility. At the end of 2002, about 130 certificates were 'effective'. Some of them are generic and apply to the waste originating from various, but similar, facilities. One certificate, for instance is valid for the ion exchange resins produced by French pressurized water reactors (PWRs). The purpose of the certification procedure is to provide an explicit operational definition of any package type used to condition waste in order to comply with ANDRA requirements.

The certificates are issued on the basis of the technical criteria determined by ANDRA when the facility was commissioned. The criteria were revised in 2000 in the form of new specifications. This section describes the overall procedure — from the definition of specifications to the acceptance of waste packages and their final control.

The general criteria concern all packages. They provide requirements on the physicochemical properties of the waste: inert material only, no free liquid. They focus on the radiological characterization of the package, particularly on the identification of potential radionuclides. A list of 143 radionuclides has been drawn up as part of a procedure intended to detect any waste that may generate higher levels of activity than taken into account in the safety assessment. Activity limits are derived from the safety scenarios. Some limits are prescribed to avoid any 'hot spots' in the disposal facility. Long lived beta emitters belong to that category. Requirements are expressed in terms of activity limits per specific mass.

Another highlighted aspect in ANDRA's new specifications is the identification of materials that may have a chemical impact. Those requirements are partly derived from regulations relevant to disposal facilities for non-radioactive substances, such as lead, boron, nickel, chrome, antimony, selenium, cadmium, mercury, beryllium, arsenic, free cyanides, ammonia and asbestos. Limits for these materials must be established in the waste packages.

A detailed description of containment properties is specified. Containment properties may be obtained either from the leaching performances of the waste embedding matrix, in the case of a 'homogeneous waste', or by a 'containment barrier' provided by a sufficient thickness of concrete around the waste (Fig. 2). The diffusion coefficient of concrete (using tritiated water as a reference material for diffusion) is specified depending on the thickness of the barrier.

Some parameters specified by ANDRA may actually be monitored directly on the waste package or during the fabrication process. The weight of a package, for instance, may be measured and compared with the maximum specified weight; radiation dose rate may also be measured. Other parameters are impossible to control directly during the package fabrication process: such is the case for containment parameters (i.e. leach rate, diffusion coefficient). For those parameters, it is necessary to destroy the package and to perform experiments of duration of up to, and more than, one year.

During the certification procedure, investigations are therefore made in order to determine compliance with the parameters specifications for the package or for the conditioning process. They are monitored during the fabrication process to ensure compliance with ANDRA requirements. For example, for the diffusion coefficient, the operational parameters may include the composition of the cement constituting the diffusion barrier, its water content, etc.

FIG. 2. Two ways of achieving containment.

The choice of operational parameters relies on a qualification step. Experiments are performed on prototype packages or samples to demonstrate compliance with the waste acceptance criteria. Such investigations are performed by the waste producer, with ANDRA's support, for each technical disposal requirement. A description of the package model which is consistent with the actual package that the producer agrees to manufacture must be provided before ANDRA agrees to it being allowed to go into the disposal facility. Hence, the certification procedure leads to an operational definition of the package in accordance with ANDRA requirements and associated relevant quality assurance procedures (Fig. 3).

Through the certification procedure, ANDRA is confident in the waste producers' ability to manufacture sound waste packages. ANDRA must maintain that confidence by monitoring the quality of packages on a constant basis.

Different monitoring approaches have been implemented. All packages are controlled upon delivery at the Centre de l'Aube, especially for radiation dose rate and surface contamination. Audits are performed by ANDRA in waste producers' facilities. Approximately 60 audits are carried out every year. Deviations are analysed with a follow-up of corrective actions. Another important tool consists of destructive and non-destructive tests on actual packages. Those tests constitute an important aspect of ANDRA's surveillance. Packages to be investigated are selected upon delivery at the disposal facility. Between 150 and 300 non-destructive tests, as well as 10 to 15 destructive tests are conducted every year. In relation to the 25 000 to 30 000 delivered packages

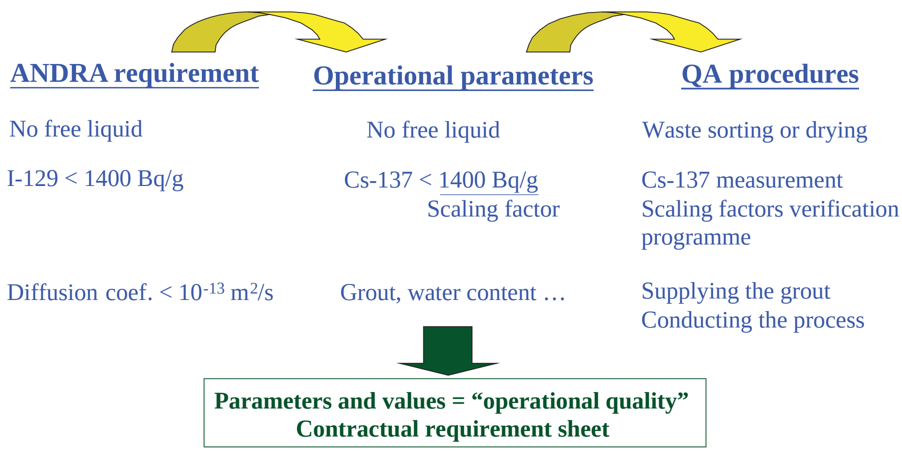

FIG. 3. General flow chart of agreement process and examples.

and to the 130 certification files, those tests do not have a statistical meaning. However, the data collected during the 1500 non-destructive tests and the 200 destructive tests provide significant information that may be used to adjust some conditioning processes or parameter evaluations. A criterion used to select packages for investigation purposes is their significance in relation to the overall radioactive inventory. Tests also focus on recently certified packages. Depending on the type of packages, non-destructive tests involve weight, dimensional controls, dose rate, surface contamination, gamma spectrometry, gammagraphy, X radiography and neutron measurements. Destructive tests are used to investigate the waste content of the packages and the general quality of the conditioning. Cores or samples are taken to allow the measurement of mechanical strength, diffusion coefficient and leaching rate. Alpha or beta emitters (especially long lived beta emitters) or chemical compounds are also investigated.

Feedback from the experience of Centre de la Manche shows that it is essential to ensure the strictest monitoring and control possible over the waste packages. The measures described above constitute effective tools to ensure such monitoring. In addition, a rigorous computerized waste inventory has been created with an individual control of every package, thus providing an uninterrupted traceability of every waste package from the producers' premises up to the disposal cell.

3.5. Status report on the operation of the facility

At the end of 2003, 200 000 waste packages occupying a volume of approximately 150 000 m^3 had been disposed of in the facility and represent about 15% of its total capacity. Among the 82 existing disposal vaults, 61 have already been completely filled and sealed.

The first 12 years of operation have shown that the standard types of accepted waste packages are able to meet most of the waste generators' needs. However, it appears that specific packages might occasionally be useful for large waste items. Forty cubic metre metal boxes containing storage racks for spent fuel have been conditioned and disposed of within the vaults. Specific vaults are under construction for the disposal of 52 reactor vessel heads, scheduled to start in 2004.

In parallel, the repository content in relation to the radiological capacity prescribed for the facility in the safety report and the constituting decree is being carefully monitored. It shows that that the allocated space is being used cautiously, and at a lesser rate than the volume capacity, especially in relation to the fraction of long lived radionuclides that are inevitably present in some waste packages. The presence of these radionuclides is regulated very strictly.

A maximal capacity was prescribed on the basis of the estimations conducted during the safety assessment. The radiological capacity consumption corresponding to a 15% volume consumption amounts to less than 10%.

At the same time, close to 17 000 measurements are made every year in the neighbouring environment of the facility. So far, no significant environmental impact or contamination has been detected. Similarly, the underground drainage network has collected no contaminated water under the disposal structures. Those results demonstrate the effectiveness of the existing mechanisms for isolating the waste from human beings and the environment.

Another important aspect is the operating cost of the facility, since the costs of the management of LL/ILW must remain under strict control. The Centre de l'Aube represents an initial investment of approximately 200 M€ financed by three major French waste producers (CEA, COGEMA and EDF). The overall annual technical cost of the facility (excluding income tax and insurance) amounts to approximately 25 M€, corresponding to an effective cost of 1700 €/m^3. It should be noted that such a cost has been optimized over time and has been stable for several years.

ANDRA's overall industrial process has been granted the double ISO-9001 and ISO-14001 certification since 2001, thus confirming the Agency's concern and determination to comply with strict prescriptions in terms of industrial rigour and environmental protection.

4. PROSPECTS

In France, the current management system for LL/IL–SLW benefits from the existence of mature industrial tools. Several decades of experience have allowed surface disposal to become a reference solution with widely demonstrated advantages in terms of safety, reliability and robustness. Now that the Centre de la Manche has entered into its post-closure monitoring phase, it will be possible soon to assess, in more detail, the constraints associated with the long term surveillance of such facilities. Moreover, the lessons learnt from its operation were taken into account in the design of the second generation facility at the Centre de l'Aube in the framework of a continuously evolving approach, thus resulting in a more effective industrial system with no significant impact on the environment. The system relies on a very strict control of waste packages. In addition, the disposal facilities have demonstrated their flexibility throughout the years and their capability to accommodate a diversified array of waste categories, provided that a careful safety assessment is carried out. In the summer of 2004, the disposal of reactor vessel covers from EDF, the electrical utility, constitutes another example of that capability to accommodate new challenges. So far, the Centre de l'Aube has accepted approximately 150 000 m^3 of waste packages, representing 15% of its total capacity. With an average annual disposal rate varying between 10 000 and 15 000 m^3 and with a total capacity of 1 million cubic metres, the facility should remain in operation for close to 50 years. Using these disposal facilities, France has the means to manage the waste produced by the nuclear power industry and also the waste produced by all the activities involving the use of radioisotopes in medical, industrial and research applications.

DISCUSSION

J. VANWILDEMEERSCH (Belgium): With regard to very low activity waste, is a policy of free release or industrial reuse foreseen?

F. JACQ (France): One should distinguish between, on the one hand, materials containing natural radionuclides and produced outside so-called 'basic nuclear installations' and, on the other, materials from such installations.

As regards the latter, there is no systematic free release. In principle, such very low activity waste should go to the very low level waste disposal facility opened at Morvilliers. However, specific studies may be carried out and the results submitted to the safety authority with a view to the release of particular materials. In such cases, an environmental assessment has to be performed. The general rule is that there should be no release 'a priori'.

As regards the former, the materials containing natural radionuclides, they may be disposed of at 'non-nuclear' disposal facilities provided that there are only small amounts of the material and that the impact on workers has been shown to be less than 1mSv/year.

It should be emphasized that a strategy of reuse has always been a very difficult issue. In particular, it raises concerns within the general public, which generally prefers to see a uniform radioactive waste management approach.

M. BEN BELFADHEL (Canada): What are the time frames for very long term monitoring in France?

F. JACQ (France): The general subject has not yet been fully clarified in France. However, one example I can cite relates to the monitoring at the low level disposal site at the Centre de la Manche. The general idea is that the monitoring of the facility will be less and less as the years pass.

At the Centre le la Manche, we are considering an initial phase of 20–30 years of 'very active' monitoring, followed by an approximately 50 year phase of 'active' monitoring and then by a phase of 'less active' monitoring. Throughout the monitoring period of 300 years (ten times the longest half-life of short lived radionuclides, taken to be 30 years) there will be institutional controls.

The general framework for monitoring will be gradually defined by the safety authority, taking account of developing experience.

POLICY ON MANAGEMENT AND DISPOSAL OF LOW LEVEL WASTE IN JAPAN

Y. KAWAKAMI
Japan Nuclear Energy Safety Organization,
Tokyo, Japan
Email: kawakami-yutaka@jnes.go.jp

Abstract

In Japan, under the national policy of limiting the use of nuclear energy to peaceful purposes, research, development and utilization of nuclear energy for the generation of electricity have proceeded with priority being given to ensuring safety. The producers of waste have the prime responsibility for disposing of radioactive waste and the regulatory body is responsible for establishing the necessary safety regulations. The basic policy for the disposal of radioactive waste is to develop disposal methods commensurate with the characteristics of the radionuclides in the waste (physical and chemical nature, half-life and activity concentration). For low level radioactive waste (LLW) and very low level radioactive waste (VLLW) arising from nuclear power plants, systems for safety regulation have already been established under the Nuclear Reactor Regulations Law and disposal activities have started. Discussions on institutionalizing a system for the clearance of materials from regulatory control in 2005 are under way. In the near future, it will be necessary to give consideration to the safe disposal of uranium waste and transuranic (TRU) waste.

1. BACKGROUND

More than 40 years have passed since Japan started on the development and utilization of nuclear energy and there are 52 commercial nuclear power reactors in operation and 3 others under construction. Currently, electricity from nuclear power accounts for one third of the total amount of all domestic electricity. In support of the development of nuclear power generation, nuclear fuel cycle facilities for uranium enrichment, fuel fabrication and reprocessing of spent fuel have been constructed and operated. In addition, there are many other facilities at which radioactive materials are being used. Some facilities have already reached the end of their useful lives; the gas cooled reactor (GCR) at the Tokai nuclear power station of Japan Atomic Power Company (JAPC) is the first commercial nuclear power plant at which commercial operation has been terminated. Decommissioning of the plant is already under way. Thus, the dismantling and removal of nuclear power plants from service have become actual activities in Japan.

The increase in the development and utilization of nuclear energy has been accompanied by an increase of the variety and amounts of the associated radioactive waste. In this paper, discussion will focus on the relatively institutionalized disposal of LLW arising from commercial nuclear power plants.

2. BASIC POLICY ON UTILIZATION OF NUCLEAR ENERGY IN JAPAN

In Japan, under the national policy of limiting the use of nuclear energy to peaceful purposes, research, development and utilization of nuclear energy for the generation of electricity have proceeded with priority being given to ensuring safety. This policy is specified in the Atomic Energy Basic Law. The national strategy for the long term development of nuclear energy is contained in the document Long Term Programs for Research, Development and Utilization of Nuclear Energy (Long Term Programs) formulated by the Atomic Energy Commission (AEC).

3. CURRENT STATUS OF UTILIZATION OF NUCLEAR ENERGY IN JAPAN

At present there are 52 nuclear power reactors in operation, 3 nuclear power reactors under construction and 1 nuclear power reactor at the decommissioning stage. As for the nuclear fuel cycle facilities, there are 4 fuel manufacturing facilities and 2 uranium enrichment facilities in operation and one reprocessing facility in operation and another under construction. In addition, there are 2 radioactive waste disposal facilities in operation.

In addition to these nuclear facilities, there are 2 power reactors used for research and development, one of which is at the preparation stage for decommissioning, 16 research reactors and more than 5000 facilities utilizing radioisotopes for medical, industrial and research purposes.

4. RADIOACTIVE WASTE MANAGEMENT POLICY OF JAPAN

Beginning in the first half of the 1980s, progress has been made towards establishing a basic policy to cover the disposal for each kind of radioactive waste and of the national institutional arrangements for making these disposals possible. The generators of radioactive waste have the prime responsibility for disposing of radioactive waste and the regulatory authority is responsible for establishing the necessary safety regulations. The AEC determines the national policy for the disposal of radioactive waste and then, on the basis of this policy, the Nuclear Safety Commission (NSC) establishes the basic policy for safety regulation. From the requirements of the policies of these two commissions, the regulatory authority establishes the associated laws and rules and implements them. One important element of the basic policy is that nuclear facilities have to be decommissioned safely.

As shown in Table 1, the basic regulatory framework for radioactive waste is specified in the Law for the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors (Reactor Regulation Law), the Law Concerning Prevention from Radiation Hazards due to Radioisotopes, etc. (Radiation Hazards Prevention Law), and the Medical Care Law. There are three nuclear regulatory authorities; they are the Nuclear and Industrial Safety Agency (NISA) of the Ministry of Economy, Trade and Industry (METI), the Science and Technology Policy Bureau (STPB) of the Ministry of Education, Culture, Sports, Science and Technology (MEXT) and the Ministry of Health, Labour and Welfare (MHLW). The NISA regulates nuclear power reactors, nuclear fuel cycle facilities and the radioactive waste management and disposal facilities for wastes arising from operation of nuclear power reactors and nuclear fuel cycle facilities. The STPB of MEXT regulates research reactors, facilities utilizing radioisotopes, radioactive waste arising from these facilities and radiation generation devices. The MHLW regulates medical care facilities.

The NSC formulates the basic concepts to be used in regulations and safety inspection guidelines and the regulatory authorities conduct their regulatory activities in accordance with the basic policy and guidelines. The NSC overviews the safety inspections conducted by the nuclear regulatory authorities.

The coordination of technical standards for radiation hazards prevention is carried out by the Radiation Review Council.

Concerning the status of the development of national legislation, the AEC has already established the basic policy on disposal of all types of radioactive waste and the NSC has established the regulatory principles for the safety regulation of high level radioactive waste (HLW) disposal. The next step will be to formulate the associated regulatory requirements. All matters related to the management and regulation of TRU and uranium waste have yet to be considered. The consideration by the national authorities of the basic policy, upper bounds of radioactive concentration, etc, for relatively high level LLW, such as reactor internals, has already taken place and policy has been established; the appropriate disposal depth and the associated technical standards

TABLE 1. REGULATORY BODIES AND SCOPE OF REGULATIONS

Laws	Scope	SF	RW	Regulatory Bodies
Reactor regulation law	Construction and operation of NPPs and power reactors at R and D stage Fuel cycle facilities	Yes	Yes	NISA/METI
	Construction and operation of research reactors			STPB/MEXT
Radiation hazards prevention law	Utilization of radioisotopes Radioactive waste (from radioisotopes use) Radiation generation devices	N/A	Yes	
Medical care laws, etc.	Medical facilities	N/A	Yes	MHLW

SF: Spent fuel management or storage facilities.
RW: Radioactive waste management or disposal facilities.

are still being considered. Criteria for regulating relatively low level LLW and VLLW have already been established. The NSC has completed its discussions on the basic policy relating to disposal of waste generated from utilization of radioisotopes in research, industry and medicine and will move on to the consideration of the remaining issues and the development of relevant statutes.

5. CLASSIFICATION AND METHOD OF DISPOSAL OF RADIOACTIVE WASTE

Radioactive waste as shown in Table 2, is divided into two categories in Japan, namely, HLW and LLW. HLW is generated from reprocessing of spent fuel. All remaining waste including uranium waste, TRU waste, the waste generating from operation and decommissioning of nuclear facilities are classified as LLW.

The basic policy for the disposal of radioactive waste is to establish disposal methods commensurate with the characteristics of radionuclides present in the waste, in terms of physical and chemical form, activity concentration, half-life, etc. For HLW, and a part of TRU waste, deep geological disposal has been determined to be the appropriate option. For LLW, different disposal methods are specified, based on the activity concentration of the radionuclide in the waste. For higher levels of radioactive waste within the

TABLE 2. CLASSIFICATION AND METHODS OF DISPOSAL OF RADIOACTIVE WASTES

Classification		Source	Repository
HLW		Reprocessing plant	Geological disposal
TRU waste		Reprocessing plant, MOX fuel fabrication plant	Geological/near surface disposal
Waste from NPP	Relatively higher radioactive waste	Reactor decommissioning	Intermediate depth disposal (Dispose at 50–100 m below the surface)
	Relatively lower radioactive waste	Operation and decommissioning of nuclear facilities	Near surface disposal with Artificial barrier
	Very low level waste	Operation and decommissioning of nuclear facilities	Near surface disposal without artificial barrier
Uranium waste		Uranium enrichment and fuel fabrication plant	Geological/near surface disposal
Waste from research facilities and radioisotope users		Research facilities, hospitals and RI licensees	Near surface disposal

☐ HLW waste ☐ LLW waste

category LLW (mainly, wastes of reactor internals, etc.), sub-surface disposal (disposal at intermediate depth of 50–100 m below the surface) is specified and for lower level radioactive waste within the LLW category, near surface disposal with artificial barriers is specified. The specification for VLLW is disposal in near surface repositories without artificial barriers.

For LLW and VLLW arising from nuclear power plants, the regulatory systems have already been established under the Reactor Regulation Law and disposal activities have started.

Since 1992, Japan Nuclear Fuel Ltd (JNFL) has disposed of LLW arising from commercial nuclear power plants in a near surface disposal site at Rokkasho-mura in the Aomori Prefecture. In 1996, Japan Atomic Energy Research Institute (JAERI) completed a near surface repository for VLLW (concrete rubble, etc.) generated from the dismantling of the Japan Power Demonstration Reactor (JPDR) within the site of its Tokai establishment. The operators of these two disposal sites have responsibilities for continuing the institutional control of the sites until the radioactivity in the waste decays with time such that the potential radiation exposure of the public which could be caused by the radioactive waste is reduced to a level below which it is no longer necessary to continue management from a radiation protection perspective.

6. DECOMMISSIONING OF NUCLEAR FACILITIES

The basic policy for the decommissioning of commercial nuclear power plants is that after the permanent termination of the operation of the reactor, all spent fuel is removed from the site and system decontamination completed. The nuclear power plant is then placed in safe storage for 5–10 years. Dismantling and removal of the facility are carried out after the safe storage period. After decommissioning, the plant site will be used for a new nuclear power plant, assuming acceptance by the local community. Some experience already exists of decommissioning nuclear power reactors in Japan. The demonstration projects for the decommissioning of JPDR by JAERI began in 1986 and were completed in 1996. The commercial operation of the GCR at the Tokai power station of JAPC, which was the first commercial nuclear power plant, was terminated in 1998 and decommissioning activities are proceeding. The operation of the Advanced Thermal Reactor (ATR) named Fugen of the Japan Nuclear Cycle Development Institute, which was being used for research and development, was terminated in 2003 and is now under preparation for decommissioning.

The amount of waste arising from the decommissioning of a typical 1000 MW(e) BWR is estimated as follows:

- Higher level part of low level radioactive waste (LLW) such as reactor internals, etc., amounts to about 100 t;
- Low level radioactive waste (LLW) amounts to about 2000 t;
- Very low radioactive waste (VLLW) amounts to about 10 000 t;
- Waste lower than clearance level amounts to about 9000 t;
- Non-radioactive waste amounts to about 495 000 t.

Subsurface disposal is used for the high level part of LLW, near surface disposal with artificial barriers is used for LLW and near surface disposal without artificial barriers is used for VLLW.

7. CURRENT STATUS OF RADIOACTIVE WASTE DISPOSAL FACILITIES

7.1. Rokkasho Low Level Radioactive Waste Disposal Centre

JNFL operates this LLW disposal facility. The functions of JNFL include the disposal of radioactive wastes, the enrichment of uranium and the reprocessing of spent fuels. This radioactive waste disposal facility is planned to have a capacity of 600 000 m^3 at the final stage. At the first stage, the approved licence granted in 1990 allows the disposal of up to 40 000 m^3; commercial operation started in 1992. The present available disposal volume at the disposal facilities is about 80 000 m^3. The construction cost of the existing disposal facility was about 160 billion yen.

7.2. JAERI's VLLW disposal facility

The disposal facility for JAERI's VLLW was constructed in order to demonstrate the safety of the burial disposal method for VLLW. The repository, used for the disposal of VLLW from the dismantling of JPDR, is a near surface disposal without artificial barriers.

8. CONSIDERATIONS ON A CLEARANCE LEVEL POLICY

The NSC established a clearance level for concrete and metal arising from the operation and decommissioning of nuclear power plants based on the IAEA's Technical Document, TECDOC-885 (1996). The NSC is now considering whether or not the clearance level established previously should be reviewed to take account of the new IAEA Safety Guide Application of the Concepts of Exclusion, Exemption and Clearance (RS-G-1.7, (2004)).

For the monitoring for compliance with clearance levels, the operators generating radioactive waste have to ensure that the released materials are in compliance with the clearance level. For this purpose, the regulatory authority reviews the appropriateness of the method of compliance measurement and the assessment of results provided by the operator.

9. MATTERS FOR FUTURE DISCUSSION

In Japan the decommissioning of commercial nuclear power plants is going on and waste will be generated on a massive scale, including waste of a relatively high radioactive level, such as reactor internals, etc., waste which does not need to be managed as radioactive waste and conventional (non-radioactive) waste.

It is necessary, therefore, for the regulatory authority to continue to develop safety standards, such as the technical standards relating to sub-surface disposal. In addition, regulatory infrastructures must be established for the clearance of materials from regulatory control by 2005, criteria must be developed for large size metal waste, and regulatory infrastructures must be created for the disposal of uranium and TRU waste.

DISCUSSION

J.R. COCHRAN (United States of America): I noticed in your presentation that for both transuranic waste and reactor internals the preferred method of disposal is at intermediate depths (50–100 m). Could you comment on which standards will be applied to these disposals?

Y. KAWAKAMI (Japan): In fact, transuranic waste may be distributed between the three identified disposal options; near surface, intermediate depth and geological repositories. The most hazardous variety of the transuranic waste is likely to go to geological repositories. With respect to the reactor internals, they are mainly disposed of at intermediate depth. In this case, Japan will apply standards for near surface disposal.

MANAGEMENT OF LOW ACTIVITY RADIOACTIVE WASTE FROM RUSSIAN NUCLEAR POWER PLANTS AND RADIOCHEMICAL PLANTS

P.P. POLUEKTOV, L.P. SUKHANOV
A.A. Bochvar Research Institute,
Moscow

Y.V. GLAGOLENKO, A.A. ABRAMOV, S.I. ROVNY,
G.M. MEDVEDEV
PA Mayak,
Ozersk

Russian Federation
Email: lpsoukh@bochvar.ru

Abstract

This paper describes the present arrangements for the management of low and intermediate level radioactive waste arising from the operation of nuclear power plants and radiochemical plants in the Russian Federation. The disadvantages of the present system of management are summarized and new planned schemes to resolve current problems are described.

1. MANAGEMENT OF RADIOACTIVE WASTE FROM NUCLEAR POWER PLANTS

There are 15 VVER (PWR) reactor units, 10 RBMK (BWR) reactor units and 5 reactor units of other types in operation in the Russian Federation. Four reactor units have already been removed from operation.

The radioactive waste management (RWM) system of the first Russian nuclear power plants (NPPs) was based on the concept that the conditioning of the radioactive waste produced during operation should be performed at the same time as the conditioning of radioactive waste produced during decommissioning. In accordance with this concept, the solid radioactive waste (SRW) from several first generation Russian NPPs is stored without treatment. Liquid radioactive waste (LRW) is concentrated by evaporation and ion exchange methods. Evaporator concentrates and spent filter material sludges are stored in steel tanks.

The radioactive waste management systems of newer NPPs provide for the conditioning of radioactive waste during the operational period. The earlier generation of NPPs will be equipped with conditioning facilities in the near future.

The general concept of radioactive waste management at Russian NPPs is shown in Fig. 1. The following main disadvantages of the system are:

(a) The volume of radioactive waste generated at Russian NPPs is considerably greater than that at similar foreign NPPs.
(b) At the majority of Russian NPPs, a full set of facilities for the conditioning of liquid and solid radioactive waste is not available. For this reason, a considerable part of the radioactive waste is stored in forms that cannot be considered stable and safe (evaporator concentrates, sludges, salt cake).
(c) Disposal facilities are not available; all radioactive waste is sent for long term storage.

To eliminate these disadvantages, a programme aimed at improving radioactive waste management at NPPs has been adopted [1]. The implemen-

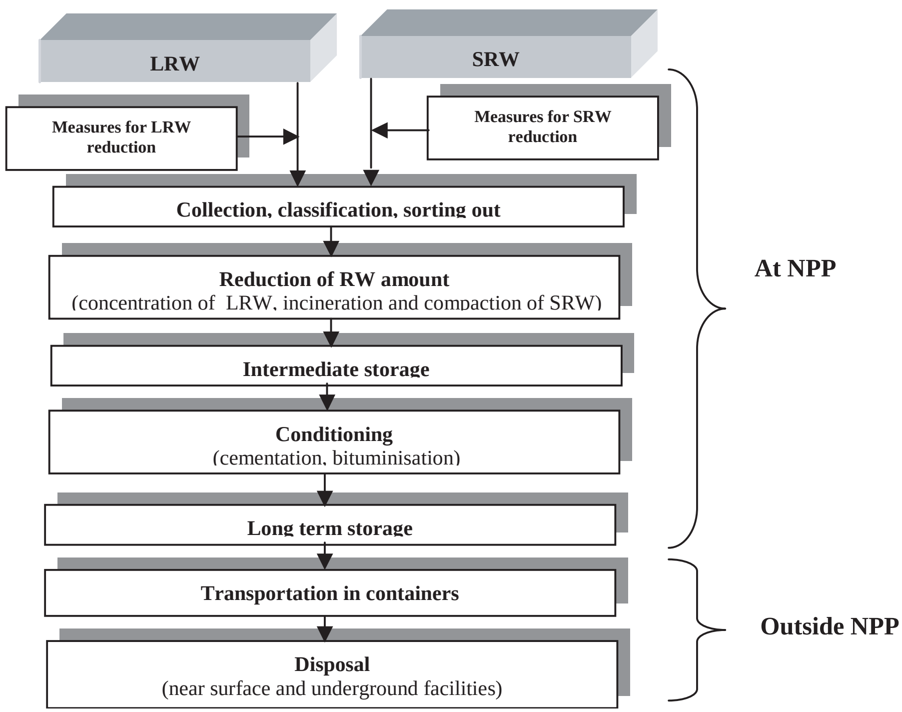

FIG. 1. General concept of radioactive waste management at NPPs.

tation of the programme is controlled and financed by the ROSENERGOATOM Corporation.

The main features of this programme are:

(a) Reduction in the amounts of radioactive waste generated by:
   (i) The introduction of a limit for radioactive waste generation for each type of NPP based on statistical data and the specific conditions at each NPP (Table 1);
   (ii) The introduction of new processes generating minimal radioactive waste (decontamination, washing etc.);
   (iii) The introduction of financial incentives for personnel at NPPs to encourage the reduction in the amounts of radioactive waste.

The measures introduced to reduce waste generation during the past five years have resulted in its reduction by ~30% per year.

TABLE 1. AUTHORIZED ANNUAL RADIOACTIVE WASTE LIMITS AT NPPS (PER REACTOR UNIT)

No.	Reactor unit type anddesignNumber	Primary LRW (m^3/a)	Salt quantities in LRW (t/a)	Evaporator concentrate (m^3/a)	Spent filtering materials (m^3/a)	SRW (m^3/a)
1	VVER-440, V-179	15 000	50	140	15	250
2	VVER-440, V-213	25 000	70	140	10	120
3	VVER-440, V-230	15 000	55	140	7	120
4	WWER-440, Design V-187	14 000	45	100	15	250
5	VVER-1000, V-320, V-338	11 000	35	120	15	250
6	RBMK-1000, 1st generation	80 000	80	135	35	300
7	RBMK-1000, 2nd generation	80 000	75	135	60	300
8	BN-600 (jointly with inactive AMB-100 and AMB-200)	20 000	38	110	5	55
9	EGP-6	4500	0.5	2.0	5.0	40

(b) The introduction of technologies for the recovery of ‘non-radioactive’ components from radioactive waste:
   (i) Ion selective purification of evaporator concentrates and the formation of a non-radioactive salt solution (this salt solution is later evaporated to produce a salt cake; the salt cake is intended to be stored together with industrial non-radioactive waste);
   (ii) Deep decontamination of spent ion exchange resins to produce non-radioactive products, decontamination and melting of contaminated metals for subsequent recycle.
(c) The introduction of radioactive waste conditioning:
   (i) Radioactive waste cementation processes at NPPs (the cement compound will be loaded into reinforced concrete containers that are suitable for both long term storage and their transportation to disposal sites);
   (ii) Solid radioactive waste compaction and incineration at NPPs.

1.1. Storage and disposal of radioactive waste

A planned national programme for establishing regional and local repositories for conditioned radioactive waste was not implemented due to local opposition and lack of funding. For this reason it was decided that radioactive waste from NPPs should be stored on the territory of the NPPs. The storage arrangements depend on the technologies used at the individual NPPs: the waste includes untreated and compacted solids, bitumen compound, evaporator concentrates, salt cakes, sludges (Table 2).

TABLE 2. THE STATUS OF STORAGE FACILITIES OF NPPS AT THE END OF 2002

Type of RW	Total amounts	Storage facilities at different NPPs (% full)
Liquid concentrate (evaporator bottom and different sludges)	~130 000 m^3	from 45 to 85%
Bitumen compound (at Leningrad NPP and Kalinin NPP)	~10 000 m^3	
Salt cake produced as a result of deep evaporation of LWR (at Balakovo NPP and Novovoronezh NPP)	~17 000 containers	
Solid waste	~150 000 m^3	from 45 to 75%

As NPPs become equipped with facilities for conditioning, the product will be stored in containers. Reinforced concrete containers (of the NSK-150-1.5P type) of 1.5 m^3 capacity are intended to be used as the standard method. Conditioned radioactive waste will be loaded into these containers in 200 l drums. In the near future, after radioactive waste repositories have been established, containers loaded with conditioned radioactive waste will be removed from the NPP storage facilities to be disposed of at the disposal sites. In these operations, the contents of the containers will not be reloaded.

Presently, in the Russian Federation, efforts are being intensified to find disposal sites suitable for the radioactive waste from the NPPs. Suitable sites are being considered near to the Kalinin, Leningrad and Kola NPPs.

In the context of disposal, the following Federal Standards have been developed and are at the stage of being issued. They are intended for the regulation of the processes of near surface and underground disposal of radioactive waste.

According to Near surface Disposal of Radioactive Waste (Safety Requirements) and Disposal of Radioactive Waste: Principles, Criteria and Basic Requirements for Safety, near surface disposal facilities may accept conditioned radioactive waste containing radionuclide concentrations as specified in Table 3.

Conditioned radioactive waste with radionuclide content exceeding those given in Table 3 must be sent to geological disposal facilities.

However, it has to be recognized that in the area of radioactive waste repository development, the Russian Federation lags behind other countries with highly developed nuclear power industries where disposal facilities have been available for many years.

2. RADIOACTIVE WASTE MANAGEMENT AT RADIOCHEMICAL PLANTS

Three radiochemical enterprises are currently being operated in the Russian Federation: Mountain Chemical Combine (MCC) and Siberian Chemical Combine (SCC), both in Siberia, and Production Association Mayak (PA Mayak) in the Urals.

The radioactive waste management systems used at these enterprises each has specific individual features.

TABLE 3. PERMISSIBLE LIMITS OF RADIONUCLIDE CONTENTS IN RADIOACTIVE WASTE IN NEAR SURFACE DISPOSAL FACILITIES

Radionuclides	Activity concentration limit (Bq/g)
N-14	3.0×10^{11}
C-14 in activated metal	3.0×10^{12}
Ni-59 in activated metal	8.1×10^{12}
Ni-63, Ni-63 in activated metal, Sr-90	2.6×10^{13}
Nb-94 in activated metal	7.4×10^{9}
Cs-137	1.7×10^{14}
Tc-99	1.1×10^{11}
I-129	3.0×10^{9}
Pu-239	1.3×10^{5}
Cm-242	7.4×10^{5}
U and transuranium α emitting radionuclides having half-lives of more than 5 years	3.7×10^{3}

2.1. Radioactive waste management at MCC and SCC

For more than 30 years liquid low level wastes (LLW) and part of the intermediate level wastes (ILW) of MCC and SCC are disposed of by pumping into isolated underground horizons at depths of 180 to 500 m [2]. The solutions are subjected to preliminary preparation to avoid the mud grouting of the boreholes.

The annual volumes of underground disposed liquid LLW from MCC and SCC are 200 000–1 000 000 m^3 and 150 000–200 000 m^3, respectively.

At the sites of underground liquid radioactive waste disposal, a system of monitoring boreholes allows the constant monitoring of the radiological and hydrogeological situation. The monitoring results provide evidence that the pumped solutions will remain located at the sites of their disposal for thousands of years and that this disposal method for liquid LLW may be considered to be environmentally safe.

The process of underground pumping of liquid radioactive waste will be employed at SCC and MCC for several more years. Later, it will be replaced by the more traditional scheme of conditioning and subsequent solid radioactive waste disposal.

2.2. **Radioactive waste management at PA Mayak** [3, 4]

The radioactive waste management system at PA Mayak includes special open type ponds for the storage of liquid radioactive waste. The special ponds are divided into three groups: (1) circulating water supply ponds (B-2), (2) ponds along the Techa River (B-3, B-4, B-10 and B-11) and (3) storage ponds (B-9 and B-17).

The location of the ponds in the total scheme of water supply at PA Mayak is shown in Fig. 2. The data on the activities and volumes of liquid radioactive waste in the ponds are given in Table 4.

The use of special storage ponds for long term storage of liquid radioactive waste at PA Mayak does not corresponded to modern environmental safety requirements. For this reason, in 2003, the Ministry of Atomic Energy of the Russian Federation approved a Complex Plan of measures for solving environmental problems at PA Mayak for the period 2003–2025.

TABLE 4. CHARACTERISTICS OF THE PONDS OF PA MAYAK

Pond	Total activity in the pond (TBq)		Volume of the pond (million m$^{3)}$	Activity (LWR/bottom slag)
	Circulation water supply ponds			
B-2	4×10^3		86.2	LLW/ILW
	Ponds situated along Techa river			
B-3	7×10^2		0.88	LLW/ILW
B-4	5×10^2		4.6	LLW/ILW
B-10	5×10^3		82.5	LLW/ILW
B-11	8×10^2		270	LLW/ILW
	LRW storage ponds			
B-9	β emitters	4×10^6	0.4	LLW/HLW
	α emitters	4×10^4		LLW/HLW
B-17	β emitters	4×10^4	0.36	LLW/ILW
	α emitters	1×10^3		LLW/ILW

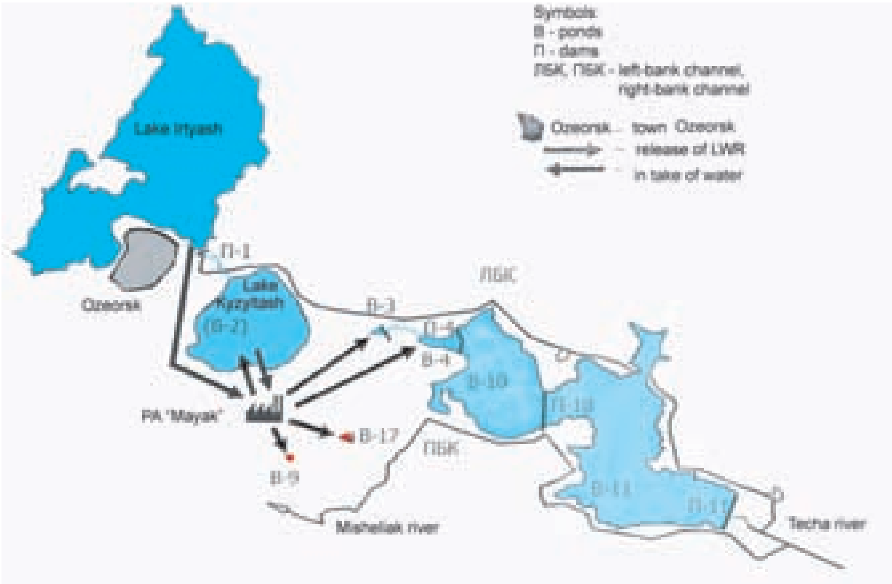

FIG. 2. Special technological ponds system at PA Mayak.

In relation to liquid radioactive waste management, the Complex Plan provides for the following:

(a) Introduction of modern radioactive waste conditioning technology;
(b) Cessation of discharge of liquid radioactive waste into the special storage ponds, with priority on V-9 (Karachay), where works are under way to decrease the lake water area and to immobilize bottom sediments;
(c) Closure of the special storage ponds.

All of these activities are currently under way, however, the completion time will depend on the funds allocated to the Plan.

2.2.1. Liquid LLW management at PA Mayak

The main groups of liquid LLW are summarized in Table 5.

Today, the liquid LLW from the radiochemical production plants is processed by purification on ion exchange filters. The purified water is sent to the B-2 pond while regeneration solutions from processing and sludges are discharged into the B-3 and B-4 ponds. Water from the laundries is discharged into the B-3 pond without processing.

TABLE 5. VOLUME AND ACTIVITIES OF LIQUID LLW AT PA MAYAK

Kind of LLW	Volume (m^3/a)	Specific activity (Bq/kg)		Management
		α activity	β activity	
LLW of radiochemical production plants	300 000–400 000	3.7×10^3	1.1×10^5	Discharge into B-2, B-3 and B-4
Special laundry water	70 000	370	1.1×10^4	Discharge into B-2

The scheme of the liquid LLW management employed at PA Mayak has the following disadvantages:

(a) The final product consists of solutions and sludges, i.e. the waste is in a non-conditioned form,
(b) Open ponds are used for the long term storage of radioactive solutions and sludges which does not comply with the current environmental safety requirements,
(c) The current waste purification technology is neither effective nor economic because of the large amounts of secondary waste generated and the failure to provide an adequate reduction of the concentration of some nuclides,
(d) Significant amounts of waste are discharged into the ponds without any purification at all.

When the new waste management scheme was being developed, attention was focused on the following specific features of the liquid LLW at PA Mayak:

(a) The waste is in large volumes (~400 000 m^3/a) which indicates the advisability of using low energy consuming methods to process it,
(b) The specific activity of waste concentrates will not exceed ~40 MBq/L, hence cement and similar inorganic binders seem to be most acceptable as matrix materials for immobilization,
(c) Preference has to be given to methods which result in minimal quantities of secondary waste.

Taking these considerations into account, PA Mayak together with its associated scientific institutes has developed a membrane sorption process flow sheet for liquid LLW conditioning as shown in Fig. 3.

Putting this scheme into practice will make it possible to terminate the discharge of liquid LLW into the open storage ponds, to incorporate the secondary waste into cement compounds and to produce purified liquid effluent that might be discharged or recycled. The volume of conditioned waste will be less than 1.5% of that of the processed liquid LLW.

2.2.2. Management of liquid ILW at PA Mayak

Liquid ILW from the radiochemical plants is currently neutralized and discharged without processing into the B-9 and B-17 storage ponds.

In the near future, it is planned that most of this waste will be processed together with liquid high level waste to produce glass or mineral-like compounds as end products.

This report only discusses liquid ILW, the concentrates of which, because of their specific compositions, cannot be solidified by vitrification.

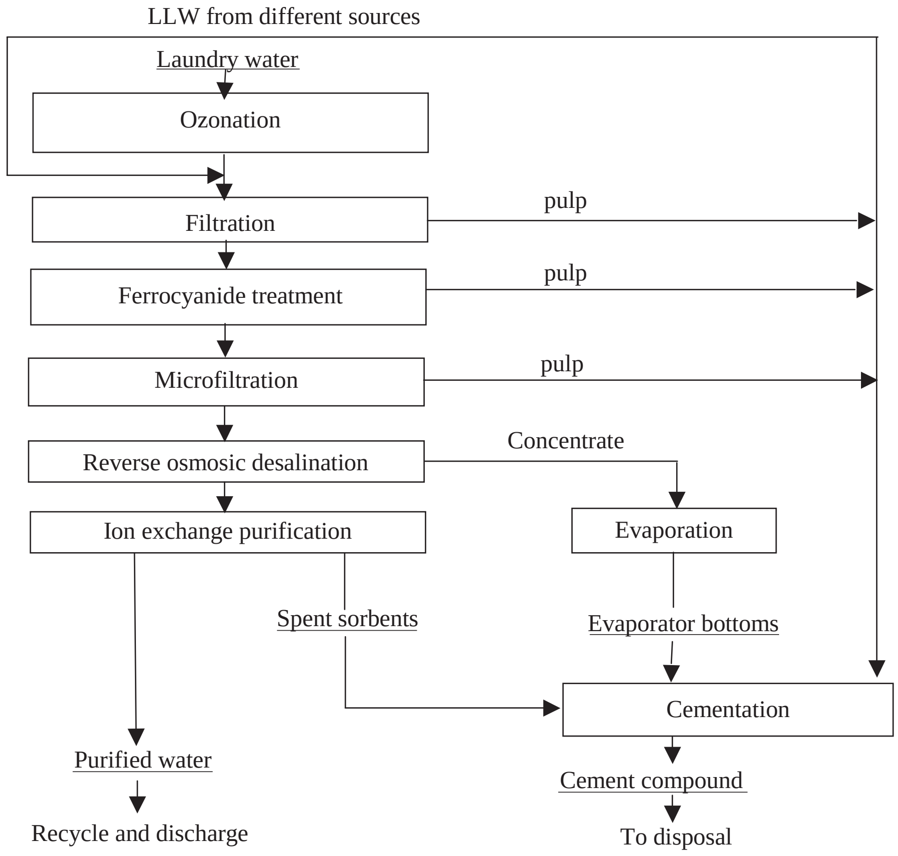

FIG. 3. Proposed scheme for liquid LLW processing at PA Mayak.

The main groups of ILW include solutions from ammonia precipitation of uranium, spent acid decontamination, acidic raffinate from plutonium extraction, concentrate after membrane sorption processing of liquid LLW, spent ion exchange resin sludges, manganese dioxide suspended sediments, and perlite sludges.

The process flow sheet for the planned cementation is based on the following general scheme:

(a) The ILW is concentrated via two-stage evaporation;
(b) At the evaporation stage, nitric acid and ammonia are distilled off and removed by rectification.

This substantially reduces the cement compound volumes required and the consumption of alkali to neutralize the acidic solutions. The recovered nitric acid will be recycled.

The flow sheet for ILW preparation for cementation is shown in Fig. 4.

The proposed scheme will make it possible to eliminate the discharges of liquid ILW into open storage ponds. The ponds can then be remediated. The immobilization of the waste concentrates in a cement compound followed by placement in surface storage or an underground repository facility will provide an environmentally safe solution for this waste stream at PA Mayak.

3. CONCLUSION

Significant volumes of LLW and ILW arise at the nuclear power plants and at radiochemical plants in the Russian Federation. However, there is a trend towards a gradual reduction of waste volumes at NPPs as a result of recent organizational and engineering measures.

The radioactive waste management systems at NPPs and radiochemical plants prevent the entry of radioactive waste into the environment. However, the systems need updating. The main goal of the schemes being introduced for this purpose is to introduce conditioning facilities at all sites where radioactive waste is generated and to establish disposal facilities for these waste types.

A number of programmes have been adopted in the Russian Federation that are intended to eliminate the existing deficiencies in the area of radioactive waste management.

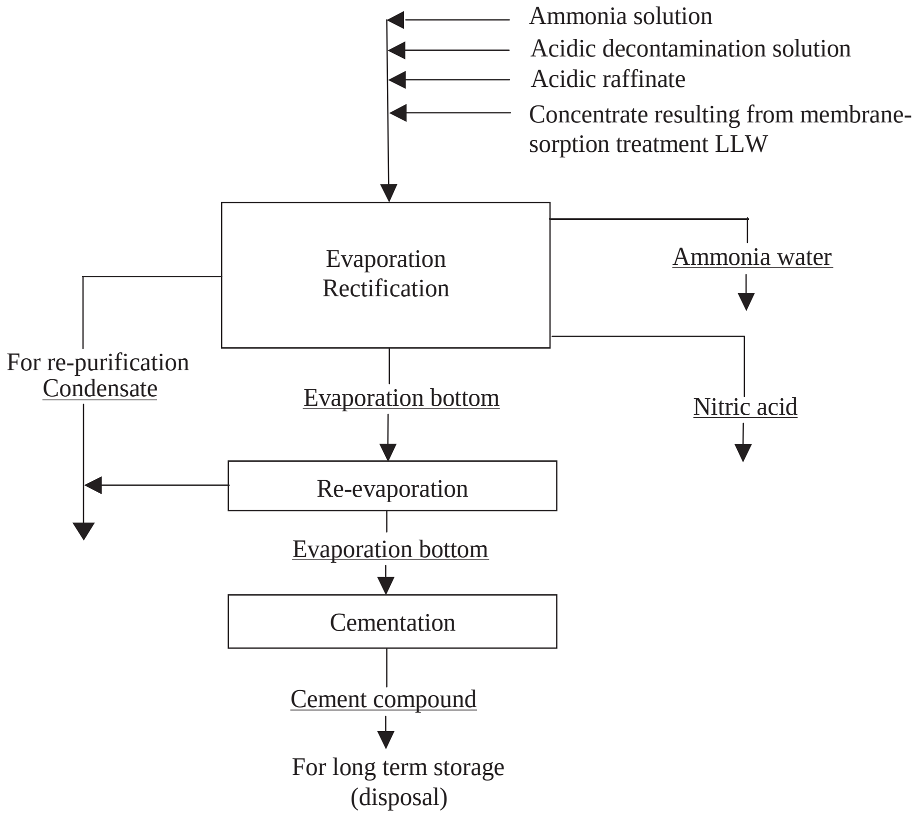

FIG. 4. Proposed scheme for liquid ILW processing at PA Mayak.

REFERENCES

[1] CORPORATION "ROSENERGOATOM". The Working Program of RW management at "ROSENERGOATOM" NPPs for the period from 2003 to 2008.

[2] RYBALCHENKO A.I., PIMENOV M.K., KOSTIN P.P. et al. In-underground disposal of LRW, Moscow, Edition Atom Technique, 1994.

[3] GLAGOLENKO YU.V., ROVNY S.I., MEDVEDEV G.M., POLUEKTOV P.P. Development of process flow sheet to manage liquid RW at PA "Mayak". Technologic Journal of PA "Mayak". "Radiochemical Safety Issues", 2003, No. 1, pp 5–13.

[4] GLAGOLENKO YU.V., ROVNY S.I., MEDVEDEV G.M., SLYUNCHEV O.M., DROGHKO E.G., GELIS V.M. System of managing low activity liquid waste at PA "Mayak" – present status and basic directions of evolution. Development of process flow sheet to manage liquid RW at PA "Mayak". Technologic Journal of PA "Mayak". "Radiochemical Safety Issues", 2003, No. 1, pp 20–26.

THE JOINT CONVENTION AND IMPROVED MANAGEMENT OF LOW ACTIVITY RADIOACTIVE WASTE

G.C. JACK[*]
Nepean, Ontario,
Canada
Email: george.j@sympatico.ca

Abstract

This paper explains the objectives of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, lists some of the obligations on the Contracting Parties to the Convention, describes how the Convention is implemented, discusses the Convention's first review meeting, projects the future of the Joint Convention, and indicates ways in which the Convention could be an effective mechanism for improving the worldwide safety of low level radioactive waste management. The paper summarizes the discussion of the topics discussed at the first review meeting, held in November 2003, relevant to this Symposium, expresses views about the completeness and value of those discussions, and suggests how improvements might be made in future meetings.

1. INTRODUCTION

The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, very simply, is an agreement among countries on one mechanism to advance the cause of worldwide safety in radioactive waste management. It is called the 'Joint Convention' because it also applies to the safety of spent fuel management. In many countries – but far from all – spent fuel is regarded as one particular form of radioactive waste. The Convention applies to all categories of radioactive waste related to the fuel cycle, whether high level, low level, or mine/mill tailings. The scope of the Convention has some flexibility, so that Contracting Parties can choose to limit its application to their situation to some extent. Examples of the optional scope

[*] G.C. Jack was the Chairperson of the meetings held in preparation for the First Review Meeting of the Joint Convention and advisor to the President of the First Review Meeting.

are naturally occurring radioactive materials (NORM) not associated with the fuel cycle, and military wastes. The Convention is relevant to every country in the world, since every single country has some radioactive waste.

2. THE JOINT CONVENTION

2.1. Objectives and obligations

The objectives of the Joint Convention are, in abbreviated form:

(a) To achieve and maintain a high level of safety worldwide in spent fuel and radioactive waste management;
(b) To ensure that the needs of the present generation are met without compromising the ability of future generations to meet their needs and aspirations; and
(c) To prevent accidents with radiological consequences and to mitigate their consequences should they occur during any stage of spent fuel or radioactive waste management.

The text of the Convention spells out the obligations of a country that becomes a Party to the Convention. These obligations cover topics such as general safety requirements, siting, design and construction requirements, safety assessment, operational safety, and institutional measures after facility closure, as well as the safety of facilities that existed prior to the time when the Convention came into force. Other details include: requirements for the independence for a national regulatory body, responsibilities of the licensee, emergency preparedness, decommissioning considerations, export and import limitations, and the control of disused sealed sources. The Convention contains, within a legally binding instrument, the safety principles that had been agreed upon in many of the safety documents of the IAEA — which are, usually, only advisory in nature. None of the obligations set out in the Convention is prescriptive, instead, there are general principles, within which Parties to the Convention have considerable latitude to choose their own national approaches. The existence of the Convention is an expression, by the countries involved, of dedication to the cause of improving safety, and of willingness to have national situations reviewed and discussed by peers. In most cases, the Contracting Parties' national reports have been posted on websites for the whole world to see. That degree of openness would have been unthinkable even in the quite recent past.

Two of the most important obligations are:

(1) To submit a national report to each review meeting (which occurs every three years); the national report addresses the measures taken by the country to implement the Convention's obligations; and
(2) To attend the three yearly review meeting at which each country presents its own national situation and also participates in reviewing the reports and presentations of other Parties to the Convention.

2.2. Ratification status

It is generally agreed that the sum total of all of the obligations required of Contracting Parties by the Convention is very modest and it might therefore be expected that there would be a high level of participation in the Convention by countries that are conscious of radioactive waste issues and that want to, and want to be seen to, act responsibly in the management of radioactive waste. But it is now over seven years since the Convention was first open for ratification, and still only 34 countries have ratified it.

It is therefore appropriate that the countries represented here in Córdoba at this Symposium should each try to persuade their neighbours or trading partners to become participants in the Joint Convention. The IAEA is taking all opportunities it has available to it to try to persuade countries to join, but individual Contracting Parties should also be exerting whatever influence they have in that direction. After all, the Joint Convention is the only forum that exists at the highest level for discussing radioactive waste management issues, and such a forum should be used to the full.

It is surprising that more countries are not yet Parties to the Convention considering the benefits that can be obtained from it. It is clear, for example, that the review meetings can be excellent venues for one country to discuss with others any specific problems that it has encountered. It should expect active support, suggestions, and the benefit of the experience of other countries. In situations where one country might feel that the health and safety of its citizens are threatened by the actions of another country, the review meetings of the Joint Convention would provide a good opportunity for such concerns to be raised and for support to be sought from other countries. The costs of being a Contracting Party cannot be regarded as being excessive; they comprise the costs of attending the two week long review meetings held in Vienna at intervals of three years and the costs of preparing the national report in advance of the meeting. The IAEA is even willing to try to find ways to help new Contracting Parties to write their first national reports. In summary, given the benefits, it should be expected that the number of Contracting Parties will increase significantly in the next few years.

3. REVIEW MEETING DISCUSSION

3.1. General

At present, the Convention membership is dominated by countries having nuclear power programmes, since there are 25 Contracting Parties with at least one power reactor and only 9 without. As more non-nuclear power countries ratify the Convention, that balance will change — and with that change in balance, the focus of discussion may be expected to be different. For example, at the first review meeting held in November 2003, high level waste and spent fuel management occupied much of the discussion time. But as more countries participate it is likely that low level waste management will receive greater attention. The fact that review meetings occur at three yearly intervals means that discussions can progress and build on previous ones, more easily than through 'ad hoc' technical meetings or conferences. Also, in the rules for implementing the Joint Convention, there is specific allowance for having so-called 'topic sessions' during the review meetings, as well as the country group sessions that already exist. The management of low level radioactive waste, or certain streams in it, might be a very appropriate topic for one of those sessions — and then a miniature version of this Symposium could be held every three years, if so desired.

Although much of the discussion at the first review meeting was on high level waste, low level waste also received significant attention. Some of the topics discussed at the review meeting are listed in the following sections, with a summary of the first review meeting discussions, to illustrate how useful the Convention is as a forum for developing solutions to low level waste management issues.

3.2. Clearance

There was some animated discussion in one country group, in particular, on the topic of clearance, but it was also discussed in most groups, and again in the plenary session of the review meeting. It was agreed that renewed efforts are required to reach international consensus on this issue – which, because of its very nature, is an international issue Once a country releases material from its regulatory control system for radioactive materials, that material could easily be exported to other countries without anyone realizing that it is radioactive. If the regulatory body in the importing country is not aware of the circumstances that exist in the exporting country, or the criteria by which that country's regulatory body decides on clearance, it is not in a position to give assurances that will be credible concerning the safety of the imported material. Almost as if in response to the call for renewed efforts, in the early summer of this year, agreement was reached on an IAEA document giving advice on the application of the clearance concept. It will be very interesting to see how this document is implemented by Member States, and whether the case by case approach used by some countries in the past will be superseded. Clearance, possibly including the recycling of the released materials, is the ideal way of managing materials containing very low levels of radionuclides (provided that safety is assured). It is clear that the subject will be discussed further at the next review meeting, and that Parties to the Convention will be very interested in knowing how other countries are dealing with the issue.

3.3. Decommissioning

An added impetus for progress on clearance arises from the increasing interest worldwide in decommissioning activities. Decommissioning produces large amounts of material containing very low levels of radionuclides, some of these materials being potentially suitable for clearance and reuse. Of course, it is necessary to have an agreed recycling policy first. Another prerequisite to widespread decommissioning is to have somewhere to put the waste that results from the dismantling operations, in other words, a disposal facility. This was discussed at some length in the review meeting, and it was interesting to hear the very varied approaches of the participating countries. What was, perhaps, of even more value was the plenary discussion involving countries that have actually completed some decommissioning projects. That discussion highlighted the fact that successful decommissioning requires, in addition to waste disposal facilities, and in addition to a recycling or clearance policy, detailed planning far in advance — ideally right at the design stage of the facility — good planning for the actual decommissioning phase, and the provision, in advance, of adequate financial mechanisms to provide for the decommissioning. Nothing very new was revealed, but any country interested in decommissioning in the near future would have benefited by being involved in that discussion.

3.4. Storage versus disposal

Just as countries have a wide spectrum of approaches to decommissioning, so they also have a wide spectrum of approaches to the whole question of storage versus disposal. This too led to some animated discussion at the review meeting. Some claim that a country's waste management safety package is not complete unless, and until, a plan exists for disposal of the waste. Others dispute that. For many countries — particularly those without the infrastructure associated with a well-developed nuclear power industry — developing a disposal facility is a major project, with very large economic implications. For some of those countries, long term storage is a more attractive option for obvious reasons. Equally obvious, however, are some of the dangers inherent in the indefinite storage option, and so this is an issue that will not easily disappear. The preamble to the Joint Convention refers to the possible benefit to be derived from regional repositories, while recognizing the responsibilities of the originating country for its own waste, and the subject of regional repositories was discussed at the first review meeting. Indeed, one of the Contracting Parties followed up the review meeting by hosting a meeting of its neighbouring countries to discuss the topic, in a general and very preliminary way. Some prefer that this subject is not discussed publicly, in case it generates negative reactions in countries where plans are well advanced for developing national repositories, and that sensitivity must be respected. Nevertheless, it was notable that some countries voluntarily met together to, at least, start discussing an issue that could be of such enormous benefit to them all. Again, the Joint Convention provided a suitable forum for such a discussion.

3.5. Regulatory infrastructure

Another, sometimes sensitive, subject concerns regulatory regimes. It is sensitive because the regulatory infrastructure in some countries is not ideal, and few countries are eager to hear others comment negatively on their national institutions. That is understandable. But the Convention contains some very specific words on the subject of regulatory bodies, the desired degree of independence of those bodies, the level of resources available, and also the relative responsibilities of the regulator versus the operator, or licensee. The Convention also recognizes that countries with small nuclear programmes do not need the elaborate infrastructure that exists in a country with a large nuclear industry. Several countries are in the process of modifying existing statutory instruments or developing new ones, and so this will be another topic whose progress will be closely followed in future review meetings.

3.6. Disused sealed sources

Another area that was identified for more detailed discussion in future was the control of disused sealed sources. This topic is only marginally within the scope of this Symposium, but its relevance to waste management safety has been demonstrated in the worst possible way – by the occurrence of serious radiation exposures to citizens. It is clear that the systems of control vary enormously from country to country, as do the effectiveness of those systems.

3.7. Lessons learnt

A summary version of all of the discussions that took place at the review meeting is contained in the publicly available Summary Report. This is an 18 page document that will be a very useful reference for those who organize, and participate in, the next review meeting. The next meeting should be even better than the first, which was agreed by all as being a success, although at times issues were not discussed to the depth that some believed appropriate. One main reason for that slight criticism of the meeting was a genuine misunderstanding by some countries about the scope of the Convention. For example, some seemed to be unaware that the scope of the Convention includes uranium mining and milling wastes, while others were unclear about the applicability of the Convention to the decommissioning of nuclear facilities other than power reactors. There were also other misunderstandings. In the final plenary session of the meeting, these were clearly addressed and should therefore not recur. Another possible contributing reason was the attitude of many of the delegations. Instead of taking advantage of the opportunity to discuss problems and thereby generate solutions, too many countries' delegates seemed to be more interested in leaving at the end of the meeting with a 'report card' that contained no implied criticisms. There were some notable and praiseworthy exceptions to that, but the prevailing wish to avoid criticism was remarked upon by many, with regret. It is certainly to be desired that this will change when Parties come to future review meetings in Vienna. A third reason for the sometimes limited level of discussion was that some of the appointed officials (country group chairs, vice-chairs, rapporteurs) perhaps did not do as much as might be desired to stimulate and provoke discussion. Again, steps have already been taken to try to supply them with the necessary guidance so that this aspect will be improved at the next review meeting.

4. CONCLUSIONS

The first review meeting of the Joint Convention directly addressed many of the issues that are current in low level waste management. Future meetings will continue to do so. It is easily agreed that the more that problems and difficult situations are discussed between knowledgeable people, the more likely it is that the problems can be mitigated. The Convention's review meetings present a great opportunity for such discussion. Of course, discussion by itself does not solve problems but the exchange of views with others having the same problems can be very helpful. And when the issue comes up for discussion at regular intervals, the resulting focus makes it less likely that the problems will be ignored and hence become chronic.

If, as is hoped, many more countries ratify the Convention and become Parties to it, and if a significant number of those countries have radioactive waste arising from outside the nuclear industry, the Convention will become even more relevant to low level waste management. One reason is that there are accumulations of legacy wastes in many countries, and in some instances, the governments of the countries concerned are not even aware that a potential problem exists. The first step in solving a problem is to recognize its existence – and so, once again, given the appropriate atmosphere and membership in the Joint Convention, a real advance could be made in the worldwide safety of radioactive waste management.

The Joint Convention provides an excellent forum, every three years, at which peers can discuss with each other, with senior personnel also present, a wide spectrum of issues related to the management of low level radioactive waste. The resulting documents, in the form of national reports and the reports from the meetings themselves, constitute a huge repository of current information on the subject. It seems, therefore, that the Joint Convention simply ***must*** help improve low level waste management over a period of time.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the valuable comments and suggestions received from G. Linsley, J. Rowat and K Hioki during the preparation of this paper.

DISCUSSION

P. METCALF (IAEA): Would very low activity waste disposal facilities such as the facility at Morvilliers, France, fall within the scope of the Joint Convention?

G.C. JACK (Canada): The Joint Convention applies to — among other things — the safety of 'radioactive waste management' (Article 3.2), which is defined (in Article 2(i)) as "all activities, including storage, or disposal of radioactive waste". Radioactive waste is defined (in Article 2(h)) as "radioactive material for which no further use is foreseen and which is controlled as radioactive waste by a regulatory body under the legislative and regulatory framework of the Contracting Party".

The material referred to in the question is controlled by the regulatory body since it is required to be put into a specific facility, it is waste and it is radioactive. Thus, the Joint Convention applies to the material until it is in the facility.

My understanding is that the material is still regarded as radioactive waste when in the facility even though the facility is not regulated by the nuclear regulatory body. In that case, the material remains within the scope of the Joint Convention. If, on the other hand, the regulatory body does not regard the material as radioactive waste, the opposite conclusion is reached, because in that case the regulatory body has in effect 'cleared' the material without putting the 'clearance' label on it.

P. CARBONERAS (Spain – Chairperson): Why have some countries not acceded to the Joint Convention?

G.C. JACK (Canada): My answer is based largely on hearsay and conjecture, mixed with occasional first-hand information.

The reasons given to me have included:

(a) A lack of awareness of the Joint Convention's existence;
(b) A lack of awareness of the Joint Convention's relevance to, for example, countries without spent fuel;
(c) A desire to avoid public embarrassment caused by the exposure of deficiencies in the national regulatory infrastructure or of the status of national radioactive waste management; and
(d) Bureaucratic delays in translating recommendations to ratify the Joint Convention made at the technical level into action at the political level.

RADIOACTIVE WASTE MANAGEMENT IN PORTUGAL

R. TRINDADE, I. PAIVA, L. PORTUGAL
Nuclear and Technological Institute,
Department of Radiological Protection and Nuclear Safety,
Sacavém, Portugal
Email: romao@itn.mcies.pt

Abstract

Radioactive waste produced in Portugal results mainly from the application of radioactive materials in medicine, research and industry. In this paper, the Portuguese legislation related to radioactive waste management is presented. Up to now and concerning the management of spent and disused sealed sources, 123 drums containing mainly ^{60}Co, ^{137}Cs, ^{226}Ra, and ^{241}Am have been stored at the Radioactive Waste Interim Storage site. The main method used for the conditioning of this waste is incorporation in a cement matrix.. In order to optimize radiation protection waste drums are arranged in grids optimized using a Monte Carlo simulation technique.

1. INTRODUCTION

In Portugal, sealed and unsealed radioactive sources are collected, segregated, conditioned and stored at the Radioactive Waste Interim Storage Facility at the Nuclear and Technological Institute (ITN) located in Sacavém. All of the activities involving the management of radioactive waste, including the long term storage of spent sealed sources, are, at national level, the exclusive responsibility of the Department of Radiological Protection and Nuclear Safety (DPRSN), according to the Portuguese legislation. DPRSN also carries out the licensing of all activities involving sealed sources for the industrial, research and medical sectors, in collaboration with Ministry for Health and Ministry of Environment.

2. LEGAL REGULATORY FRAMEWORK

In Table 1, the Portuguese legislation related to the radioactive waste management activities is summarized. Many of the national laws and regulations are transpositions of Euratom Directives.

TABLE 1. PORTUGUESE LEGAL FRAMEWORK

D.L. No. 348/89, Ministry for Health	Establishes rules for Radiological Protection
R.D. No. 9/90, Ministry for Health	Transposes Directives 80 / 836 / EURATOMand 466/84/EURATOM
Ministerial Order No. 242/96, Ministry for Health	Establishes classification of medical wastes
D.L. No. 138/96, Ministry of Environment	Transposes Directive 92/3/EURATOM
D.L. No. 153/96, Ministry of Environment	Regulates activity using sealed sources
Ministerial Order No. 7714/2002, Ministry for Science and Technology	Costs of collection and elimination of radwaste
D.L. No. 165/2002, Ministry for Health	Partial transposition of Directive 96/29/ EURATOM
D.L. No. 180/2002,Ministry for Health	Transposes Directive nº 97/43/ EURATOM
D.L.No267-A/2003, Ministry of Housing Transports and Public Constructions	Transposes ADR (Revised)

3. MANAGEMENT OF DISUSED SEALED SOURCES AT THE RADIOACTIVE WASTE INTERIM STORAGE FACILITY

The system adopted in Portugal for the classification of radioactive waste is that recommended by the European Commission [2]; it comprises three categories: transitory waste, low and medium activity (short and long lived) and high activity waste. Heterogeneous materials such as gloves, papers and clothing contaminated with radioactive material, which make up the main bulk of the radioactive waste produced in the country, are conditioned in metallic drums after compactation. In the specific case of spent and disused sealed sources, the sources are conditioned by enclosing them in a cement matrix inside a concrete drum.

The drums are arranged in grids taking into account the radionuclide half-life period ($T_{1/2}$). They grouped as follows: (i) $T_{1/2}$ up to 30 years; (ii) 30< $T_{1/2}$<100 years; (iii) 100< $T_{1/2}$<1000 years; and, (iv) $T_{1/2}$ above 1000 years. Up to now, 123 drums containing mainly ^{60}Co, ^{137}Cs, ^{226}Ra and ^{241}Am, are in storage at the Radioactive Waste Interim Storage Facility. This facility, with a storage capacity of 300 m^3, has a solid waste compactor and adequate conditions for the segregation, treatment, and conditioning of the radioactive waste produced in Portugal.

The disposal of spent and disused sealed sources in Portugal is normally achieved by returning the sources to the supplier. If this is not possible, the sources are sent to ITN/DPRSN for interim storage at the Radioactive Waste Interim Storage Facility. The following minimum information is normally required from the owner before the disused source(s) will be accepted: type of source and application, identification of the radionuclide, activity of the source, licence number and the description of the package.

Once the source has been received at the Radioactive Waste Interim Storage Facility, it is stored temporarily at the operational storage site. Following their conditioning by incorporation in a cement matrix, the concrete drums containing the sources are transferred to the interim storage area for long term storage.

The ^{241}Am and ^{226}Ra spent sealed sources in storage result mainly from smoke detectors and lightning rods but also from ‘radium needles’ used in historic brachytherapy. Neutron emitting sealed sources of ^{226}Ra–Be and ^{241}Am–Be are also part of the inventory of radioactive sealed sources of DPRSN/ITN. While sealed sources are conditioned in cement matrixes, open sources are conditioned in 200 L steel containers. Radioactive liquid waste containing ^{3}H, ^{14}C, ^{32}P and ^{35}S is currently being stored on site without pre-treatment; it awaits a decision concerning its future management.

DPRSN keeps records of each source received, its location and the identification of each container. Fees are charged for conditioning and long term storage in accordance with the national law.

4. OPTIMIZATION OF RADIATION PROTECTION AT THE RADIOACTIVE WASTE INTERIM STORAGE FACILITY

At the Radioactive Waste Interim Storage Facility, disused sealed sources in concrete drums are arranged in a grid formation. Gamma dose values around each grid depend on the radionuclides and the activity within the drums as well as on the distribution of the drums in the various layers of the grid. In order to optimize the radiation protection around the drums in the grids [3], a method based on the Monte Carlo simulation using the MCNPX code has been applied. It was first used experimentally to the grids containing radium sealed sources as shown in Fig.1 [4]. This method is now being used generally at the Radioactive Waste Interim Storage Facility as part of the radioactive waste management process to optimize arrangements of the grids of waste drums.

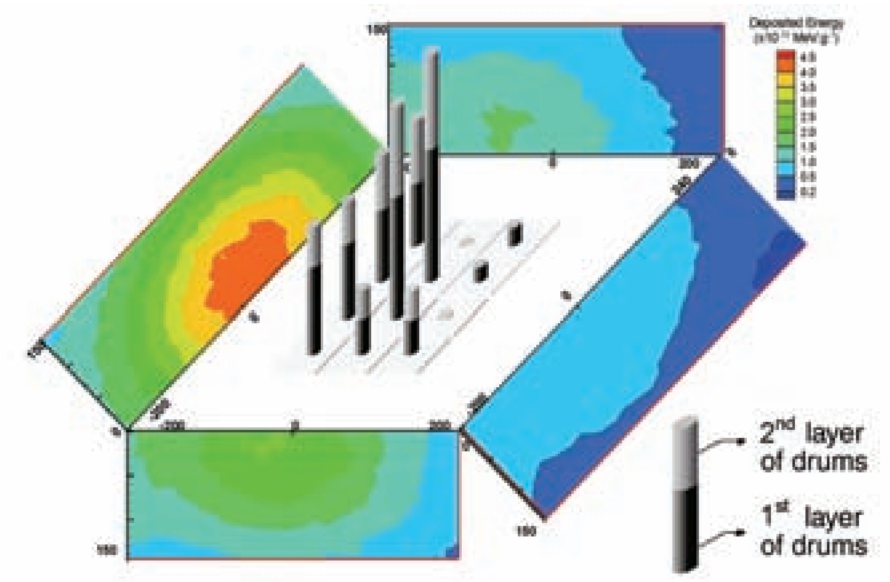

FIG. 1. Deposited energy by unit mass along planes located 1 metre distance from a Grid having a 4×3×2 arrangement of ^{226}Ra drums. The height of each layer is proportional to the radiation dose rate.

REFERENCES

[1] HENDRICKS, J. S. et al, MCNPX™ User's Manual, Version 2.5.d, LA-UR-03-5916, Los Alamos Laboratory, August (2003).

[2] EUROPEAN COMMISSION, Recommendations on a System of Classification for Solid Radioactive Wastes, SEC, 1302 FINAL, September 15th, Brussels (1999).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Principles of Radioactive Waste Management, Safety Standards Series No. 111-F, IAEA, Vienna (1995).

[4] PAIVA, I, OLIVEIRA, C., TRINDADE, R. AND PORTUGAL, L., Interim Storage of Spent and Disused Sealed Sources: Optimization of External Dose Distribution in Waste Grids Using the MCNPX Code. Contributed Paper and Communication to the 10th International Conference on Radiation Shielding and the 13th Topical Meeting on Radiation Protection and Shielding, Funchal, 9-14 May, Madeira (2004).

DISCUSSION

M. VESELIC (Slovenia): Why has Portugal not yet acceded to the Joint Convention?

R. TRINDADE (Portugal): I do not know, but I think that the reason is a political one. We have several times urged the relevant ministry and the Government to take steps in order that Portugal may accede to the Joint Convention, but without success. I hope that things will change in Portugal in due course.

PANEL

(Session 1)

HOW CAN EXISTING RADIOACTIVE WASTE MANAGEMENT STRATEGIES BETTER ADDRESS THE NEEDS OF COUNTRIES WITH LIMITED RESOURCES?

Chairperson: **P. Carboneras** (Spain)

Members: **P. Bredell** (South Africa)
J.P. Boyazis (Belgium)
J. Tomás Zerquera (Cuba)
V. Štefula (Slovakia)

Statement

P. Bredell
Nuclear Energy Corporation of South Africa (NECSA),
Pretoria, South Africa
Email: pbredell@necsa.co.za

South Africa, with a small nuclear industry, has limited economic resources, a limited infrastructure and limited expertise.

One of the problems that one faces in such a situation is unfavourable economics of scale. The unit costs are high because of small scale operations, and that reflects unfavourably on predisposal and even more unfavourably on disposal.

The need to ensure public participation in nuclear matters adds to the problem. We simply do not have the resources to cope with the additional burden of having to get the public behind us.

Altogether, that results in disposal delays and sometimes in the paralysis of predisposal activities — for example, because the conditioning requirements have not been specified.

How does one counteract this? The 'panacea', the universal solution that many countries like South Africa opt for, is the 'national radioactive waste management policy'. In South Africa, we have been battling for years to put such a policy in place, because we believe that, once it is in place, we will obtain all the answers we need in order to address the disposal issue.

Such a policy has to be very clear about roles, decision making structures, the optimum utilization of resources, international cooperation, guidance and, in particular, public participation, because the wrong handling of public participation normally paralyses the process. Besides a policy, you need people, especially in government, who are committed to implementing it.

Statement

J.P. Boyazis
ONDRAF/NIRAS,
Brussels, Belgium
Email: jp.boyazis@nirond.be

I shall focus on the subquestion “How do you adapt solutions from countries with large nuclear infrastructures to meet the needs of countries with modest resources?” You can do it in several ways.

The first thing I would highlight is knowledge transfer — through books, through the organization of training in countries with modest resources, through the provision of services or by inviting persons from such countries to your own country for training.

The second thing I would highlight is the transfer of experience by showing invited persons how you do things at various sites, laboratories, engineering establishments and so on.

Thirdly, there often exist ready made solutions that can be directly applied — for example, a not too expensive high activity waste container that can be supplied to and used by developing countries.

Finally, countries with extensive experience in areas such as safety assessment can assist countries without such experience. That helps to increase local confidence.

The main problem I see is that every kind of assistance has a cost and many radioactive waste management agencies are commercial organizations which cannot afford to provide assistance without charging at least something. However, assistance can be provided through international organizations and through bilateral cooperation between countries. Some countries have development cooperation departments, and it would be nice if those countries would pay more attention to helping other countries in the area of radioactive waste management.

Statement

J. Tomás Zerquera
Center for Hygiene and Radiation Protection,
Havana, Cuba
Email: jtomas@ephr.edu.cu

In July 2004, a workshop was held in Havana as part of an initiative of several countries of Europe, Central America and the Caribbean aimed at strengthening the radioactive waste management infrastructures in the countries of Central America and the Caribbean — the STRECA project, details of which will be presented during the poster session tomorrow. At that workshop, the present situation regarding radioactive waste management in the countries of Central America and the Caribbean was described and the immediate needs of those countries were identified: a need for stronger regulatory systems; a need for clear national strategies for radioactive waste management; a need for more education and training; a need for the transfer of safety assessment and environmental monitoring methodologies; and a need for improved transfer of information to the public.

Statement

V. Štefula
DECOM Slovakia,
Trnava, Slovakia
Email: stefula@decom.sk

When considering the question "How can radioactive waste management strategies better address the needs of countries with limited resources?" I thought of two issues which might be relevant — the management of radioactively contaminated soil in Slovakia and the idea of establishing shared regional repositories in Europe.

In the vicinity of the A1 nuclear power plant at Bohunice, there are hot spots of radioactively contaminated soil due predominantly to the poor storage of liquid waste in the past. These hot spots are found around underground bulk storage tanks in which we kept the liquid waste in the 1970s and which became leaky with time.

One management option was to collect the contaminated soil, package it and place it in a landfill. The second option was to leave the soil in place, construct barriers above it and use the voids in the tanks for the disposal of soil stored in drums elsewhere. With limited time and a limited budget, a safety assessment of those options was made. In the safety assessment, of which I was the main author, the IAEA's ISAM methodology was used.

From a radiation protection optimization perspective, the results supported the second option, but the regulators strongly preferred the first one.

A clear strategy for the management of such very low level waste would be very helpful for decision making, as would some regulatory assistance.

As regards the idea of establishing shared regional repositories in Europe, a project called SAPIERR has been launched and I am the project manager.

This two year project, funded by the European Commission, was launched in December 2003. The goal is to establish boundary conditions and define requirements.

At present, 21 organizations in 14 countries are participating in the project. The countries are Latvia, Lithuania, Belgium, the Netherlands, Italy, Switzerland, Austria, the Czech Republic, Slovakia, Hungary, Slovenia, Croatia, Romania and Bulgaria. Representatives of regulators, operators and ministries are involved.

We had a kick-off meeting in Slovakia in February 2004, and subsequently we produced two technical reports and submitted them to the

European Commission. The first report was on legal aspects of shared repositories in Europe — a subject complicated by the fact that most European countries have banned the importation of radioactive waste. The second report was on national radioactive waste inventories and how they will develop during the period until 2040, on national management strategies and on the availability of storage facilities in the 14 participating countries, which together have less radioactive waste than France or any other country with a big nuclear power programme.

Both reports have been published on the Internet. The address of the project website is www.sapierr.net.

DISCUSSION

HOW CAN EXISTING RADIOACTIVE WASTE MANAGEMENT STRATEGIES BETTER ADDRESS THE NEEDS OF COUNTRIES WITH LIMITED RESOURCES?

Session 1

P. CARBONERAS (Spain — Chairperson): Following on from what Mr. Boyazis said and speaking as someone from a potential donor country, I would like to ask how assistance should be provided. Should it always be provided through international organizations, or is bilateral assistance preferable?

J. TOMÁS ZERQUERA (Cuba): In Cuba, we have experience both of bilateral cooperation and of multilateral cooperation through the IAEA, and I am not sure which is preferable. Some projects have been successful, others less so. If there is a determination to succeed on both sides, perhaps it is not important how the assistance is provided.

C. TENREIRO LEIVA (Chile): During this symposium, I heard references to ‘public awareness’, ‘confidence’ and ‘participation’.

In Chile, the public is not aware that we have a problem with radioactive waste, because awareness comes through the media, and the media say that radioactive waste is a problem only when a Japanese ship carrying nuclear waste comes near to our coast. As we don’t have nuclear power plants, the public believes that otherwise we don’t have a problem with radioactive waste. But we do have a problem.

Regarding ‘confidence’, the public doesn’t have much confidence in nuclear experts, so we have a second problem.

Regarding ‘participation’, there is the social problem associated with radioactive waste disposal — nobody wants a disposal site near his home.

I should also like to touch on the question of legal powers. You may have the best managers or best decision maker in the world, but without a strong legal framework they can’t be effective. In Chile, we have more than 10 000 sealed sources being used by mining companies. Nobody knows what the companies are going to do with those sources. How can the companies be pressured into disposing of them properly? The decision makers, knowing that Chilean law doesn’t give them much leverage, can only suggest. In that connection, I feel that the IAEA’s recommendations are too broad — not as specific as the recommendations of, say, the World Bank, which, moreover, insists that one follow them.

Regarding the sharing of radioactive waste management technology, we have found that the cost of shared technology can be unexpectedly high.

Perhaps the IAEA could establish a programme for the sharing of cost information.

D. LOUVAT (IAEA): In response to Mr. Tenreiro Leiva's comment about the IAEA's recommendations, I would recall that, in order to ensure adequate levels of radiation safety in all its Member States, the IAEA some years ago launched a Model Project from which a lot of Member States — including Chile — have benefited. The countries participating in the Model Project are expected ultimately to pass five 'milestones'. The first milestone relates to regulatory infrastructure, while the second and third milestones relate to issues like nuclear medicine, patient protection and worker exposure. The fourth milestone relates to public protection, with emphasis on radioactive waste management and disposal and the control of radioactive releases. We are concerned that so far very little work connected with this milestone has got under way, and we are hoping for some stimulus from this symposium.

In this connection, I would recall that in my presentation I mentioned the IAEA's Waste Safety Standards Committee (WASSC), membership of which is a good way of gaining access to information. The IAEA's Member States can be full members of WASSC, attending the meetings held every six months in Vienna, or corresponding members, entitled to comment on safety standards made available on an IAEA website.

Regarding Mr. Tenreiro Leiva's point about sealed sources, on the basis of the import and export guidance supplementary to the Code of Conduct on the Safety and Security of Radioactive Sources, which was approved by the IAEA's Board of Governors in September 2004, Chile's regulatory body could put pressure on the mining companies by not allowing the importation of sealed sources if there was no provision for them to be shipped back to the suppliers after being used. Some IAEA Member States are applying the Code of Conduct in this way very strictly. Of course, it would not help with the 10 000 sealed sources already in Chile, but it certainly could with the sealed sources imported from now onwards.

L. JOVA SED (IAEA): Fortunately or unfortunately, the IAEA safety standards are not legally binding on countries unless they are incorporated into national legislation. On the other hand, the Joint Convention is legally building on the Contracting Parties, which must implement the radioactive waste management principles which are the basis of the Joint Convention.

Regarding the STRECA project, referred to by Mr. Tomás Zerquera, the IAEA is planning a regional technical cooperation project for all of Latin America on radioactive waste safety, drawing on results of the STRECA project. We hope that it will lead not only to broad recommendations but also to site-specific recommendations for each participating country.

J. ROWAT (IAEA): Mr. Tenreiro Leiva may be right about the IAEA's recommendations. Maybe the standards, guides, safety reports and technical reports which we produce are rather too general — and directed a little too much towards countries that have a lot of resources.

H.M. FERNANDES (Brazil): We have not talked about the integration of operators — the generators of radioactive waste — into the regulatory process in order to promote among them a real understanding of the principles of radiation protection and radioactive waste management. When you go to IAEA meetings, you see many regulators, but not many operators.

A colleague from Brazil, Ms. Diniz, representing a company which is a major producer of iron, has come to this symposium in order to listen, and I believe that such people should be 'brought into the system' so that they can, through better planning, reduce the problems associated with the generation of radioactive waste.

P. CARBONERAS (Spain — Chairperson): It is not easy to make generators of radioactive waste aware of the principles of radiation protection and radioactive waste management.

J.P. BOYAZIS (Belgium): In that connection, I would emphasize the importance of understanding the legislation. In our organization we have a section that interacts with the authorities in matters of legislation, and, as a manager of research and development, I have asked this section not to limit itself to passing legislation on to us, but to help us interpret it.

At the international level, it is very important what organizations like the IAEA and OECD/NEA help people to understand the publications which they issue.

P. CARBONERAS (Spain — Chairperson): In my view, it is difficult to develop a radioactive waste management policy and strategy for more than one country as the boundary conditions differ from one country to the other. On the basis of our experience in Spain, however, I would say that, once the policy and strategy are clear, it is fairly easy to obtain the collaboration of operators.

P. BREDELL (South Africa): In South Africa, operators sometimes even help to clarify regulatory issues.

NECSA, an operator, participates in IAEA conferences, workshops and so on together with our regulator body, with which we have quite a mature relationship and collaborate in trying to find mutually satisfactory solutions. So, even in a developing country like South Africa, it's quite possible for operators to play an active role in the regulatory process.

M. BEN BELFADHEL (Canada): I have never heard anyone say "I have enough resources". However, I believe that the advanced countries are wasting resources as a result of duplication of effort in areas such as safety assessment. Maybe we need to pool our knowledge and develop consistent approaches based on international guidance, and also develop further generic concepts along the lines of the borehole disposal concept.

S.A. SYED HAKIMI SAKUMA (Malaysia): Does one need to have a strong regulatory structure in place in order to have a disposal site?

P. BREDELL (South Africa): Let me attempt to answer that question. In South Africa, we have a low to intermediate level waste repository at Vaalputs which receives waste from the country's only nuclear power station — at Koeberg, near Cape Town. We want to send other waste as well to this repository, for example, waste that we have at Pelindaba, in the interior of the country. However, we have a problem of public acceptance — the public accepts the present situation — but rather reluctantly, and it will not accept an extension of the disposal operation. Public acceptance will be gained only when there is a national policy on radioactive waste management in place.

So for us the problem is not one of regulatory structure.

M.I.F. PAIVA (Portugal): In countries which have no nuclear power stations it is difficult to raise the money needed for radioactive waste management, which has only low priority. In Portugal, those responsible for managing radioactive waste have to request financial support from the Government. It's a terrible problem.

The recommendations of the IAEA and directives of the European Commission are important, but costly to implement, and it's not easy for countries like Portugal to obtain financial support from such organizations. Most of their financial support goes to countries with nuclear power programmes.

P. CARBONERAS (Spain — Chairperson): I share your view.

P. METCALF (IAEA): In response to what has been said by Mr. Ben Belfadhel and Ms. Paiva, I would mention that the IAEA's ISAM and ASAM projects have been developed for harmonizing safety assessment methodologies, but we would like to turn them into networks for the sharing of knowledge about harmonized methodologies.

Countries like Portugal participating in these projects will then have access to international networks through which they can ask "How did you deal with that problem? Can you transfer the necessary information to us?" I strongly recommend participation in these projects.

J.R. COCHRAN (United States of America): Many countries will never have enough resources to properly manage long lived radioactive waste, and developing countries wouldn't have long lived radioactive waste but for the exportation of radiation sources by a few advanced countries. How does the panel feel about the take-back of radiation sources?

P. BREDELL (South Africa): It is obviously the ideal solution, but there are difficulties. In Africa we have a legacy of radium needles which, ten years or so ago, under the guidance of the IAEA, we tried to return to the donors. However, either the donors did not exist or they were very reluctant to take the radium needles back. So one needs to find solutions like boreholes.

D. LOUVAT (IAEA): Regarding disused sealed sources, as I indicated earlier, the IAEA's Board of Governors has approved import and export guidance supplementary to the Code of Conduct on the Safety and Security of Radioactive Sources. The Code of Conduct is not a binding a convention, but I hope that some day such a convention relating to radioactive sources will be concluded.

As to the borehole option, it's something which we hope any country will be able to afford.

P. CARBONERAS (Spain — Chairperson): Not all types of radioactive waste are equally hazardous, so perhaps we should set priorities and focus first on the most hazardous types, establishing a basis on which we can later deal with the other waste.

G. SMITH (United Kingdom): I suggest that, for countries which don't have sufficient resources, the IAEA devise a methodology for evaluating national waste management strategies and demonstrating the consequences — in terms of damage to human health and the environment and of social costs — of not having an adequate strategy.

L. JOVA SED (IAEA): That is a good suggestion. We have found that many countries, because of the lack of an adequate national strategy, are not complying with one of the basic radioactive waste management principles — the interdependence of the different stages of radioactive waste management. They are taking steps to solve particular problems without thinking about the subsequent steps.

Regarding Mr. Carboneras's last comment, we are trying to promote what we call a 'graded approach', whereby the safety efforts are proportional to the hazards. The approach will not be the same in a country with, say, ten sources in one storage facility and a country with, say, 10 000 sources at many locations, and that will have to be taken into account in the development of national strategies, in the allocation of resources and so on.

P. BREDELL (South Africa): A national strategy is almost indispensable, especially for countries with limited resources, and I believe that in each case the national strategy should be developed by the country in question, perhaps with the assistance of an impartial arbiter without commercial interests such as the IAEA. It should not be imposed from outside the country but, developed by people within the country who understand the country's institutional requirements.

P. CARBONERAS (Spain — Chairperson): I would add that, for the establishment of a national strategy, the first thing you need is the determination to establish it. Then everything becomes much easier.

G. JACK (Canada): Regarding the borehole option, it's basically very cheap. However, finding a suitable place to drill your borehole and assessing the geological surroundings can be very costly.

I should now like to make what may be a politically incorrect remark. Perhaps we radiation safety experts have been so careful in developing elaborate safety standards that it is extremely difficult for countries — especially ones with limited resources — to comply with them. Perhaps the radiation safety community has 'gone overboard' with safety.

I. OTHMAN (Syrian Arab Republic): Regarding the suggestion made by Mr. Smith, the IAEA's Model Project provides for peer reviews, and possibly these could include the evaluation of national waste management strategies.

Regarding Mr. Boyazis's comments about transferring knowledge and experience, I would point out that it is being made more and more difficult for people from developing countries to go and study at universities in advanced countries, and especially to study nuclear-related subjects. It should be recalled that ionizing radiation does not recognize national borders.

D. LOUVAT (IAEA): In response to Mr. Othman's first comment, I would mention that the Model Project provides for peer review missions related to radioactive waste management. In an effort to expand this aspect of the Model Project, we are developing a peer review support document.

C. DINIZ (Brazil): As a representative of a mining company, I would like to stress the importance of IAEA education and training for us users of standards issued by the IAEA.

G. LINSLEY (United Kingdom): Regarding the SAPIERR project described by Mr. Štefula, I should be interested to know whether the participating countries are seriously engaged in it — to the extent of having made commitments at the governmental level. Also, is the repository siting issue being addressed?

V. ŠTEFULA (Slovakia): No commitments have been made at the governmental level. The organizations involved in the project represent themselves, not their governments.

Regarding the siting issue, I don't think I will see a site for a European regional repository selected before the end of my career. However, the political situation in Europe has been changing so rapidly that almost anything is possible. We are concentrating on the economic and technical issues, and hope that at some time in the future a European regional repository will be established.

J.-M. POTIER (IAEA): It will be very difficult to find a country willing to host such a shared repository, but there are other types of nuclear fuel cycle facility which can be shared and which are less controversial than low level radioactive waste repositories — for example, spent fuel encapsulation plants. Perhaps one could make a start with the sharing of such other facility types.

I thing that a number of countries in Europe and Latin America would benefit from getting together and considering the legal, institutional and financial aspects. I am sure that the IAEA would assist them.

If the cooperation in operating less controversial facilities worked, with the achievement of economies of scale, it might be easier to tackle this issue of shared disposal facilities for low level radioactive waste and even for spent fuel.

VERY LOW LEVEL RADIOACTIVE WASTE (VLLW)

(Session 2)

Chairperson

J. AVÉROUS
France

VERY LOW LEVEL WASTE — THE NEED FOR A NEW CATEGORY OF RADIOACTIVE WASTE?

L. BAEKELANDT
Federal Agency for Nuclear Control,
Brussels, Belgium
Email: luc.baekelandt@fanc.fgov.be

Abstract

The classification of radioactive waste may be established from different points of view, such as physical and chemical properties, short term and long term safety related aspects, communication aspects, etc. In 1994, the IAEA published a Safety Guide on Classification of Radioactive Waste, introducing a classification system that takes account of the radionuclide concentration levels and their radioactive half-lives in the material. The following categories were defined: exempt waste, short lived low and intermediate level waste, long lived low and intermediate level waste and high level waste. Very recently, the IAEA has developed guidance on the application of the concepts of exclusion, exemption and clearance. This guidance refers to the application of a graded approach in the making provision for safety and radiological protection. Furthermore, there is some related ongoing work to establish a common framework for radioactive waste management which is closely linked with the further development of the classification system. This paper will address this recent evolution and will discuss the need for a revision of the classification system and the need for a new category of radioactive waste with activity levels slightly above the exemption/clearance levels.

1. INTRODUCTION

A classification of radioactive waste may be established from different points of view, such as physical and chemical properties, short term and long term safety related aspects, communication aspects, etc. In 1970 the IAEA published a technical report on Standardization of Radioactive Waste Categories [1] and in 1981 basic guidance on underground disposal of radioactive wastes [2]. In these documents a classification of radioactive waste was proposed: low level waste (LLW), medium level waste (MLW) and high level waste (HLW). In 1994 the IAEA published a specific Safety Guide on Classification of Radioactive Waste [3], introducing a classification system that takes account of the specific activity of radionuclides and the half-lives of the radionuclides in the material. In particular a category ‘exempt waste’ was introduced. Reference was made to a Safety Guide (to be published) Principles for the Exemption of Radiation Sources and Practices from Regulatory Control. This safety guide has never been issued, but very recently, the IAEA has published guidance on the application of the concepts of exclusion, exemption and clearance [4], in which a set of nuclide specific values were recommended. This guidance also emphasises the need for a graded approach in relation to the level of the provisions for safety and radiological protection. Furthermore, there is some ongoing work on a common framework for radioactive waste management in general and disposal of radioactive waste in particular which is closely linked to the development of future waste classification systems.

2. THE 1981 IAEA CLASSIFICATION

In the basic guidance for underground disposal of radioactive wastes [2], a distinction was made between three categories of radioactive waste:

(1) High level waste: (i) the highly radioactive liquid, containing mainly fission products, as well as some actinides, which is separated during chemical reprocessing of irradiated fuel; (ii) any other waste with radioactivity levels intense enough to generate significant heat due to radioactive decay; (iii) spent reactor fuel, if declared as waste;
(2) Medium level waste which, because of its radionuclide content requires shielding but needs little or no provision for heat dissipation during handling and transport;
(3) Low level waste which, because of its low radionuclide content, does not require shielding during normal handling and transport.

A differentiation was made between short and long lived waste, as well as alpha bearing waste. This classification was based mainly on physical characteristics and was useful for general purposes. But there were some serious limitations:

(a) No clear linkage to safety aspects, in particular with respect to disposal;
(b) No quantitative boundaries between the classes;
(c) No recognition of waste that contains so little radioactive content that it can be considered as not radioactive;
(d) No recognition of waste that contains small quantities of natural radionuclides dispersed through very large volumes (for instance, uranium mining and milling waste).

3. THE 1994 IAEA CLASSIFICATION

To address these limitations and to improve communication, the IAEA proposed a new classification in 1994 [3]. The method for classification was derived not only from the physical characteristics, but also from the safety aspects of radioactive waste disposal.

The classification scheme is reproduced in Fig. 1. Considering this figure vertically, radioactivity levels range from negligible to very high concentrations of radionuclides. As the level rises, there is an increased need to isolate the waste from the biosphere. There is an increased need to consider shielding from radiation, and the generation of heat from radioactive decay. Considering the figure horizontally, half-lives range from short (seconds) to very long time spans (millions of years) and similarly radioactive wastes range from those containing minor quantities of long lived radionuclides to those containing significant quantities thereof. This situation was taken care of by defining two subclasses of low and intermediate level waste: short lived and long lived.

In comparison to the earlier classification, a new category was introduced, namely exempt waste. It was defined as waste that contains so little radioactive material that it must not be considered 'radioactive' and might be exempted from nuclear regulatory control. That is to say, although still radioactive from a physical point of view, this waste may be safely disposed of,

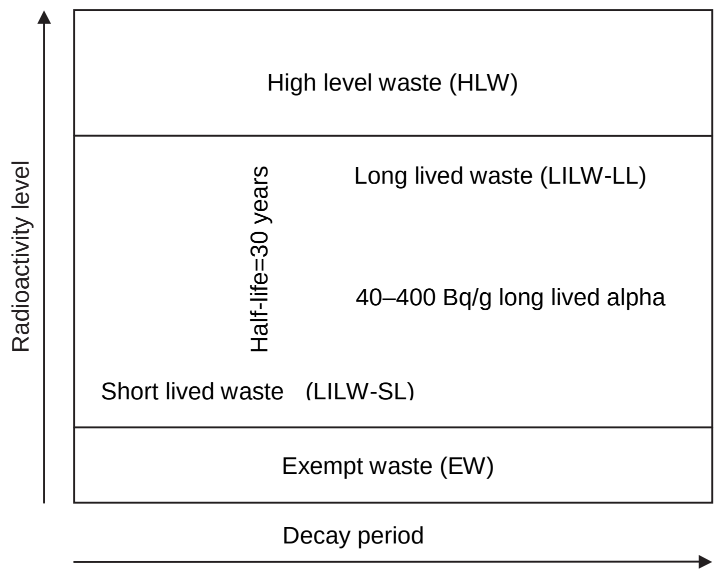

FIG. 1. Waste classification according to IAEA Safety Series No. 111-G-1.1.

applying conventional techniques and systems, without specifically considering its radioactive properties.

It was noted that an exact boundary level between the different categories is difficult to quantify without precise planning data for individual facilities. Any specific activity limits are dependent on many parameters, such as the type of radionuclide, the decay period and the conditioning techniques. Such a classification can therefore not be considered as a substitute for specific safety assessments performed for an actual facility involving well-characterized types of radioactive waste.

It was recognized that the disposal of very large amounts of waste containing long lived natural radionuclides has also to be addressed. Such waste typically contains natural radionuclides like uranium, thorium, and radium and is frequently generated from uranium/thorium mining and milling or similar activities. It may also include waste from the decommissioning of facilities, where other radionuclides may also be present. The characteristics of this waste are sufficiently different from other waste types that they may require an individual regulatory approach.

Although this waste does contain long lived radionuclides, their concentrations are generally sufficiently low that either they can be exempted or disposal options similar to those for short lived waste may be considered, depending on the results of safety analyses.

4. THE IAEA SAFETY GUIDE ON EXCLUSION, EXEMPTION, CLEARANCE

After more than ten years of meetings and discussions, a consensus was reached in 2004 on the application of the concepts of exclusion, exemption and clearance [4]. The resulting Safety Guide RS-G-1.7 includes specific values of activity concentration for both radionuclides of natural origin and those of artificial origin that may be used for bulk amounts of material for the purpose of applying the concepts of exclusion or exemption. That means that the materials with activity concentrations below the levels specified, should not be subject to the system of radiological control (notification, authorization, licence). It also elaborates on the possible application of these values to clearance, and as such may be used to define the boundary between 'exempt waste' and '(very) low level waste'.

Two different approaches were used to establish the values of activity concentration provided in this safety guide. The first approach applies the concept of exclusion (exposures are unamenable to control, regulatory control is not practicable or is a waste of resources because the benefits of regulatory control measures are almost zero) to derive values of activity concentration for radionuclides of natural origin. The second approach makes use of the concept of exemption (doses are trivial) in order to derive values of activity concentration for radionuclides of artificial origin, whatever the amount of material involved.

The levels are given in terms of activity concentrations (Bq/g):

(a) For natural radionuclides: 10 Bq/g for ^{40}K and 1 Bq/g for the other natural radionuclides;
(b) For artificial radionuclides: 0.01 Bq/g for ^{129}I, 0.1 Bq/g for most alpha emitters and high energy beta emitters, up to 10 000 Bq/g for ^{58}Co^{m}.

These levels are to be interpreted as averages over larger amounts of material. The Safety Guide promotes a graded approach (consistent with the optimization principle) when activity concentrations exceed the values in the Safety Guide. According to the BSS, such a graded approach "…shall be commensurate with the characteristics of the practice or source and with the magnitude and likelihood of the exposures and shall also conform to any requirements specified by the [regulatory body]".

For activity concentrations that exceed the relevant values in the Safety Guide by several times (e.g. up to ten times), the regulatory body may decide (where the national regulatory framework so allows) that the optimum regulatory option is not to apply regulatory requirements to the legal person responsible for the material. In some cases, the regulatory body may specify that exposure arising from certain human activities involving activity concentrations of this magnitude need not be regulated.

Where the regulatory body has determined that regulatory controls do apply, the stringency of the regulatory measures should be commensurate with the level of risk associated with the material. When the human activities involving the material are considered to constitute a practice, the regulatory measures that are applied should be consistent with the requirements for practices established in the BSS. The minimum requirement is that such practices be notified to the regulatory body. For some practices involving low or moderate risks, registration as defined in the BSS, may be sufficient. Other practices may need to be licensed, with the stringency of the licence conditions reflecting the level of risk.

An example of a graded approach can be found in the IAEA Transport Regulations [5] with respect to the transport of low level radioactive waste that falls within the categories of Low Specific Activity material (LSA-1, 2 or 3).

5. THE COMMON FRAMEWORK

Over the past few decades various generic options for the safe management and disposal of radioactive waste have been developed and the IAEA has defined a set of principles that apply to all radioactive waste management activities [6]. These safety fundamentals provide a common basis for the development of more detailed IAEA Safety Standards.

All types of radioactive waste need to be safely managed, and eventually disposed of, by appropriate technical solutions and with appropriate levels of control. What constitutes an appropriate solution and level of control will depend on the potential of the waste to give rise to radiation hazards. More specifically, it may depend on the total quantity and concentrations of radionuclides present, their half-lives, and their physical and chemical forms and distributions within the waste. In addition, waste management arrangements need to take account of the total amounts of different types of waste that are generated nationally or regionally, the time-frames of waste generation, and the waste processing capabilities and disposal options that may be available. In practice, it is convenient to classify radioactive waste broadly according to the level of radiation hazard that it presents and the options for its safe management and/or disposal.

There is a well-established international consensus concerning the principles for radioactive waste management, but consensus on how these principles should apply to the management and disposal of the whole range of waste types is still developing. In order to ensure that all radioactive waste is managed in an acceptably safe manner, it has been suggested that a 'common framework'should be established to provide an approach for ensuring such safe management, and particularly disposal, of all radioactive wastes types consistent with the IAEA waste management principles.

This common framework is illustrated schematically in Fig. 2. This framework would provide a general understanding of:

(a) The basis on which radioactive waste forms can be classified for the purpose of identifying appropriate generic waste disposal options;
(b) The identification of appropriate generic waste disposal options for each waste type that are in accordance with internationally agreed safety principles; and
(c) The means by which the safety of such options can be assured through the development of storage and disposal systems with the suitable

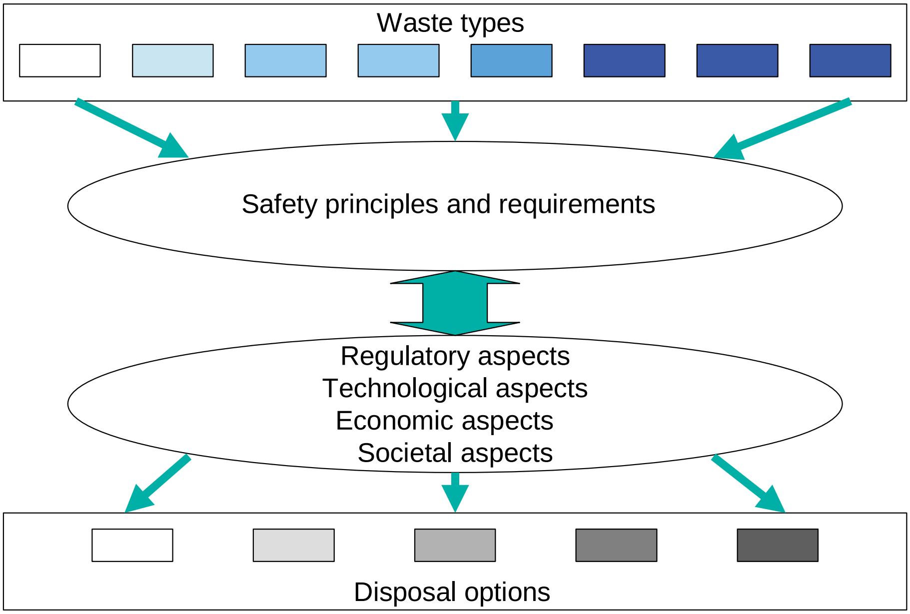

FIG. 2. Schematic view of the common framework.

characteristics and degrees of robustness, so as to offer an acceptable degree of protection of human health and the environment as defined in international guidance and national regulations.

Factors other than safety play a role in the decision making process to determine the linkage between a waste type and a disposal option. There are also legal and regulatory aspects, technological aspects, economical aspects and societal aspects to be taken into consideration.

An example of the application of this common framework is summarized in the following tables. Table 1 shows a summary of generic waste types that may be considered. In addition to the 1994 classification, a new category is introduced: very low level waste (VLLW), i.e. waste with activity concentrations one or two orders of magnitude above the clearance levels, for which safety provisions as stringent as those for the disposal of low and intermediate level waste are not needed.

In addition to these generic waste types, a specific classification for disused sealed sources may be useful, taking activity and half-life into consideration. Similarly, a specific classification for naturally occurring radioactive material, taking the following aspects into account: normal and enhanced concentrations, large and small volumes.

TABLE 1. GENERIC WASTE TYPES

Waste type	Half-life (a)	Activity	Mass	Example
VLLW	various	Typically 10 Bq/g or lower	10^5–10^6 t	Operational arisings from nuclear industry, decommissioning waste — concrete rubble, scrap metal, all other material possibly slightly contaminated
SL LILW	<30	Typically 10^5–10^6 Bq/g	About 50 t per year and per installed GW	Solid waste with variety of natures (cellulose, metals, resins, sludges)
	with ‘residual’ long lived activity	100–1000 Bq/g of long lived radionuclides	Arising in some 10^4–10^6 t during a life cycle of a plant of 1 GW installed power	Raw waste usually embedded in concrete Waste arising from operation of nuclear industry Decommissioning waste
LL LILW-1	>30	~10^8 Bq/g of fission/ activation products,	About 5 t per year and per installed GW	Ends and hulls embedded in cement or compacted Bituminized or dried compacted sludge
		~10^6 Bq/g of actinides	About 10^3–10^5 t during a life cycle of a plant of 1 GW installed power	Various contaminated equipment (technological waste) arising from processing of spent fuel or treatment of active effluents or from facilities Decommissioning waste
LL LILW-2	>30	10^4–10^5 Bq/g, mainly C-14	Around 1000 t	Graphite waste from gas cooled reactors

TABLE 1. GENERIC WASTE TYPES (cont.)

Waste type	Half-life (a)	Activity	Mass	Example
LL LILW-3	>30	Some Bq/g of U contaminated waste	Around 10 000 t	Depleted uranium waste from operation of enrichment plant and fuel fabrication Reprocessed uranium (at present not considered waste) Waste arising from fuel fabrication or recovered by fuel processing
HLW	>30	>10^{15} Bq/g	Hundreds to thousands of tonnes per year	Spent fuel Vitrified high level waste

Table 2 shows the generic disposal categories and facility types that may be considered.

The selection of a disposal option for a particular waste type will depend on various factors: the need to respect the fundamental waste safety principles, the amount of particular waste types generated, the available facilities and technologies, disposal costs and the acceptability of particular disposal facilities to the various interested and affected stakeholders. In terms of meeting the safety principles, the various waste types can be linked first to a category of disposal facility, i.e. near surface, intermediate depth or geological, and then to a particular disposal option within that category.

In Table 3 a linkage is suggested between the different generic waste types and the different disposal categories and disposal facility types. Similar tables may be drawn for disused sealed sources and for NORM.

TABLE 2. GENERIC DISPOSAL CATEGORIES AND FACILITY TYPES

Category	Depth	Facility type	Footprint	Example
Near surface	On the surface or at depths up to a few tens of metres	Landfill	Large — up to several hectares	Municipal refuse facilities
		Mine tailings	Large — up to several hectares	Mine tailings dam Waste rock piles Tailing ponds
		Trench	Medium — up to tens of hectares	Trench disposal facility — waste disposed just below ground level — waste may be emplaced in engineered works; a cover limits the ingress of water (Indian example)
		Vault	Medium — up to tens of hectares	Mound disposal facility — surface area of some 10–100 ha — usually waste is emplaced in engineered works of which void volumes are filled and water ingress is limited by use of an impervious cover Examples: Centre de l'Aube (France), El Cabril (Spain), Mochovce (Slovakia)
Intermediate depth	Depths of a few tens of metres up to a few hundreds of metres	Cavern	Medium — up to tens of hectares	SFR Forsmark (Sweden), Olkiluoto (Finland)
		Borehole — shallow	Small — less than a few m^2	Radon type facility (Russian Federation)
Deep	A few hundreds of metres or more	Borehole — deep	Small — less than a few m^2	Proposed South African BOSS concept
		Deep geological	Medium — up to a few hectares	Yucca Mountain; in mountain disposal with (sub) horizontal access tunnels

TABLE 3. LINKAGE BETWEEN WASTE TYPES AND DISPOSAL CATEGORIES AND FACILITY TYPES

Disposal category	Disposal facility type	VLLW	LILW-SL	LILW-LL-1	LILW-LL-2	LILW-LL-3	HLW
Near surface	Landfill	✓	X	X	X	X	X
	Mine tailings	✓	X	X	X	✓	X
	Trench	✓	✓	X	✓	✓	X
	Vault	*	✓	X	X	X	X
Intermediate depth	Cavern	*	✓	✓	✓	✓	X
	Borehole — shallow	*	*	✓	✓	✓	X
Deep	Borehole — deep	*	*	*	*	*	X
	Geological	*	*	✓	✓	*	✓

✓ The waste type is generally acceptable in the generic disposal option.
* The waste type would generally not be appropriate for this generic disposal option. The reason could be economic, size incompatibility, the hazard may not warrant the level of protection provided or other reasons.
X The waste type is generally not acceptable in the generic waste disposal option because the level of safety or degree of assurance is not provided by this generic disposal option.

6. CONCLUDING REMARKS

Given the evolution of radioactive waste management safety during the last decade (consideration of long term safety, terminology, RS-G-1.7, involvement of stakeholders), there is a need to review and revise the 1994 Safety Guide on classification of radioactive waste. The ongoing work at the IAEA on the common framework for waste disposal will be a valuable input. VLLW (roughly speaking waste with an activity concentration one or two orders of magnitude above the clearance levels) would be a useful category.

Although such a revised classification might be useful for communication purposes, it must be noted that such it is not a substitute for a classification based on specific safety assessments performed for an actual facility involving well-characterized types of radioactive waste.

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Standardization of Radioactive Waste Categories, Technical Reports Series No. 101, IAEA, Vienna (1970).
[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Underground Disposal of Radioactive Wastes: Basic Guidance, Safety Series No. 54, IAEA, Vienna (1981).
[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Classification of Radioactive Waste, Safety Series No. 111-G-1.1, IAEA, Vienna (1994).
[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Application of the Concepts of Exclusion, Exemption and Clearance, Safety Standards Series No. RS-G-1.7, IAEA, Vienna (1994).
[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the safe Transport of Radioactive Material, 1996 edition as amended 2003, Safety Standards Series No. TS-R-1, IAEA, Vienna (2004).
[6] INTERNATIONAL ATOMIC ENERGY AGENCY, The Principles of Radioactive Waste Management, Safety Series No. 111-F, IAEA, Vienna (1995).

DISPOSAL OF VERY LOW LEVEL WASTE AND SAFETY ASSESSMENT

M. DUTZER, F. CHASTAGNER, N. RICQUART, F. DURET
Agence nationale pour la gestion des déchets radioactifs,
Châtenay-Malabry, France
Email: michel.dutzer@andra.fr

Abstract

According to French regulations, waste 'zoning' must be established in nuclear facilities to identify areas where waste may be radioactively contaminated or activated and areas where waste cannot be contaminated or activated. Waste that comes from the first zoning category is called 'nuclear waste' and must be managed by specific means with emphasis on traceability. Considering the important decommissioning programme that is forecast in France over the next thirty years, it was considered necessary to create a new disposal facility dedicated to very low level radioactive waste (VLLW). The design of the facility is consistent with the design of disposal facilities for non-radioactive hazardous waste. Disposal cells are excavated in a clay layer and are covered by a clay capping system when they are filled. A site was chosen near to the village of Morvilliers, in the vicinity of the Centre de l'Aube disposal facility that accommodates low and intermediate level short lived radioactive waste. The capacity of the VLLW facility is 650 000 m^3. A safety assessment was performed of the facility which takes into account the radioactive impact as well as the chemical impact. Both of the predicted impacts are very low. After two public inquiries in 2001 (deforestation) and 2002 (construction of the facility), a licence was granted by the local prefecture in 2003 and the first disposals occurred in October 2003.

1. INTRODUCTION

In France, the decision to establish a disposal facility for very low level waste (VLLW) at Morvilliers, Aube Department, fulfils the need to manage the large amounts of waste that will be generated, especially as a result of the dismantling of the first generation of nuclear power plants (NPP) undertaken by Électricité de France (EDF), the French electrical utility. It is also necessary following the establishment of 'waste zoning' within basic nuclear facilities (Installation Nucléaire de Base (INB)) in accordance with an order issued on 31 December 1999 [1]. This facility will also be available for the management of some waste arising from industrial activities that use natural radioactive materials.

This paper describes the various waste categories to be accommodated at the Morvilliers facility (Fig. 1). It outlines the design principles of the disposal facility, especially with regard to the arrangements to provide for waste containment. Lastly, it explains the safety approach adopted for the waste repository.

2. WASTE CATEGORIES INVOLVED

2.1. Waste zoning

Pursuant to the Order of 31 December 1999 [1], every French INB must establish zoning arrangements on its site with a view to separating any sector where waste is actually, or likely to be, radioactively contaminated or activated (nuclear waste zone) from other sectors where there is no waste contamination or activation risk (conventional waste zone). Zoning criteria must also take into account the operations carried out in the different parts of the installations and of the case history of those installations. The zones must be confirmed through periodical measurements.

Every operator must prepare a waste study describing how the waste is generated, what the annual production rates are and how the waste is classified in relation to the waste area. The study must also clearly describe the waste management methods to be used and provide a detailed overview of the operator's efforts to reduce waste quantities. The document is subject to the approval of the safety authority.

Conventional waste is managed according to classical systems, the only restriction being that the disposal facilities accepting it must be authorized to

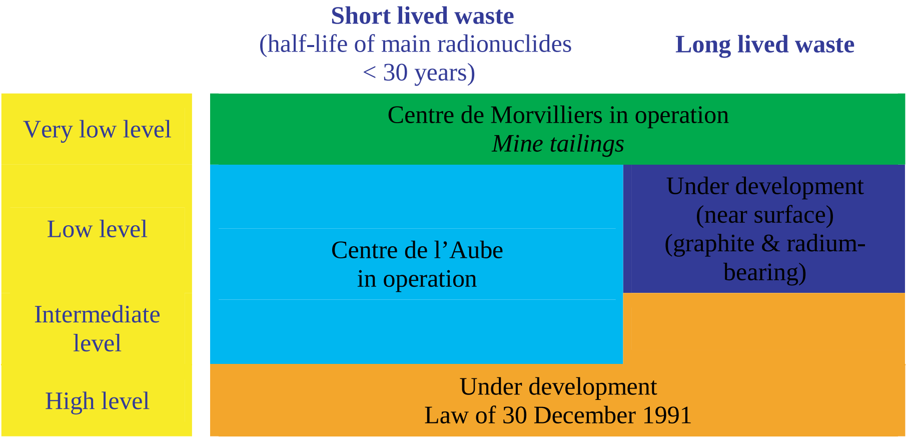

FIG. 1. French radioactive waste classification.

accommodate waste originating from INBs. Nuclear waste must be managed according to specific systems with reinforced traceability. The principle of waste zoning implies that a large part of the waste has a very low activity and, as a matter of fact, there is sometimes only a presumption of contamination. The waste is therefore integrated within a special category of the French radioactive waste classification system: the VLLW category.

2.2. Inventory of the VLLW disposal facility

A working group comprising the three major French radioactive waste producers, EDF, the French Atomic Energy Commission (CEA) and COGÉMA, together with the French national radioactive waste management agency (ANDRA) has prepared a provisional inventory of the radioactive waste arisings in France over the next 30 years. Some 800 000 t of waste are expected to arise within the following categories (see Fig. 2):

(a) Inert waste (52%), over half of which consists of concrete rubble.
(b) Metal waste (44%), divided as follows:
  (i) Waste with no pre-conditioning requirement before disposal;
  (ii) Waste with surface contamination to be grouted before disposal;
  (iii) Small metal residues to be compacted.
(c) Non-metal residues to be compacted (3%).
(d) Sludges to be solidified (1%).
(e) Hazardous residues to be stabilized.

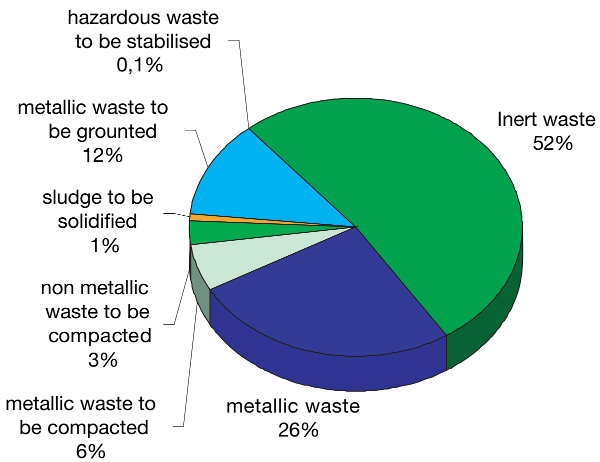

FIG. 2. Provisional VLLW inventory for the next 30 years.

In order to take into account the amount of additional incoming waste from other small producers, the waste capacity of the disposal facility was set at 650 000 m^3, corresponding to about 1 000 000 t of waste to be disposed of.

In addition, a chemical inventory of toxic elements, such as chromium, lead, nickel, cadmium, arsenic and mercury, was prepared.

3. REPOSITORY DESIGN

One basic principle of the repository design is that it should comply with regulations governing disposal facilities for non-radioactive hazardous waste (Fig. 3). By applying such a principle, it is possible to accommodate both radioactive waste and toxic chemicals. Containment, therefore, relies on the properties of a low permeability surface clay layer in which the repository is situated. Within the clay layer, trenches are excavated with their sides and the their bottoms protected by a watertight membrane. The waste is piled on top of the membrane. A mobile roof is provided to protect operations throughout loading. Trenches are backfilled and sealed with the same type of membrane. The repository is finally covered with clay. An inspection hole is used to check that there is no water seepage around the waste.

Except in the case of hazardous waste, for which the potential pollutant, measured by leach tests, is subject to acceptance criteria, there are no specific waste containment requirements. Hence, the conditioning of packages only serves to facilitate handling operations and to prevent the dispersion of labile contamination in the disposal trenches during loading. Some waste, such as bulky items, may be disposed of without any form of preliminary packaging.

After operations, a post-closure monitoring phase of approximately 30 years is scheduled.

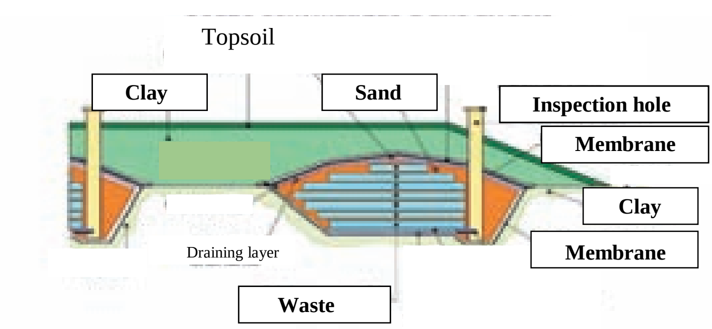

FIG. 3. Cross-section of the repository.

4. REPOSITORY SITING, CONSTRUCTION AND COMMISSIONING

ANDRA chose a site in the village of Morvilliers, Aube Department for the VLLW facility, close to the Centre de l'Aube Disposal Facility, thus allowing for synergies between the two operations (Fig. 4). An area of 45 ha was surveyed and a clay layer varying between 15 m and 25 m in thickness was characterized during two reconnaissance campaigns in 1999 and 2000.

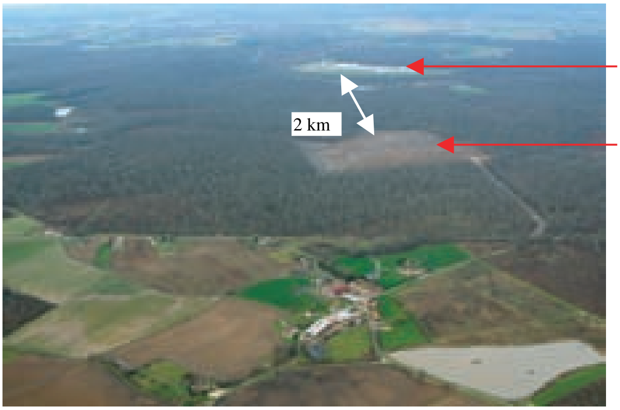

FIG. 4. Site location.

Owing to the low radiological inventory of the repository, the facility is not subject to the licensing system for INBs, but, instead, to that for classified facilities for the protection of the environment (installations classées pour la protection de l'environnement (ICPE)). The local prefecture reviews the application and issues authorizations. The siting of the facility gave rise to two public inquiries in 2001 and 2002, the first dealing with the clearing of a forest area and the second with the creation of the facility itself.

Construction started in August 2002 and the first waste packages were deposited in October 2003 in disposal cells measuring 80 m long by 25 m wide by 6 m deep (Figs 5–8). Waste treatment units (compactors and facilities for solidifying and rendering the waste inert) should be commissioned by the end of 2004. The annual flow of waste is expected to range between 20 000 and 30 000 m^3.

At the end of June 2004, about 7000 m^3 of waste had already been disposed of.

FIG. 5. Removable rain protection structures (one is under construction).

FIG. 6. Waste handling (big bags).

5. SAFETY APPROACH AND WASTE ACCEPTANCE CRITERIA

The safety approach selected for the VLLW disposal facility is consistent with the safety approach adopted for the Centre de l'Aube facility. It covers the impact of the facility with regard to both the radiological and chemical toxicities of the waste.

FIG. 7. General view of a disposal cell (big bags, drums and sand backfill).

FIG. 8. Waste handling (metal waste).

The toxic risk was considered for chemical elements with a threshold for health effects (As, Zn, Pb, Cd) and for chemical elements with carcinogenic effects (As, Cd). Corresponding indicators were established: a hazard ratio in relation to the threshold and an individual additional probability in relation to carcinogenesis.

The radiological risk is evaluated by estimating radiation doses. Doses are compared with value limits set by ANDRA and consistent with the regulations or the proposed criteria of international organizations, such as the IAEA or the International Commission on Radiological Protection. More specifically, ANDRA has adopted a maximum value of 0.25 mSv for the exposure of individual members of the public and 5 mSv for workers in normal conditions.

5.1. Water transfers

With regard to the potential migration of radionuclides or toxic chemicals through water flow, the impact of the repository was examined by means of a conservative scenario in which the cover would lose its impermeability and in which the water table located under the clay layer would discharge by resurgence into the nearest stream. It is assumed that a group of members of the public would live in self-sufficiency close to the stream.

Calculations take into account the transfer time (estimated at approximately 160 years) through the clay. They take into account both the hydrogeological and retention properties of the terrains.

The estimated radiological impact, on the basis of a provisional inventory, and using conservative parameters in the assessment, would not exceed 0.1 μSv/a. As for the chemical impact, it was also very small. The hazard ratio and the additional probability of carcinogenic effects are estimated at 1.2×10^{-5} and 5.5×10^{-9}, respectively.

Other altered scenarios were investigated, such as the case in which water would seep into the disposal facility and flood it, before overflowing at the boundaries of the facility and reaching the stream.

These studies show that the radioactive and chemical inventory being considered for the disposal facility is acceptable. More particularly, they have also helped to define a radiological capacity for 25 radioelements, as reflected in the Order authorizing the operation of the repository (see Table 1).

5.2. Airborne transfers

Initially, various scenarios were examined by referring either to the average radioactive waste inventory or to a specific waste type, when it was not relevant to consider the average of the waste spectrum. The scenarios cover not only the operating phase of the facility (e.g. accidental fire scenario), but also the long term (road worksite, home construction on the site, etc.).

Radiological impacts (less than 45 μSv/a in the most pessimistic cases) are much lower than the dose limits set by ANDRA. As for chemical toxicity, the hazard ratio and the additional probability are of the order of 1.4×10^{-3} and 4.8×10^{-8}, respectively.

TABLE 1. RADIOLOGICAL CAPACITY OF THE MORVILLIERS REPOSITORY

^{36}Cl	64 GBq	^{90}Sr	37 TBq	^{126}Sn	100 GBq
^{129}I	31 GBq	^{14}C	1.9 TBq	^{239}Pu	1.2 TBq
^{135}Cs	1.8 TBq	^{108m}Ag	3.8 GBq	^{226}Ra	1.4 TBq
^{99}Tc	130 GBq	^{79}Se	740 GBq	^{232}Th	11.6 GBq

From a radiological standpoint, a second approach consisted in determining what would be the maximum admissible waste radioactivity content that would not only ensure compliance with the maximal doses for the public set by ANDRA for the different scenarios under investigation, but also protect the workers under both normal and accident conditions. ANDRA converted that maximum radioactivity content into a requirement on the average specific activity of a 'waste batch' delivered by the producer. That activity is expressed in the form of an index taken from the International Radiation Accident Scale (IRAS), as follows:

$$IRAS = \sum_i \frac{Am_i}{10^{Class_i}}$$

where Am_i is the average specific activity of waste batch for radioelement *i* and $Class_i$, the activity class for that radioelement. ANDRA has defined four activity classes: 0, 1, 2 and 3.

The IRAS index for the entire batch must not exceed 1, but variations are allowed up to 10 for a single package of the batch.

Table 2 shows the specific activity class of some specific radioelements.

TABLE 2. SPECIFIC ACTIVITY CLASSES

^{3}H	^{14}C	^{60}Co	^{63}Ni	^{90}Sr	^{137}Cs	^{232}U to ^{238}U	^{236}Pu to ^{240}Pu, ^{241}Am ^{242}Pu, ^{244}Pu
3	3	1	3	3	1	2	1

The reference activity is therefore 10 Bq/g for ^{60}Co and ^{137}Cs, 100 Bq/g for U isotopes and 1000 Bq/g for ^{14}C.

Control of the index at the time any waste batch is accepted ensures the acceptability of the batch in relation to its impact.

6. CONCLUSION

The Morvilliers VLLW Disposal Facility was built in accordance with the regulations concerning disposal facilities for hazardous waste. A specific safety approach covering both radiological and chemical aspects was used, based on methods already in use at the Centre de l'Aube.

The first waste packages were delivered in October 2003 pursuant to a strict administrative procedure and after three years of work. The operator's goal at the end of 2004 is to increase production and to commission the conditioning units while maintaining rigorous safety requirements.

REFERENCES

[1] Arrêté du 31 décembre 1999 fixant la réglementation technique générale destine à prévenir et limiter les nuisances et risques externes des installations nucléaires de base – Journal Officiel de la République Française du 15 février 2000, pages 2359 to 2365.

DISCUSSION

H. FERNANDES (Brazil): What can you tell us about the long term performance of the capping system? Was it taken into account in the impact assessment?

M. DUTZER (France): The capping system includes a membrane, a drainage layer, a clay layer with a permeability less than or equal to 10^{-9}m/s, a layer to level the ground and a vegetated earth layer.

For the safety assessment, 'long term' means 30 years — that is to say, the institutional control period. In the safety assessment, intrusion scenarios are considered. Also, we assume a gradual decline (by a factor of 10–100) in the permeability properties of the capping system, leading to an infiltration of water that fills the disposal cells and leaches waste.

These are assumptions for safety studies. From the regulatory point of view, an order to be issued by the local prefecture will prescribe conditions for the monitoring of the site in the 'long term'.

G. JACK (Canada): If the French regulatory body does not control the facility as a nuclear facility, will it, at the end of the projected 30 year institutional control period, be involved in the taking of decisions about releasing the site from control, or are such decisions entirely in the hands of the local prefecture?

J. AVÉROUS (France — Chairperson): Given the level of activity in the repository, control during and after operation is the responsibility of the local prefecture. That does not mean that the nuclear regulator cannot be involved; in France, the nuclear regulator is also responsible for radiation protection.

The 30 years of institutional control derives from the general regulation for hazardous waste repositories. Safety studies are therefore performed by ANDRA as if there were no controls maintained afterwards. However, the commissioning profectoral order prescribes that conditions for the long term follow-up of the repository shall, if necessary, be defined in an additional order. Of course, as the regulator, the local prefecture can obtain advice from any relevant organization.

J. KOLOVANY (Czech Republic): What kind of cost reduction does one achieve by having a very low level waste repository?

M. DUTZER (France): A cost reduction of about a factor of 10. On the basis of the inventory forecast, we expect the mean operational cost for a very low level waste repository to be €240/t. The mean operational cost for low and intermediate level waste disposal, without conditioning costs, is €2500/m^3.

A.K. DARBAN (Islamic Republic of Iran): What is the permeability coefficient of the clay layer at the selected site, and what are the clay mineral components?

M. DUTZER (France): The permeability coefficient is 10^{-10} m/s — sometimes less at some points. This compares with a permeability coefficient requirement of 10^{-9} m/s or less.

The main clay mineral components are kaolinite (40%), smectite (10%), illite (40%) and chlorite (10%).

REVIEW OF LOW LEVEL RADIOACTIVE WASTE MANAGEMENT IN THE UNITED KINGDOM

T. SELBY
NDA Team,
Calderbridge, Cumbria,
United Kingdom
Email: Terry.Selby@dti.gsi.gov.uk

Abstract

From 1 April 2005, the Nuclear Decommissioning Authority (NDA) will assume ownership of sites currently owned and operated by the United Kingdom Atomic Energy Authority (UKAEA) and BNFL, including the LLW disposal facility at Drigg. The NDA will be responsible for developing strategy and will have a remit to accelerate decommissioning and cleanup and to ensure that the Drigg facility is operated as a national asset. One of the first actions of the NDA will be to organize a UK policy review to determine whether alternative disposal arrangements or methods for management of low level radioactive waste are required. This paper outlines the current situation with respect to low level radioactive waste management in the UK and summarizes the issues that must be addressed. Finally, it describes the methodology that will be used to conduct the policy review in the UK.

1. INTRODUCTION

Within the UK, British Nuclear Fuels plc (BNFL), currently owns and operates a national facility for the disposal of low level radioactive waste (LLW) at Drigg in Cumbria. The facility has been operated successfully for over forty years, benefiting from an upgrade in the 1980s. Although the Drigg site has the capacity to accommodate LLW arisings for many years to come, there is uncertainty about its ability to accommodate all future LLW arising in the UK. These questions need to be resolved, particularly in the light of the UK's current programme of nuclear facility decommissioning — a programme which is likely to lead to the generation of large volumes of LLW at the lower end of the activity spectrum of this waste category (below about 100 Bq/g beta–gamma). A UK national policy review is therefore being proposed to determine whether alternative disposal facilities or methods of managing the waste are required. This review will pay particular attention to the large volumes of very low activity waste arising during decommissioning. The policy review will involve taking the views of experts and of stakeholders.

From 1 April 2005, the Nuclear Decommissioning Authority (NDA) will assume ownership of sites currently owned and operated by the United Kingdom Atomic Energy Authority (UKAEA) and BNFL, including the LLW disposal facility at Drigg.

The NDA will be responsible for developing strategy and will have a remit to accelerate decommissioning and cleanup and to ensure that the Drigg facility is operated as a national asset.

Broadly speaking, there are three main classes of solid radioactive waste in the UK. These are high level waste (HLW), intermediate level waste (ILW) and LLW. With certain specific exceptions, LLW is defined as waste that has an activity concentration greater than 0.4 Bq/g and up to 4000 Bq/g for alpha emitters and 12 000Bq/g for beta–gamma emitters. This is a range of around five orders of magnitude.

The Radioactive Substances Act 1993 (RSA93) requires controls to be put in place before radioactive waste is disposed of, or transferred from any location. These controls are contained in Authorizations which must be sought by a site licensee from the environmental regulator (the Environment Agency for England and Wales, and the Scottish Environment Agency for Scotland).

Certain naturally occurring radioactive elements are excluded from the provisions of RSA93 up to certain concentrations. For instance, all isotopes of uranium up to a concentration of 11.1 Bq/g may be disposed of without prior authorization. These naturally occurring radioactive elements are listed, with the relevant concentration limits, in Schedule1of RSA93. Since the first Radioactive Substances Act came into force, a number of exemptions have been introduced by means of statutory instruments known as Exemption Orders. Of particular note, when considering the long term management of LLW, is the Substances of Low Activity Exemption Order (SoLA). The SoLA Exemption Order exempts materials and waste that contain radionuclides (excluding certain radionuclides that also occur naturally, up to specifed levels) at levels of less than 0.4 Bq/g, in substantially insoluble forms, from any form of specific regulation under the Radioactive Substances Act regime.

UK legislation allows for disposal routes, for certain low level waste, other than the Drigg disposal facility. In particular, some LLW has been disposed of in purpose built facilities on the site where the waste originates. Some waste can be disposed of in conventional landfills, some has, in the past, been authorised for burial in situ at certain nuclear sites. The disposal arrangements in the latter two examples have generally been reserved for LLW at the lower end of the activity range of the waste category.

Despite the availability and use of these disposal routes, two main factors will increase the demand on the Drigg disposal facility over the next few decades. One is the accelerating programme of nuclear site decommissioning and remediation. The second is the expected introduction of a new regulatory regime for the remediation of radioactively contaminated land. The capacity of the Drigg site is limited by both volume and radionuclide inventory. The important question is whether Drigg has the capacity to provide for the disposal of all of the LLW currently predicted to arise within the UK, much of which will lie in the lower activity range of the LLW category. The capacity issue has been highlighted in a recent review carried out by a national independent advisory committee on behalf of the UK government [1]. It is expected that, in the near future, the government will make a policy statement on the management of low level radioactive waste. The purpose of such a policy statement is to provide a high level framework within which specific waste management decisions can be made. The policy statement would not provide detailed prescriptions of engineering solutions for LLW management but would, instead, give general policy directions. Government policy could, for example, simply say that any disposal option must demonstrate compliance with a specific risk or dose target. On the other hand, policy could go further to define ‘acceptable’ waste routes for LLW, while still leaving the detailed options assessment (using cost–benefit or cost–risk analysis techniques, for instance) as a matter for the industry to determine. The NDA, which will assume responsibility for BNFL and UKAEA sites on 1 April 2005, will have to determine how government policy is to be implemented across its range of nuclear site management responsibilities, and how the Drigg site should be managed as a national asset.

2. INFORMATION REQUIREMENTS

2.1. General

The outline methodology for policy review is described below in Section 3. The first step is to assemble and consider all of the relevant information. This will be followed by its arrangement in a format suitable for policy options assessment and stakeholder engagement.

2.2. Inventory of low level waste

A waste inventory is compiled and updated regularly by UK Nirex Ltd and the Department Environment Food and Rural Affairs (DEFRA). The latest full version of the inventory reflects waste holdings and anticipated arisings on 1 April 2001 [2]. The next update, for 2004, will be published in 2005. These inventory data will be used to inform the policy review.

The basic data from the published inventory will be analysed and organized for the purposes of policy review under the following headings:

(a) Activity in the waste;
(b) Waste type (e.g metals, graphite, demolition rubble, contaminated soil etc.);
(c) Half-life;
(d) Time of waste arising.

Although greater attention will be given to LLW streams in the 2004 UK inventory, a number of uncertainties and omissions are already known to be present. These arise from:

(a) Uncertainty in knowledge of some waste streams, and, in particular, the extent (both in terms of volume and activity concentration) of possible ground contamination on nuclear licensed sites;
(b) For some waste streams, different uses of definitions by different operators;
(c) Incomplete knowledge of the extent of radioactively contaminated land outside the nuclear industry;
(d) Uncertainty of the extent to which decontamination and recycle are economic, and socially acceptable;
(e) The availability and applicability of standards for cleanup (delicensing) at nuclear sites.

For these reasons, the data needed for the policy review may require additional work, in addition to that carried out in compiling the national inventory. Where uncertainties remain, estimates will be made (and the bases for such estimates explicitly stated) such that the data is ‘fit for purpose’, the purpose being policy formulation. In some cases, and particularly for the lower volume waste streams, order of magnitude estimates are believed to be sufficient for the purposes of policy review.

2.3. Management options

Disposal routes that are currently open or that have been used in the past for LLW, are:

(a) Disposal in the engineered vaults at the national LLW disposal facility at Drigg in West Cumbria. Waste is compacted (where practical), grouted into half-height ISO containers, and placed in concrete vaults.
(b) Disposal in specific areas of nuclear licensed sites (e.g. LLW pits at UKAEA Dounreay, landfill type disposal at BNFL Sellafield).
(c) In situ disposal; that is, burial at the point of arising. This option is no longer used (or authorized) outside of the nuclear industry.
(d) Controlled burial at ordinary landfill sites, under 'special precautions burial arrangements'.
(e) General disposal at landfill sites, currently reserved for very low level waste (VLLW) from commercial and domestic sources (also with some nuclear industry waste), and disposal of materials from radioactive land remediation projects for which the radionuclides and activity limits are specified in the Phosphatic Substances and Rare Earth Exemption Order of the Radioactive Substances Act.

Disposal routes which are theoretically available, but not currently utilized, are:

(a) Dilution and dispersal into the terrestrial environment;
(b) Sea disposal in drums.

For the purpose of the policy review, it will be necessary for there to be a complete description of the existing operation of these disposal routes under the headings:

Definition
Current practice
Restrictions
Regulatory authorization requirements
Practical availability
Transport issues, including transport risks
Costs.

Such information is being compiled in concise, easily understandable, data sheet form for the purposes of the policy review.

2.4. Treatment options

Information must also be provided on the currently available, or technically feasible, waste pretreatment methods. Pretreatment methods are of two types, and fulfil two different functions: volume reduction and activity reduction. Methods for volume reduction include melting, compaction and incineration.

Methods for activity reduction include:

(a) Chemical or mechanical decontamination;
(b) Soil washing (with or without chemical agents) or phytoremediation.

An important point to recognize is that incineration and decontamination produce secondary wastes, that, in turn, have to be managed.

Compaction is a standard practice used for all compressible wastes destined for the Drigg facility. Incineration is also practised, particularly for organic LLW at the low end of the LLW category. The UK nuclear industry has experimented with a variety of decontamination methods for the purpose of preparing certain wastes for recycle.

Work has been commissioned to define these pretreatment options and to present them in a similar format to that used for the long term waste management options.

2.5. Strategic options

The availability and acceptability of treatment and disposal options depends largely on available technology and public acceptance. Therefore, in considering policy development, safety, economic, environmental and public perception issues are all factors that will have to be taken into account.

For both waste treatment and disposal options, the final choice for a particular waste will depend upon the detailed characterization of that waste and the perceived ‘end point’ for the site at which the waste arises, together with the acceptance criteria for the appropriate disposal route. In order to place such options in the context of a UK wide strategy (and hence to determine the need for additional policy) the following points may need to be considered:

(a) The possibility of developing a new Drigg type facility;
(b) The impacts of some or all of the LLW waste from the major waste producers and holders (at Dounreay, and at Sellafield) being disposed of at the sites of origin;
(c) The need for new incineration and/or landfill capacity in the UK;
(d) The potential for large quantities of very low activity waste to be dug up and transported over long distances for burial at some other location.

2.6. Other considerations

In order to assess the practicality and desirability of adopting any of the options described above, a number of important questions arise, for example:

(a) What is the legal position under current and intended European legislation? Of particular note is the EU Landfill Directive. A number of other Directives need to be examined to see what impact, if any, they might have on the review.

(b) In order to refine the inventory data (Section 2.2 above), it is necessary to know the standards that will be applied in relation to ground contamination for particular site end points, delicensing being one such end point. The criteria used in these standards will have a marked influence on the volumes and activities of materials classified as LLW. The standards have not yet been fully established in the UK, although work is in hand to do this. The range of activity concentration within the LLW category definition in the UK covers five orders of magnitude. For the purposes of analysis, this range may need to be broken down into manageable subranges. What would be the most appropriate way of defining subranges, and is there a case for a new definition of LLW covering the lower activity end of the current LLW range?

(c) What are the markets, if any, for materials recycled from the nuclear industry?

3. REVIEW METHODOLOGY

A steering group has been established, to oversee the proposed policy review. It held its first meeting in September 2004.

Current plans are for the information and options analysis to be presented to a stakeholder workshop early in 2005. Representatives of the following groups or organizations might be invited to attend:

(a) Major LLW producers (UKAEA, BNFL, Ministry of Defence, British Energy, GE Healthcare-Amersham etc.);
(b) Small user representatives;
(c) Local government representatives;
(d) Local stakeholders, that is, representatives of citizens who live close to current LLW stores or to actual or potential LLW disposal facilities;
(e) Representatives of the waste disposal industry (e.g. landfill operators);
(f) Representative non-governmental organizations (NGOs);

(g) Representatives of government;
(h) Independent experts in radioactive waste management;
(i) Independent experts in radiological protection.

The aim of the workshop will be to:

(a) Agree on the amounts of waste and the options its management;
(b) Make preliminary decisions on the practicality and acceptability of the options presented and, in the light of this, identify the key policy issues that need to be addressed.

The findings of this first workshop will be used to produce a draft policy framework. This will be presented to a second stakeholder workshop in summer 2005 for consideration and, where necessary, amendment. The aim is to publish a proposed government policy framework statement in autumn 2005 for national consultation. Subsequently, a statement of proposed government policy will be prepared and issued for consultation. This formal consultation step is an important prerequisite to announcements of new or revised UK government policy.

4. TIMETABLE

The timetable for policy review falls into three broad phases and is expected to be finalized early in 2006.

(1) October 2004–February 2005: Preparation of information and workshop planning;
(2) March 2005–July 2005: Workshops and analysis;
(3) September 2005–March 2006: Formal consultation on proposed policy.

5. CONCLUSIONS

The proposed programme described in this paper will enable the UK to decide its future long term policy for the management of low level radioactive waste. This will provide a framework within which operators of nuclear sites and other waste holders and producers can plan for LLW management over the coming decades. It will allow, in particular, for the NDA and Site Licensees to develop appropriate strategies for managing LLW arising from decommissioning activities, and for the operation of the Drigg site as a national asset.

REFERENCES

[1] RWMAC, The Radioactive Waste Management Committee's advice to ministers on management of low activity solid radioactive wastes within the United Kingdom. ISBN 0-85521-019-2 (March 2003).

[2] DEFRA/NIREX, Radioactive wastes in the UK: a summary of the 2001 inventory, Defra/Ras/02.003, Nirex report N/041 (2002).

DISCUSSION

C. TENREIRO LEIVA (Chile): Is the Nuclear Decommissioning Authority prepared to share with other countries its experience of stakeholder engagement?

T. SELBY (United Kingdom): In principle, yes. We would be happy to share the experience gained by us through the stakeholder engagement process.

L. JOVA SED (IAEA): Will the Nuclear Decommissioning Authority have licensing responsibilities?

T. SELBY (United Kingdom): No, the licensing of nuclear sites will continue to be undertaken by the Nuclear Installations Inspectorate.

The regulatory regime in the United Kingdom has not been changed by the emergence of the Nuclear Decommissioning Authority.

MANAGEMENT OF VERY LOW ACTIVITY RADIOACTIVE WASTE IN SPAIN

P. ZULOAGA
ENRESA,
Madrid, Spain
Email: pzul@enresa.es

Abstract

ENRESA, the Spanish radioactive waste management agency, operates a low and intermediate level waste (LILW) disposal facility in El Cabril, Córdoba. Significant amounts of radioactive waste containing very low activity have been identified, caused by some incidents outside the nuclear regulated domain and in the foreseen nuclear facilities decommissioning operations. ENRESA has applied for the construction authorization of a specific installation intended for the final disposal of very low activity radioactive waste, at the El Cabril site and as a part of the existing facility. The very low activity waste will have activity concentrations of up to tens of of thousands of becquerels per kilogram, although the precise limits will be defined as a part of the licensing process currently under way. The design criteria for the facility were proposed by ENRESA and approved by the Nuclear Safety Council in June 2003. The design of the engineered barriers is based on the technical requirements of the current European and Spanish regulation for the final disposal of dangerous waste. Many general design principles are in common with to the disposal facility for LILW, namely the isolation of the waste by means of a multibarrier system, but adapted to the characteristics and activity of this specific type of waste by using bentonite and high density polyethylene membranes instead of the generalized use of concrete barriers.

1. INTRODUCTION

The construction of an installation specifically designed for the disposal of the very low level (VLLW) radioactive waste responds to various recommendations from different Commissions of the Spanish Parliament in the last years in order to use efficiently the available disposal space existing at the El Cabril LILW disposal facility.

In a preliminary step for the VLLW disposal facility concept development, ENRESA proposed, and the Nuclear Safety Council (CSN) approved a set of basic design criteria [1] which provide guidance for the further activities of the project. A major feature of these criteria is the adoption of the technical requirements of the Spanish regulation for the disposal of hazardous waste [2], based on the corresponding European Directive [3], as a basis for the isolation requirements for VLLW disposal. It has been proposed that the new facility will be constructed within the limits of the El Cabril disposal facility site, to become part of the existing facility, thus obtaining a synergy with the infrastructure and organization and the characterization and surveillance programmes of the existing operating facility.

The general design principles used for the LILW disposal facility at El Cabril — use of a multiple barrier isolation system, limitation of activity, establishment of a surveillance period, implementation of a leachate collection system — are also applicable to this new facility, but using technologies and other conditions adapted to the type and associated risk of the intended waste.

2. CHARACTERISTICS OF THE VLLW

A majority of the VLLW will come from the decommissioning operations at nuclear power plants. Waste from the operation and modification of nuclear power plants is also expected to be a significant component. Another component may be the waste from potential incidents at non-nuclear facilities in Spain. Experience shows that the generation of a significant amount of material containing activity concentrations slightly above the free release criteria, but very low in comparison to standard packages from nuclear power plants operation, can be expected.

The VLLW is, in most cases, scrap or granulates and debris demolition materials with a slight contamination. A small percentage of the radioactive waste of very low activity would be classified as hazardous if it were not classified as radioactive (in Spain there is not a legally established category of mixed waste). These will be stabilized prior to their final disposal.

The VLLW is not considered as a new category of radioactive waste but as a subcategory of the current definition of LILW. The proposed maximum specific activity for some radionuclides in waste packages is shown in Table 1.

The maximum total activity of a package is given by $\Sigma a_i / A_{i\,max} \leq 1$, where a_i is the average specific activity of radionuclide i in a waste package.

The total approximate volume of VLLW expected with the present Spanish nuclear programme is 120 000 m^3, including the provisions for the decommissioning of the existing nuclear installations.

TABLE 1. MAXIMUM SPECIFIC ACTIVITY IN A VLLW PACKAGE

Nuclide	Proposed maximum specific activity of individual radionuclides in waste packages ($A_{i\ max}$) (Bq/g)
H-3	10 000
Co-60	100
Sr-90	10 000
Cs-137	300
Pu-230	100

3. DESCRIPTION OF THE VLLW DISPOSAL INSTALLATION

The installation for VLLW disposal can be divided into three main parts:

(1) Four disposal cells that will be located in a zone in the middle of the El Cabril facility site, with an approximate total volume capacity of 130 000 m^3. The surface area of the disposal zone is 10 ha. In a first stage, only the first of the four disposal cells will be built. The three additional ones will be constructed according to needs in the coming years.
(2) A treatment building, will be located in a nearby area where three interim storage buildings already exist. Treatment and conditioning processes are foreseen for the waste, including compaction and the stabilization of hazardous components.
(3) Ancillary and support infrastructures, such as access roads, security fences, etc.

Figure 1 shows the location and proposed layout of the VLLW disposal area.

3.1. Disposal cells

Each disposal cell will be built up from the present level of the hill slopes, after preparation of the area.

Figure 2 shows the main components of the multibarrier system selected. From bottom to top, each disposal cell is formed by:

(a) the geological barrier: the artificial geological barrier is made of compacted clay with a minimum thickness of 1 m and a bentonite film,

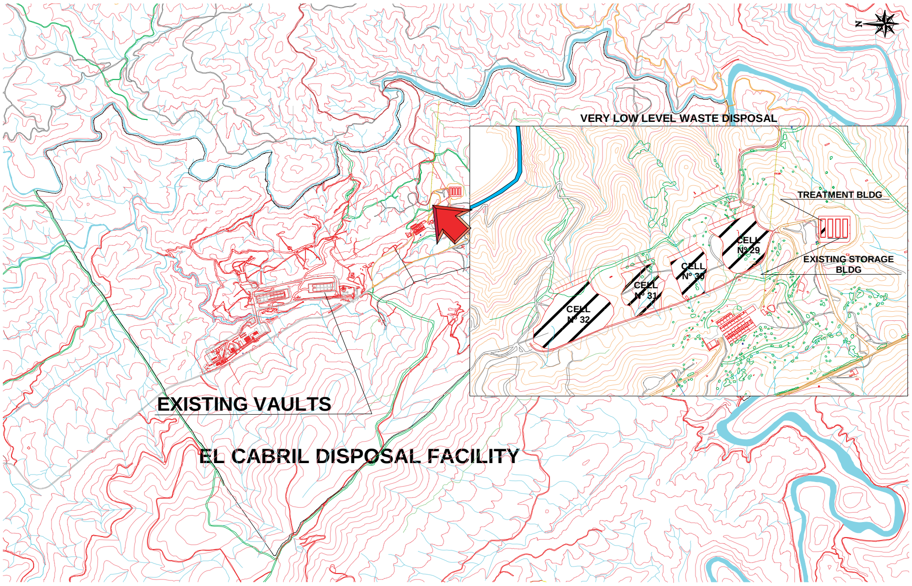

FIG. 1. General layout.

providing together an equivalent thickness of a 5 m thick clay layer with permeability, K = 10^{-9} m/s.

(b) The waterproofing film: a high density polyethylene (HDPE) film is placed above the clay.

(c) Geotextiles placed to protect the polyethylene membrane.

Owing to the depth and extension of the cells, each cell will be made in several phases, forming two layers 4–6 m high that will constitute independent sections inside each cell.

Each section, thus defined, is further divided into so-called ‘lines of operation’, with the intention of controlling smaller areas to facilitate the surveillance of the disposal system. Each individual line of operation will have a size proving room for the waste expected in the next one to two years. The bottom of each line of operation will have an additional HDPE film to provide separate leachate collection.

The line in operation is covered by a light roof in order to minimize the rainwater infiltration and the amount of leachate to control. When a line of operation is filled with waste, it is closed provisionally with a plastic film and earth layer to minimize the volume of potentially radioactive effluents.

In order to control the water that could have been in contact with the waste, a leachate collection system (LCS) is installed. This system is

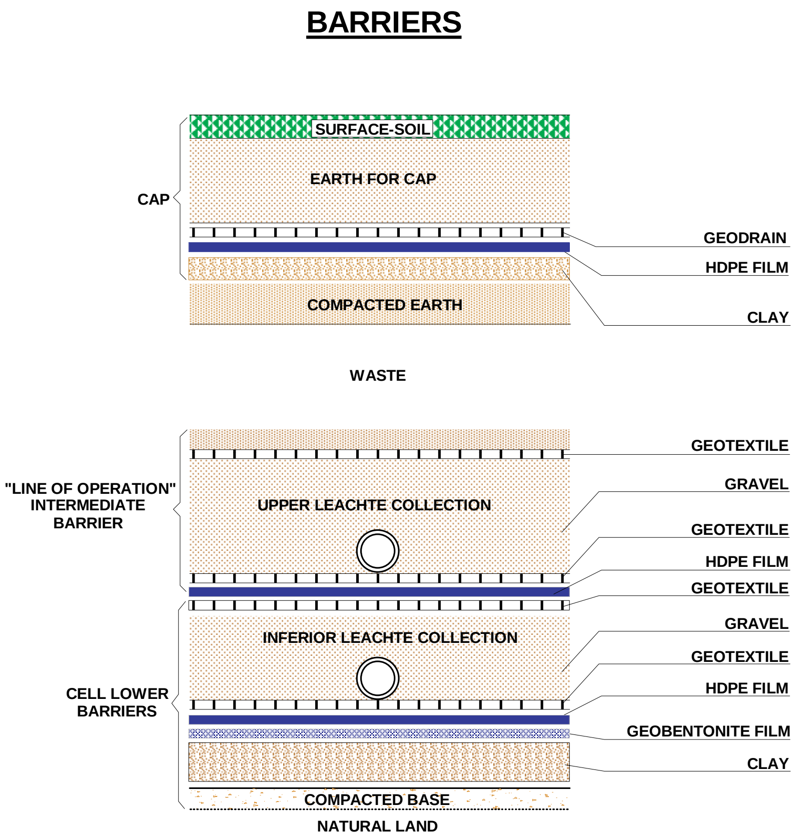

FIG. 2. Scheme of a VLLW disposal cell.

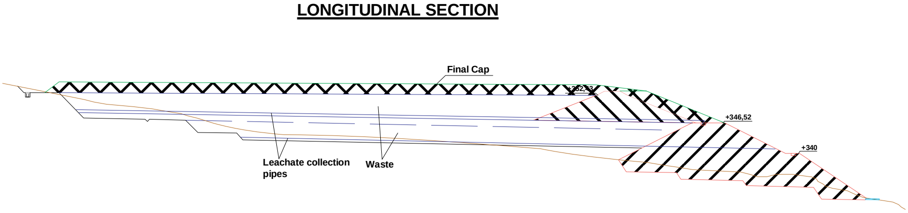

FIG. 3. VLLW disposal cell (longitudinal section).

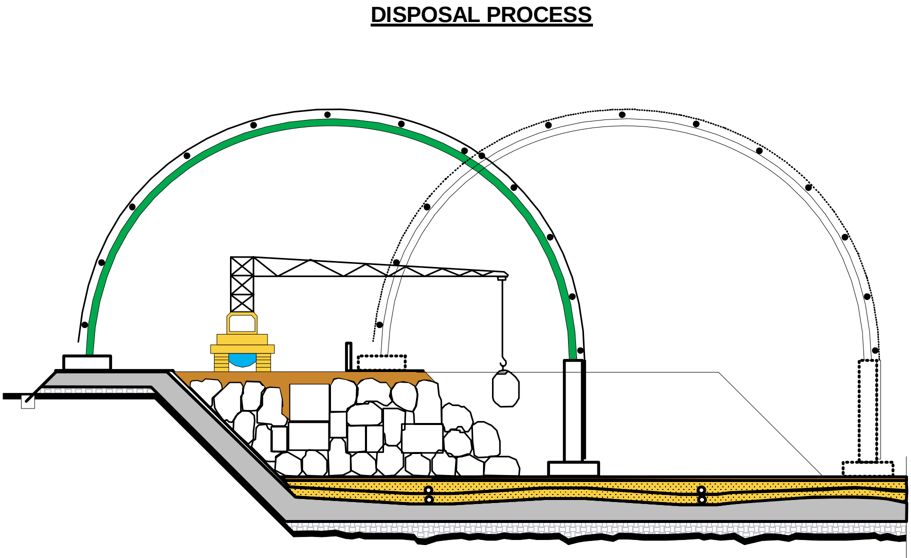

FIG. 4. Operation of a VLLW disposal cell.

differentiated for each cell and drives the effluents to 100 m^3 final control tanks. There are two leachate collection systems. There is an inferior LCS collector formed by a slotted HDPE pipe in a gravel bed, located in the lowest part of each disposal cell, just above the HDPE film. There is also an additional piping network to gather any water that infiltrated into each single line of operation in which the cell is divided, facilitating the identification of potential failures and, thereby, the monitoring and maintenance of the system. Both collection systems are located inside gravel layers built onto the HDPE films.

A scheme of the operation of the disposal cell and the design of the light roof protecting the line in operation is shown in Fig. 4. Alternative designs proposed by different bidders will be considered. At the end of the operation, an engineered multilayer cap of clay and drainage layers will be constructed.

3.2. Treatment building

The functions associated with the treatment building are: reception and unloading of the transportation vehicles, identification and control of the waste, interim storage of the waste, segregation of the waste for treatment and/ or disposal, stabilization of the waste when required because of non-radiological hazardous characteristics (by mixing with an appropriate hydraulic conglomerate); compaction of some compactable waste streams.

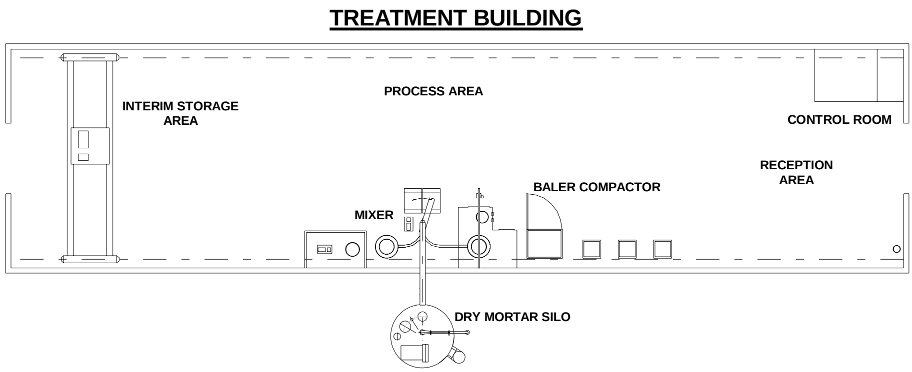

FIG. 5. VLLW treatment building.

The dimensions of this building will be 50.4 m × 12.5 m. Figure 5 shows its general layout.

4. LICENSING AND SAFETY

ENRESA applied for the authorization to implement the plans, as required by the Spanish regulations [4], by presenting, in May 2003, to the Directorate General for Energy Policy and Mines (DGPEM) and to the CSN, the preliminary safety analysis report and other licensing documents. Additionally, in June 2003 ENRESA presented to the Ministry of the Environment (MIMA) the basic documentation to initiate the Environmental Impact Assessment procedure and, recently, in September 2004, after an institutional consultation step performed by the MIMA, ENRESA has submitted, to this Ministry, the Environmental Impact Study in order to proceed with the public consultation process. Previously the Municipal Council of Hornachuelos had granted the municipal urban planning licence.

The safety assessment is coherent with and follows a similar methodology to the current safety assessment for the existing disposal facility. The situations analysed include both present and future anticipated conditions, including events associated with the normal evolution of the disposal facility and less probable events (accidents and intrusion events).

The safety assessment methodology applied is based on the main guidelines currently developed through international fora, such as those promoted by the IAEA. The methodology is adapted to a process that identifies the following key components:

(a) Assessment context;
(b) System description;
(c) Development and justification of scenarios;
(d) Scenario evaluation (formulation and implementation of models);
(e) Analysis of results.

The safety assessment performed has a double objective: (a) the derivation of waste activity acceptance criteria for disposal, and (b) the demonstration that an acceptable level of protection of human health and the environment will be achieved both now and in the future.

The methodology is characterized by the interaction between the different components listed above and has been applied in an iterative manner assuring the review and modification of the different components as appropriate. The assessment context identifies the work frame (objective, timescales, safety and radiological protection criteria)and the sytem description covers the characteristics of the different system components (waste, operational practices, design of the disposal facilities, the site).

The scenario generation process results in the identification of important safety significant scenarios. The scenarios are classified in two groups: those relevant to the assessment of specific activity waste limits per package, and those that are relevant to the demonstration of an acceptable level of protection of human health and the environment. Its does not mean that the scenarios are different for each group; one or more scenarios can be relevant for both groups.

The analysis carried out to support the proposed activity limit per package is based on calculations for each radionuclide. The scenario development methodology and the formulation and implementation of the proper model process assure that the analysis is coherent.

The safety performance of the disposal facility for the long term is evaluated taking into account the analysis of the normal evolution scenario and intrusion events, assuming that the average activity in the waste packages is 1/10 of the maximum activity per package and that the total activity in the disposal cells has, additionally, been limited to a low percentage of the reference inventory established for the existing concrete vaults (no higher than 1% of the reference inventory of the El Cabril facility as a whole, defined in its operating authorization [5] and shown in Table 2).

TABLE 2. REFERENCE INVENTORY PROPOSED FOR THE VLLW DISPOSAL

Radionuclide	Activity (TBq)
H-3	2.00E+00
C-14	2.00E-01
Ni-59	2.00E+00
Ni-63	2.00E+01
Co-60	2.00E+02
Sr-90	2.00E+01
Nb-94	1.00E-02
Tc-99	3.20E-02
I-129	1.50E-03
Cs-137	3.70E+01
Pu-241	1.15E+00
Total alpha (at 60 a)	2.70E-01

ACKNOWLEDGEMENTS

The author would like to thank Ms Higuera (CSN) and Mr Carboneras, Mr Navarro and Ms Lopez (ENRESA) for their comments and advice.

REFERENCES

[1] ENRESA. 035-IF-IN-0035, Revisión 2. Criterios básicos para almacenamientos de residuos radiactivos de muy baja actividad. Mayo 2003

[2] Real Decreto 1481/2001, de 27 de diciembre, por el que se regula la eliminación de residuos mediante depósito en vertedero (BOE de 29 de enero de 2002).

[3] Directiva del Consejo de la Unión Europea relativa al vertido de residuos. (1999/31 CE, de 26 de abril de 1999)

[4] Reglamento sobre instalaciones y radiactivas. Real Decreto 1836/1999 (BOE 31 de diciembre de 1999).

[5] Orden Ministerial del Ministerio de Economía por la que se otorga autorización de explotación de la instalación nuclear de almacenamiento de residuos radiactivos sólidos de Sierra Albarrana, de 5 de octubre de 2001 (BOE de 6 de noviembre de 2001).

DISCUSSION

P. METCALF (IAEA): The clearance levels quoted by you appear to be lower than those in the recently published IAEA standards. Would you care to comment?

P. ZULOAGA (Spain): The quoted clearance levels are specific for an authorized practice — the recycling of metal scrap from the Vandellos 1 Nuclear Power Plant — and are (as far as I know) consistent with those in the relevant IAEA documents — for cobalt-60, 0.3 Bq/g and 1 Bq/g for unconditional and conditional release respectively.

What I tried to make clear was that, owing to the presence of other radionuclides, to measurement difficulties and to difficulties in the calculation of scaling factors, the associated uncertainties are such that, in practice, the levels are kept to one tenth of the approved values.

G. VIERU (Romania): Did you consider, in your safety assessment, the possibility of a terrorist attack?

P. ZULOAGA (Spain): No. In my view, the non-radiological harm that would be caused by a terrorist attack on a very low activity radioactive waste disposal facility would be far greater than the harm caused by the dispersal of radionuclides as a result of the attack.

VERY LOW LEVEL RADIOACTIVE WASTE: PERSPECTIVE OF THE EUROPEAN COMMISSION

A. JANSSENS, U. BLOHM-HIEBER, B. ANDRÉS ORDAX
European Commission,
Brussels
Email: augustin.Janssens@cec.eu.int

Abstract

The management of radioactive waste is essentially a national responsibility, but it is subject to a number of radiation protection requirements deriving from European law, in particular the Basic Safety Standards (Directive 96/29/EURATOM) and the Directive on shipments of radioactive waste (92/3/EURATOM). Furthermore, new specific legislation on safe management of radioactive waste is under preparation. In addition, plans for the disposal of radioactive waste by Member States are subject to the procedure under Article 37 of the EURATOM Treaty, the European Commission giving an Opinion on such plans prior to their authorization at national level. With regard to very low level waste (VLLW), the paper discusses to what extent the provisions for exemption and clearance from the requirements of the standards apply. Guidance on the application of the concepts of exemption and clearance has been issued by the Group of Experts under Article 31 of the EURATOM Treaty. Guidance has also been provided on the management of materials with low levels of naturally occurring radionuclides, in particular residues from NORM industries. While a properly designed VLLW repository should have a very low radiological impact, the volume of such waste, and hence the surface area of the repositories, may become very important. This raises questions with regard to land use and the possible relevance of environmental legislation. The environmental and economic impact of disposal versus recycling, in particular for metals is considered. The option of specific VLLW repositories is compared with disposal in (industrial) landfills.

1. COMMUNITY LEGISLATION

In the European Union (EU), all competencies with regard to nuclear energy and radiation protection are laid down in the EURATOM treaty. Chapter 3, Health and Safety, contains provisions which are directly applicable (primary legislation) and offers the legal framework for the establishment of the EU Basic Safety Standards and other derived legislation. Article 31 of the Treaty requires that any such legislation be submitted to a Group of Experts for an opinion.

1.1. Basic safety standards

1.1.1. Exemption and clearance

There is no specific European Community radiation protection legislation related to the management of very low level waste (VLLW). The disposal of radioactive waste (RW) is, however, a practice subject to the requirements of the Basic Safety Standards (BSS). Directive 96/29/EURATOM specifies (Article 5.1) that the disposal, recycling or reuse of materials arising from a (reported or) authorized practice is itself subject to prior authorization.

The 1996 Basic Safety Standards introduced two very important new concepts: exemption and clearance. Materials may be released from the requirements of the Directive subject to complying with clearance levels established by national competent authorities (Article 5.2). This provision allows the large volume of materials arising e.g. from dismantling of nuclear installations, with no, or very slight, levels of contamination, to be released for recycling or reuse, or for disposal in ordinary (industrial) landfills.

Article 5.2 further specifies that clearance levels shall be derived from the basic exemption criteria and taking into account any other technical guidance provided by the Community. These criteria are the same as those underlying the exemption values laid down in Annex 1 of the Basic Safety Standards, i.e., an individual dose of 10 Sv and a collective dose of 1 man Sv. The exemption values, however, have been calculated on the basis of scenarios involving only moderate amounts of materials.

There is a clear conceptual distinction between exemption and clearance. For an undertaking to decide whether a practice involving radioactive substances needs to be reported to the authorities (i.e. is exempt or not), it is necessary that it can refer unambiguously to established values. In the case of clearance, materials not only leave regulatory control rather than entering it, but the decision to do so is still part of the authorization. Thus the regulatory or licensing authority can adapt or modify the clearance levels on an ad hoc basis, or define conditions prior to the release. Clearance is thus still a form of authorized release, it being understood that if such a release occurs below clearance levels, then the resulting doses can be regarded as trivial and not requiring any follow-up of the destination of the material; no ‘traceability’ is required.

From a regulatory perspective, one should deal with materials below clearance levels as if they were not radioactive. Unfortunately, even very low levels of radioactivity can easily be detected.

1.1.2. VLLW

For materials above clearance levels recycling or reuse may be appropriate, subject to regulatory control, for specific applications that would cause a lower level of exposure than assessed on a generic basis. In general however no such uses will be found or agreed upon, and the materials will be regarded as waste, 'radioactive' waste. The category VLLW applies within a certain range above clearance (or exemption) levels. There is however no common precise definition of this category.

VLLW waste may either be disposed of in a specific repository or in ordinary or industrial landfills. In the former case, the disposal is a practice subject to full regulatory control and the requirements of the BSS apply. In the latter case, it will be required to comply with the basic exemption criteria, which can be met at concentration levels higher than the clearance levels, provided there are restrictions on the total amount of radioactive waste an individual landfill may receive.

1.1.3. NORM materials

Directive 96/29/EURATOM introduced a new category of practices, labelled 'work activities', involving the presence of natural radiation sources. Title VII of the Directive requires Member States to identify the work activities that are of concern, e.g. NORM industries processing naturally occurring radioactive materials (ores or by-products from other industries). In most cases such industries will be made subject to controls for the protection of workers. The same industries may be of concern because of the levels of radioactivity in liquid or airborne effluent or in waste materials, bearing in mind that the volume of residues is often very large and will require large land surfaces for on-site or off-site disposal. In some industries, radioactivity builds up in scales or dust filters to such an extent that these materials can be regarded as radioactive waste.

The Directive does not require that Member States apply all requirements of the BSS to identified work activities. In particular, the provisions of exemption and clearance may be regarded as inappropriate, or concentration levels may be established on a different basis.

Where NORM residues are included in the category of VLLW, it should be borne in mind that most naturally occurring radionuclides are long lived; high activity concentrations relate mostly to ^{226}Ra, with a half-life of 1600 years.

1.2. Other legislation

Council Directive 92/3/EURATOM of 3 February 1992, on the supervision and control of shipments of radioactive waste between Member States and into and out of the Community, provides for a common, mandatory system of authorization for the shipment of radioactive waste within the Community. For shipments from a Member State to a third country, the competent authorities of the Member State of origin must inform the competent authorities of the country of destination.

This control system is only applicable where the waste being shipped exceeds the exemption levels laid down in the Basic Safety Standards.

The provisions of this Directive also prohibit the export of radioactive waste to the African, Carribean and Pacific Group of States (ACP) in line with the Lomé IV Convention signed on 15 December 1989, to a destination south of latitude 60° south of the equator or to a third country which does not have the resources to manage the radioactive waste safely.

Directive 2003/122/EURATOM of 22 December 2003 on the control of high activity sealed radioactive sources and orphan sources requires that practices involving the use of a source are authorized. Granting of the authorization is, however, subordinated to guarantees being given by the holder concerning the safe management of the source, in particular, when it becomes a disused source. Such guarantees include provisions and arrangements for the return of the source to the supplier or its placement in a recognized installation. The Directive also requires Member States to take action with regard to orphan sources on their territory, e.g. by establishing (or encouraging the establishment of) systems aimed at detecting orphan sources in places such as large metal scrap yards. Orphan sources are any source above exemption values that is not under regulatory control.

1.3. Commission proposal on radioactive waste management

On 30 January 2003, the EC adopted two proposals for Directives, forming a ‘nuclear package’. The first is a proposal for a Council EURATOM Directive setting out the basic obligations and general principles for the safety of nuclear installations [1] (usually referred to as the Safety Directive) and the second for the management of spent nuclear fuel and radioactive waste [2] (referred to as the Waste Directive). The proposals are based on Chapter 3 of the EURATOM Treaty concerning Health and Safety and supplement the basic safety standards (relating to the health protection of the population and of workers against the dangers resulting from ionizing radiation).

The approach proposed by the Commission is political and legal. It is not normative and technical. It gives legal status to the general principles unanimously accepted internationally and, in particular, within the IAEA of which all the Member States of the enlarged European Union are members. Thus, the international conventions on nuclear safety and on the safety of spent fuel and of radioactive waste adopted under the aegis of the IAEA largely inspired the texts of the two proposals for Directives.

The proposed Waste Directive covers all radioactive waste categories, with the exception of NORM waste and small quantities of radioactive materials, such as sealed radioactive sources unless declared as radioactive waste by a Member State. One of the main provisions of the Waste Directive is that each Member State shall establish and keep updated a clearly defined national programme, including a timetable, for the long term management of all radioactive waste, including their disposal. The programme shall be communicated to the Commission at regular intervals for review by a Committee of Experts designated by the Member States.

The two Directives have now been very extensively debated within the European Institutions and in many other fora. They have received the very strong endorsement of the European Parliament (in January 2004) and are supported by a majority of Member States. However, the proposals were blocked by a minority of Member States in the Council. In September 2004, the Commission adopted revised proposals for the Directives, taking into account proposed amendments by the European Parliament and the discussions in the Council working group. The revised texts are currently being discussed in the Council.

1.4. Primary legislation

1.4.1. Article 37

Article 37 of the EURATOM Treaty requires Member States to provide the Commission with general data on the planned disposal of radioactive waste, in whatever form, so as to allow the Commission to give an opinion on whether the plan is liable to affect the territory of another Member State.

Commission Recommendation 99/829/EURATOM specifies that the dismantling of nuclear reactors and reprocessing plants is a type of operation for which, under Article 37 of the EURATOM Treaty, general data need to be submitted. The type of information requested is broadly the same as for an operating plant, except for information on the envisaged types of waste and amounts of released materials (and applied clearance levels). This allows the Commission to examine on a case-by-case basis whether there is compliance with Community guidance and, where appropriate, make recommendations in the Opinion published in the Official Journal.

While Member States should take Community guidance into account they could introduce different (less restrictive) clearance levels than in Community guidance. Member States should, in any case, demonstrate that they nevertheless comply with the basic criteria (in particular, individual annual doses of less than around 10 μSv).

Member States are not obliged to apply the concept of clearance. They may, in principle, prefer that all materials are to be disposed of as radioactive waste (presuming facilities for the disposal of large volumes of very low level waste are available). They may use criteria relating to the history of the material to legitimately assume that the material is not contaminated ('zoning' concept). While this concept has great merit, it is often still necessary to rely on measurements and the decision threshold of the measurement should obviously be at or below clearance levels.

The impact of clearance or authorized release of materials on other Member States is a relevant issue for materials with a potential for recycling or reuse, since these materials are placed on the internal market of the EU. Metal scrap yards in particular collect materials from all over the world. For waste, the impact on other Member States is indirect: the exposure from a specific VLLW repository concerns only the local population, in particular waste management workers; however it cannot be precluded that private contractors re-route materials labelled as waste.

The procedure under Article 37 also applies to any facilities for the processing, storage or (final) disposal of radioactive waste. The Commission Recommendation does not distinguish between different categories of radioactive waste, hence the submission of general data is also required for new VLLW disposal sites (if on a different site than an existing disposal site, or with modified pathways of exposure).

1.4.2. Article 35

Under Article 35 of the EURATOM Treaty, the Commission has a right of access to the facilities established by Member States to monitor levels of radioactivity in air, water and soil. The Commission verifies the efficiency and adequacy of the environmental monitoring arrangements. This right of access applies to facilities relating to any type of operation, including dismantling and waste disposal. Thus the Commission may verify the measurements carried out to establish activity concentrations in materials that are being prepared for clearance.

2. COMMUNITY POLICY WITH REGARD TO EXEMPTION, CLEARANCE AND EXCLUSION

2.1. Community guidance on clearance levels

Article 5.2 of the Basic Safety Standards requires competent authorities to take Community guidance on clearance levels into account. Such guidance has been issued for metals, for buildings and building rubble, and for any (other) type of material (general clearance levels). The guidance documents were approved by the Article 31 Group of Experts and published in the EC Radiation Protection Series [3–5].

2.1.1. Clearance levels for metals

Guidance on clearance levels for steel scrap from nuclear power stations was offered already in 1988 (Radiation Protection 43). In this document, the exemption criteria were laid down for the first time, they were subsequently confirmed internationally (IAEA–NEA, Safety Series No. 89). In the meantime, new studies had been conducted on the features of recycling (1985–1990). In addition, it was considered appropriate to have clearance levels also for aluminium and copper, and different steel alloys, and to consider also surface contamination. The work of the Article 31 Working Party on metal recycling and reuse was very much a test case for the clearance concept that emerged from the Basic Safety Standards (1996).

The approach followed for the establishment of clearance levels included the detailed identification of exposure scenarios and the careful choice of parameters: physical parameters (distribution factors), parameters related to the industrial practice (type of furnace) and to the exposure pathway (exposure time, dust concentration). A ‘prudently realistic’ deterministic approach was followed for the identification of reference groups of the population (workers, consumers) to calculate annual doses for compliance with the 10 Sv criterion.

This has yielded a broad range of values (for all types of metal) ranging from 1 Bq/g (e.g. ^{60}Co, ^{239}Pu) to 10 000 Bq/g (e.g. ^{55}Fe). It was further specified that compliance with clearance levels should be demonstrated for items or batches of a few hundred kilograms. This averaging mass was chosen for coherence with the scenarios, but also dictated by the concern that, for larger amounts, operators could be tempted to dilute low level radioactive waste into non-contaminated material.

Surface criteria were considered in a similar way, and it was laid down that mass and surface criteria be applied simultaneously, the latter being the more restrictive for thick slabs even in case of actual mass contamination. For reuse, surface criteria are more restrictive and no mass clearance levels were introduced, the reason being that ingots could be transformed directly into finished products without being mixed with other material in the furnace.

It took until 1998 [3] for the clearance levels for metals to be published, hence too late for inclusion in the Basic Safety Standards.

2.1.2. Clearance levels for buildings and building rubble

For building rubble a similar approach was followed as for metals, but it was soon concluded that for the large amounts that need to be considered, the levels, in terms of mass activity concentrations, would be extremely low [4]. On the other hand, the use of surface criteria for reuse of the building for non-nuclear purposes (industrial or other) was found to be a very feasible option. If the building is to be demolished, one may consider even higher surface contamination levels. For small scale demolition works yielding less than 100 t/a, one may multiply the mass clearance levels by a factor of 10 so that they are, in general, of the same magnitude as for metals. This may be an option, for instance, for the disposal of activated shielding blocks in accelerator buildings.

Again, as a precaution, averaging constraints were imposed (1 m^2 for surface activity, 1 t for mass activity).

2.1.3. General clearance levels

As soon as the work on building rubble was completed, rather than specifying clearance levels for other types of material (plastics, etc.), it was decided to set default levels for any type of material (and any release pathway).

The approach to setting general clearance levels was different. It is not feasible to consider, in detail, all possible scenarios for any type of material. Instead, enveloping scenarios have been defined to cover the different exposure pathways in a way that is consistent with the scenarios used for building rubble and by examining whether they are appropriate in other situations as well.

While the specific levels (for metals and building rubble) will, in general, be applied only subject to certain conditions being complied with prior to release, the general clearance levels (default values for any type of material and any destination) may be laid down in national legislation for direct application by the operator. The idea of default values has been very appealing to Member States and the levels have promptly been introduced in some national legislation.

Nevertheless, the guidance on specific clearance levels, in particular for metals, may still be useful, despite the fact that scrap metal industries are reluctant to accept such materials. Portal monitors will trigger an alarm for a conveyance of scrap metal containing radioactivity at the specific clearance levels. This should not be the case below general clearance levels.

The 'general clearance levels' have been published in Radiation Protection 122, Part I [5]. Part II [6] of the same publication addresses naturally occurring radionuclides.

2.1.4. Naturally occurring radionuclides

All work activities are assumed to be within the scope of the BSS Directive. It is up to Member States to identify which work activities are of concern and require an appropriate form of regulatory control, on the basis of surveys on the characteristics of industries processing materials with (enhanced levels of) naturally occurring radionuclides (NORM).

This approach offers flexibility for the Member States to take into account national circumstances. Such flexibility is necessary in view of the fact that in most Member States there is little experience with the regulation of natural radiation sources and, in addition, a new legal framework must be set up for this purpose.

The Group of Experts referred to in Article 31 of the EURATOM Treaty has provided general guidance [7] on the implementation of a system of protection.The Group of Experts also adopted a Guide (Radiation Protection No. 95) providing reference levels for identifying those industries for which occupational exposure requires regulatory control. The reference levels are specified in terms of activity concentrations of the input material in relation to marker points in terms of annual effective dose (1 mSv and 6 mSv per year).

Since the adoption of the Directive, Member States have considered that there is merit in using the concept of reporting and prior authorization and its corollaries, exemption and clearance, laid down in Title III of the Directive for practices, for work activities as well.

The Group of Experts examined this option and drew the following main conclusions:

(a) As a result of the large volumes of material processed and released by NORM industries, the concept of exemption and clearance merge, and it is appropriate to lay down a single set of levels both for exemption and clearance.
(b) While the basic concept and criteria for exemption clearance for work activities are very similar to those for practices, it is not meaningful to

define the levels on the basis of the individual dose criterion for practices (10 μSv/a); instead, a dose increment, in addition to background exposure from natural radiation sources, of the order of 300 μSv is appropriate.

Exposure to radon gas is not included in the dose increment of 300 μSv. Radon concentrations in workplaces below 500 Bq/m³ are excluded from the overall exposure. For radon in dwellings, the reference level for future constructions is 200 Bq/m³. For the considered activity concentrations of ^{226}Ra, these radon concentrations are never exceeded.

On this basis, exemption clearance levels for NORM materials have been established [6]. They are 0.5 Bq/g for uranium and thorium in secular equilibrium (and 5 Bq/g for ^{40}K). This is in the upper range of concentrations usually found in ores and thus ensures that regulatory control is practicable. The merit of deriving values from a dose criterion is that it offers a coherent and transparent approach and allows higher clearance levels to be derived for segments of the decay chain of the parent radionuclides.

While the general clearance levels in RP122, Part I [5] may, in principle, apply to the release of materials from regulated practices (e.g. uranium mining, milling and processing), it may often not be possible to verify compliance as a result of the high natural background. It is also clear that an industry receiving materials cannot, in general, distinguish between residues from a practice or from a work activity. Depleted uranium can be distinguished from natural uranium, but from a radiation protection point of view there is little difference.

2.2. The concept of exclusion

The EU guidance on clearance levels has also received a lot of positive attention internationally. There have been many bilateral contacts with authorities outside Europe pursuing a similar development. So there was hope for the EU guidance, in particular for general clearance, to be confirmed internationally as an IAEA Safety Guide. International harmonization is important in view of the fact that scrap metal is traded globally. The Commission has repeatedly offered to reconsider its own guidance for the sake of international consensus.

A General Conference Resolution (GC(44)/21 adopted in September 2000 and requesting, within two years, submission to the Board of Governors of “radiological criteria for long lived radionuclides in commodities, particularly foodstuffs and wood” was the starting point for a new initiative relating to the international trade of commodities, irrespective of their origin (dismantling, Chernobyl, natural radiation sources).

The IAEA took on board the task of defining such levels (originally labelled ‘scope defining levels’ (SDLs)) for any type of commodity, which soon turned out to be a huge undertaking. It proved impossible to define a unique set of values for foodstuffs, building materials, metals, wood, etc. At the same time there was a strong plea for simplification. The new levels should not add another layer to the existing exemption levels laid down in the Basic Safety Standards and to the clearance levels established in EU guidance.

Hence, there was a shift from “trade of commodities” to defining a borderline for inclusion in a regulatory control scheme. If there was a unique set of levels, it would indeed be appealing to consider this as a kind of ‘exclusion’ level. The plea for simplification even led to the consideration of just a few radionuclide categories, rather than a nuclide specific list, but this attempt was soon abandoned. However, in the draft new Recommendations of ICRP (cf. version presented at the IRPA conference in Madrid, 2004), this idea was reintroduced.

This conceptual shift to exclusion had implications for the choice of the levels in relation to clearance levels. If only trade was envisaged, since there should be no barriers to trade for cleared materials, the SDL should be higher than or equal to at least the general clearance levels, preferably also the specific levels, e.g. for metals. The pursuit of exclusion levels, for any type of material and for any possible use, has led to levels even below general clearance levels.

It was eventually agreed that the SDLs for artificial radionuclides fit within the conceptual framework of exemption, not exclusion [10]. They should be regarded as the lower boundary to a graded approach to regulatory control.

For naturally occurring radionuclides, the concept of ‘amenability to control’ underlying exclusion would, in principle, apply. Eventually, values were chosen at the upper end of the distribution of concentrations in soils around the world (from UNSCEAR data): 1 Bq/g for the U and Th families and 10 Bq/g for ^{40}K. This is a factor of two higher than the values derived in RP122, Part II [6] on the basis of a dose criterion of 0.3 mSv/a. It should be noted that much higher doses arise if structural building materials are used with activity concentrations at this level.

3. VIEWS ON THE MANAGEMENT OF VLLW IN THE EU

3.1. Situation in the EU

Several EU Member States are considering the use of (or indeed are already using) very low level waste (VLLW) as a new specific category of radioactive waste.

In these countries, VLLW results mainly from:

(a) Industrial processes that concentrate NORM;
(b) Nuclear medicine in hospitals;
(c) Dismantling of nuclear installations;
(d) Remediation of contaminated sites.

Taking into account that the concepts and levels related to exemption and clearance levels are not always clearly defined in the EU, there is often not an explicit definition of VLLW in Member States.

This new category of radioactive waste had not been envisioned at the time the European Commission adopted a recommendation on a classification system for solid radioactive waste (1999/669/EC, EURATOM). The Recommendation nevertheless already distinguished between radioactive waste and "materials (of category 1) that can be managed outside the regulatory control system". It also introduced the concept of 'transition radioactive waste' for a type of material which will decay within the period of temporary storage and may then be suitable for management as category 1 materials. In all cases, reference is made to the clearance levels introduced by BSS Directive 96/29/ EURATOM.

Generally, the activity range for VLLW waste considered by Member States lies between 1 and 100 kBq/kg, but for beta emitters it can be higher. The UK has defined limits for VLLW: either <400 kBq beta–gamma in 0.1 m^3 (~4000 kBq/kg) or <40 000 kBq/kg beta–gamma per single item. Other countries, such as Ireland and Italy, prioritize the half-life as a determining factor; a waste has to have a half-life of less than a few months to be considered VLLW for a given low activity.

Currently, Member States authorize dedicated repositories on a case-by-case basis. For example, since September 2003, France has operated a site with a capacity of 650 000 m^3 intended exclusively for VLLW, and Spain is licensing one with a capacity of 130 000 m^3. These capacities are of the order of expected volumes arising from the dismantling of existing nuclear power plants in these countries in the next 30 years.

3.2. NORM residues

Guidance has been offered on the possible application of the concepts of exemption and clearance (in Radiation Protection 122, Part II [6]) for naturally occurring radioactive materials (NORM) and the same levels have been proposed for both exemption and clearance. The concept of clearance must, however, be applied by the authorities with some flexibility, allowing for specific features of industries and for the best option for the management of residual materials. There is little benefit in having a rigid threshold above which materials would be regarded as radioactive waste.

It should be borne in mind that NORM residues are often characterized by their huge volumes and by the fact that the materials are inert and are chemically (with the possible exception of heavy metals) and biologically suitable for recycling in landfill, dykes, refill in mines, etc. Recycling into building materials (phosphogypsum, fly-ash) is performed on a large scale, but requires a specific assessment of the resulting exposure in dwellings.

The recycling of NORM residues can be regarded as simply returning the material to its origin: the lithosphere. This also implies that, for NORM residues, the preferred management option is dispersion rather than containment (in general favoured for artificial radionuclides). This also holds for discharges of NORM residues with effluents [8]. Process water from marine oil platforms is mostly reinjected into the wells or marine waters.

In view of the long half-lives of NORM residues, it seem advisable to keep them separate from most types of VLLW with artificial radionuclides. NORM residues above the clearance levels will arise mostly through deposition in scales or dust filters. It may be appropriate to regard such materials with high activity concentrations as LILW. Metal tubes with NORM scales trigger alarms in scrapyards and metal plants. However, the recycling of such metal scrap will not cause any radioactivity in the metal product, and the radioactivity in the slags will be very much diluted as compared with the original surface levels.

While considering options for the management of NORM wastes with regard to their radioactivity content, under the EURATOM Treaty, it should be remembered that environmental legislation under the EC Treaty applies and in some cases prevails.

Considerably higher clearance levels could be applied for wet sludges, e.g. from the oil and gas industry, mainly because the suspension/inhalation pathway can be ignored. Thus, for this type of material, it is permitted to use specific values, but only as long as the material does not dry out. However, this implies some form of engineering or regulatory control which is not strictly compatible with the idea of clearance.

3.3. Hospital waste

Radioactive waste from hospitals is often short lived, and it therefore makes sense to store the waste on-site for decay prior to release. Allowance has to be made for the fact that hospital waste is often also hazardous biological waste requiring special precautions. The favoured management option is often incineration, so that with regard to residual radioactivity, allowance must be made for the exposure of workers to ash and of the population to volatile radionuclides and aerosols released through the stack.

With regard to releases of radioactive waste with liquid effluent, the current growth of nuclear medicine, often with different units in the same town area, may give cause for concern as a result of the accumulation of sludges in the sewer system.

The European Commission will undertake a major study on the management of hospital waste in 2005.

3.4. Materials from dismantling of nuclear installations

The dismantling of nuclear installations (and other premises such as hospital accelerators) gives rise to very large volumes of materials, most of which are not contaminated (or activated). It is not always possible to demonstrate the absence of radioactivity simply from records; in many cases it is necessary to rely on measurements. The concept of clearance is therefore very important for the management of such materials.

It should be recalled that clearance is a part of operations that are under strict regulatory control. The guidance offered by the European Community therefore addresses not only the levels but also the conditions that need to be fulfilled. The most important are:

(a) The segregation of clean material from contaminated or suspect material;
(b) No dilution of LILW with clean materials to meet the clearance levels (hot spots are dealt with through appropriate averaging rules, or size of individually monitored batches).

With regard to metals, it is recalled that surface contamination (fixed or non-fixed) and mass activity criteria apply simultaneously. The clearance levels do not apply to ingots (to ensure dilution prior to manufacturing); lower levels should apply to ingots from on-site smelting.

It should be emphasized that the application of clearance levels is part of a comprehensive scheme for putting the dismantling under regulatory control. This includes establishing an inventory of contamination, including contamination-free areas and areas with a potential for clearance. Clearance will rely on suitable measurements for a set of reference radionuclides (applying the sum rule for other radionuclides on the basis of estimated levels) and proper documentation, before an explicit permission is granted to clear the material.

4. CONCLUDING OBSERVATIONS

4.1. Environmental legislation

Contamination levels in some VLLW may be so low as to be considered almost negligible and may also, within a short period of time, fall below clearance levels. In such cases, especially where there is a much greater ‘conventional’ hazard (e.g. asbestos, heavy metals, etc), it may be necessary to consider general environmental legislation such as: the Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste, for the licensing of VLLW repositories or for the disposal of VLLW at conventional disposal sites, Directive 2002/96/EC of 27 January 2003 on waste electrical and electronic equipment (WEEE), which contains provisions on the reuse, recycling and other forms of recovery of such wastes, as well as Directive 85/337/EEC of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment, as amended by Directive 97/11/EC, as far as authorization for new waste landfills is concerned. A proposal for a Directive of the European Parliament and the Council on the management of waste from the extracting industries will soon be adopted. It makes no reference, however, to NORM waste from such industries.

4.2. Options assessment

It is up to Member States to decide on the options available for managing VLLW. It is difficult to reach consensus at Community level in view of national differences in types and volumes of generated waste, existing legislation and societal factors, such as public perception. In the view of the authors, the main features of the different options are the following:

(a) Recycling:
- (i) Only for materials below clearance levels;
- (ii) An ecological benefit (preserve natural resources);
- (iii) Sensitive to public perception (trace radioactivity in ordinary consumer products);
- (iv) Sensitive with regard to commercial interests (scrap market prices, preservation of the image of the industry (and of metals as a clean product);
- (v) Needs for monitoring to detect orphan sources in batches of scrap metals and to prevent them from being melted (difficulty of distinguishing sources from diffuse enhanced activity concentrations).

(b) Landfill:
   (i) Low specific cost;
   (ii) Spread of radioactive waste over many sites decreases individual doses;
   (iii) No need for long term surveillance;
   (iv) Specific arrangements for monitoring and for protecting workers may be required.

(c) VLLW repository:
   (i) Low cost (compared to LILW repositories);
   (ii) Concentration of the waste in a single area;
   (iii) Specific arrangements needed for containment/surveillance;
   (iv) Need to reduce the total volume (and land area needed) by also making use of the other options.

It seems advisable to keep all options open at this stage so as to allow a long term environmentally and radiologically safe management of such materials.

The Commission will discuss with Member States whether a harmonized Community policy can be pursued. In the meantime the Commission will undertake the further harmonization of clearance levels in the Basic Safety Standards (the current implementation in national legislation shows important differences [9]), and of the definition of different categories of radioactive waste.

The Commission will also further pursue international consensus on the concepts of exemption, clearance and exclusion on the basis of the Safety Guide published by the IAEA [10].

ACKNOWLEDGEMENTS

The authors acknowledge the fruitful input of their colleagues, E. Henrich, T. Ryan, Y.-H. Bouget, W. Hilden, S. Murphy and E. Pla.

REFERENCES

[1] Proposal for a Council (EURATOM) Directive setting out basic obligations and general principles on the safety of nuclear installations.

[2] Proposal for a Council Directive (EURATOM) on the management of spent nuclear fuel and radioactive waste.

[3] RADIATION PROTECTION 89, "Recommended Radiological Protection Criteria for the Recycling of Metals from the Dismantling of Nuclear Installations", Luxembourg (1998).

[4] RADIATION PROTECTION 113, "Recommended Radiological Protection Criteria for the Clearance of Buildings and Building Rubble Arising from the Dismantling of Nuclear Installations", Luxembourg (2000).

[5] RADIATION PROTECTION 122, "Practical Use of the Concepts of Clearance and Exemption, Part I — Guidance on General Clearance Levels for Practices", Luxembourg (2000).

[6] RADIATION PROTECTION 122, "Practical Use of the Concepts of Clearance and Exemption, Part II — Application of the Concepts of Exemption and Clearance to Natural Radiation Sources", Luxembourg (2000).

[7] RADIATION PROTECTION 88, "Recommendations for the Implementation of Title VII of the European Basic Safety Standards Directive (BSS) Concerning Significant Increase in Exposure due to Natural Radiation Sources", Luxembourg (1997), ISBN 92-827-5336-0.

[8] RADIATION PROTECTION 135, "Effluent and Dose Control for European Union NORM Industries: Assessment of Current Situation and Proposal for a Harmonised Community Approach", Luxembourg (2003).

[9] RADIATION PROTECTION 134, "Evaluation of the Application, of the Concepts of Exemption and Clearance for Practices According to Title III of Council Directive 96/29/EURATOM of 13 May 1996 in EU Member States", Luxembourg (2003).

[10] International Atomic Energy Agency, "Application of the Concepts of Exclusion, Exemption and Clearance", Safety Standards Series No. RS-G-1.7, Vienna (2004).

All EURATOM legislation and most publications in the Radiation Protection series can be downloaded from http://europa.eu.int/comm/energy/nuclear/radioprotection.

PANEL

(Session 2)

CLEARANCE AND VLLW DISPOSAL:
COMPETING OR COMPLEMENTARY APPROACHES?

Chairperson: **J. Avérous** (France)

Members: **R.L. Jackson** (United Kingdom)
I. Othman (Syrian Arab Republic)
K.-L. Sjöblom (Finland)
R.L. Zelmer (Canada)

Statement

R.L. Jackson
DEFRA,
London, United Kingdom
Email: robert.jackson@defra.gsi.gov.uk

I work for the United Kingdom Government, and basically I advise ministers on radioactive waste policy.

My response to the question addressed to the panel is that, coming from the UK, I can't answer it at this point in time. I will try to say why. I believe that, while radioactive waste management is based to a very large degree on scientific analysis, it also depends to an equal degree, in practice, on what is politically possible. This in turn depends on national circumstances.

Let me illustrate this. As a scientist, I may be impressed by the latest IAEA safety guide, which tells me that, based on an analysis of a number of representative scenarios, it's safe to clear radioactive material into the public domain if it contains a specified low level of radioactivity. I might then go and explain this to my minister. What might he say? He could say "Yes, but what are my electors going to think about me allowing radioactive materials to be incorporated into cars and toys?" Or, he might say "The green pressure groups will be very upset about this and will stir up the media. I have to take that into account." Or, "Yes, I know these scenarios are meant to reflect real life, but they aren't real life, are they?" Or, "Yes, it's a good idea. However, we would have to change national legislation that's been in existence for 40 years and the regulations that go with it, and we don't have a lot of parliamentary time for this. Do we really need to change anything?"

We experienced that kind of reaction in the negotiation and implementation of the EU Basic Safety Standards Directive.

Or, I might find myself in a situation where my government commits itself fully to nuclear power and, just to avoid problems, decides that it's best to dispose of all nuclear waste — whatever the level of activity — in special, purpose-built facilities. Or, the government might say "Yes, clearance is sensible. We know there will be objections in some quarters, but we'll live with that."

It all depends on the circumstances — on political influences and on the views of the public and stakeholder groups. We're trying to reflect that in the UK in the way we try to deal with our radioactive waste management policy.

Of course, once we start talking about particular sites, it really gets difficult. Then we have to think about political issues such as the next elections.

Just to clarify the position on clearance in the UK: 'clearance' is not a term that is employed or defined in any UK legislation. There has been some clearance and recycling on the basis of guidance drawn up by the nuclear industry. It hasn't been formally acknowledged by the regulators, and what happens in practice depends very much on a case-by-case analysis of the situation and the proposed destination of the material.

Regarding disposal, ten years ago I imagine most people thought that we in the UK had the low level waste management problem solved. High level and intermediate level waste? Yes, we needed to think about it, but low level waste — no problem. We had the national low level waste facility at Drigg, and one of our other big sites — at Dounreay — had its own low level waste disposal facility. But then we realized that our nuclear power plants and also some of our other important nuclear facilities were coming to the end of their lives. We started thinking about decommissioning and cleanup, and people started doing calculations and surveying sites. Unfortunately, we didn't have nice new reactors and other facilities — we had old ones, and perhaps in the past operators had not been as careful with their radioactivity as they are today. Suddenly, it began to look as though, instead of filling one Drigg, we would need to fill several Driggs. The question is "Where are you going to put this?", and we come back to the very difficult political decision.

Does it really make sense to put the low level waste in an expensive engineered facility like Drigg? Does it make sense to dig up large amounts of waste, to transport it over long distances just to bury it somewhere else? But conversely, our ministers might say "People thought they were going to get a green field site and, if we leave the waste where it is, they won't!"

So, that is why we are currently in the position, as Mr. Selby explained, of reviewing our low level waste management policy, and he described the action we are taking.

This brings me back to my original point: radioactive waste management decisions depend on the art of the politically possible as well as the scientifically correct. We must, of course, try to persuade people and politicians of scientific correctness, but I am sure that, as we go forward, our ability to sell solutions to the public and politicians will depend as much on our presentational abilities and the views of local communities as on scientific and technical analysis.

That is why I feel I can't answer the question. I don't think we've reached the answer in the UK. I may be able to tell you the answer at the next symposium, in four years' time — but I am not sure. It will depend on national political circumstances.

Statement

I. Othman
Atomic Energy Commission of Syria (AECS),
Damascus, Syrian Arab Republic
Email: iothman@aec.org.sy

In my case, the situation will be different, as we are a non-nuclear State, so our waste is not from the nuclear industry. But we have experience with NORM from the oil industry, which presents problems of large volumes and low specific activity materials. National policies on clearance levels and VLLW should — as Mr. Jackson said — take account of all potential disposal options within a specific country environment. What is good for the United Kingdom, or for Europe as a whole, may need to be looked at again before application in the Middle East, Africa or Asia.

The economics of waste disposal may influence decisions on clearance or controlled disposal. If the clearance route is chosen, the setting of levels and the demonstration of compliance may prove to be difficult, and we should expect that some people will try to escape from complying with the established levels.

Again, the absence of a national disposal site in a country has an important influence on the setting of clearance levels. I think the conditions in the country have to be taken into consideration.

Statement

K.-L. Sjöblom
Radiation and Nuclear Safety Authority (STUK),
Helsinki, Finland
Email: kirsti-liisa.sjoblom@stuk.fi

Finland is a developed country with a high level of technological education. We have a nuclear programme — two power plants — but we don't have any nuclear legacies; we have no NORM, and the people are known for rational thinking.

Our situation is so much easier than that in many other countries. We have been using clearance for 20 years. It is in our legislation, and the regulator, STUK, is making regulations on clearance, following, all the time, the international developments.

As regards this question of "clearance versus very low level waste disposal, competing or complementary?", I would definitely say that they are complementary, although in Finland very low level waste disposal is not regarded as a special disposal option. But, in general, they are definitely complementary.

We have operating low level waste repositories at both nuclear power station sites, but we are really implementing clearance. The strategy for VLLW management is a combination of several management options, and the waste producers want to choose the most economical one — of course, taking into account the radiation safety requirements.

One of the issues is the minimization of waste generation. After that, the steps are waste segregation, decontamination and decay storage — taking into account hazards besides radioactivity, because much of the waste cleared by us goes to a conventional hazardous waste management facility.

As regards unconditional clearance and conditional clearance, I think conditional clearance is not very far from authorized disposal of VLLW, so even in our case we can consider that we are doing some VLLW management using the disposal option, because some of the scrap goes to the normal hazardous waste disposal site.

Regarding societal acceptance, I think it is related very much to the general acceptance of the recycling and reuse of materials in a country. They are generally accepted in Finland because we don't have very many natural resources; the natural resources in Finland are, more or less, forests and people. So we are very used to recycling and reuse. Also, societal acceptance is related to the general attitude to nuclear power and radioactive waste management.

You may know that Finland is about to build a new nuclear power plant, and that is accepted by Parliament and by the population. So, the waste management options used are accepted in Finland.

As to the acceptance of clearance and the clearance regulations, it is the general attitude towards the regulatory body that is important. If people are trusting and consider that the regulators are professional, and if the regulators are open for discussion, then it's easier to have the options open.

With the IAEA safety guide in place, what are the prospects for the general application of clearance in the world? During this week I have heard some colleagues from other countries saying that they will adopt the safety guide figures. But I have also heard some views which are similar to ours — that we need some relaxation criteria for small amounts of waste, because it is particularly aimed at decommissioning waste and — for example, in Finland — decommissioning will probably come only after 20 years, or even later.

So that is what we need, and then, if we think about some countries which have only limited nuclear applications (medicine, industry, education), they actually don't need the safety guide. There is already IAEA-TECDOC-1000, which is enough for the clearance of limited amounts of material.

Then there is the question of the general application of clearance in the world. If you consider that cleared materials such as metals can go around the world, then we have to be really careful about this, because, as you know, all metals these days go to China! The metal prices are getting higher and higher. So that is, I think, the worldwide implication of clearance: metals are going round, and of course the clearance levels are important to ensure that we have so-called 'clean metal'.

Statement

R.L. Zelmer
Low Level Radioactive Waste Management Office,
Atomic Energy of Canada Ltd,
Gloucester, Ontario, Canada
Email: zelmerr@aecl.ca

The perspective I bring is all about public trust, and I wish I could report that the public thinks as rationally in Canada as in Finland.

The Low Level Radioactive Waste Management Office is the agency of the Government of Canada charged with resolving historical LLW issues which are the responsibility of the Government, so we have a limited mandate. We are an operational unit charged with resolving environmental problems in the public domain. We are not a regulator, nor radiation protection specialists, nor a waste management service, nor a facility design and construction business. But we must conduct activities in all of those areas in a responsible, credible way, and public trust is essential to our success, and we benefit from, and are subject to, national and international regulatory definitions and oversight, because these build public trust where we do our work. Would our task be easier if all historical low level radioactive waste in Canada were excluded or exempt or cleared from regulation and safety oversight? My answer is "Perhaps, but there must be a federal or provincial or local approving or permitting authority". It's essential that we conduct business in the context of this kind of oversight when we are working in the public domain.

We deal with a spectrum of materials from LLW down to background environmental levels. For many years, we have benefited from the distinction between what we call 'marginally contaminated soil' and 'licensable material'. Each category can be handled in a different way and at different sites. This can reduce the scale of operations and our long term obligations. This also assures the public that any radioactive material is safely managed.

DISCUSSION

CLEARANCE AND VLLW DISPOSAL: COMPETING OR COMPLEMENTARY APPROACHES?

Session 2

J. AVEROUS (France — Chairperson): I see there is a call for flexibility in the implementation of LLW disposal and clearance policies, and we have heard about the need for more guidance on VLLW and NORM waste disposal.

H.M. FERNANDES (Brazil): At a recent technical meeting in Vienna it was recommended that NORM material not be called 'waste' but 'residues', because in some cases such material can be reused for different purposes. The term "waste" has a particular connotation. For example, in Brazil, if something is called 'radioactive waste', there is a very special regulatory framework to deal with it.

Another point concerned clearance and transport requirements. Some material may be cleared from a working practice, but maybe at higher or lower values than apply for exemption from transport requirements — possibly leading to complications.

I. OTHMAN (Syrian Arab Republic): With the large amounts of waste produced in the oil industry, transport is a big problem. The public does not distinguish between whether you are carrying high level waste or very low level waste because, for them, it is radioactive material and they oppose any transport of radioactive material unless there are a lot of precautions taken, and to take those precautions is very expensive. Therefore, it really is a problem.

R.L. JACKSON (United Kingdom): Yes, I think transport is a factor that has to be taken into account when one is dealing with LLW. Certainly, we will be discussing with interested groups, stakeholders of various kinds, the question "Does it make sense to dig up large amounts of waste and transport it over long distances just to bury it somewhere else?"

Regarding terminology, we are struggling with it at this symposium. We have so many different terms, and you have to be careful because different terms mean different things to different people.

M.I.F. PAIVA (Portugal): A comment regarding education. In Europe, there has during the past few years been a decrease in the number of youngsters studying subjects relevant to this symposium (for example, radiochemistry, nuclear science and radiation protection), and this is going to be a problem in the future. When we face issues such as public perception, if we don't have the right experts, who will be able to talk about these subjects knowledgeably?

K.-L. SJÖBLOM (Finland): Regarding education and public perception, my organization, STUK, has recognized that education of the public is one of its tasks, and we have a very proactive public education programme. Each week we issue information for the public on what STUK is doing, usually through the press and, last summer we organized one week's training for the press in Finland. They came at their own expense to STUK, and in connection with this training they were taken to Sweden to see the waste disposal options being considered there. That was very successful, and we plan to repeat it in one or two years' time.

P. CARBONERAS (Spain): After many years of working on this issue, I find that we are still mixing the decision aiding process and the decision making process.

I fully accept whatever decision is taken by a legally established decision maker, but I position myself in the decision aiding part of the process, and from that point of view I fully believe that clearance is a complementary concept for whatever radioactive waste disposal option is available and being applied.

Let me give two reasons for this. The first is that the available resources should be used responsibly because they are always limited. The second is that we, as experts, need to fight against the idea that radiation is the most harmful agent in the world. We have to inform the public and politicians that it is just one of many harmful agents; it can be managed safely. From a technical perspective, clearance is a logical concept that should be used to save resources. We need to transmit this message.

R.L. JACKSON (United Kingdom): What we are trying to do in United Kingdom is to involve the stakeholders in several initiatives, both on LLW and on HLW, but to do it in a manner that is informed. If you explain to people the reality of the situation and what the options are, you have a much better chance of getting a sensible decision. If people do not understand what they are dealing with, you will probably get irrational decisions.

The objective is to obtain policy decisions which command wide support. I don't think we will ever get total support, that is unrealistic, but I think we must get a level of support which is sufficient to legitimize the decisions we take.

Regarding clearance, I think that it has a big role to play and that we must try to make optimum use of it. An important point was made: conditional clearance, which is the kind of thing we have gone for in the United Kingdom, is potentially much easier than unconditional clearance. We have seen public reaction against unconditional clearance, and our politicians are sensitive about it. Perhaps we need to work on that more, in a spirit of scientific logic. I was trying to say in my statement that we have to work in a balanced manner in arriving at decisions on policy. So I think I am generally supportive, but in a conditional way!

I. OTHMAN (Syrian Arab Republic): Whether you live in London or at Dayr az-Zor, where we produce the oil and most of the people are Bedouins, radiation arouses the same feelings. Some of the people at Dayr az-Zor have never heard the word ‘radiation’, but, when they found scientists going around with survey meters, they started avoiding the area and spread the word that something harmful to health was being done there.

I think that radiation, although it’s only one of the risks in life, is coming to be seen by the public as one of the worst risks. Whatever our education level, we don’t like the medical doctor to take another chest X ray; we prefer that he take only one.

Therefore, we have to be very careful with clearance. In the Syrian Arab Republic, at the beginning we ignored the whole issue of radiation from the oil industry because it is NORM, but the public was concerned and started exerting pressure. So we took action and the Shell Company has spent a lot of money on rehabilitating the area.

J. AVEROUS (France — Chairperson): I would like to add something to this. In France, for the waste from the nuclear industry, the regulator now requires very strict segregation between VLLW and conventional waste. One of the main reasons is a scandal that occurred at the beginning of the 1990s; a facility was doing clearance but not in a good way, and this led to a big public outcry, as a result of which both the regulator and politicians called for a very strict system which avoids any radioactivity coming out of the nuclear industry.

R.L. ZELMER (Canada): I would like to move from my position of ‘perhaps’, but only to a more convenient position. I cannot conceive of coping, in the years ahead, without having some LLW disposal capacity, simply because, certainly in our experience, you always reach a point when there is some material, suspect material or measurable material, that brings discomfort to the property owner that you are dealing with, and to have a licensed, credible, robust, engineered facility to take that material is a tremendous asset and helps with environmental remediation problems.

M. FEDERLINE (United States of America): The panellists did a very good job of identifying the key factors in their own environments that have driven choices about VLLW — for example stakeholder or political pressure or cost-benefit considerations. How can we work internationally to achieve some understanding among members of the general public who see different countries pursuing different solutions to the VLLW problem?

R.L. ZELMER (Canada): I think this is an area where, in Canada, the federal regulator can be of great help. The public in Canada can look around the world — for example, using the Internet — and see different solutions to LLW problems being adopted. But if our regulator supports our applications for particular solutions, that can go a long way towards enhancing public support. So I would say that the regulatory approach in each country is key.

R.L. JACKSON (United Kingdom): I think it is very important to identify, in a scientific way, the appropriate levels of clearance.

As to how we do that, I think that part of the problem for some of the older, larger nuclear programmes is that we carry too much baggage from past operations, past legislation and past approaches, and I almost wonder whether it is easier for countries that do not have large nuclear programmes or embarked on such a programme later to implement what I would call scientifically rational policies.

K.-L. SJÖBLOM (Finland): Regarding the acceptance of different kinds of solutions in different countries, I think that what we have now, through IAEA Safety Guide RS-G-1.7, is essentially a worldwide approach for clearance. The countries which will use it can also, on the other hand, have VLLW disposal, because it is not actually the same thing at all. VLLW disposal accepts higher concentrations than realized through clearance. Then, on the other hand, some countries can just decide not to clear anything. I don't think it is a global problem; it is rather a national problem of wasted resources and not a problem of worldwide acceptance. So I really believe that now there will be more or less worldwide acceptance of clearance.

J. AVÉROUS (France — Chairperson): I think that one thing we have in common internationally is radiation protection objectives, even if the way we reach those objectives may differ from one country to another.

L. JOVA SED (IAEA): I wish to support Ms. Sjöblom's comment, because for many countries clearance is a complement to any disposal solution, but for countries with no nuclear power programmes clearance could be a solution for much of the waste.

I welcome the reference made yesterday by Mr. Kawakami in his presentation to 'clearance infrastructure', because it is a question not only of establishing a set of values — international or national — but also of understanding what is behind the values, how they were reached, how they can be implemented, how to manage clearance and how to check compliance. In this regard, I think there is more work for the IAEA to do.

J. AVÉROUS (France — Chairperson): With the very low clearance levels proposed by different agencies or multilateral bodies, there is the issue of how you measure them, the question of averaging and things like that. I would stress that around the table of numbers in RS-G-1.7 there are a lot of caveats and comments on their application, and obviously there is still a need for more guidance on how you measure and verify these very low levels.

D. LOUVAT (IAEA): We are just developing a safety report on the application of the concepts in RS-G-1.7 which includes techniques for verifying compliance with the levels in that publication. The safety report will be published in 2005.

J. AVÉROUS (France — Chairperson): I think there is a very important fact to be taken into account, at least in developed countries — the fact that checking compliance with clearance levels involves a lot of work and costs a lot.

S.M. WOOLLETT (Australia): In my country, which does not have a nuclear power industry, the concept of ‘clearance’ is quite important. It enables us to dispose of airborne and liquid effluent and of solid waste in landfills, in municipal tips and in hazardous waste facilities. Therefore, I am a little concerned about this morning’s presentations about VLLW and the possible competition with clearance. I think it does compete with clearance. In a country that does not have significant amounts of VLLW, it is difficult enough for us to dispose of the small amounts of LLW that we have. To split the LLW category and create a more complex classification system will not help us. I can see the value of doing so in countries with nuclear power industries, but I would not encourage the IAEA to make a more complex classification and include VLLW as pa\rt of it.

G. BENDA (United States of America): Regarding terminology, Tennessee has for the past 15 years been implementing the ‘conditional’ release or conditional clearance of very low level radioactive waste into landfills. Other people consider it municipal waste, because it goes to municipal landfills. The term used, ‘very low level radioactivity waste’ or ‘municipal waste’, will make a big difference to the public.

On criteria, I prefer using dose criteria instead of concentration criteria, because dose criteria of, say, 1 mrem/a (10 μSv/a) can cover many different types of radionuclides and situations, whereas concentration criteria are usually situation specific.

R.L. ZELMER (Canada): I think that, if some of the materials we deal with were officially identified as cleared materials, there would be a greater likelihood of them being acceptable not just to the operators of commercial facilities but also to the operators of government facilities. That could lead to great transport and disposal cost savings and obviate the difficulties that go with creating and operating a purpose built facility and monitoring it for hundreds of years into the future.

R.L. JACKSON (United Kingdom): I support the view just expressed by Mr. Benda. We do suffer from terminology problems. In the United Kingdom we have a class of waste called ‘VLLW’, but it applies to small amounts of non-nuclear waste. It is used, incorrectly to my mind, in relation to large amounts of nuclear decommissioning waste. We have considered whether there might be a role for a type of lower activity waste and we have struggled with the terminology, talking about 'very low radioactive material', 'very low active waste'. The related question is "Where do you set the upper limit?" There are various possibilities.

Another thing that complicates matters is the fact that, when we do safety case assessments, we work in terms or risk and, by implication, dose. That does not equate directly to set concentration levels, which have to be derived through scenarios.

At the end of the day, what is important is the dose and the risk that goes with it. That is what we look at in safety case assessments.

We are always struggling with terminology and with the relationship between activity concentrations and dose and risk. I don't know how we can resolve those issues.

K.-L. SJÖBLOM (Finland): Regarding terminology, given the title of this symposium Disposal of Low Activity Radioactive Waste, I started to wonder what 'low activity radioactive waste' is, because we are used to speaking about 'low level waste' and maybe sometimes 'very low level waste'. It would be very much appreciated if the IAEA could decide how to term the types of waste we are speaking about.

Regarding dose criteria or concentrations, for me, dose criteria are the prime criteria. My understanding of triviality for clearance is in terms of dose. Concentrations are derived in many ways, and the concentrations now in the IAEA safety guide are very low. When we take different scenarios, with different amounts, we can get higher concentrations, but still the dose criteria are fulfilled.

I. OTHMAN (Syrian Arab Republic): When you have clearance, that means the released material can be recycled into another industry. Although the initial concentration was low and the associated dose was low, we cannot guarantee that later on, because of the recycling, the activity concentration will not become higher and use of the material more risky.

J. AVÉROUS (France — Chairperson): In the categorization of waste in France, we do not think that you can define from the beginning what will be the limits for each waste category in becquerels per gram, because what is important is the waste acceptance criteria at the management facilities. So, at the beginning you can think conceptually about the different types of waste, but at the end of the day, when you have created your waste disposal or waste management facility, it is the waste acceptance criteria from the safety assessment for that facility which will define the limits for each category of waste. So I would be very cautious in trying to make a conceptual classification from the beginning with limits in terms of activity.

D. LOUVAT (IAEA): The last three speakers have made useful contributions to the discussion on the way to revise the IAEA classification of waste. It seems to us important that any new waste classification be linked to the generally agreed disposal route for the waste category being considered. This concept was mentioned by Mr. Baekelandt in his presentation today ('the common framework').

H.M. FERNANDES (Brazil): On the question of dose or concentration criteria — dose criteria are generally applicable and easier to agree internationally, but the regulating agencies need a more practical concept. That is why activity concentrations are needed; they allow checking by means of direct measurement.

On the question of NORM — when you have contaminated areas, you should use the concept of 'intervention', and for this no limit can be applied. We in Brazil have found that it is rather difficult to convince legal representatives to accept any kind of dose limits higher than those used in operational radiation protection.

R.L. JACKSON (United Kingdom): In the United Kingdom we are moving away from the old concept of 'decide, announce, defend' and trying to involve people in decision making. However, clearance levels are often just figures in a table with very little explanation of how they were arrived at, and that causes problems for members of the public and possibly also for politicians, who don't understand how the figures were arrived at. I think the relevant international organizations should do more about explaining the derivation of such figures to members of the general public, so that when they see a figure for a controversial radionuclide like ^{239}Pu, they understand where it came from.

R.L. ZELMER (Canada): I would like to expand on that point. Something very interesting happened at a location where we are engaged in cleanup operations. We needed to obtain the community's agreement on cleanup criteria. There were no criteria at that point, so we started to develop them together with the community, and it was on the question of the numbers and understanding them that the debate broke down on several occasions, because we entered a realm where it was beyond the ability of the parties to converse.

What we found very useful was to stop and think about the objectives of the cleanup and the uses of land that could be achieved once the cleanup was completed, rather than about the values of the numbers and the units being used. The community was satisfied with knowing that principles which it was comfortable with were being considered and that the regulatory authority would do the technical work based on numbers and criteria later. This would perhaps happen mostly out of the hearing of the community, but the community could still gain access to the numbers if it so wished.

J. AVÉROUS (France — Chairperson): Do you think we should have a different approach to VLLW management or clearance for the nuclear industry and for other industries, such as the oil industry, and other users of radioactivity, such as users of radioactivity in medicine?

M. BEN BELFADHEL (Canada): When we talk about waste that is within the nuclear fuel cycle and about clearance and disposal, we only discuss radiological criteria. We should remain flexible, however, because there is no black — or white answer — disposal or clearance. Flexibility is possible provided that there is a transparent regulatory framework for decision making, mainly to make sure that the hazards that are not of a radiological nature are captured.

L. BAEKELANDT (Belgium): The numbers in IAEA Safety Guide RS-G-1.7 are based on calculations that are explained in a safety report that will soon be published. The numbers are very low, but they can be used to define the scope of the regulatory control system. However, that does not mean that practices involving materials with activity concentrations slightly above the clearance levels or the exemption levels for bulk quantities have necessarily to comply with all the regulatory provisions. I think that might not be cost-effective. It may not be worthwhile to regulate some practices in detail, and I can only repeat what I said during my presentation: in the safety guide there are two very important paragraphs dealing with the graded approach. I think one should not forget these two paragraphs; they are very important for the application of the safety guide.

A. JANSSENS (EC): As Mr. Baekelandt rightly indicated, Safety Guide RS-G-1.7 refers to a safety report that is still to be published, and this morning he said — also rightly — that one has to be careful when referring to unpublished material. We have pursued a policy of complete transparency about the way the values in the safety guide were derived in order to gain political and public acceptance of them.

The levels proposed in the safety guide are very low, and there is sometimes a need to use higher levels. We have such higher levels as guidance for metal waste and building rubble, but is there a need for international consensus on a set of levels that would be higher and suitable either for smaller amounts of material or for different types of material? Or is it rather a matter of ad hoc, case-by-case decisions by the regulatory authorities because the local political and historical background that they have to face is much more important than the scientific consensus around the values?

J. AVÉROUS (France — Chairperson): I would like to summarize the main points emerging from the discussion:

1. I think everyone said there is a need for flexibility in the management of VLLW whether you choose regulated disposal, disposal in a landfill or clearance: you must have flexibility, and probably you must have flexibility between countries and flexibility within your own country. I gathered that perhaps you want to have a different approach for VLLW management in the nuclear industry, in other industries, in transport and for NORM waste. There are differences between cleanup situations relating to past activities and situations where you are managing waste from operations. So everything points to flexibility in the management of VLLW.

2. If you have an available licensed VLLW disposal facility, whether it is a dedicated stand alone facility or part of a hazardous waste landfill, it is a valuable national asset. It facilitates the management of radioactive waste in expected and unexpected situations. I think one of the conclusions is then: if you are applying clearance policies, it is also valuable to have the capacity for waste disposal, possibly in a LILW and VLLW facility.

3. I think there is agreement about the fact that you need to have a basic conceptual classification of waste, probably with VLLW as part of that classification. However, the exact distinction between categories has to be based on the acceptance criteria for disposal or management, and they will be different from country to country.

4. There is an issue of terminology, with difficulties about terms like 'low activity' and 'low level', and maybe about the fact that the term 'VLLW' is perhaps not well suited to waste management routes that are outside dedicated pathways for this kind of waste. For example, if you use clearance or conditional clearance, 'VLLW' may not be a suitable term.

LOW ACTIVITY RADIOACTIVE WASTE FROM DECOMMISSIONING

(Session 3)

Chairperson

L. VALENCIA
Germany

OVERVIEW OF DECOMMISSIONING WASTE

T. ENG, C. PESCATORE
OECD Nuclear Energy Agency,
Paris
Email:torsten.eng@oecd.org

Abstract

Data on existing volumes of decommissioning radioactive waste and materials are sparse. From the data collected by international organisations supplemented by that from a few national databases, the conclusion can be drawn that each decommissioning project is unique in the amount of waste that is generated, and, that the decommissioning of reactors of the same type has often generated very different waste and material volumes. This highlights the importance of management, the national culture and the regulatory regime. Key parameters to keep radioactive waste volumes down are careful planning before decommissioning and extensive follow-up work during the actual decommissioning. These types of efforts will also have a great impact on the overall costs of decommissioning projects.

1. INTRODUCTION

In OECD Nuclear Energy Agency (NEA) member countries, the average age of nuclear power plants is now near 20 years. Given an average operating life span of at least 30 years, a significant number of nuclear facilities will reach the ends of their working lives by around 2015. A significant issue, in terms of cost and effort, is the management of the waste and materials arising from decommissioning. The bulk of the materials that are generated consist of non-radioactive concrete, steel, graphite or other valuable materials, only a small part being radioactive waste.

Apart from the nuclear power plants, there is a large number of other types of nuclear facilities, plants and equipment that have now served their purpose and need to be decommissioned and dismantled. This range includes research and development facilities for chemical processing, uranium and plutonium production, isotope separation, nuclear fuel fabrication as well as research reactors, experimental and demonstration reactors, uranium mill facilities and facilities for the treatment and storage of radioactive waste. Some countries also have military facilities associated with nuclear weapons production and naval nuclear propulsion systems that need to be decommissioned.

During decommissioning, substantial quantities of scrap metals are generated, the major part being only slightly contaminated but still characterized as radioactive waste. One option for the disposal of this type of waste is at low level radioactive waste disposal sites. However, owing to the amounts involved, this option is costly. In order to minimise the commitment of disposal space and costs for this waste type, a policy of characterization, sorting, decontamination and clearance followed (if possible) by recycling and reuse could be effective.

In order to specify the disposal requirements and the related cost, an accurate estimate of the radioactive waste arising during the decommissioning of any nuclear facility is required. It would be expected that the waste amounts generated during the decommissioning of facilities of the same type would be approximately the same, if compared on a normalized basis. Experience from previous decommissioning projects, however, shows that this is not the case. Each project is unique and estimations of waste and material arisings and overall decommissioning costs must be done individually for each decommissioning project. Experience from earlier decommissioning projects are, however, very valuable for estimating waste arisings and costs for specific parts of the work.

2. DATA ON WASTE VOLUMES

Data on decommissioning volumes of materials and radioactive waste can be obtained from different sources, formal and informal:

(a) IAEA Net Enabled Waste Management Database (NEWMDB) [1];
(b) Internal data from the NEA and its Cooperative Programme on the Decommissioning of Nuclear Installations (the CPD Group);
(c) European Community;
(d) National data sets.

2.1. Net Enabled Waste Management Database (NEWMDB)

In this database, the IAEA member countries have reported data on their inventories of decommissioning waste. The following data are from the year 2003. The total volume reported worldwide is about 18 700 000 m^3. Out of this total figure, about 80% has been disposed of without conditioning and 3.6% has been disposed of as conditioned waste. Stored, but not conditioned, waste is about 16.1% of the total volume and only about 0.1% of the total volume is stored as conditioned waste.

Looking at the origin of the reported radioactive decommissioning waste, about 80% is from the United States of America, 10% from Ukraine, 9% from Canada, and all other countries have together about 1% of the total radioactive waste volume. It should though be noted that there are countries with large nuclear programmes that have not reported any decommissioning waste (e.g. the Russian Federation) and the database is therefore not complete and probably does not give the full picture.

2.2. Data from the NEA

During 2001 a questionnaire was sent out to the NEA member countries regarding decommissioning issues. The questionnaire mostly dealt with policy and funding issues but also covered some estimates of radioactive waste volumes from nuclear power plants and the availability of storage and disposal facilities.

From this study it was concluded that the waste volumes shown in Table 1 are expected from different reactor types [2]:

There are also data from the Cooperative Programme on the Decommissioning of Nuclear Installations (the CPD Group) which is a programme containing 41 ongoing decommissioning projects. These data have not yet been compiled in an easily accessible way.

2.3. Data from EC

The European Commission also has data on waste volumes in EU member countries. The data presented in Ref. [3] is based on estimated amounts of materials and radioactive waste from the decommissioning of nuclear power reactors. Looking at different sizes of power reactors, a trend

TABLE 1. VOLUMES OF RADIOACTIVE WASTE FROM DIFFERENT REACTOR TYPES

Reactor type	Mass of radioactive waste (t/1000 MW(e))
PWR	10 000
BWR	10 000
PHWR/CANDU	13 000
WWER	17 000
GCR	100 000

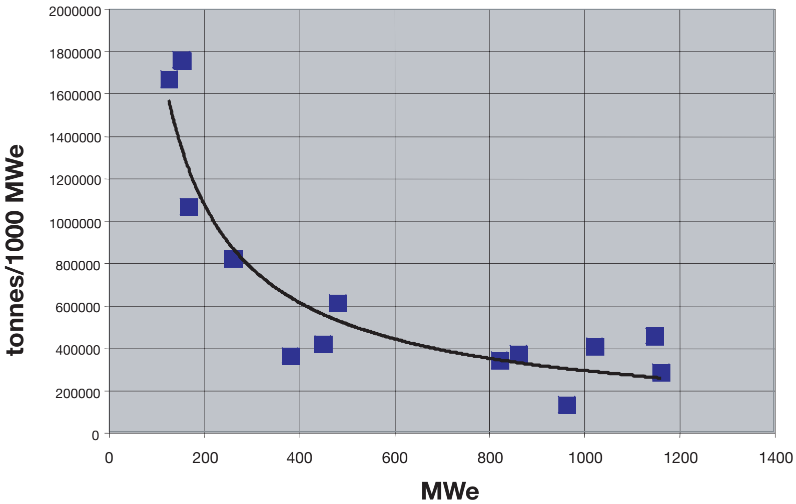

FIG. 1. Predicted normalized amounts of waste and materials versus generating power (from the decommissioning of nuclear power plants).

can be seen in the normalized values of the total amounts of materials and radioactive waste (see Fig.1).

If the same estimation is done but now only for the radioactive waste part the result in Fig. 2 is obtained from the data set.

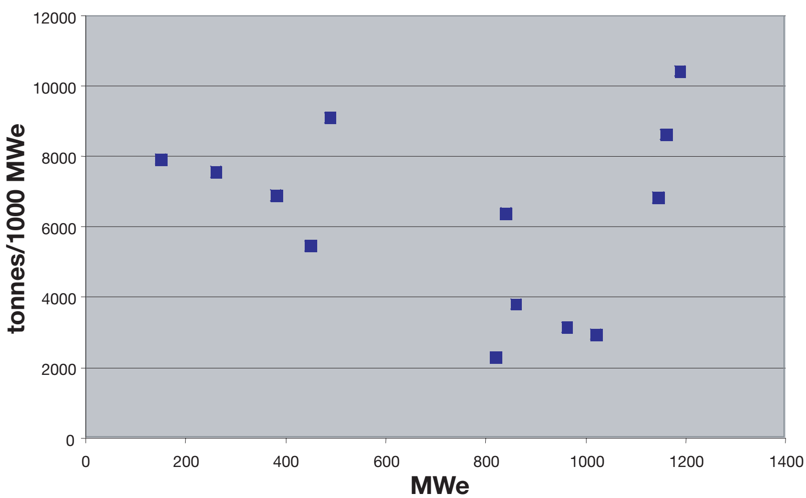

FIG. 2. Predicted normalized amounts of radioactive waste versus generating power (from the decommissioning of BWRs and PWRs).

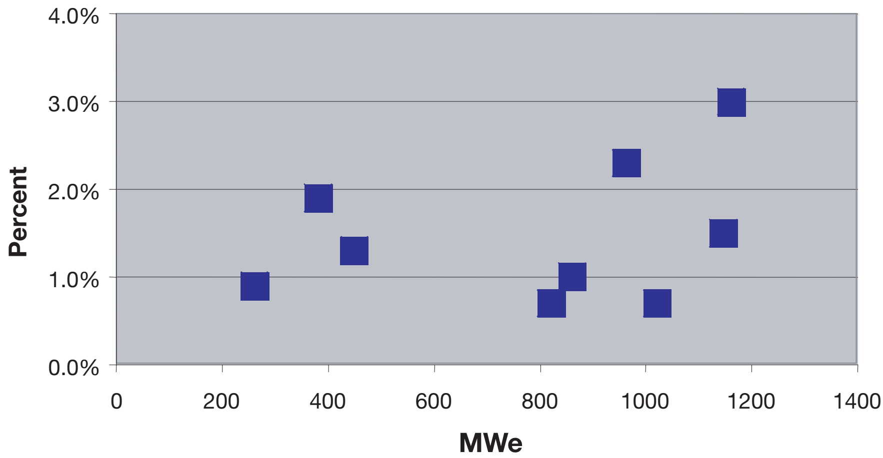

FIG. 3. Fraction of radioactive waste (by mass) in the total waste from decommissioning (for BWRs and PWRs).

Also from these data, the fraction of radioactive waste compared with the total amount of decommissioning materials is shown in Fig. 3.

2.4. National data sets

As an example of national data, the following data sets can be shown.

France (ANDRA November 2004). At the final repository for low and intermediate level waste at Centre de l'Aube about 20 100 m^3 (11.5%) of the total amount of 176 600 m^3 at the site is considered to be decommissioning waste. At the site Centre de Morvilliers intended for very low level waste about 12 400 m^3 (87%) of a current total of 14 300 m^3 is considered to be decommissioning waste.

Spain (ENRESA November 2004). The estimates of residual materials from the decommissioning of the 10 Spanish nuclear power plants are shown in Table 2. The very low level waste (VLLW) and the low and intermediate level waste (LILW) will be disposable in El Cabril but not the intermediate long lived waste (ILW).

Sweden (SKB November 2004). The estimated amounts of radioactive waste and materials (in tonnes) that will be generated when decommissioning the Swedish nuclear power plants are shown in Table 3.

The radioactive material, 90 000 t, will, after treatment and packaging, occupy about 150 000 m^3 in the repository for short lived waste and 9000 m^3 in the repository for long lived waste [4]. If these data are normalized in the same way as the data from EC and NEA/CPD above the results are shown in Fig. 4.

TABLE 2. ESTIMATES OF AMOUNTS OF MATERIALS AND RADIOACTIVE WASTE FROM THE DECOMMISSIONING OF NUCLEAR REACTORS IN SPAIN

	Unit	PWR 160 MW(e)	BWR 500 MW(e)	GCR 500 MW(e)	6 × PWR 1000 MW(e)	BWR 1000 MW(e)	Total
			Radioactive material from decommissioning				
VLLW volume	(m^3)	3511	6226	13 068	6 × 8778	15 422	90 895
LILW volume	(m^3)	1142	2026	5808	6 × 2772	4884	30 492
ILW mass	(t)	35	90	41	6 × 82	120	781
			Conventional (non-radioactive) material from decommissioning				
Concrete	(t)	83 000	146 910	277 000	6 × 502 787	112 000	3 635 630
Scraps	(t)	11 200	19 824	21 000	6 × 63 596	5200	438 800

The Swedish data also indicate that the normalized average amount of radioactive waste from the PWRs is of the order of 65% of the corresponding amount from BWR reactors.

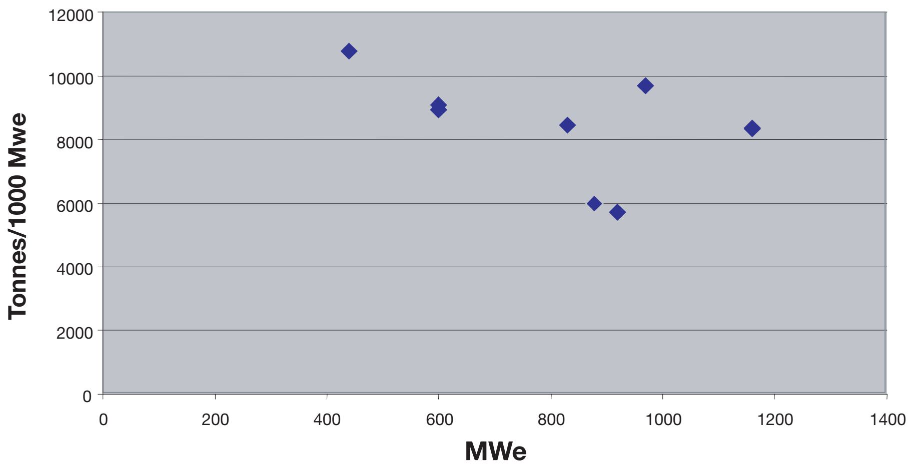

FIG. 4. Predicted normalized amounts of radioactive waste versus generating power from the decommissioning of NPPs in Sweden.

TABLE 3. ESTIMATED AMOUNTS (t) OF RADIOACTIVE WASTE AND OTHER MATERIALS FROM THE DECOMMISSIONING OF THE SWEDISH NUCLEAR POWER PLANTS

Unit	Radioactive material						Non-radioactive material		
	Reactor pressure vessel (including internal parts)	Other radio-active system	Opera-tional waste	Sand	Concrete	Total	Concrete	Other	Total
B1	650	3170	400	250	900	5370	172 350	4960	177 310
B2	650	3170	400	250	990	5460	196 350	4960	201 310
F1	760	5950	400	1050	1230	9390	229 500	7700	237 200
F2	760	5950	400	1050	1230	9390	220 200	7700	227 900
F3	760	6040	400	1050	1440	9690	322 920	7830	330 750
O1	650	2820	400	250	615	4735	135 150	4420	139 570
O2	650	3170	400	250	900	5370	175 500	4960	180 460
O3	760	6040	400	1050	1410	9660	318 570	7830	326 400
R1	650	4700	400	350	915	7015	190 200	5910	196 110
R2	463	3420	400		975	5260	267 300	9260	276 560
R3	466	3420	400		975	5260	198 600	9260	207 860
R4	466	3420	400		975	5260	219 300	9260	228 560
Total (t)*	8450	56 400	5280	6110	13 810	90 050	2 910 530	92 460	3 002 990

* Including 10% supplement.
B=Barsebäck; F=Forsmark; O=Oskarshamn; R=Ringhals.
IR2, R3 and R4 are PWR reactors while the other 9 are BWRs.

Germany (BfS November 2004). Estimates of the expected volume of radioactive waste from decommissioning of all power and prototype reactors in Germany are shown in Table 4.

2.5. Factors affecting materials/waste volumes

There are many factors that can affect the volumes and the relative distribution between conventional materials and radioactive waste from decommis-

TABLE 4. PREDICTED AMOUNTS OF RADIOACTIVE WASTE FROM DECOMMISSIONING NUCLEAR REACTORS IN GERMANY

	Number	Expected disposal volume of radioactive waste per site (m^3)	Total volume (m^3)
PWR	12	5200	62 400
BWR	6	6800	40 800
Already decommissioned	2	860	1720
Safe enclosure	2	4600	9200
In decommissioning process	15	2900	43 500
Total amount			157 620

Note: Immediate decommissioning is assumed except where it is stated 'safe enclosure'.

sioning. The most important factor will probably be the strategy chosen for decommissioning of the nuclear facility. Obviously, owing to radioactive decay, the radioactive waste volumes will be different if the decommissioning is done early after shutdown of operations as compared to the case of deferred decommissioning. The dismantling techniques used and the appropriateness of these in the situation at hand, will also affect the generated waste volumes. Careful planning of the work as a part of the decommissioning strategy will be a key element for the minimizing waste. Characterization and sorting of radioactive waste and materials will also be important factors, as well as, the use of different volume reduction and packaging methods.

The relative distribution between decommissioning materials and radioactive waste will also depend on the clearance levels set by the authorities.

If the buildings and materials can be reused on the site, there might be less material to move to other locations.

The availability of disposal or storage facilities for low level radioactive waste and the cost of using these facilities, compared to costs for decontamination and clearance, will influence the amount of effort invested in measuring and characterizing the decommissioning materials and waste.

There might also be other local factors, for the facility in question, affecting waste volumes.

From the above it can be concluded that each decommissioning project is unique and will be difficult to compare directly to other decommissioning projects. However, for some types of decommissioning work or for the dismantling of certain system parts, experience from earlier projects will be very valuable when making estimations of the waste/material arisings and costs.

2.6. Special waste forms

Some of the radioactive waste can be unique to decommissioning. One example is radioactive oil that is difficult to handle and dispose of in a good way. Another example is radioactive sludge. In earlier constructions asbestos was frequently used, and in cases where this material has become slightly radioactive its handling can be very difficult.

When decommissioning certain types of nuclear facilities there are ‘exotic’ or special types of radioactive waste generated containing toxic or hazardous materials such as sodium, beryllium or lead.

In the graphite moderated reactors there is a special problem with the graphite containing long lived radionuclides, and the graphite itself may constitute a fire hazard.

In some cases, very large components from nuclear power plants (steam generators, reactor tanks, etc.) might be taken out and transported in one piece for storage or disposal. These transports might be subject to problems in achieving public acceptance.

2.7. Public acceptance issues

The rather large volumes of materials and waste generated during a decommissioning project will demand a lot of handling and transport activities. The level of these activities and their impact on the environment must be discussed with all stakeholders involved and especially with those living close to the facility. An environmental impact assessment (EIA) dealing with these issues is normally requested by the authorities. The EIA may serve as a vehicle for public involvement. A key for public acceptance of a decommissioning project will be discussions at an early stage of the decommissioning planning.

An example of different views that might be encountered is that the reuse of materials can be seen as very positive from an economical point of view and for saving of overall resources, but can, on the other hand, constitute a psychological problem. If steel scrap from decommissioning of a nuclear facility is reused in armour steel for constructing industrial buildings, is probably not as sensitive as if the same reused materials were to be used when producing cars.

3. CONCLUSIONS

Data on decommissioning material and radioactive waste volumes are sparse compared to that on waste from the operating phase of nuclear facilities. There are data sets at the NEA, IAEA and EC and also national databases, but they all are limited and gathered for specific purposes.

Analysing the sparse data, one conclusion that can be drawn is that every decommissioning project is unique. Two reactors of the same type and age may produce very different waste volumes. Different regulations and clearance levels in different countries can also result in a different relative distribution between materials and radioactive waste volumes when decommissioning similar nuclear facilities.

The careful characterization before and during decommissioning and the follow-up of waste types and waste volumes are essential steps in keeping volumes and, thereby, cost down. “Plan the work and work the plan!”

Future international cooperation work would help bridge the information gap, would enable abetter understanding of commonalities and differences, and could also favour a higher degree of harmonization of decommissioning practices.

REFERENCES

[1] IAEA, Net Enabled Waste Management Database (NEWMDB), www-newmdb.iaea.org

[2] OECD/NEA, “Decommissioning Nuclear Power Plants. Policies, Strategies and Costs”, 2003

[3] “The Specificity of Decommissioning Waste for Disposal and from Different Facilities”, J. Jones Consultant, UK, W. Hilden and E. Pla Campana, European Commission, Luxembourg.

[4] Paper at the NEA International Workshop on “Safe, Efficient, and Cost-effective Decommissioning”, Rome, September 6-10, 2004.

[5] SKB Report R-04-44 “Teknik och kostnader för rivning av svenska kärn-kraftverk”, Juni 2004.

DISCUSSION

G. BENDA (United States of America): Have you looked at transport and disposal costs together in order to compare the waste volumes from different reactor decommissioning projects? Higher transport and disposal costs tend to create less volume.

T. ENG (OECD/NEA): That is an interesting question. However, the specific data that would be needed are not available at the moment. The collection of such data might be useful with a view to future decommissioning projects and should be considered during the future build-up of databases.

H. EFRAIMSSON (Sweden): It is not obvious to me that radioactive decay will have a great influence on radioactive waste volumes. Can you name any studies on this issue?

T. ENG (OECD/NEA): Not off hand. The remark in my presentation to which you are referring simply reflects the obvious fact that, thanks to radioactive decay, some material with short lived radionuclides will become easier to handle with time.

However, the differences in waste volumes depending on whether decommissioning is carried out early or is deferred are probably small. Other arguments — such as the fact that operational personnel are still available to provide information based on their experience — favour early decommissioning. Such arguments are likely to be more important than the waste volume argument for the selection of the time for decommissioning.

BUILDING CONFIDENCE IN DECOMMISSIONING IN FRANCE: A NATIONAL SYSTEM FOR MANAGING THE ASSOCIATED RADIOACTIVE WASTE

J. AVÉROUS, E. CHAPALAIN
Direction générale de la sûreté nucléaire et de la radioprotection,
Fontenay-aux-Roses Cedex, France
Email: jeremie.averous@asn.minefi.gouv.fr

Abstract

The rate of decommissioning in France is accelerating as the first generation of power reactors reach the end of their active lives. Experience has been gathered from past decommissioning activities and some pilot decommissioning operations. This experience has shown that a national system has to be put in place to deal with decommissioning, the associated waste and the cleanup of affected sites. This system must be designed to be coherent, safe, transparent and industrially applicable. To satisfy these requirements, a system founded on successive lines of defence has been developed. The system does not involve the release of sites or waste from regulatory control because it is considered that the criteria associated with such releases are always subject to controversy. This system is based on the following concepts: (1) 'nuclear waste' is waste likely to have been contaminated or activated; it is segregated from 'conventional waste' using a system involving successive lines of defence thereby building a high level of confidence that no nuclear waste will be released without control to conventional waste disposal sites or to recycling facilities; (2) nuclear waste is disposed of in dedicated repositories, or in conventional waste repositories under a special authorization based on a radiological impact study and a public inquiry; (3) an overall safety evaluation of a nuclear site is conducted after decommissioning in order to define possible use restrictions. In all cases, minimum restrictions must be included in future land use plans to ensure the safety of any planned future uses of the ground or buildings. This paper describes the system in some detail.

1. INTRODUCTION

The rate of decommissioning in France is accelerating as the first generation of power reactors reach the end of their active lives. Experience has been gathered from past decommissioning activities and some pilot decommissioning operations. The management of waste produced during the decommissioning of nuclear facilities involves problems linked to radiation protection, but also to the social acceptability of the possible presence of artificial radionuclides in consumer goods if this waste is recycled to conventional industries. To respond to these concerns an original system has been implemented in France.

2. RATIONALE FOR A BETTER SYSTEM OF WASTE MANAGEMENT

2.1. Reliability of measurements in the context of decommissioning waste

Experience has shown that systems relying only on measurements to determine whether materials are contaminated or not are susceptible to failure when applied to large amounts of material and to the kind of objects encountered when decommissioning a nuclear facility. The available measurement systems do not allow a precise measurement to be made of the objects that are generated in decommissioning. This weakness has led in the past to several situations in France where objects have been released from regulatory control with unacceptable surface contamination or mass contamination levels, mainly because the objects were hidden within a bulk volume of less contaminated material. Moreover, the measurement procedures for bulk quantities at the typical levels of activity at which release from control can be considered are very costly, because they are labour intensive.

2.2. Uncertainties in generic radiological impact studies of recycling

In some countries, general clearance levels have been defined that allow the release of slightly contaminated materials from regulatory control. These levels are established by means of studies of the impact of scenarios involving the recycle of these materials, (e.g. metals or concrete materials) and using a basic radiological criterion of 10 μSv/a. However, these studies are generally based on cautious, but average, approaches that involve the definition of dilution factors, for example, for metal scrap. These dilution factors are usually based on evidence from current national industrial practice. Hence, this type of approach is vulnerable to discussion; practices and technologies are subject to change in the future and special uses of these materials can lead, in some cases, to higher levels of exposure of individuals. There have been some cases in France where improper use of low level radioactive materials has received adverse publicity and has led to social rejection. Moreover, in some cases, the industrial processes used for recycle can lead to increased radionuclide concentration in some materials, such as slag, that can lead to disposal or recycling problems.

2.3. Social acceptance

It is not the object of this paper to try to explain the origin of public concerns in relation to radioactivity in consumer goods. In France, the regulator has, nowadays, to take note of the fact that the French consumer is not willing to buy any goods which cannot be certified as being free from added radioactivity, whatever the level of this radioactivity is. Obviously, this is not realistic, as natural radionuclides, and artificial radionuclides from past atmospheric weapon tests can be detected in the environment. However, there is a strong social desire that no added radioactivity should be traceable to decommissioning activities. If a link is established between the radioactivity content of a consumer product and nuclear activities, it always gives rise to a social scandal. As an example, steel manufacturers are not willing to mix scrap coming from conventional industries with scrap coming from the nuclear industry if they are not sure, with a high degree of confidence, that the scrap is free from any artificial radioactivity.

2.4. How to improve the system

A usual practice in the safety field, to improve the overall safety of a system, is to provide several successive and independent lines of defence. Hence, a system was sought in which the line of defence consisting of radioactive measurement would be supplemented by another line of defence. In order for the system to work properly, this additional line of defence has to be entirely independent from any measurement process.

3. DEFINING AND SEGREGATING ‘NUCLEAR’ AND ‘CONVENTIONAL’ WASTES

The preceding remarks have led to the implementation of a new line of defence, called ‘installation zoning’.

3.1. Definitions

The objective is to achieve segregation between ‘nuclear waste’ (waste susceptible to being radioactively contaminated or activated or which has been previously contaminated or activated) and ‘conventional waste’ (waste that is not susceptible to being contaminated or activated). Note that this distinction is made without using any screening level to distinguish between nuclear and conventional waste categories. Since the segregation between nuclear and conventional wastes has to be made without any measurement basis in order to provide a valid additional line of defence, other rationales must be called upon to make this distinction. These are:

(a) By means of an analysis of the use of the materials within the facility, which determines if they can ever become contaminated or activated.
(b) By means of an analysis of the past operating history of the facility, including incidents and accidents, in order to determine whether the materials have served another purpose or could have been contaminated during an incident or an accident. It can be seen that these rationales are strongly linked to the physical position of the object or material in the facility, hence the discrimination between nuclear and conventional waste can be made on a geographical basis.

3.2. Zoning the facilities

It is required that the operators perform a 'zoning' of their facilities to distinguish between 'nuclear waste zones' and 'conventional waste zones'. This zoning must be done only on the basis of a functional analysis and a historical review, taking into account the normal operation of the facility and past incidents. Measurements are only used to check the zoning that has been developed.

There are of course some rules concerning separations between nuclear waste zones and conventional waste zones: these must be physical boundaries and any passageway between these two types of zones must be equipped with appropriate contamination detection instruments for people and objects, in order to prevent the spread of contamination within the facility and to reinforce the functional analysis that has been done. The physical boundaries between zones have to be submitted to a regular check of their functionality.

The zoning of the facility should be the simplest possible; it should be compatible with ventilation design and radiation protection zoning. Transportation movements within the facility should also be taken into account.

Markers are to be put in place so as to enable quick identification of the type of waste zone in each part of the facility. The workers must be properly informed about the system.

It is accepted that the border between nuclear waste zones and conventional waste zones can be within the volume of concrete walls if the operator can demonstrate that radioactive contamination or activation cannot physically exceed a given depth. This assertion must be based on a physical model that has been extensively tested with experimental data. The assumed depth of contamination or activation must be adequately increased as a precaution when defining the applicable depth of removal of the radioactive materials.

3.3. Measurement as an independent, additional line of defence

As a second line of defence, the operator has to define and justify measurement procedures whose goal is primarily to check that conventional waste is not contaminated or activated. Additionally, these measurement procedures can be used to characterize radioactive waste.

The measurement procedures have to be adapted to the radionuclides likely to be present in the facility and to the type of waste produced. The goal is to implement the best possible measurement procedures (i.e. the lowest levels of measurement) according to the best technologies available for the situations and waste forms involved. It is noted that the measurements are being implemented as one line of defence; they generally do not need to be exhaustive and have only to be such as to demonstrate, with a high level of confidence, the absence of artificial radionuclides in conventional waste.

Any waste arising from a nuclear site must be submitted to at least a bulk measurement as a precaution.

In general, a third line of defence is implemented. This consists of the radiation monitors placed at the entrance to conventional waste management facilities in accordance with the general regulations for these facilities. This monitoring is mandatory in France for any waste management facility (repository, incinerator, recycling plant).

3.4. Quality assurance requirements

Implementation of the facility zoning and of the measurement procedures must be done in accordance with general quality assurance principles. In particular, failures of the system must be identified and corrected. Procedures must be defined to respond to the discovery of a problem with the facility zoning. It may be necessary to reconsider the zoning arrangements in response to the identified problem. In the case of materials incorrectly released as conventional waste, it should be possible to trace the waste management facility to which it was sent.

3.5. Lines of defence and flexibility

A system in which two successive lines of defence are defined provides flexibility in reaching a given level of confidence that conventional waste is indeed conventional. The specification of the measurement requirements in a particular situation is, to some extent, dependent on the level of confidence that can be attached to the zoning of the facility.

As an example, it is usually acceptable that waste coming from the site restaurant is only submitted to a bulk radiological measurement with not too low a detection level. On the other hand, for objects or zones for which there is little confidence in the knowledge of past history, much stricter and complete measurement procedures have to be implemented in order to attain the same overall level of confidence.

Overall, the line of defence system allows more flexibility than a system based only on measurement.

4. THE NEED TO DEFINE A COMPREHENSIVE SYSTEM OF WASTE MANAGEMENT

4.1. A national waste management scheme

When implementing a policy of nuclear waste and conventional waste segregation without clearance, it is necessary to make advance arrangements for disposal or recycle. Because of the need to obtain sufficient volumes to make waste disposal facilities economically viable (a waste amount on the order of 1×10^6 m^3 is generally quoted as being needed to achieve economical sustainability for a near surface disposal facility), it is necessary that they are shared by several nuclear facility operators. Hence, it is necessary to promote a national waste management scheme that takes into account the waste types that have been and will be generated, the annual arisings, the sites of production. Such information is needed to determine the number and capacity of the waste disposal facilities in order to optimize available resources.

4.2. Case by case authorization of radioactive waste disposal in conventional facilities

Nuclear waste, i.e. waste susceptible to be contaminated or activated, can be treated or disposed of in conventional facilities, especially waste with very low level activity concentrations. It is required that, in this case, a special authorization be granted to a conventional waste disposal or treatment facility on the basis of an impact study by the facility operator, taking into account the possible radiological hazard, and after a public inquiry. In France, at the moment, two conventional facilities are thus authorized, one to treat slightly contaminated asbestos waste by vitrification (disposal will be carried out in a dedicated nuclear waste repository), the other to recycle U_3O_8 steel containers. Recycling of nuclear waste is only permitted within the nuclear industry.

4.3. Dedicated facilities for the disposal of very low level nuclear waste

In order to eliminate the large amounts of very low level nuclear waste (VLLW) that cannot be disposed of in conventional facilities, a dedicated facility has been built. This centralized facility has been designed on the basis of conventional hazardous waste repositories, since for VLLW, the chemical hazard can be shown to be as much of a concern as the radiological hazard. This repository should be able to accept of most of the VLLW generated by decommissioning activities in the next decades. Its design volume is 650 000 m^3 (1×10^6 t) and the waste disposal cost is about €250/t, not including pretreatment (i.e. the same order of magnitude as for conventional hazardous waste). However, some operators are considering creating repositories on, or near, nuclear sites where the large volumes of waste generated make it uneconomical to transport the waste to the central VLLW repository.

From the regulator's standpoint, this centralized VLLW repository should not preclude the development by operators of other recycling and disposal pathways in conventional facilities.

4.4. Waste minimization

The first basic way of not generating nuclear waste is to prevent waste from becoming contaminated. This is especially important for some special objects for which treatment and disposal poses technological problems leading to the need for specialized, dedicated facilities, of which only a few exist in France. A good example is the case of phosphorescent lighting tubes. This has led some operators to implement special procedures involving wrapping the tubes in a plastic coating to prevent any contamination, and thus allowing these tubes to be disposed of in conventional facilities.

4.5. Economic aspects

The national system of radioactive waste management is now being implemented in France, and feedback is available. It is believed that if operators succeed in bringing nuclear waste amounts to a minimum through optimization, very low level waste disposal should not be very much more expensive than conventional hazardous waste disposal.

In fact, nuclear waste volumes can be kept down by careful delineation of zones, clean operation of plants, and optimized application of zoning procedures. Recent experience shows that when decommissioning concrete walls, only about 10% to 15% of the concrete volume is to be considered as nuclear waste, while the rest can be considered as conventional waste. New optimized design concepts should lead, in future facilities, to even lower nuclear waste volumes, due to the use of special paints and other techniques to avoid extensive in-depth contamination.

It should be noted that the economical sustainability of the approach for very low level waste developed in France is mainly due to the magnitude of the nuclear programme and the social acceptability of surface disposal that permitted the building of a dedicated VLLW disposal facility. This would probably not be the case for countries with very small nuclear programmes, or with a social or political acceptance problems. In these cases, clearance, while involving very expensive measurement procedures, could still be a valid option and would lead to the same level of public and environment protection.

5. MANAGING CONDITIONAL SITE RELEASE

5.1. Precautionary use restrictions on former industrial sites

Recent experience in the nuclear industry, as well as in the conventional industry, has shown the need to keep track of past uses of land and to define the minimum future use restrictions for sites when they have been occupied by facilities in which hazardous materials have been used. This conclusion is based on technical considerations (how far can it be proven that a piece of land has been absolutely cleaned of all hazardous contaminants) as well as on social considerations (cases where observation of a population cluster of with some sickness is automatically linked to past uses of the land, even if the link between this sickness and potential contamination cannot be proven).

Minimum precautionary use restrictions should include minimum measurement requirements when performing any civil works (in particular digging and earthworks), and the prohibition of erecting buildings involving potentially more sensitive persons, such as schools.

5.2. Local waste repositories

Some operators envisage creating local repositories on the sites of their facilities for waste, such as conventional concrete, or other, more hazardous, waste. These repositories have to be dealt with in the same way as any other repository of the same kind, including requirements for post-closure surveillance and land use restrictions.

5.3. Other use restrictions

It is possible that some low levels of chemical or radiological contamination remain at sites after decommissioning. It may often be shown that further treatment would be costly and would not bring any significant radiological improvement. Moreover, the operator will often not leave the site completely free of buildings. He may wish to proceed with some non-nuclear activities or activities that do not necessitate a nuclear facility licence. It is hence necessary that the operator conducts a safety assessment of the site before licence termination is considered, so that all these factors can be taken into consideration.

In these cases, it is necessary to prescribe surveillance schemes and use restrictions in order to preclude future unwanted practices on the site. The operator's responsibility has also to be explicitly defined concerning the removal of remaining structures and buildings if they may have been contaminated or activated.

6. CONCLUSION

This paper has shown how and why a specific system has been put into effect in France to ensure a safe and transparent waste disposal system for waste generated by nuclear facilities. It has been shown that, without having a clearance policy, it is possible to implement an industrially practicable system of waste management. The fact that the system does not rely only on measurement allows it to be more suitable for the operational necessities of industrial decommissioning projects. The issue of the site use restrictions to be imposed on a decommissioned site is quite new and is not yet fully implemented in French regulations; however, the main directions of future regulation are shown in this paper.

A national waste management scheme is necessary in order to optimize the use of the operator's and the nation's resources by building large enough waste disposal facilities to allow for economically sound investments.

The concept of successive, independent lines of defence, so widely used in nuclear safety, has been successfully used in the area of radiation protection and radioactive waste management to achieve a high level of confidence in the goal to be reached.

The system described here implies some difficulties; not the least is that it is not implemented by all neighbouring countries, which often have defined clearance levels. This should lead, in the future, to appropriate discussions at an international level in order to define common requirements in this field, but experience shows that it is a difficult subject.

DISCUSSION

S. WISBY: (United Kingdom): How do you intend to achieve 'information permanence'?

J. AVÉROUS (France): By transmitting information to as many stakeholders as possible and, in order to avoid — as far as possible — legal liabilities on the State, by placing information in land registry files so that it becomes available to any prospective purchasers of a piece of land, who thereby learn about past activities on that piece of land and cannot later complain that they were not aware of those activities at the time of purchase.

P. CARBONERAS (Spain): In your presentation you spoke about zoning as part of your strategy for dealing with the waste from decommissioning activities and about the need to carry out measurements on waste from non-contaminated areas in order to have reassurance as regards the absence of radioactive content. Could you elaborate on those points?

J. AVÉROUS (France): The principal purpose of the zoning methodology is to achieve sufficient confidence regarding the segregation of nuclear and conventional waste. This is achieved through the addition of several lines of defence, one of them involving measurements.

It is up to the licensee to propose the measurement methodology, the measurement techniques, the detection levels, the sampling methods and so on, within the framework of an overall methodology involving the other lines of defence.

The safety authority will assess the appropriateness and effectiveness of the methodology on a case-by-case basis. Thus, there are no general requirements as regards the performance of measurements and the measurement techniques. It is up to the licensee to make case-by-case proposals. In most cases, thanks to the existence of other lines of defence, the measurement requirements are much less stringent than if the demonstration of compliance with clearance levels was being sought.

K.-L. SJÖBLOM (Finland): The French policy for very low level waste disposal calls for a 30 year period of institutional control, whereas the Spanish policy calls for a 60 year period. What is the reason for the difference?

J. AVÉROUS (France): Most very low level waste contains long lived radionuclides, and an increase in the duration of surveillance would not be relevant from a radioactivity decrease point of view. In France, the only country for which I can speak, the 30 years for the post-closure surveillance phase were chosen as being consistent with the regulations for disposal sites for hazardous waste (the half-life of which is infinite).

MANAGEMENT OF LOW LEVEL RADIOACTIVE WASTE ARISING FROM THE OPERATION AND DECOMMISSIONING OF THE NUCLEAR FUEL PRODUCTION FACILITIES AT NECSA — A SOUTH AFRICAN EXPERIENCE

P.J. BREDELL
NECSA,
Pretoria, South Africa
Email: pbredell@necsa.co.za

Abstract

The paper focuses on the decommissioning of the Nuclear Energy Corporation of South Africa's (NECSA) redundant nuclear fuel production facilities and on the the waste management and site remediation activities at Pelindaba, near Pretoria. These facilities include the uranium conversion plant (U plant), the pilot enrichment plant (Y plant), semi-commercial plant (Z plant), fuel fabrication plant (Beva) and ancillary facilities. The Y plant was used to produce highly enriched uranium for strategic purposes, whereas the Z plant was used for commercial application and licensed for a maximum enrichment level of 5% ^{235}U. The management of the materials arising from the decommissioning activities is discussed, including the decontamination and recycling of useful scrap metals as well as the subsequent management of the radioactive waste, culminating in final disposal. The overall nuclear liability management programme is discussed against the background of South Africa's draft Policy and Strategy on Radioactive Waste Management. It aims to coordinate the various radioactive waste management activities within the country as well as to provide the necessary guidance regarding the development of a national radioactive waste management system.

1. INTRODUCTION

The overall nuclear liabilities management programme of the Nuclear Energy Corporation of South Africa (NECSA) can be subdivided in three phases: Phase 1 was the partial decommissioning of the pilot enrichment facility (Y plant) and the semicommercial plant (Z plant) facilities, including the decontamination and the management of the radioactive waste arising from these activities. This phase was completed during the period 1995–1998. Phase 2, which is currently in progress, involves the decommissioning and decontamination (D&D) of the rest of the redundant nuclear fuel production facilities as well as the management of historical and decommissioning related wastes at

Pelindaba. As part of this phase, currently operating facilities on this site will also be decommissioned in the medium term. Phase 3, which is envisaged in the longer term, encompasses the conditioning and transfer of all radioactive waste from Pelindaba to suitable disposal end points. One of the disposal options involves the radioactive waste disposal facility at Vaalputs in the arid Northern Cape region of South Africa, situated 500 km north of Cape Town. This facility is presently licensed for the disposal of low and intermediate level radioactive waste and has been accepting operational waste from the Koeberg nuclear power plant (KNPP) near Cape Town since 1986.

2. HISTORICAL BACKGROUND

The South African Nuclear Fuel Programme commenced in 1948 with the focus on uranium exploration. During the 1960s, South Africa built the Safari Research Reactor and embarked on a nuclear enrichment programme utilizing a novel isotope separation concept that led to the establishment of the pilot enrichment facility (Y plant). This facility, commissioned in 1976, produced highly enriched uranium for strategic purposes and continued operating until 1990, when it was finally shut down.

The electricity utility, ESKOM, started a nuclear power programme in the mid-1970s which culminated in the construction of two 960 MW PWR units of French design at Koeberg near Cape Town. The KNPP was commissioned in 1986. Owing to the difficulties experienced by ESKOM in obtaining nuclear fuel services from abroad, the emphasis within the South African nuclear power industry shifted toward self-sufficiency. The impetus for self-sufficiency resulted largely from the US embargo on enrichment supplies to South Africa introduced in 1976. This embargo adversely affected KNPP and Safari Research Reactor fuel supplies. In response to these international political developments, several nuclear fuel processing plants were constructed at Pelindaba near Pretoria. The first facility in the series of nuclear fuel processing plants was the uranium conversion plant (U plant) commissioned in the mid-1980s. This plant, having a nominal capacity of 1500 tU/a, generated feedstock for the Z enrichment plant. The latter facility was constructed during the 1980's and came into production in 1987. The Z plant had a separative work capacity of nearly 300 tSW/a, and continued operating until 1995 when it was finally shut down. A small percentage of the U plant and Z plant surplus production was exported.

During the early 1990s a complete reassessment of the viability of the South African nuclear fuel programme was necessary. Several factors played a role in determining the future course of this programme: firstly, unfavourable economies of scale resulting from the under utilization of the nuclear fuel production capacity; secondly, ESKOM's nuclear fuel procurement diversification programme led to increased overseas nuclear fuel supplies and thirdly, the energy inefficiency of the Z plant rendering it internationally uncompetitive and finally forced the closure of the entire South African nuclear fuel programme. Consequently, a new organization, NECSA, embracing these realities within a democratic South Africa was established within the terms of the Nuclear Energy Act 1999.

3. DECOMMISSIONING PROGRAMME: PHASE 1

The South African Government agreed to make funds available for the decommissioning of the Y and Z enrichment plants. The original plan [1] covered the decommissioning of the entire Y and Z plants and extended over a period of 8 years, but government funds were allocated for only 4 years, resulting in the partial completion of the original task. Finally, an amount of approximately US $16 million (1997 values) was allocated for this purpose.

Decommissioning is carried out in three stages: Stage 1 involves plant shutdown, including the removal of the process inventory, Stage 2 is the dismantling, removal and decontamination of all process equipment followed by the superficial cleaning of the process buildings, and Stage 3 is the complete decontamination of the buildings, allowing them to be released from regulatory control. During Phase 1 of the nuclear liabilities management programme, facilities were decommissioned to the level of Stage 2 only.

The guiding principles in the planning of the decommissioning activities were (1) the unrestricted release from regulatory control of as much of the equipment and materials as possible, (2) the reduction of residual contamination levels in the buildings to acceptable levels, (3) the minimization of waste generated during the decommissioning process and (4) the optimization of the decommissioning methods to achieve the above goals in the most cost effective way. It was recognized, at the outset of the project, that there were many uncertainties regarding the process which would affect the programme schedule. Fortunately, the prompt decommissioning of the Y and Z enrichment plants after closure ensured that the services and facilities necessary for decommissioning were still available. Likewise, skilled personnel familiar with the plants were also available to assist in identifying and managing problem areas.

The Y plant consisted of three virtually identical buildings, each of which had three vertical levels, namely, a service basement, a process floor and a heat exchanger floor. The construction material used in the Y process plant was mostly aluminium, selected to combat corrosion, UF_6 degradation and hydrogen ignition. The process gas comprised a mixture of UF_6 and hydrogen, the latter serving as a carrier gas. The following provides some idea of the types and quantities of equipment involved in the decommissioning of the Y plant: 396 compressors and electric motors, 18 176 valves, 714 damping vessels, 71 330 m of heat exchanger coil tube and 14 large vessels ranging in size from 15 m^3 to 60 m^3.

The Z plant was housed in a single process building measuring 260 m × 70 m floor area and consisted of an oil basement, a cable basement, a process floor, a pipe bridge and a control corridor. The oil basement was below ground level and contained the cooling water and lubricating oil systems. There were 112 cooling water pumps and 56 plate heat exchangers, 15 oil systems, each of which consisted of a 50 m^3 storage tank, two vertical multistage oil pumps, two heat exchangers and two oil filters, including three oil storage tanks for new and used oil. The 1000 m^3 oil inventory had been contaminated. The cable basement housed all the electrical cables having a total length of 200 km.

The process floor housed the 56 enrichment stages, which were installed in two parallel rows. Each enrichment module measured 12 m × 4 m diameter and housed two axial flow compressors, 280 000 gas separating elements, 20 sets of heat exchanger tubes and a complex arrangement of partitioned gas flow channels. The two process motors, having a capacity 2 MW and 5 MW respectively, were mounted on either side of the module. Each separation stage module weighed approximately 130 t when fully assembled and was moved by means of an aerocaster transport system from the process floor to the maintenance area and back.

The pipe bridge was constructed immediately above the two parallel rows of process stages in the main process hall and supported 63 centrifugal compressors, 56 in-line filters, 600 mm and 300 mm diameter parallel header pipes with a total length of 5.6 km, 112 specially designed 300 mm and 600 mm four-way valves, instrumentation transducer racks and an assortment of cold traps. The control corridor above the pipe bridge was 250 m long and 15 m wide with a control panel for each of the 56 enrichment stages. The whole process was controlled from a central control room situated in an adjacent area.

The decontamination facilities utilized during the decommissioning programme were originally erected as chemical cleaning facilities for the construction of the Y and Z plants and later converted to maintenance service facilities. Chemical decontamination methods offer the most cost effective way of decontaminating large volumes of materials, and were consequently extensively used. No nationally approved clearance criteria existed at the time and therefore a general unconditional clearance level for surface contamination applicable to all radionuclides was adopted. This was regarded as overly conservative when applied to materials contaminated only with uranium.

A comprehensive radioactive waste management system was used for the minimization and control of waste generated during decommissioning. This involved the physical, chemical and radiological categorization and temporary storage of the waste resulting from the decommissioning activities.

In 1998, based on the experience gained during the decommissioning programme (Phase 1), NECSA adopted a comprehensive nuclear liabilities management approach [2]. This approach aimed to integrate into a single management system all NECSA's decommissioning, decontamination, waste management and site remediation activities. The NECSA nuclear liabilities management process involved the assessment of the magnitude of the total liabilities based on a long term plan, the establishment an efficient project and operational management system for liability discharge, the definition of a realistic programme for the cleanup of the Pelindaba site (Phase 2) and finally the transfer of the waste to suitable disposal sites (Phase 3).

4. NUCLEAR LIABILITIES MANAGEMENT PROGRAMME: PHASE 2

For the purposes of assessing the nuclear liabilities, it was necessary to make assumptions where uncertainties existed. In the first instance, there was uncertainty about the scope and extent of the nuclear cleanup operations at Pelindaba. Hence it was assumed that the entire Pelindaba site would be cleared of radioactive material. This approach implied that all nuclear facilities on site would be cleaned to the stage where the facilities could be unconditionally released from regulatory control. It was further assumed that decommissioned buildings would be decontaminated to the extent that they could be reused in future for non-nuclear purposes. In the second instance, there was uncertainty about the disposal end points for the wastes. In this regard the assumption was made that Vaalputs would be used for disposing of all low and intermediate level wastes (short and long lived varieties), low grade bulk uranium bearing waste would be moved to a suitable mining site for uranium extraction followed by waste disposal on mine tailings dams, and research reactor spent fuel would be disposed of in a deep geological repository [3]. The latter assumption was later replaced with an assumption based on 100 years surface storage. In the third instance, there was uncertainty about the the level of funding that would be made available by government. Here, it was assumed that current annual funding levels would be maintained in real terms over the liability discharge period. On the basis of the above three categories of assumptions a total nuclear liability magnitude was determined for NECSA [4].

A long term nuclear liability discharge programme (Phase 2) was developed for the Pelindaba site based on the above assumptions. The programme includes all decommissioning waste handling, storage, conditioning, transportation, infrastructural support facilities and site remediation work. It extends over a period of approximately 30 years and is aimed at clearing the entire site of all radioactive waste. A particularly difficult aspect of this programme is the remediation of the Thabana historical waste disposal site at Pelindaba used since 1965 and closed in 1997.

South Africa is presently in the process of developing a national policy and strategy for the management of radioactive waste. A draft document has been published for public comment in 2003 [5]. The policy and strategy aims, inter alia, to create structures for the resolution of waste management issues, the most challenging aspect of which involves the waste disposal end points.

5. NUCLEAR LIABILITIES MANAGEMENT PROGRAMME: PHASE 3

The liability management programme (Phase 3) covers the transfer of waste from Pelindaba to appropriate disposal sites. NECSA based its nuclear liability management programme on certain assumptions, which enabled it to continue with liability discharge activities in a consistent manner. These assumptions, however, need to be re-evaluated in terms of the government's policy and strategy on radioactive waste before the programme can be fully implemented. The policy and strategy in draft form makes provision for the establishment of an executive regulating body to approve the waste generators' plans. The approval process envisaged for these plans is presently uncertain, not only because finalization of the policy and strategy is still lacking, but also because the involvement of the public in the discussions still needs to be mapped out. NECSA has put forward proposals [6] to government in terms of which such an approval process can be conducted in its own case. These proposals are based on the Swedish RISCOM model [7] that proved to be effective as a guide to conduct public communications in the nuclear industry. This model still has to be customized to South African conditions, especially with regard to the domestic polical decision making processes.

In the NECSA proposal, the first step in the approval process is for waste generators to approach the executive body with a comprehensive set of alternative waste disposal end points. The executive body needs to satisfy itself that this set of options is indeed exhaustive, before giving a provisional go-ahead for generators to approach their stakeholders. It is deemed preferable for the executive body to appoint a facilitator to guide the public participation process. The different waste disposal end points need to be presented to interested and affected parties for clarification and comment. It is imperative to point out to these parties that their input would be duly taken into account in the decision making process, but that the final decision regarding the selection of disposal sites would rest with the executive body. After completion of this consultative process the generator, in conjunction with the facilitator, needs to make recommendations to the executive body regarding its waste management plans, including a selection of disposal end points. The executive body's decision in this regard would be final.

6. CONCLUSIONS

Much experience has been gained to date with the decommissioning of the closed nuclear facilities at Pelindaba — notably the two enrichment plants. An integrated nuclear liabilities management system has been developed at NECSA incorporating all aspects of decommissioning, waste management and site remediation. An overall long term liability management plan has been drawn up on the assumption that government funding would continue at current levels. The assessment of NECSA's nuclear liabilities has been completed based on certain assumptions regarding final disposal end points. The project and operations organization — mostly utilizing in-house expertise — has been optimized with regard to the execution of the liability management task. The finalization of the national policy and strategy on radioactive waste is being awaited in order to obtain approval for the waste disposal end points.

REFERENCES

[1] SMITH, S.W., et al., The Omega Project, NECSA Report OM-PLN-0057, Pretoria (1998).

[2] NUCLEAR ENERGY AGENCY (OECD), Future Financial Liabilities of Nuclear Activities, Paris (1996).

[3] DEPARTMENT OF MINERALS AND ENERGY, The Status of Radioactive Waste Management in South Africa, Pretoria (2001).

[4] SMITH, S.W., et al., Nuclear Liabilities Management Plan, NECSA Report, NLM-PLN-04/001, Pretoria (2004).

[5] DEPARTMENT OF MINERALS AND ENERGY, Radioactive Waste Management Policy and Strategy for the Republic of South Africa – Draft for Public Comment, Pretoria (2003).

[6] BREDELL, P.J., A Methodology for obtaining approval for NECSA's Long Term Radioactive Waste Management Plans, NECSA Report, NLM-QPLN-002, Pretoria (2004).

[7] WENE, C.O., et al., A Meaning for Transparency in Decision Processes, Sweden (1999).

PRESENT STATUS AND PLANS FOR DISPOSAL OF DECOMMISSIONING WASTE IN JAPAN

S. KARIGOME
Japan Atomic Power Company,
Tokyo, Japan
Email: satoshi-karigome@japc.co.jp

Abstract

The decommissioning of the first commercial power reactor, Tokai power station of The Japan Atomic Power Company, gas cooled reactor (GCR), was started in December 2001. The project consists of the following phases: (1) first phase (2001–2005): conventional facilities are removed and some preparation works are done; (2) second phase (2006–2010): steam raising units and primary gas duct outside the safestore are dismantled; (3) third phase (2011–2017): all reactor structure and miscellaneous buildings are demolished. The management of radioactive waste, generated from the decommissioning activity is the most important issue in the safety of decommissioning process. All radioactive waste arising from dismantling is treated and finally disposed of. The disposal of reactor internals and the establishment of clearance levels are key issues of decommissioning. In addition, in the case of the GCR, the treatment and disposal of activated graphite inside reactor vessel is also an important issue. The Atomic Energy Commission and the Nuclear Safety Commission have established a disposal policy and a basic regulatory concept for the disposal of this waste. Reactor internals, which are contaminated to relatively high activities, will be disposed of at 50–100 m depth. The regulatory authority, the Nuclear and Industrial Safety Agency, established laws on the upper limit of activity level for this type of disposal facility in 2000. The utilities and Japan Nuclear Fuel Ltd are carrying out basic studies and a site investigation. The establishment of regulations for clearance is now being considered.

1. INTRODUCTION

Tokai-1 nuclear power plant (gas cooled reactor) of the Japan Atomic Power Company (JAPCO) started commercial operation in 1966 as the first commercial nuclear power plant in Japan and ceased its operation in 1998. Spent fuel elements were removed from the reactor core and shipped to the reprocessing plant shortly after the termination of operation; these defuelling activities were completed in June 2001. JAPCO launched Tokai-1 decommissioning in December 2001 after the submission of the notification of the decommissioning plan to the competent authorities. This is the first instance of the decommissioning of a commercial nuclear power plant in Japan. As the whole project is planned to take a long time (17 years in all), the project programme is divided into three phases. The site survey and the basic design of the radioactive waste disposal facilities are currently under way, and work on the construction of the facilities is expected to commence when the third phase of Tokai-1 decommissioning starts.

2. PROJECT SCHEDULE

In accordance with METI's standard decommissioning process, JAPCO's strategy on Tokai-1 decommissioning project is that the Tokai-1 plant will be dismantled continuously through three phases (stages) and, finally, the land will be a greenfield site for future nuclear power generation as shown in Fig. 1. The reactor area, i.e. reactor and biological shield envelope, will be stored in a safe condition for 10 years to reduce radioactivity levels.

Prior to the reactor dismantling, conventional facilities outside the reactor area will be removed for the purpose of securing a transportation route for the reactor dismantling waste, and also to create space for new waste treatment facilities.

The first phase lasts from 2001 to 2005. The first activity was preparation for the reactor safe store; i.e. all primary loop valves connecting to the reactor were closed in December 2001. Then the cartridge cooling pond water was drained subsequent to the removal of underwater equipment such as the spent fuel storage racks in 2002. The turbine generator and associated equipment were removed in 2003. The reactor auxiliary equipment in the reactor service building and the fuel handling building and the fuel charge machines will be removed and decontaminated in 2004 and 2005.

Phase \ JFY	2001–2005	2006–2010	2011–2017
First	Preparation work Remove conventional facilities		
Second		Remove SRUs	
Third	<- - - Safe store of reactor area - - -	- - - ->	Reactor dismantling Building demolition

FIG. 1. Decommissioning project schedule.

The second phase lasts from 2006 to 2010. The steam raising units (SRUs) of the primary gas duct outside the safe store area will be dismantled during this phase.

The third phase lasts from 2011 to 2017. All reactor structures will be dismantled and the reactor building and miscellaneous buildings will be demolished after a radioactive contamination survey. The decommissioning project will be completed when the land is levelled to ground level and all radioactive waste is removed from the site.

3. WASTE TREATMENT AND DISPOSAL

All radioactive waste from the Tokai-1 decommissioning, except spent fuel reprocessing waste, is classified as low level radioactive waste (LLW), and the LLW is further categorized into three classes according available disposal options.

The amount of waste arising from Tokai-1 decommissioning is estimated at 192 000 t in total, and about 10% is estimated to be radioactive waste, as shown in Table 1. Radioactive waste is treated (decontaminated, melted, compacted, etc.) and packaged in containers. Eventually the radioactive waste will be disposed of at appropriate disposal facilities depending upon its radioactive level and characteristics.

TABLE 1. ESTIMATED WASTE AMOUNTS (AFTER DECONTAMINATION) FROM TOKAI-1 DECOMMISSIONING

Classification		First phase (10^3 t)	Second Phase (10^3 t)	Third Phase (10^3 t)	Total (10^3 t)
LLW	Comparatively high radioactive level L1	0	0	1.55	1.6
	Comparatively low radioactive level L2	0.01	0.56	7.84	8.5
	Very low radioactive level L3	0.01	0.06	8.01	8.1
				Subtotal	18.2
Non-radioactive waste (including clearance waste)		11	7	156	174
Total		11	8	173	192

The amount of waste arising in the first and second phases is small and it will be stored in the existing storage facilities on the Tokai site until the commencement of the third phase. The disposal facility is expected to have been constructed before the commencement of the third phase (reactor dismantling); the majority of waste arises in this phase.

Japan Nuclear Fuel Limited (JNFL) has already, in 2001, completed a preliminary site survey for the L1 disposal facility at the Rokkasho site in the Aomori prefecture and is now carrying out a detailed site survey and basic design for the facility. It will be constructed at a depth of 50–100 m with engineered barriers. For the purpose of site survey, a pilot tunnel (about 1 km in length) has been constructed and geological data for use in safety evaluation is being gathered. The facility is for the disposal of L1 waste generated not only from decommissioning but also from nuclear plants in operation. The waste comprises: control rods, channel boxes, spent resins, and waste from JNFL's reprocessing plant.

L2 waste from the operation of nuclear power plants, solidified in 200 L drums, is disposed of in a near surface concrete pit disposal facility at the JNFL Rokkasho site. Investigations are under way on a disposal facility for the waste arising from decommissioning. In this context, consideration is being given to the differences in shape and configuration of the waste packages and the composition of radionuclides.

In the case of the disposal facility for L3 waste, an engineered barrier is not necessary, and the period of restrictions after closure can be terminated within 30–50 years. The Japan Atomic Energy Research Institute (JAERI) constructed and disposed of their JPDR decommissioning L3 waste inside its Tokai site. JAPCO also intends to construct an L3 disposal facility on its Tokai site, and, in 2004, it started to implement a preliminary site survey to determine the ground water level and the local geological characteristics.

As the total volume of GCR waste is much greater than that from LWRs, the volume reduction of the waste to be disposed of is the most important aspect of the project. JAPCO is investigating remote handling methods for putting as many activated graphite blocks as possible into a waste container in order to reduce the number of waste containers. JAPCO has also started a study on incineration of the graphite blocks and on separation of ^{14}C from the off-gas of the incinerator, as an alternative disposal option. The technology of graphite incineration has already been proven to be feasible, and JAPCO is focusing on research and development of a ^{14}C separation system — utilizing the absorption/desorption characteristics of zeolite, based upon the earlier tests conducted by the Nuclear Power Engineering Corporation (NUPEC).

Cleared materials will arise early in 2005 from the Tokai decommissioning. NISA and NSC are now discussing the establishment of a clearance level and the verification scheme for demonstrating compliance with it. At the same time, JAPCO is carrying out preparation work for clearance; such as, investigating measuring devices, materials handling procedures, and so on, to make it possible to bring out the cleared materials from the restricted area soon after the establishment of the associated regulations. The recycling of the cleared material is a very important strategy for saving resources, and unrestricted recycling is the final target. To achieve unrestricted recycling, public acceptance is important, and therefore a step-by-step approach is planned. As the first step, the cleared materials will be used by the electric power industry, to demonstrate the safety of the practice.

4. CONCLUSION

Decommissioning of Tokai-1 nuclear power plant, the first decommissioning of a commercial nuclear power plant in Japan, is currently under way on schedule. It has been announced that JAPCO's Tsuruga-1 (BWR) will be permanently be shut down in 2010. The Tokai-1 decommissioning project plays an important role in demonstrating that the decommissioning of a commercial nuclear power plant can be executed safely and economically, and for establishing the key technologies for future LWR decommissioning in Japan. In addition to that, the project plays a role in accelerating the process towards the establishment of regulatory framework for decommissioning and LLW disposal, and towards the construction of a LLW disposal facility.

MANAGEMENT OF DECOMMISSIONING WASTE FROM FACILITIES OF THE JAPAN NUCLEAR CYCLE DEVELOPMENT INSTITUTE

S. KAWATSUMA, H. SAIKI, K. KUDO, H. RINDO
Japan Nuclear Cycle Development Institute,
Ibaraki, Japan
Email: kawatsuma.shinji@jnc.go.jp

Abstract

The Japan Nuclear Cycle Development Institute (JNC) has developed a decommissioning programme for its own facilities. As part of this programme, decommissioning costs and amounts of waste from the decommissioning have been estimated. In order to keep radiation exposure to employees and the public as low as reasonably achievable, to keep decommissioning costs as low as possible, and to reduce the amount of waste, several technical schemes are being developed. A comprehensive decommissioning engineering system is being developed, which is expected to be based on worldwide decommissioning experience. In relation to the disposal system for radioactive waste, JNC will support government level discussions on the subject. The Radioactive Waste Management and Nuclear Facility Decommissioning Technology Center has surveyed the chosen site in cooperation with JNC, the Japan Atomic Energy Research Insitute and the Japan Radioisotope Association.

1. INTRODUCTION

The Japanese Government has decided that the Japan Nuclear Cycle Development Institute (JNC) and the Japan Atomic Energy Research Institute (JAERI) shall be unified into a new organization as of October 2005; the new organization will be an institute for comprehensive research and development on atomic energy, and will be the largest research and development institute among Japanese governmental organizations.

The mission of this new organization will be basic research on the nuclear fuel cycle, decommissioning and waste disposal, including safety aspects and non-proliferation.

The organization will be responsible for 112 existing facilities and two planned facilities. The existing facilities range from nuclear reactors and nuclear fuel cycle facilities to research laboratories:

(a) Reactors:
  (i) Large reactors, such as power plants;
  (ii) Small reactors, such as research reactors.
(b) Nuclear fuel cycle facilities:
  (i) Uranium plants, such as the uranium enrichment demonstration plant;
  (ii) MOX Plants, such as the MOX fuel fabrication plants;
  (iii) Reprocessing plant.
(c) Laboratories:
  (i) Hot laboratories;
  (ii) Small laboratories.

As a part of the preparation for the unification, JNC has developed a decommissioning programme, which includes estimates of the cost of decommissioning and of the amount of waste from decommissioning the new organization's own facilities together with a management programme for the waste.

2. DECOMMISSIONING OF JNC's FACILITIES

JNC has developed the decommissioning programme for the existing 112 facilities and 2 planned facilities and a management programme for the radioactive waste as a part of the preparation for the unification with JAERI.

The first five year period, from 2005 to 2009, will be a preparation phase for decommissioning large facilities such as the uranium enrichment demonstration plant (DP) and the Fugen prototype of the advanced thermal reactor for which it is planned to initiate decommissioning during the second five year period, 2010–2014. During this first five years period, experience obtained from the decommissioning of small facilities will be collected and analysed.

It is expected that it will take until around 2050 before the new organization can decommission all existing 112 facilities and the 2 planned facilities. Large amounts of waste will be generated by these activities. More than 90% of the waste will be concrete and only a few per cent of the waste will be metal. Figure 1 shows the ratio of concrete waste and metal waste from the decommissioning of JNC's facilities.

Most of the waste is non-radioactive which could be released freely, or very low level radioactive waste which could be cleared and not need to be dealt with as radioactive waste. Figure 2 shows the proportions of non-radioactive waste and radioactive waste from the decommissioning of JNC's facilities.

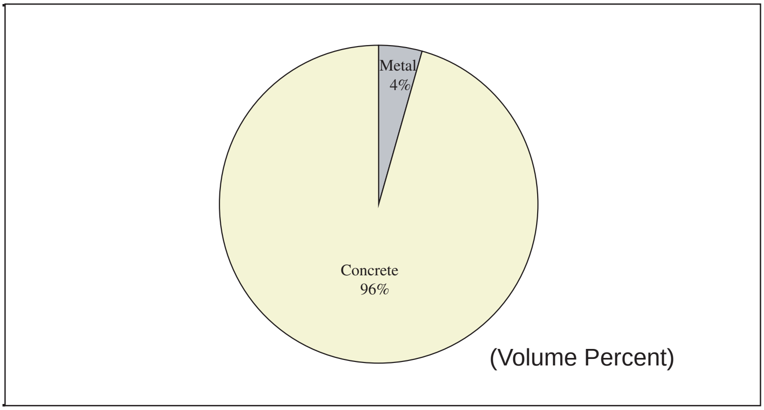

FIG. 1. Decommissioning waste from JNC's facilities.

It is estimated that 140 000 200-L drums of radioactive waste will be generated from the decommissioning of JNC's facilities, not including non-radioactive waste or cleared waste. This waste will be buried as radioactive waste in disposal sites in Japan.

The major sources of waste from decommissioning are reactors such as Fugen, reprocessing related facilities in Tokai, MOX fuel producing plants, and uranium fuel related plants (see Fig. 3).

The cost of decommissioning for JNC's facilities is estimated to be 420 billion yen (almost 4 billion US dollars).

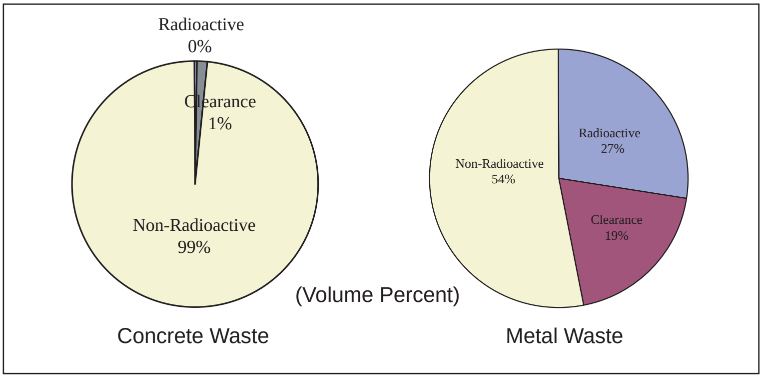

FIG. 2. Non-radioactive waste and radioactive waste from decommissioning.

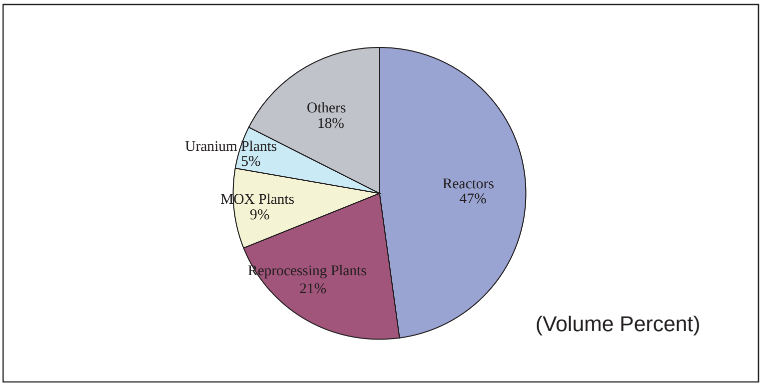

FIG. 3. Major sources of decommissioning waste.

It is important to reduce the decommissioning cost and to reduce the generation of radioactive waste, while keeping radiation exposure to employees as low as reasonably achievable and maintaining general safety.

For this purpose the following plans are being developed:

(a) Comprehensive decommissioning engineering system — this simulates the radiation exposure of employees and the public and estimates the amount of generated waste from decommissioning and the decommissioning cost.

(b) Decontamination method — approaches and techniques to be applied to the processes and equipment before dismantling in order to reduce radiation exposure and radioactive waste generation. For the fuel cycle plants, the development of decontamination techniques should be focused on the chemical form of the contamination and the configuration of the equipment and piping.

(c) Remote dismantling and handling system — this could be applied not only in the high radiation dose area but also to areas which are highly contaminated with plutonium, for example, in the MOX fuel fabrication plant.

(d) Inspection system for the clearance level — this will allow confirmation that the waste from decommissioning does not need to be dealt with as radioactive waste. For the fuel cycle plant, an inspection system for alpha contaminated materials are specially needed.

3. STATUS OF DISPOSAL SYSTEM FOR RADIOACTIVE WASTE

Radioactive waste, which cannot be cleared from regulatory control, will be disposed of in deep geological repositories, in shallow land disposal repositories, in near surface repositories with concrete isolation (concrete pit) or in near surface repositories without isolation (trench), according to the radioactive level of the waste.

Figure 4 shows the disposal concepts and Fig. 5 shows the estimated proportions of the waste in the four repository systems.

The disposal systems for radioactive waste are still under discussion, except for the concrete pit disposal system for low level waste (LLW) which is in operation. Table 1 shows the status of the disposal system in Japan.

JNC will support government level discussions on the radioactive waste disposal system, and will contribute with its experience obtained in managing radioactive waste and with its estimates related to the planned disposal system (Fig. 6).

After the disposal system is approved by the government, JNC will construct the disposal facilities and will begin the disposal.

JNC's basic policy for LLW management is as follows:

(a) To secure safety by complying with regulations and to seek ways of reducing and re-using waste materials;

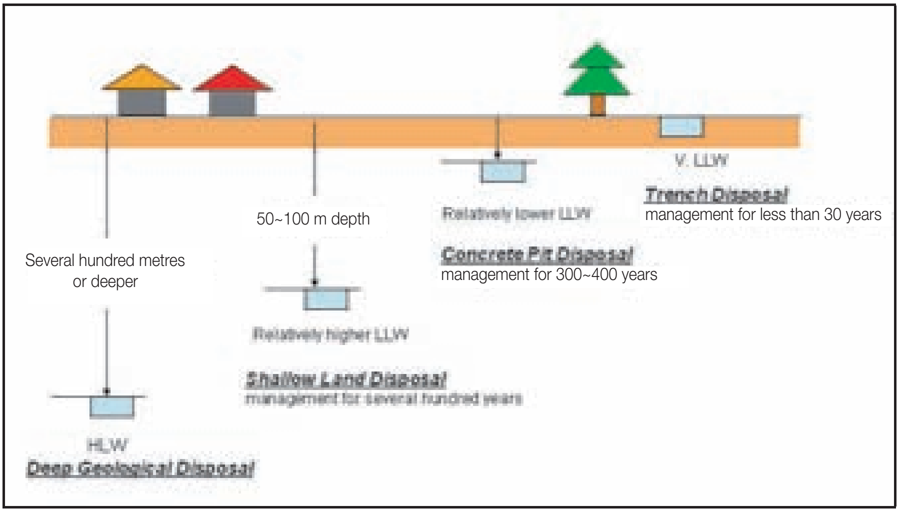

FIG. 4. Disposal concept of radioactive waste.

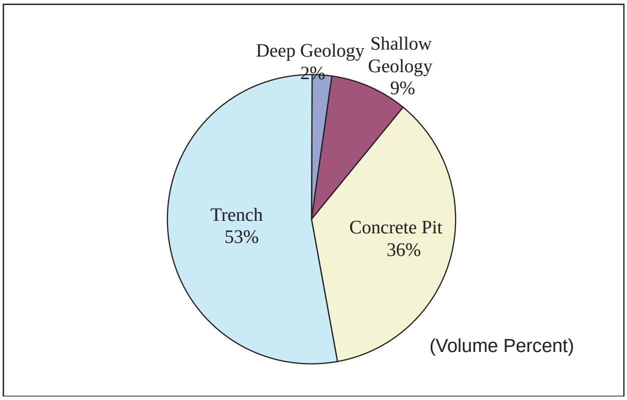

FIG. 5. Estimated proportion of waste in the various repositories.

(b) To rationalize and utilize resources (budgets, manpower and facilities) effectively;
(c) To reduce waste generation by analysing waste generation mechanisms;
(d) To disseminate information on the waste management programme and to develop the confidence of the public; and
(e) To collaborate with the Government and governmental organizations in establishing the disposal system for radioactive waste.

TABLE 1. STATUS OF THE DISPOSAL SYSTEM FOR RADIOACTIVE WASTE IN JAPAN

Origin and Characteristic		Atomic Energy Committee	Nuclear Safety Committee				Legal System
		Basic Policy for disposal	Common Issues important	Policy for Safety Regulation	Limitation	Guideline for Safety Regulation	
Reactors	Relatively Higher	Completed	Completed	Completed	Completed	To be fixed	Partially Completed
	Relatively Lower	Completed		Completed	Completed	Partially Fixed	Not Completed
Fuel Cycle Facilities	TRU Contaminated	Completed		Under Discussion	Discussion in future	To be fixed	To be fixed
	Uranium Contaminated	Completed		Under Discussion	Discussion in future	To be fixed	To be fixed
Laboratories		Completed		Under Discussion	Discussion in future	To be fixed	To be fixed

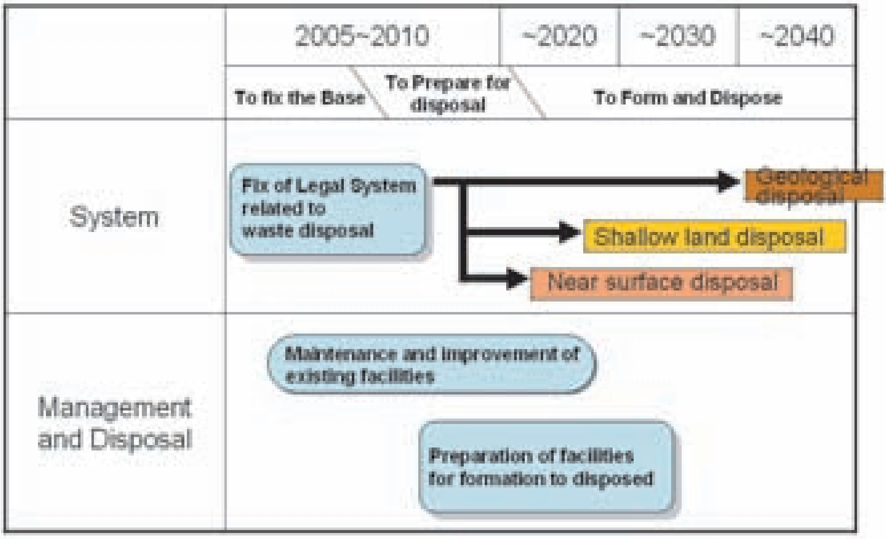

FIG. 6. Procedure to disposal.

4. DISPOSAL SITE FOR LLW

No LLW disposal site is operating in Japan except that of Japan Nuclear Fuel Corporation (JNFL) which has operated since 1992 at Rokkaso-mura, Aomori prefecture.

The Radioactive Waste Management and Nuclear Facility Decommissioning Technology Center (RANDEC) was established in December 2000, in cooperation with JNC, JAERI and Japan Radioisotope Association to carry out site surveys for a new LLW disposal site for waste. The plan for site development is shown in Fig. 7 and an impression of the site fifty years after operations start is shown in Fig. 8.

RANDEC has already been surveying potential sites; the site will require around one million square kilometres.

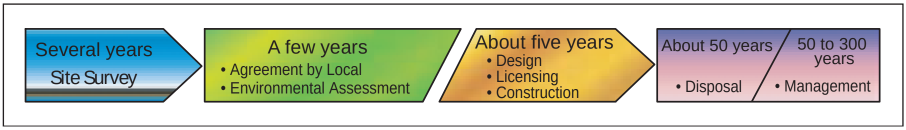

FIG. 7. Plan for the development of the new LLW disposal site.

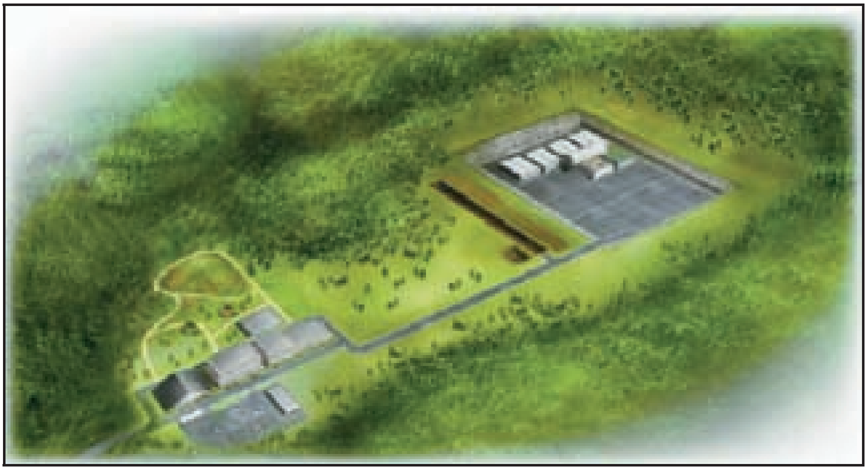

FIG. 8. Impression of the new LLW disposal site, 50 years after operation start.

5. URANIUM CONTAMINATED WASTE FROM DECOMMISSIONING

The amount of uranium contaminated waste from JNC's facilities is not large, however, attention it is being paid to it because it will arise in the near future and because of it's unique features.

Most of the waste arising during the first five year period (2005–2009) and half of the waste during the second period (2010–2014) will be uranium contaminated waste from the former Uranium Enrichment Pilot Plant (PP) and the Uranium Enrichment Demonstration Plant (DP) at Ningyo-Toge, Okayama.

The PP was operated from 1979 to 1990 and the DP was operated from 1988 to 2001. Because uranium exists naturally, the disposal and clearance system cannot be established in the same way as for other waste. The exemption level of 1 Bq/g for natural isotope contaminated waste, as recommended in IAEA RS-G-1.7, can be used as a reference for the clearance level (see Fig. 9).

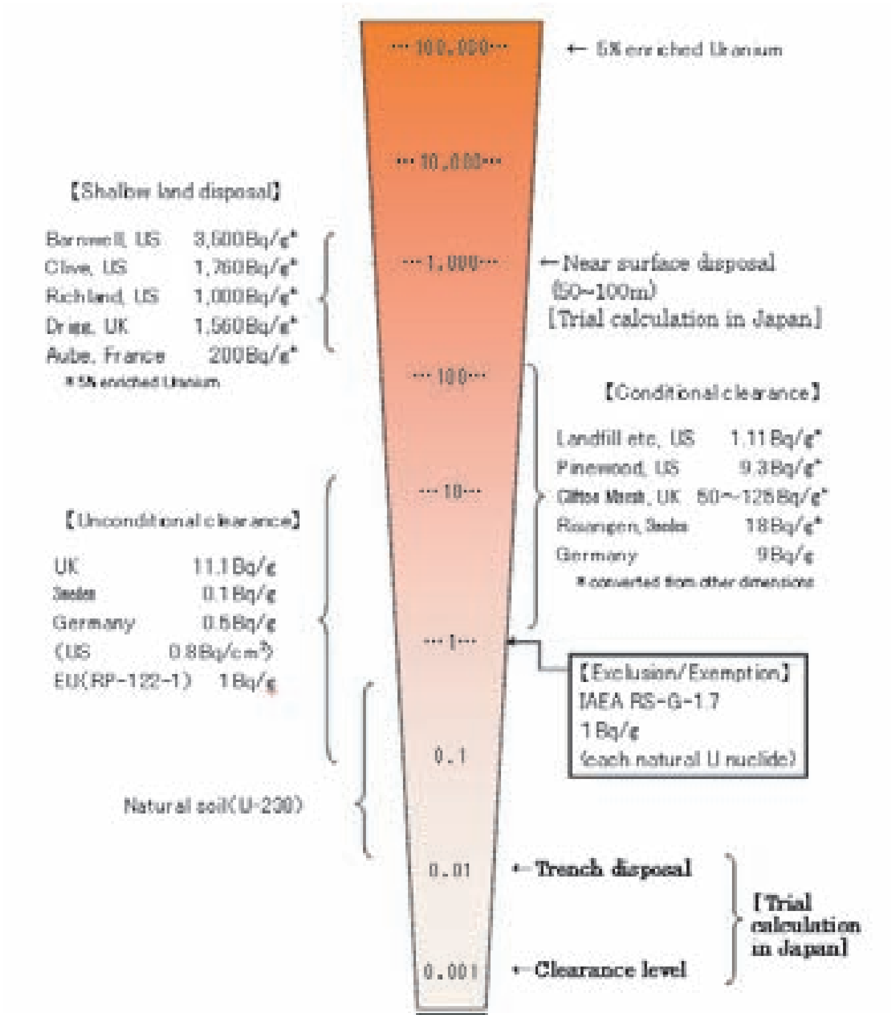

FIG. 9. Rationale for the clearance level.

6. CONCLUSION

JNC has developed a decommissioning programme for its own facilities, and has estimated that it would cost 420 billion yen (almost $4 billion) and that it would generate 140 000 200-L drums of radioactive waste.

In order to keep radiation exposure to employees and the public as low as reasonably achievable, to keep decommissioning cost as low as possible, and to reduce the amount of waste, a comprehensive decommissioning engineering system will be developed.

Most of the decommissioning waste generated during 2005–2009 and half of the waste during 2010–2014, will be from uranium contaminated facilities. Therefore, the disposal system and the clearance system for uranium contaminated waste has to be established as soon as possible.

PRINCIPLES FOR ESTIMATING THE RADIOACTIVE WASTE FROM DECOMMISSIONING AT THE IGNALINA NUCLEAR POWER PLANT

P. POSKAS, R. ZUJUS, J. KOLESNIKOVAS
Lithuanian Energy Institute,
Kaunas, Lithuania
Email: poskas@mail.lei.lt

Abstract

The paper presents the main principles, criteria and methods for the estimation of the amounts of radioactive waste that will be generated during the dismantling of the Ignalina NPP. The improved computer code DECOM made it possible to compile the necessary information, to perform the initial data processing and to separate the waste into different streams on the basis of the external radiation dose rates associated with the waste.

1. INTRODUCTION

There is only one nuclear power plant (NPP) in Lithuania; it is the Ignalina NPP. It consists of two similar units each with a power rating of 1500 MW(e); the actual current power level of each is about 1250 MW(e). The first and second units were commissioned (first grid connection) in December 1983 and in August 1987, respectively. They provide approximately 70–80% of the electricity produced in Lithuania. The original design lifetime was projected to be within the period 2010–2015. However, on 10 October 2002, the Lithuanian Parliament, approved an updated National Energy Strategy in which it is indicated that the first unit will be shut down before the year 2005 and second unit in 2009, if funding for decommissioning is available from the European Union and other donors. On 26 November 2002, the Lithuanian Government approved the 'immediate dismantling' strategy for unit 1.

The decommissioning of a nuclear power plant is a long and complicated process, which requires considerable funds. The preparation for this process lasts for several years and, in the case of the Ignalina NPP, preparations had to be made for the safe dismantling of the power plant, the treatment storage and disposal of operational radioactive waste, the storage of spent nuclear fuel, etc. In order to be able to plan the dismantling activities, it is necessary to have data on the amounts, the activity and the nuclide composition of the radioactive waste which is expected to be generated during the decommissioning.

The waste management strategy at the Ignalina NPP is to implement a waste management policy and to develop radioactive waste management methods based on modern technologies and in accordance with the waste management principles of the IAEA. The waste management routes being considered are: free release, disposal in a licensed landfill, disposal in a near surface repository and disposal in a deep geological repository.

The preliminary decommissioning plan for the Ignalina NPP was established in 1999. Because of the lack of information on the radiological characteristics of the Ignalina NPP installations, the preliminary plan was based mainly on assumptions which drew on international experience of decommissioning NPPs and on engineering judgements. For the preparation of a final decommissioning plan for the Ignalina NPP more specific information is required on the radioactive contamination of the components of the system.

This paper describes the methodology and the preliminary results of the assessment of the contamination in of components of the Ignalina NPP by radionuclides, and the estimation of the waste streams that will be created during the future dismantlement process.

2. ASSESSMENT OF THE RADIOACTIVE CONTAMINATION OF THE TECHNICAL AREAS AT THE IGNALINA NPP

During the operation of NPPs, not only the reactor itself, but also other systems become contaminated, e.g. the main circulation circuit (MCC), the purification and cooling system, the spent nuclear fuel storage pools. Their contamination by radioactive particles is due to the circulation of the cooling agent (in case of the Ignalina NPP it is water). The water itself is contaminated in the reactor area because of activation; additionally the water is contaminated due to corrosion processes in structures and defects in fuel cladding. In the case of forced water circulation, radioactive particles in various systems precipitate on the internal walls of the components of the system.

The contamination is of two general types: loose contamination, capable of being removed by simple mechanical means or fixed contamination, requiring more aggressive removal methods. Contamination generally accumulates on the facility and equipment surfaces and does not (except in concrete) penetrate very deeply.

For the assessment of the radioactive contamination of closed systems, the modified computer code LLWAA–DECOM (of Belgian origin) was used. The code allows the surface activity concentration (Bq/m^2) of the deposits located on the inner surfaces of the system components to be determined taking into account the coolant specific activity (Bq/m^3) and the constructional data of system elements (constructional materials, geometrical measurements, etc.). It also allows the calculation of the contact dose rate on components (or the dose rate at a given distance, for example, in case of the presence of thermal insulation). The predicted dose rates can be compared to the measured values at Ignalina NPP. A good agreement between the predicted and measured equipment dose rates constitutes the basis for the code validation, i.e. the validation of the predicted deposited activities. The other possibility of validation is through the results of the measurement campaign carried out on steel samples removed from the MCC of unit 1during the 2002 maintenance outage.

The deposits activity assessment is based on the following equation for each system element:

$$\frac{dW_i}{dt} = K_d.Cv_i.\left(1 - frspr_i\right) - W_i.\left(K_r + \lambda_i\right)$$

where W_i is the activity concentration of nuclide i deposited on an equipment surface, (Bq/m$^{2)}$;
K_d is the deposition rate (m/s);
Cv_i is the specific activity of nuclide i in the MCC fluid (Bq/m$^{3)}$;
$frspr_i$ is the fraction of the specific activity of nuclide i in soluble form;
K_r is the release rate coefficient, (s^{-1});
λ is the decay rate of radionuclide i (s^{-1});
t is the time (s).

The deposition rate and release rate coefficients are functions of fluid characteristics (velocity, temperature, Reynolds number), the system equipment characteristics (geometry, inner wall roughness, friction factors), and the characteristics of the radioactive particles (specific weight, diameter). The contamination is concentrated in the surface layer. Contamination occurs due to contact with the contaminated coolant. Only the fuel channels (MCC elements) located in the reactor core are contaminated predominantly due to activation. The radiation dose rates due to radionuclides in the reactor water and nuclides deposited on the inner wall of the elements have also been determined. The calculations show that dose rate from the MCC fluid is much smaller than the dose rate from the deposits.

Detailed information about the assessment of the radioactive contamination of the main circulation circuit has been reported [1]. The analysis showed that the deposits mostly consist of ^{55}Fe, ^{59}Fe, ^{60}Co, ^{54}Mn, ^{63}Ni, and ^{58}Co. These nuclides are a consequence of the MCC equipment material activation

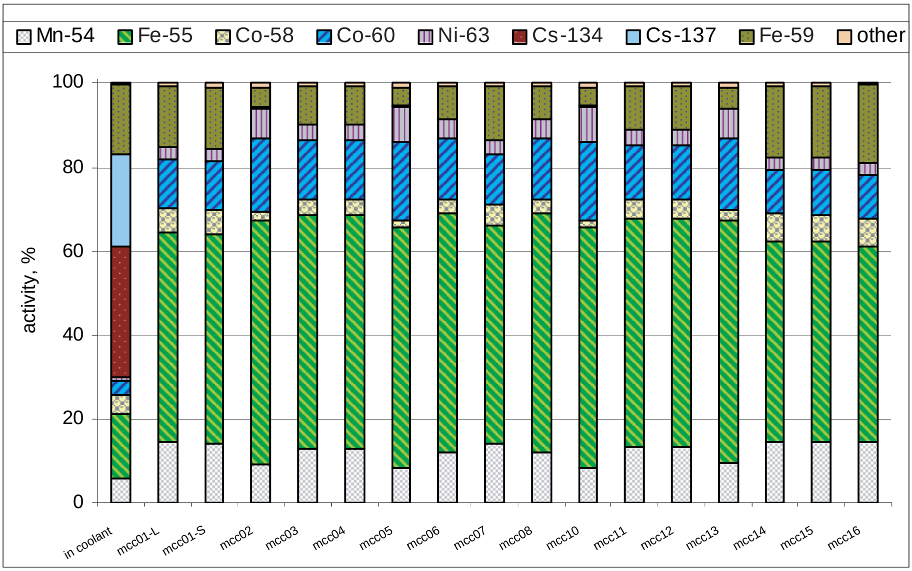

FIG. 1. Radionuclide amounts in the reactor coolant and the deposits on MCC system elements (mcc01-mcc16). "Other" denotes other nuclides present do not exceed 1% of the total contamination [1].

and corrosion processes. As already indicated, the deposition of radioactive particles on to equipment inner-surfaces depends on the coolant characteristics (pH, temperature), which have influence on the corrosion rate, and the operational conditions of the system (MCC purification rate, length of operation cycle). The concentration of radionuclides in the deposits depends on their concentration and solubility in the MCC water (coolant). Nuclide amounts in the RBMK-1500 reactor coolant and in the MCC deposits are shown in Fig. 1.

As can be seen, ^{134}Cs and ^{137}Cs are dominating nuclides in the coolant (31.04% and 22.17% respectively). In contrast, the dominant nuclides in the deposits are ^{55}Fe (46.61–57.18%), ^{60}Co (10.39–18.69%), ^{54}Mn (8.33–14.46%), ^{59}Fe (4.11–18.56%).

The radionuclide distribution in the deposits depends on their concentration and solubility in the coolant. Only the insoluble fraction of the nuclides can deposit on the surfaces. In the case of ^{134}Cs and ^{137}Cs, the nuclide volumetric concentrations in the coolant are similar or even larger than ^{54}Mn concentrations, but, in the deposits, there is larger proportion of the ^{54}Mn nuclide than ^{134}Cs or ^{137}Cs nuclides. This is a result of higher solubility of the Cs. The radionuclide deposition process is complex and depends on the chemistry of the deposit formation.

Analysis of the data on the dose rates associated with MCC contaminated equipment at the time of reactor shutdown showed [1] that the most contaminated components are the separator drum surfaces which were in contact with water, the MCC pumps, the group distribution header, the fuel channels located in the rector core, and the steam water pipes. The contamination level of the MCC equipment changes due to radionuclide decay and, with time, the long ived nuclide ^{63}Ni starts to dominate because of the decay of the short lived nuclides (^{55}Fe, ^{59}Fe, ^{58}Co, ^{60}Co, ^{54}Mn). The contribution of the long lived nuclides to the total contamination increases with time because their activity remains practically unchanged. An exception is ^{241}Am, whose activity increases as a consequence of ^{241}Pu ($T_{1/2}$ = 14.35 y) decay. Nickel-63 decay is not followed by emission, so it does not contribute to the contact dose rate. From the radiological protection standpoint, the important nuclides during dismantling are those that have the largest affect on the external dose rate, for example, ^{60}Co.

A detailed assessment of the radiological characteristics of components was performed for the five most contaminated unit 1 systems of Ignalina NPP, namely:

(1) MCC;
(2) Purification and cooling system;
(3) Spent nuclear fuel pool cooling system;
(4) Low salted water system;
(5) Core equipment cooling circuits.

Taking into account that the operational conditions and the duration of operation of the systems in both units of the power plant are almost the same, it is assumed that corresponding installations for the two units will have the same contamination levels at reactor final shutdown.

The contamination of the majority of the components of other systems is rather low. Owing to the lack of radiological characterization data, the assessment the radiological characteristics of the previously mentioned components has been performed in a conservative manner using the existing radioactive measurement data for operational waste and the estimated contamination of the components located in systems and rooms.

3. GROUPING OF INSTALLATIONS ACCORDING TO EXISTING RADIOLOGICAL DATA

For the assessment and grouping of radioactive waste at Ignalina NPP the internationally developed computer code DECOM was used. The database of

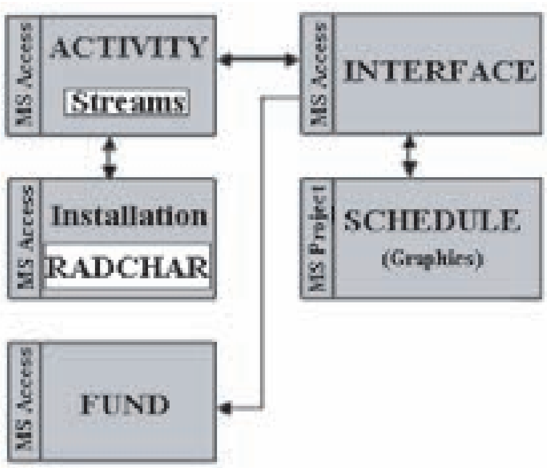

FIG. 2. Modules of the DECOM code.

this code includes the data about 42 000 components (or their groups). Later on, this database was complemented and adjusted using more detailed information about the installation. The computer code DECOM is composed of 5 separate modules (see Fig. 2).

(1) ACTIVITY module — the program for assessment of decommissioning activities and calculation of costs. A new submodule STREAMS was developed for this module;
(2) INSTALLATION module — for recording of the data concerning Ignalina NPP installations. A new submodule RADCHAR was developed for this module;
(3) FUND — the program for the assessment of decommissioning funds and cash flow;
(4) INTERFACE — a data exchange program;
(5) SCHEDULE — a program on the work performance schedule.

As it mentioned above, only the 5 most contaminated Ignalina NPP systems were analysed in detail. For this purpose, the submodule RADCHAR was developed by the Lithuanian Energy Institute; it allows the assessment of the dose rate at the surfaces of different components. The submodule STREAMS was also developed; it links dose rates to contaminated surfaces and separates components into groups according to their dose rates (Table 1):

TABLE 1. GROUPING OF THE COMPONENTS BASED ON THE DOSE RATE CRITERIA

Groups of components	Method of the estimation of the dose rate	Component type
DA	Detailed analysis of systems installations.	Multisurface components (pipes and heat exchangers).
EJM	Engineering judgment of system installations based on maximum dose rates measured during scheduled maintenance and repair works in that system.	Inner surface of the multisurface components of other (not analysed in detail) contaminated systems.
EJS-1	Engineering judgment of installations located in the room, based on the maximum dose rate measurements of the operational waste collected in the room.	Single surface components or outer surface of EJM group of the multisurface components (not analysed in detail), or non-system components.
EJS-2	Engineering judgment of installations located in the room, based on the maximum available contamination assigned to the room category.	

The algorithm for attribution of the dose rate to the component surface is presented in Fig. 3. It should be noted that the most conservative dose rates are attributed to the component that belongs to groups EJM or EJS-2.

The analysis was performed for all rooms located in controlled area of Ignalina NPP. It does not include operational radioactive waste, kept in storage facilities and activated components located in the reactor area (activated metal, graphite, concrete and sand).

4. ALGORITHM FOR THE SEPARATING OF THE SHORT LIVED WASTE INTO STREAMS

A new radiological classification system for solid waste in Lithuania [2] is presented in Table 2.

Thus, in order to assess the need for storage facilities and repositories, the short lived waste has to be assigned to the following waste classes: VLLW, LLW and ILW.

Software was developed to divide the short lived decommissioning waste from the Ignalina NPP into classes based on the algorithm presented in Fig. 4.

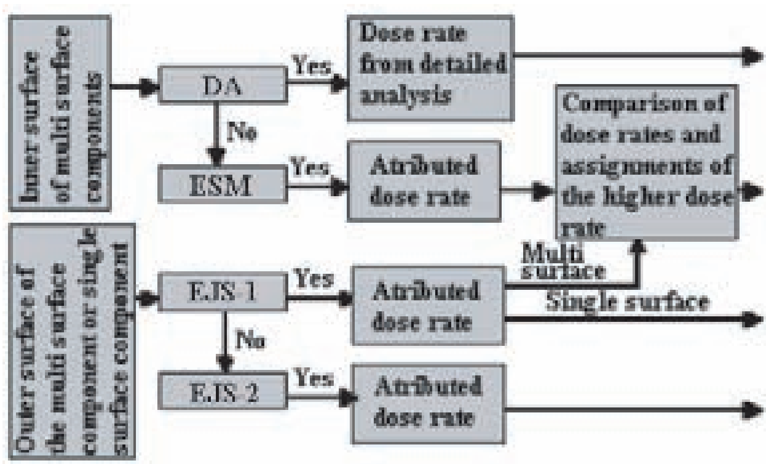

FIG. 3. *Algorithm for the assignment of contamination (dose) for components' surfaces.*

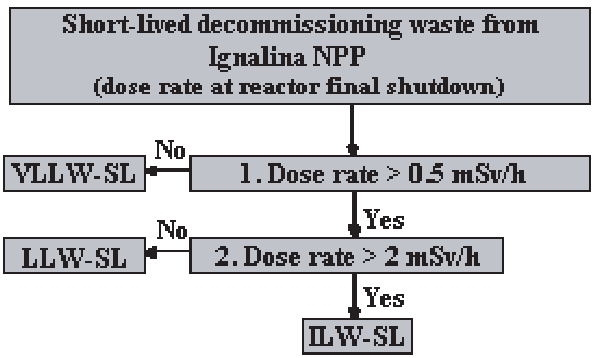

FIG. 4. *Algorithm based on the dose rate to define short lived radioactive waste streams.*

The software analyses the radiological data of each radioactive component and divides them into decommissioning waste streams based on the assessed dose rate level.

5. RADIOACTIVE WASTE STREAMS

5.1. Decommissioning waste streams for the five most contaminated systems of Ignalina NPP analysed in detail

The results show that the main circulation circuit is the only source of the intermediate level waste stream at the time of reactor final shutdown (Table 3

TABLE 2. NEW RADIOLOGICAL CLASSIFICATION SYSTEM OF SOLID RADIOACTIVE WASTE

Waste Group	Definition	Surface dose rate	Conditioning	Disposal method
0	Exempt waste		Not required	
Short lived low and intermediate level waste[a]				
A	Very low level waste (VLLW)	≤0.5 mSv/h	Not required	VLLW repository (landfill facility)
B	Low level waste (LLW–SL)	0.5–2 mSv/h	Required	Near surface repository
C	Intermediate level waste (ILW–SL)	>2 mSv/h	Required	Near surface repository
Long lived low and intermediate level waste[b]				
D	Low level waste (LLW–LL)	≤10 mSv/h	Required	Near surface repository (cavities at intermediate depth)
E	Intermediate level waste (ILW–LL)	>10 mSv/h	Required	Deep geological repository
Spent sealed sources				
F	(SSS)		Required	Near surface or deep geological repository[c]

[a] Containing beta and/or gamma emitting radionuclides with half-lives less than 30 years, including ^{137}Cs, and/or long lived alpha emitting radionuclides with activity concentration less than 4000 Bq/g in individual waste packages on condition that an overall average activity concentration of long lived alpha emitting radionuclides is less than 400 Bq/g per waste package.

[b] Containing beta and/or gamma emitting radionuclides with half-lives more than 30 years, not including ^{137}Cs, and/or long lived alpha emitting radionuclides with activity concentration more than 4000 Bq/g in individual waste packages on condition that an overall average activity concentration of long lived alpha emitting radionuclides exceeds 400 Bq/g per waste package.

[c] Depending on acceptance criteria applied to sealed sources.

TABLE 3. ESTIMATED DECOMMISSIONING WASTE STREAMS FROM FIVE SYSTEMS OF IGNALINA NPP ANALYSED IN DETAIL

No	System in which components were analysed in detail	Waste generated (mass) (%)		
		VLLW–SL	LLW–SL	ILW–SL
1.	MCC	0	14.2	85.8
2.	Purification and cooling system	97.9	2.1	0
3.	Spent nuclear fuel pool cooling system	43.2	56.8	0
4.	Low salted water system	100	0	0
5.	Core equipment cooling circuits	100	0	0
	Total waste stream mass distribution	24	13.4	62.6

TABLE 4. ESTIMATED DECOMMISSIONING WASTE STREAMS FOR IGNALINA NPP AT REACTOR FINAL SHUTDOWN

No	Group of components (see Table 1)	Waste generated (mass) (%)		
		VLLW–SL	LLW–SL	ILW–SL
1.	DA	24	13.4	62.6
2.	EJM	76	10.3	13.7
3.	EJS-1	97.6	2.4	0
4.	EJS-2	91.6	0.3	8.1
5.	Total waste stream mass distribution	79.3	6.0	14.7

and Fig. 5). The spent nuclear fuel pool cooling system will generate only LLW and VLLW.

5.2. Overall decommissioning waste streams for the whole Ignalina NPP

Analysis of Ignalina NPP decommissioning waste streams (Table 3 and Fig. 5) shows that about 80% of the waste will be VLLW that could be disposed of into licensed landfill repositories. It is necessary to bear in mind that the waste was divided into groups according to external radiation dose rate. This must be seen as only a very rough estimation because, usually, waste acceptance criteria for waste repositories are also based on specific activity limitations for some of the most important nuclides (especially ^{137}Cs).

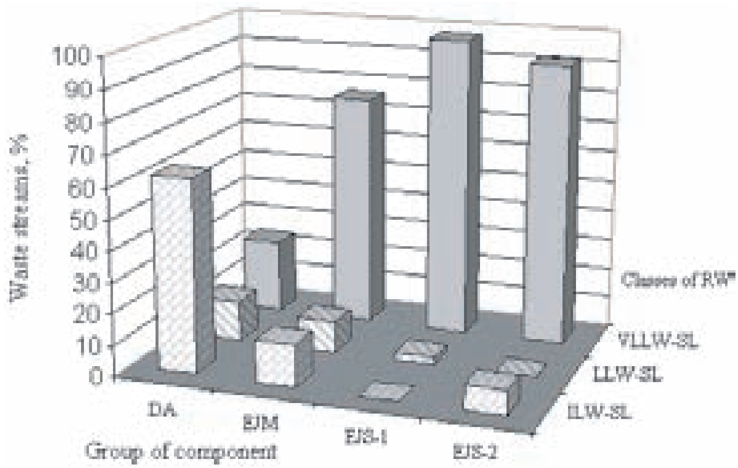

FIG. 5. Overall decommissioning waste streams for the whole Ignalina NPP at reactor final shutdown.

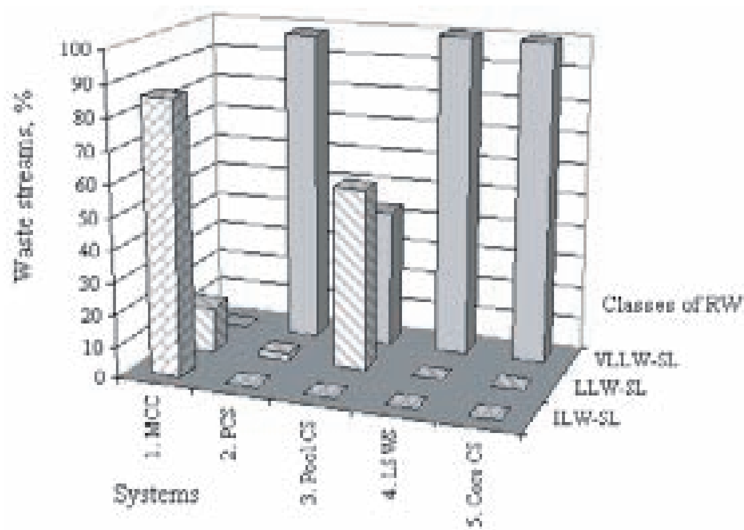

FIG. 6. Decommissioning waste streams at time of reactor final shutdown from the 5 analysed systems.

Therefore, in the future it will be necessary to assess the nuclide activity of waste and to apply the real waste acceptance criteria for the landfill facility.

Table 4 and Fig. 6 indicate that significant amounts of ILW can be expected from group EJM and group EJS-2 components. This is because very conservative assumptions were made for these groups. Therefore, it will be necessary to give more attention in future to the radiological characterization of these components.

6. CONCLUSIONS

(a) Analysis of Ignalina NPP decommissioning waste streams based on dose rate criteria shows that about 80% of the waste will be VLLW that could be disposed of into licensed landfill repositories.
(b) It is necessary to bear in mind that the waste was divided into groups according to external radiation dose rate. This is only a very rough estimate because waste acceptance criteria for repositories also include limitations on specific activity for some of the most important nuclides. In future, therefore, it will be necessary to update this analysis to take this aspect into account.

7. ACKNOWLEDGEMENTS

The present work was supported by the Ministry of Science and Education of Lithuania and by the IAEA (contract No. 12182/RO).

REFERENCES

[1] POSKAS, P., ZUJUS, R., BRAZAUSKAITE, A., Preliminary radiological characterization of the main circulation circuit at Ignalina NPP for decommissioning purposes // Proc. of International Waste Management 2004 Conf., USA, Tucson, Arizona, 2004.
[2] Requirements for radioactive waste treatment at nuclear power plant before their disposal. VD-RA-01-2001. VATESI, order No. 38, July 2001.

PANEL

(Session 3)

RADIOACTIVE WASTE DISPOSAL ROUTES:
A BOTTLENECK FOR DECOMMISSIONING?

Chairperson: **L. Valencia** (Germany)

Members: **H. Efraimsson** (Sweden)
M. Braeckeveldt (Belgium)
D. Janenas (Lithuania)
G. Benda (United States of America)

Statement

H. Efraimsson
Swedish Radiation Protection Authority (SSI),
Stockholm, Sweden
Email: henrik.efraimsson@ssi.se

In Sweden we do not have much experience of large decommissioning projects, but there are quite extensive plans for such projects. They include three different groupings of decommissioning waste: (1) very low level waste, some of it clearable, comprising potentially or slightly contaminated parts of systems and buildings; (2) contaminated parts or substantially contaminated parts of systems and buildings; and (3) components with long lived neutron induced activity, such as core components and internal parts.

For the first grouping, the preferred route is clearance. It is, of course, very important for decommissioning to be able to clear large volumes of waste, but the procedure must be accepted by the public and by a receiver of such waste. If it is not accepted by a receiver of such waste, there may be a bottleneck. So far we have not seen this in Sweden, but there are 'tendencies' — for example, the steel industry has clearly stated that it does not want to accept such waste. So the decommissioner may have to think of something else.

For contaminated parts treated as short lived radioactive waste, there is a near surface repository planned, but this is for the future. Those who are planning the decommissioning of nuclear power plants (NPPs) and other nuclear facilities are pointing out that they cannot start dismantling before this facility is in operation, so this is seen as a bottleneck in some of the decommissioning plans we have. There is, then, the extra cost that will arise in connection with the interim storage of the waste — fairly large amounts of waste — as we saw from Mr. Eng's presentation. Also, it has been argued that currently unforeseen requirements may in the future force the decommissioners to recondition the waste before disposing of it in the planned facility — an extra potential cost for them and an extra potential radiation exposure of personnel.

Sweden has a facility (the SFR facility) for the short lived waste from the operation of nuclear facilities, and the waste which we expect from decommissioning will not really differ from this operational waste. So far, however, the SFR facility is licensed only for operational waste, but this could be said to be more of a formal bottleneck than a technical one.

Regarding the third grouping, this comprises a relatively small amount of waste for which a final disposal facility is already planned, with commissioning scheduled for 2040. It is expected that some of Sweden's NPPs will have been dismantled before that date, but I understand that the absence of this facility is not seen as a bottleneck.

So this is an example of how decommissioning waste will be managed in a specific country.

I would stress that it is important, if you don't have a repository, to have a well-developed concept for a repository sufficiently before the waste arises, in order to facilitate the planning of waste management — a concept that covers, for example, the design of packages. The preliminary reviews of the plans for the long lived waste disposal facility have shown that the concept must be developed further. Although this does not constitute a bottleneck, if decommissioning were to take place today the waste treatment decisions would involve uncertainty about whether the conditioning and packaging were good enough for the future disposal facility.

Statement

M. Braeckeveldt
ONDRAF/NIRAS,
Brussels, Belgium
Email: m.braeckeveldt@nirond.be

I will talk about the situation in Belgium regarding the question put to the panel. Perhaps one could reverse the question and ask "Is decommissioning a bottleneck for radioactive waste disposal routes?" During this symposium, we have heard that in some countries the inventories of decommissioning waste to be disposed of have not been calculated accurately enough or have not been calculated at all. That is why I made that suggestion. What are the options if no disposal facility is available? Generally speaking, the answers are country-specific, depending on the nuclear energy development and the legal arrangements in each country. What are the possibilities regarding radioactive waste management? Also important are the economic aspects, and — last but not least (certainly in Belgium) — the influence of politics.

So what is the present situation in Belgium, a small country with a very high population density? We have had nuclear energy development since the 1950s, starting with several research reactors and research laboratories. We had a reprocessing facility. We have, still in operation, seven NPPs producing approximately 6 GW(e). We still have MOX and uranium fuel fabrication facilities. So we have quite a few nuclear installations still in operation.

As to the legal arrangements, there is a Federal Agency for Nuclear Control, and one of the main things that can influence the management of decommissioning waste is its position regarding, in particular, clearance levels.

Finally, we have my company, which is responsible for all radioactive waste in Belgium. We have waste treatment installations, at present more focused on operational waste. We also have storage facilities, but what we do not yet have in Belgium is a disposal facility — but we are hoping for a decision on that in the near future.

At the moment some 10 000 m^3 of LLW is in storage, and we have estimated that some 70 000 m^3 will be produced in the coming years, until the end of the lifetimes of the NPPs. Of that 70 000 m^3, some 20 000 m^3 will be from operations and the rest from decommissioning. The major part of this amount will be produced after 2015, when the first NPP will be stopped.

I would mention that we have two quite important decommissioning exercises going on — the decommissioning of the BR3 at Mol, a PWR of some 10 MW(e), and the decommissioning of a reprocessing facility. The steam generator and the primary circuit of the BR3 will be decontaminated and recycled, so they will not enter the radioactive waste stream. A common goal of the two decommissioning exercises is to minimize waste generation — through, for example, decontamination and recycling — and thereby reduce the costs of managing the waste.

What about the disposal strategy? For the moment, our disposal strategy is to have a low level waste repository, and the concept we are considering at present takes into account the estimated amounts and, specifically for decommissioning waste, allows for large waste packages. Although we are very confident, the political aspects have yet to be resolved.

So my conclusion is that, at the moment, there is no radioactive waste management reason not to decommission nuclear installations in Belgium. We have a strategy and are hoping for a decision in the near future on a low level waste repository. If the decision is not in favour of this repository, then we shall face the question "What next?" I think that for the moment this is an open question.

Statement

D. Janenas
Radioactive Waste Management Agency (RATA),
Vilnius, Lithuania
Email: dainius_janenas@rata.lt

Of course, before starting to decommission an NPP, it is good to have in place an entire radioactive waste management infrastructure, including repositories for very low level waste and low and intermediate level waste. In Lithuania, all operational waste from the Ignalina NPP is in interim storage facilities at the site. There are no repositories in Lithuania at the moment. Also, it is important to have an organization which is independent of the NPP operator and is responsible purely for radioactive waste management issues, because nuclear electricity generators usually do not care very much about long term problems.

In our case, when, four years ago, we started preparing for the decommissioning of unit 1 of the Ignalina NPP, the operator proposed the construction only of interim storage facilities for the decommissioning waste — both short lived and long lived. The proposal was supported by the foreign consultant, the Decommissioning Project Management Unit (DPMU), established by the European Bank for Reconstruction and Development, maybe because DMPU was more concerned about the most urgent actions, relating to the initial dismantling operations — or because it had a contract for only four years. Fortunately, one year later, in 2001, the Radioactive Waste Management Agency — which I am representing here — was established and, pursuant to the law on the management of radioactive waste, it is primarily responsible for radioactive waste disposal.

From the outset, we started to develop plans for the near surface disposal of low level waste, not only as a safe and reliable option, but mainly for economic reasons. Why should we construct interim storage facilities when, for waste such as LLW, we could go direct to disposal using an approach used all over the world? It was not easy at the beginning to convince the other parties concerned. We asked the nuclear power plant operator and DPMU to make some calculations. The figures were quite impressive. By 2030, when the decommissioning of both units would be completed, up to €50 million could be saved if we constructed a near surface repository immediately rather than including the interim storage facility step. That economic argument worked, and we agreed with all interested parties to move faster with the near surface repository concept and to construct only a small interim storage facility (just for 10 000 m^3 — about one tenth of the total decommissioning waste). The total amount that will be disposed of in the near surface repository is up to 100 000 m^3. Half of it will be conditioned operational waste and conditioned spent resins, and the other half will be decommissioning waste.

At this symposium, I have learned from our Ukrainian colleagues that Ukraine (with a similar RBMK reactor) also has firm plans to construct such a near surface disposal facility. In fact, it is more advanced than we are, having already started construction. I think the IAEA could help countries like ours by creating a database with information on all repositories in operation and under construction. For radioactive waste management people, such information is as important as electricity generation figures and information on the construction of new reactors are for nuclear power plant people.

Statement

G. Benda
Race LLC,
Memphis, Tennessee, United States of America
Email: gbenda@race-services.com

I am going to address two areas — our commercial utility decommissioning programme in the United States of America and our government utility decommissioning programme.

I will give two examples of what we are doing now. First, at the commercial utility Connecticut Yankee we are taking all the waste material and, starting in January 2005, we will be running about 40 trucks full time from Connecticut to Tennessee. Some of the material will be free released as recycled metal in accordance with Nuclear Regulatory Commission (NRC) regulations. Some of it will be conditionally cleared and sent to sanitary landfills. It will meet the 1 mrem/a criterion. Other material, which we consider to be of class A (the next level up), will be sent to a site in Utah, where they have a class A disposal licence, and class B and C material will be sent to Barnwell, South Carolina, where they have a class B and C permit. This repository will remain open for the next several years. The disposal costs will range from about US\$150/m^3 to over US\$50 000/m^3. So my answer to the question put to the panel is that, as far as commercial utilities are concerned, I do not think there is a bottleneck, but there are some 'bottle caps' with certain types of waste, which is creating problems. Part of the greater than class C waste material, such as reactor control blades, is too hot and we may not be able to dispose of it in South Carolina.

With respect to remediation projects, there are three sites in the USA that take NORM material for disposal — in Utah, Idaho and Texas. Also, Texas is trying to license a site for B and C waste in the future, hoping to supplement Barnwell when it shuts down or starts refusing waste. So the commercial side is, I think, in very good shape.

The US Department of Energy (USDOE) has, over a period of several years, been looking at alternatives. Most sites now have their own disposal facilities for decommissioning waste. At Savannah River, Hanford, Oak Ridge and Fernald, material is being buried on-site or there are plans for on-site burial; some of the steel is going to commercial sites.

There are certain USDOE waste streams that, because of their unique nature, I consider a bottleneck; USDOE cannot get rid of the waste without new regulations or changes in the existing ones. Fernald is one site where the

USDOE has a problem; some very concentrated radium waste cannot be shipped anywhere until a suitable site is found. Currently, there is a big push to use the planned Yucca Mountain repository in Nevada, but there is also opposition to it. So the USDOE probably has more problems right now in relation to the waste streams from its decommissioning programme than the commercial side does.

DISCUSSION

RADIOACTIVE WASTE DISPOSAL ROUTES: A BOTTLENECK FOR DECOMMISSIONING?

Session 3

J. LORENZEN (Sweden): I would like to focus on a bottleneck not mentioned here so far, and I refer to the presentation of Mr. Eng, who made a very strange remark about decontaminated scrap metal — namely, "reuse it — yes, but please don't make cars with it!"

At Studsvik, we treat radioactive scrap metal by decontamination, segmentation and melting to produce ingots for free release. We apply the free release levels in EC report RP89, which are nuclide specific, and in addition we request the steel industry to dilute the material in the ingots at a ratio of 10:1. Despite application of the free release levels in EC report RP89 and our request to the steel industry that it dilute the material in the ingots delivered by us, a double line of defence, people are still saying "please don't make cars with it!". Doesn't that confirm the fears of the public and create a bottleneck? It certainly suggests that the experts are not sure whether the material is safe.

G. BENDA (United States of America): In the USA we have the same problem as regards recycling. The DoE has a 'no radioactivity' policy whereby it does not permit the recycling of radioactive metal. The policy is currently being reviewed, and maybe it will change during this Administration.

A question I should like to ask, however, is "What is a bottleneck?". We may not like a slowing down of the decommissioning process, but it is something we can live with. It is when you can't get rid of your radioactive metal at all that you have big problems — especially the problem of the high costs associated with storage.

Right now, we have a slowing down, but not a stoppage.

M. BRAECKEVELDT (Belgium): In my opinion, the issue raised by Mr. Lorenzen it is one of stakeholder confidence. If you have good stakeholder involvement and explain to the stakeholders what the problem is — namely, the use of decontaminated scrap metal in car construction — they will be willing to buy the cars in question.

L. VALENCIA (Germany — Chairperson): The big problem with melting radioactively contaminated metal is that the radioactivity becomes distributed homogeneously throughout its volume and is relatively easily detected by scrap dealers, and also by the car industry. On the other hand, when you release decontaminated metal — for example, steel beams — without melting it, there is not a big problem, as was shown in the case of Spain, where the people in the car industry were not aware that metal delivered to them was from utilities such as the Vandellos nuclear power plant.

J. LORENZEN (Sweden): My point was that, if we comply with all the regulations and then say “please don’t make cars with it!”, we are like a cook who prepares a meal for you but then says “be careful — don’t eat it!”.

M.I.F. PAIVA (Portugal): In Portugal, we have had many cases of scrap metal containing abandoned sealed sources or resulting from the dismantling of industrial facilities such as phosphate plants and therefore contaminated with radium-226 that has not undergone monitoring control as we do not have the necessary infrastructure.

There is also another problem. We have a regulation requiring that all smelting works have radioactivity monitoring portals, but none requiring that the harbours via which scrap metal enters the country have such portals. Maybe we need to be tougher in this matter.

G. BENDA (United States of America): Such problems are not problems associated specifically with nuclear decommissioning but problems of general radioactive waste production. However, I agree that, if a radioactive source finds its way into a smelting works furnace and contaminates it, you have a big problem. We have had to bury a lot of metal from radioactively contaminated furnaces, and the furnaces have had to be decontaminated.

J. LORENZEN (Sweden): We have been treating more than 10 000 t of scrap metal a year over the past 18 years, and I believe that, thanks to our QA system, no type of sealed source could find its way into the material treated by us. Moreover, it is not only sealed sources that we would detect; when material is delivered to us, we secure data on all the different kinds of radioactivity present in it. We monitor the material which arrives and also monitor the material which we deliver to outside companies.

G. BENDA (United States of America): Over the past ten years, in the USA, there have been four or five incidents of which I know where sources have found their way into smelting furnaces, resulting in radioactive contamination. We had to clean out the contaminated material and then send it to a low level waste disposal site.

Usually what happens is that someone puts the source into a lead container or something similar and the source is missed by the detectors. The steel industry is trying to find ways to prevent this from happening.

D. LOUVAT (IAEA): To revert to the question which was put to the panel, because of the decommissioning approach which it has adopted, France has been obliged to create a new disposal facility or new disposal route. Have any other countries or any organizations, after drawing up their decommissioning plans, been obliged to change their disposal plans?

G. BENDA (United States of America): All those who engage in decommissioning consider the various possibilities for disposal as opposed to on-site decontamination. In the USA, they adapt their disposal plans to the availability of disposal sites. Right now, in the USA, the next 3–4 years represent a kind of ‘window’ while the Barnwell disposal site is still open, and many plants are being decommissioned feverishly so that the resulting class B and C material can be delivered to the Barnwell site before it is shut down. Disposal, which accounts for a large part of the total cost of decommissioning, is cheap compared to what it was five years ago, because of competition, but besides disposal costs you have to consider the costs of transportation. In our case, we sometimes ship material several thousand miles by rail or truck. You have to look at the decommissioning process as a whole.

L. VALENCIA (Germany — Chairperson): There are countries where the disposal of radioactive material is relatively cheap because they have disposal sites, and there are countries without disposal sites. In most of the latter countries, the decommissioners are forced to decontaminate, recycle and reuse material as much as they can.

In that connection, I would point out, on the basis of experience with a number of completed decommissioning projects, that, depending on the size of the decommissioned facility, the radioactive decommissioning waste accounts for 2% to 6% (sometimes 8%) of the total decommissioning waste. This is a small percentage, but the radioactive waste has to be packaged and disposed of or stored in an interim storage facility.

M. BEN BELFADHEL (Canada): To what extent is a lack of early decommissioning planning and of financial guarantees contributing to the bottleneck effect?

G. BENDA (United States of America): I don’t think that financial planning issues are causing problems.

M. BRAECKEVELDT (Belgium): In response to Mr. Ben Belfadhel’s question I would add that, in my view, it is very important for a country to have a legal basis for the raising of funds for decommissioning.

L. VALENCIA (Germany — Chairperson): Funding was one of the main topics at a decommissioning workshop held by OECD/NEA in Rome a few weeks ago. It is essential to have funds — otherwise you can't make progress, whether you have a disposal site or not.

D. JANENAS (Lithuania): I would mention that, in the preparations for decommissioning the Ignalina NPP, we found that the estimated decommissioning costs did not differ very much as between, on one hand, immediate dismantling and, on the other, safe enclosure and dismantling after 50–100 years. The difference is less than 10% – maybe because safe enclosure requires maintenance and surveillance.

M. FEDERLINE (United States of America): Reference has been made to the planning of decommissioning, but I haven't heard anyone talk about the necessary expertise. Nuclear trained individuals are becoming scarcer, and I was wondering whether any panel members considered that to be a particular problem.

I was also wondering whether any members of the panel were aware of lessons learned from decommissioning being fed back into new reactor designs so as to make sure that the bottlenecks of today are not bottlenecks tomorrow.

M. BRAECKEVELDT (Belgium): I can respond only to Ms. Federline's comment about expertise, as Belgium is unlikely in the near future to plan the construction of further reactors. In fact, the construction of further reactors in Belgium is forbidden by law at the moment.

Regarding expertise, I think it is a general problem that very few students want to study nuclear engineering. That is having an effect, not only on the planning of decommissioning operations and of the associated radioactive waste management, but also on the safety of operating nuclear power plants.

I hope that at some time in the future we will — at least in Belgium — convince politicians that they can have confidence in nuclear power. That would attract young scientists and engineers into the nuclear sector.

L. VALENCIA (Germany — Chairperson): In France, at the École Polytechnique in Lyon, it is a possible to study decommissioning technologies. Courses are being offered on decommissioning reactors, fuel fabrication facilities and reprocessing plants.

Regarding Ms. Federline's second comment, about what one might call 'decommissioning friendly' reactor designs, it would be interesting to hear what is happening in Finland. First, however, I would mention that in Germany, where we are constructing a vitrification facility, we have plans for its relatively easy decommissioning.

K.-L. SJÖBLOM (Finland): My country's existing NPPs were built in the 1980s, but times have changed. Decommissioning is considered in the plans for the next NPP to be built in Finland and in the preliminary safety assessment review being carried out by STUK (although I don't think enough consideration is being given to decommissioning). For example, at STUK we are discussing what sand to use for the concrete structures. The sand available at the site of the planned NPP, where there is already an NPP in operation, contains quite a lot of activation products.

L. VALENCIA (Germany — Chairperson): That is good to hear.

H. EFRAIMSSON (Sweden): When decommissioning a facility, it is very important to have a good knowledge of the facility's history. Often, that knowledge — which facilitates operations like dismantling in the right order and the sorting of waste – can be obtained only from older people who have worked at the facility all their lives. Their expertise should be recognized and exploited.

G. BENDA (United States of America): I believe that, when we start decommissioning on a large scale, the demand for more people will be met by retirees.

As regards decommissioning friendly reactor designs, when we started building nuclear reactors 30 years ago, waste disposal — at least in the USA — was so cheap that people didn't do much contamination control inside the plants. That caused a lot of our present contamination problems — it is hard to get a plant clean once it is really dirty. Hopefully, when future plants come into operation, starting out clean, the operators will know that the costs of radioactive waste disposal are high and will be aware of the benefits of taking action to minimize the decommissioning problems.

A. DIERCKX (Belgium): Regarding the question of attracting young scientists and engineers into the nuclear sector, I would mention a very positive experience we had recently with stakeholders. In discussions about the acceptance of waste in their community, the local stakeholders at Mol demanded that the nuclear know-how in the region be preserved.

N.B. TORSTENFELT (Sweden): I don't think the situation regarding future expertise is so bad. In Sweden, the nuclear power plants were built for 25 years of operation, and then their operating lifetimes were extended to 40 years. Now, we are considering the possibility of operating them for 60 years. In that connection, we have just had a meeting, in Forsmark, which was attended by the representatives of supplier and consultant companies. At that meeting, where plans for some very large upgrading projects were discussed, the company representatives were told that preference would be given to companies which had already hired or demonstrably intended to hire young people for implement of the projects.

M. BEN BELFADHEL (Canada): As regards the hiring of young people, several years ago the Canadian Nuclear Safety Commission initiated an internship programme under which, every two years, it hires fresh university graduates in engineering and nuclear related disciplines. The graduates undergo two years of training, working for several months at a time in different parts of the organization. At the end of the two years, they are offered permanent positions. The programme is working very well.

H. EFRAIMSSON (Sweden): I would like to make a comment about changing disposal plans in the course of decommissioning planning. As I indicated in my statement, we have planned to put the short lived radioactive waste from decommissioning into a near surface geological repository. However, the idea is now being discussed of establishing, at the NPP sites, shallow land disposal facilities that could take some of that waste — the low level part of it. This would be a more flexible and a cheaper solution and it would involve less transport of waste.

We now have plans that are expected to work, but other solutions might well be called for when decommissioning starts.

LONG LIVED LOW ACTIVITY RADIOACTIVE WASTE/ OTHER MATERIALS

(Session 4)

Chairperson

M.V. FEDERLINE
United States of America

IMPROVING THE REGULATION AND MANAGEMENT OF LOW ACTIVITY RADIOACTIVE WASTE IN THE UNITED STATES OF AMERICA

D.H. LEROY
Leroy Law Offices,
Boise, Idaho

M.T. RYAN
Charleston Southern University,
Kiawah Island, South Carolina

J.R. WILEY
Board on Radioactive Waste Management, US National Academies,
Washington, D.C.
United States of America
Email: jwiley@nas.edu

Abstract

This paper summarizes the first phase of a study in progress by a committee of the US National Academies' Board on Radioactive Waste Management. The Board initiated the study after observing that statutes and regulations administered by the federal and state agencies that control low activity radioactive waste have developed as a patchwork over almost 60 years and usually reflect the enterprise or process that produced the waste rather than the waste's radiological hazard. Inconsistencies in the regulatory patchwork or its application may have led to overly restrictive controls for some low activity waste but the relative neglect of others. In the first phase of this study, the committee reviewed current low activity waste inventories, regulations, and management practices. This led the committee to develop five categories that encompass the spectrum of low activity waste and serve to illustrate gaps and inconsistencies in current regulations and management practices. The committee completed its first phase with four findings that will lead into the final phase of the study, which is underway and planned for completion in autumn 2005.

1. INTRODUCTION

This study was initiated by the US National Academies' Board on Radioactive Waste Management (the Board), which observed that statutes and regulations administered by the federal and state agencies that control low activity waste have developed in an 'ad hoc' manner over almost 60 years since the passage of the Atomic Energy Act of 1946 (McMahon Act). These controls usually reflect the waste's origin — national defence, nuclear power, other industries, research, medicine, or natural sources — rather than its radiological hazard. In some cases, inconsistencies in the regulatory patchwork or its application may have led to overly restrictive regulation, resulting in excessive costs and other burdens on waste generators. In other cases, some waste types may present greater potential risks to the public than are generally recognized. To conduct the study, the Board obtained funding from five sponsors and nominated a study committee of independent, volunteer experts (see Acknowledgements section). This paper is excerpted from the committee's interim report.

The Board intended the term 'low activity waste' to include the spectrum of low activity materials declared as waste. This waste generally contains lower levels of radioactive material and presents less of a hazard to public and environmental health than spent nuclear fuel, high level waste from chemical processing of spent fuel, or transuranic waste — all of which are clearly defined in federal statutes and are tightly regulated. However, low activity waste may contain long lived radionuclides at well above background levels, and may represent a significant chronic (and, in some cases, an acute) hazard to public and environmental health.

2. FEDERAL AND STATE CONTROL OF LOW ACTIVITY WASTE

The main federal statutes applicable to low activity waste include the Atomic Energy Act of 1954 (AEA), as amended, the Nuclear Waste Policy Act of 1982 (NWPA), as amended, the Low Level Radioactive Waste Policy Act of 1980 (LLRWPA), as amended, and the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA). The committee noted that the AEA maintained the definitions introduced in the McMahon Act, which were established before the health hazards of radiation were fully appreciated; security of nuclear materials was then the overriding concern. Much low activity waste meets the definition of low level waste given in the NWPA and LLRWPA[1].

[1] Essentially low level radioactive waste is defined by what it is not. Low level waste is waste that is not otherwise defined as high level waste, spent nuclear fuel, transuranic waste, or AEA by-product material.

Low level waste generated or disposed of in the commercial sector is regulated by the Nuclear Regulatory Commission (NRC) under its authority to licence nuclear facilities and the possession of nuclear materials. The Environmental Protection Agency (EPA) has authority to regulate environmental radiation exposure as well as hazardous chemical waste. Waste that contains both radionuclides and hazardous chemicals is referred to as 'mixed waste' and may be subject to regulation by both the NRC and EPA. The US Department of Energy (USDOE) is self-regulating for defence waste on its own sites. The Department of Transportation regulates the shipment of radioactive materials while the NRC has the authority to regulate certain packages for transportation of nuclear materials.

Uranium and thorium contaminated waste produced after UMTRCA was passed in 1978 must be disposed of in NRC licensed radioactive waste facilities.[2] Other disposal options exist for essentially the same materials produced before UMTRCA. A large amount of pre-UMTRCA waste was produced by the former Atomic Energy Commission and is now managed under the Formerly Utilized Sites Remedial Action Program (FUSRAP).

The states have several responsibilities with regard to low activity waste. The LLRWPA makes each state responsible for disposing of its own low level waste and encourages the formation of state compacts (congressionally ratified agreements among groups of states) to provide disposal facilities. States may assume portions of the NRC's regulatory authority by becoming a NRC Agreement State. In addition, the states regulate non-AEA waste because this waste is not covered by federal statutes. Especially important for the states is their regulation of naturally occurring radioactive materials (NORM) and technologically enhanced NORM (TENORM) from activities including mining, oil and gas production, and water treatment.

3. THE COMMITTEE'S CATEGORIZATION OF LOW ACTIVITY WASTE

Given the spectrum of low activity waste and the patchwork of federal and state controls, the committee sought to develop a concise list of categories that would include essentially all low activity waste, yet by focusing on its inherent radiological properties rather than its origins, emphasize gaps and inconsistencies between its current regulation and management and its actual

[2] Strictly speaking, UMTRCA also applies to wastes at facilities licensed by the NRC before 1978.

radiological hazards. The committee agreed that five categories suffice to provide an instructive and inclusive categorization low activity radioactive waste in the United States of America.

The first three categories include waste defined and regulated as ‘low level waste’. Although their regulatory requirements are essentially the same, the waste types are very different in their radiological and physical characteristics:

(1) Waste containing types and amounts of radioactive materials that fit well within the NRC classification system for low level waste, e.g. Class A, B, and C. These include waste from nuclear utilities, other industries, medicine, and research that are disposed in NRC licensed, commercially operated facilities (‘commercial low level waste’), and similar waste produced and disposed at USDOE sites (‘defence low level waste’).
(2) Slightly radioactive solid materials (SRSM) — debris, rubble, and contaminated soils from nuclear facility decommissioning and site cleanup. They arise in very large volumes but produce very low or practically undetectable levels of radiation. They fall at the very bottom of NRC Class A (the lowest of the classes).
(3) Discrete sources — out of service radiation sources and associated materials from industrial, medical, and research applications. Although they meet the statutory definition of low level waste, they may emit high enough levels of radiation to cause acute effects in humans or serious contamination incidents. Larger sources may exceed NRC Class C (the highest of the classes).

Differences in the radiological hazards among waste in these first three waste categories are not adequately recognized by the broad statutory definitions of low level waste. At the low end, radioactivity in the very large volumes of debris, rubble, and soil is so low it is often difficult to measure. Recognizing this, the NRC has initiated a rulemaking on alternative dispositions for SRSM. Both the EPA and NRC are considering allowing the use of hazardous waste landfills for these materials. At the opposite extreme, discrete sources declared as waste are often highly radioactive. The larger sources exceed NRC Class C limits on near surface disposal. In the absence of a geological repository (e.g. Yucca Mountain if licensed and constructed) there are no means of disposal at present for these sources.

The last two categories illustrate waste types that are similar in their radiological and physical properties, but their regulation is very different.

(a) Uranium and thorium ore processing waste. This waste has been produced in large volumes from the recovery of uranium and thorium for nuclear applications and is therefore federally controlled under the AEA. Its associated radiological hazards arise not only from radioactive uranium and thorium isotopes, but also from radioactive decay products, especially radium, which can migrate into drinking water, and radon, which is a gas.
(b) NORM and TENORM waste. This waste arises coincidentally from the recovery of natural resources (extraction of rare earth minerals and other mining operations, oil, and gas) and water treatment. Like uranium and thorium waste, it arises in large volumes and its radiological hazards result from uranium, thorium, and their radioactive decay products, radium and radon. NORM and TENORM are not controlled by the AEA, but mainly by the individual states.

While the AEA waste in the first four categories receives a great deal of public attention and concern, there appears to be little public recognition of potential radiological hazards of NORM and TENORM waste. However, these materials may well be more radioactive than carefully regulated SRSM (see Box I) or other AEA waste.

4. LOW ACTIVITY WASTE OVERVIEW

The committee used its categorization of low activity waste as the framework for an overview of waste inventories and management practices in the USA. Among these waste types, low level waste from USDOE and commercial nuclear facilities has received the most attention from regulators and the public. Although similar in their characteristics, USDOE ‘defence’ low level waste and commercial low level waste are generally managed and regulated separately according to their respective origins in the USDOE or private sector.

Tailings and other waste from mining and processing uranium and thorium ores have been produced in very large amounts. Like low level waste, uranium and thorium waste is subject to the AEA, but concern about it has been limited mainly to populations living around mining and milling sites — including native Americans. Equally large or larger volumes of NORM and TENORM waste, which is radiologically similar to uranium and thorium waste, is produced in the recovery of natural resources for non-nuclear purposes (mining, oil and gas production) and water treatment. NORM and TENORM

BOX I. NUCLEAR POWER WASTE VERSUS NORM

The Big Rock Point (BRP) nuclear power plant, located in northern Michigan is in the midst of decommissioning. In 2001, BRP officials approached the NRC, seeking approval for disposing of large quantities of concrete rubble from the decommissioning project in a municipal landfill in northern Michigan.

They proposed a waste characterization and monitoring protocol that would assure that no concrete rubble would go to the landfill if any appreciable amount of radioactivity were present. All surfaces would be scanned for contamination at predetermined release limits. Any contamination would be removed. Then, the concrete would be made into rubble and bulk scanned. A 0.2 Bq (5 pCi) above background per gram of rubble cut-off value for approving or rejecting a particular load would be established. The NRC approved the proposal under the authority of 10 CFR section 20.2002, which gives NRC the authority to approve disposal for low level waste other than in a licensed low level waste facility. The plan also was approved by the Michigan Department of Environmental Quality

The BRP personnel worked closely with the landfill owner and the township board in the rural community where the landfill is located, to assure all that the disposal of their decommissioning waste would be fully protective of the environment and the public. In general, BRP efforts were fairly successful in assuaging public concerns, though some reluctance to taking nuclear power plant waste remains in the minds of some local community residents and township board members. Michigan Department of Environmental Quality representatives had pointed out that there are other things going into the landfill that contain more radioactive material than the rubble. In fact, the coal ash that is used as daily cover for the cells show radioactive material concentrations in the range of 0.5 Bq (13 pCi) of radium per gram of ash.

Recently, the landfill operator installed portal monitors at the landfill, in preparation for accepting the decommissioning rubble. However, the portal monitor alarm has been tripped when certain loads of oil and gas production sludges and coal ash have been brought to the landfill. This material has been coming to the landfill for years, without any recognition of its radiological content. The landfill operator is developing operational procedures for determining when to refuse a load, which has tripped the portal alarm. The Michigan Low Level Waste Authority has requested, and the landfill operator has agreed, to keep a log of all shipments that trip the portal alarms to develop a better sense of radioactive materials entering the landfill. *Source: Michigan Department of Environmental Quality.*

waste is not subject to the AEA, there has been almost no public concern about it, and there is no consistent system for regulating it.

4.1. Commercial low level waste

Commercial low level waste comes from nuclear power facilities and other industrial, medical, and research applications. Typical examples include protective shoe coverings and clothing, mops, rags, equipment and tools, laboratory apparatus, process equipment, reactor water treatment residues, non-fuel-bearing hardware, and some decontamination and decommissioning waste. Low level radioactive waste is produced in essentially every state. With a few exceptions, the radionuclides contained in commercial low level waste are relatively short lived fission products.

The 1978 revision of the AEA gave the NRC authority to regulate waste from the private sector. Defence low level waste becomes subject to NRC regulations if it is sent for disposal in a commercial facility. In its regulations governing the disposal of commercial low level waste, the NRC defines three classes (A — the least hazardous — B, and C) based largely on the concentrations and half-lives of radionuclides in the waste. High or essentially unrestricted concentrations of radionuclides with half-lives less than 5 years are allowed, concentrations of some specific fission and activation products with longer half-lives are restricted, and concentrations of transuranic nuclides with half-lives greater than 5 years are limited to 4 kBq (100 nCi/g). The vast majority of the volume of commercial low level waste consists of NRC Class A waste.

The Manifest Information Management System (MIMS) provides information on waste shipments to commercial disposal facilities (Barnwell, South Carolina; Clive, Utah; and Richland, Washington).[3] According to MIMS, approximately 600 000 cubic metres of waste containing almost 0.3 million TBq (9 million curies) of radioactivity were disposed of between 1989 and 2001 (see Figs 1 and 2). The vast majority of the waste, some 85% of the volume and the activity, came from nuclear utilities. Waste from other industries amounted to about 7% of the volume and the activity. Waste received from USDOE sites made up most of the remainder. Waste from medical and academic origins amounted to less than 1% of the volumes and activity disposed of.

The trend toward volume reduction begun in the mid-1990s resulted from significant efforts to reduce waste production and to further reduce volume by compaction and supercompaction of waste. The substantial volume increase

[3] See <http://mims.apps.em.doe.gov>.

beginning in 1998 reflects the large amounts of slightly contaminated soils, debris, and rubble that Envirocare of Utah began receiving in that year. The waste sent to Envirocare, however, contained less that 1% of the total activity disposed of.

4.2. USDOE defence low level waste

Defence low level waste has been generated in the course of producing or using special nuclear materials throughout the USDOE complex, including fuel fabrication, reactor operation, and isotope separation and enrichment, and it continues to be produced in site cleanup work. In general terms, USDOE low level waste is quite similar to commercial low level waste except that some radionuclides specific to nuclear fuel reprocessing appear in higher amounts. For example, some USDOE low level waste contains transuranic isotopes, mainly plutonium, at concentrations between 0.3 and 3 kBq/g (10 nCi/g and 100 nCi/g). The USDOE is self-regulating for waste generated and disposed of at its sites. On-site wastes that do not fit into other waste categories defined by Order 435.1 are managed and disposed of as low level waste. USDOE low level waste shipped to commercial facilities is subject to the NRC's or the Agreement State's commercial waste regulations.

Cumulatively through fiscal year (FY) 1999, USDOE had disposed an estimated total volume of 5.8 million cubic metres of low level waste and contaminated media containing almost 2 million TBq (50 million curies). In FY 2000, the USDOE treated about 833 000 cubic metres of low level waste and disposed of about 40 000 cubic metres. The USDOE disposed of another 29 000 cubic metres in commercial facilities. The treated and subsequently disposed of waste volumes were about equal to new additions, so the beginning and year end inventories remained almost constant at about 146 000 cubic metres. The USDOE estimates that another 2 million cubic metres will be disposed of by 2070 [1, 2].

4.3. Slightly radioactive solid materials

Nuclear facility decommissioning produces debris, rubble, and contaminated soil characterized by large volumes of materials having small quantities of radioactive contamination — including concrete, plastics, metals and other building materials, equipment, and packaging. A previous study [3] introduced the term 'slightly radioactive solid materials' (SRSM) to describe this waste. It is produced in both the USDOE and commercial sectors.

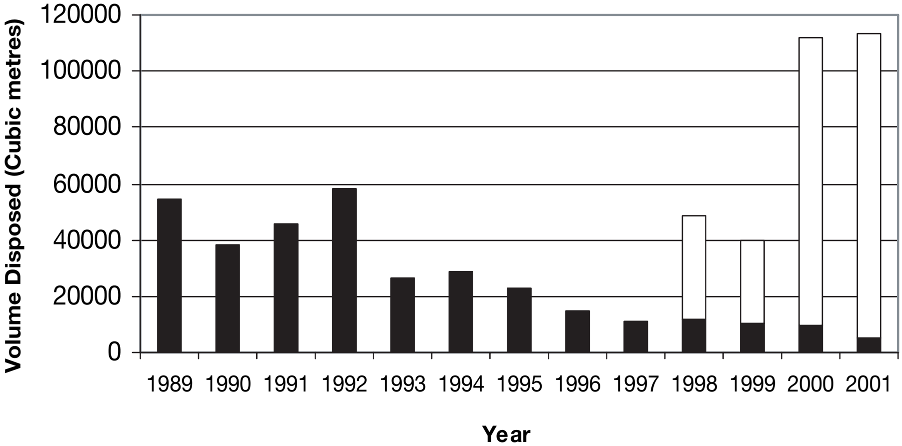

FIG. 1. Volumes of low level waste disposed of at commercial sites. Upper bars beginning in 1998 are very low level waste received at Envirocare of Utah [4].

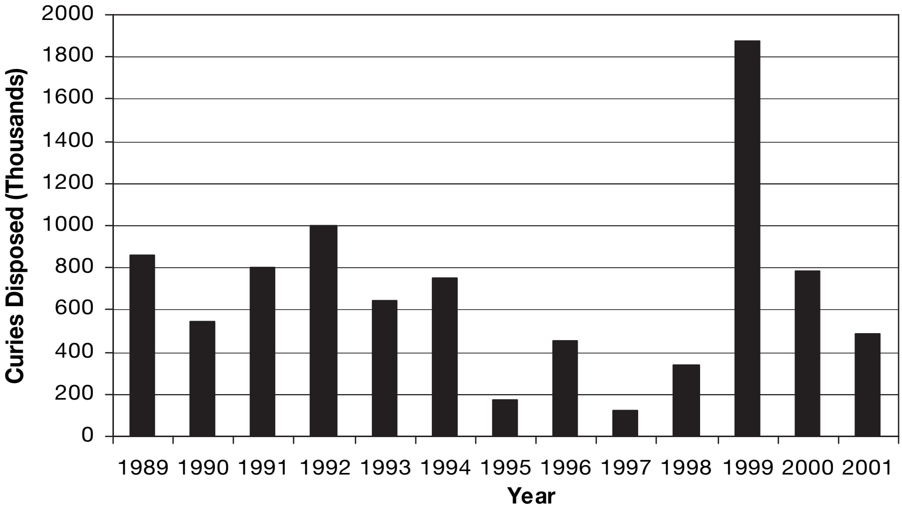

FIG. 2. Curies of low level waste disposed of at commercial sites [4].

Decommissioning the existing commercial power reactor facilities may generate up to about 8 million cubic metres of SRSM, about 90% being concrete. These same facilities may also yield around a million tonnes of metallic SRSM [3]. The USDOE estimates that about 700 of its reactor and processing facilities will be fully decommissioned in the course of site cleanup [5].

It also estimates that about 821 000 cubic metres of solid contaminated media may be excavated during its site cleanup activities between 2000 and 2010 [2].

Currently SRSM is regulated and disposed of as NRC Class A waste, which means it must be disposed of in NRC licensed facilities (or their equivalent at USDOE sites). However, this waste usually contains very small amounts of radioactivity. Debris and rubble sent to Envirocare amounted to about 90% of the total low level waste volume disposed of in 2000, but amounted to only about 1% of the radioactivity [4]. The NRC and its Agreement States have allowed alternative disposal pathways (e.g. in permitted landfills) on a case-by-case basis [6]. Both the EPA and NRC are investigating alternative disposition options for this waste.

4.4. Discrete radiation sources

Discrete radiation sources usually consist of a radioactive material in a leaktight metal casing. The amount and type of radioactive material used (e.g. ^{60}Co, ^{90}Sr, ^{137}Cs, ^{192}Ir, ^{252}Cf, ^{241}Am) determine the type and intensity of emitted radiation. Sealed sources have essential uses in medical diagnostics and therapy, industry (radiography, well logging), and research. Over the course of time, radioactive decay may reduce their intensity below a useful level, or the application may become obsolete — such as the use of ^{226}Ra in medicine or ^{137}Cs irradiators. Unused radioactive sources are often referred to as ‘spent’ sealed sources although they may continue to present a significant radiation hazard if not properly stored or disposed of [7].

Sealed sources in commercial use are licensed by the NRC or an Agreement State. USDOE controls sealed sources used at its sites. As a practical matter, however, the identifying marks and records on many sealed sources, especially older sources, are sometimes lost and the sources themselves may become lost or ‘orphaned’. According to EPA estimates, there are over 30 000 orphan sources in the USA. In cooperation with the Conference of Radiation Control Program Directors (CRCPD), the EPA, NRC and USDOE are funding a programme to assist states to retrieve and securely dispose of orphan sources.

While many discrete sources are clearly not low activity materials, they meet the NWPA definition of low level waste. Their designation as low level waste generally works in practice because the radionuclides in these sources typically have half-lives of a few decades or less, and their small volumes allow them to be safely stored in shielded containers. Regulatory authorities in most countries allow their disposal in near surface facilities designed for low level waste. Nonetheless, these sources represent the opposite extreme from the large volumes and low activities that characterize most other waste considered in this report.

4.5. Uranium mining and processing waste

Beginning with the Manhattan Project in 1942, uranium and thorium ores were mined and processed on a massive industrial scale. Initial ore production was dedicated to the manufacture of material for nuclear weapons; subsequent production supported the nuclear power industry as well. The residues from recovering and processing uranium and thorium were stored in outdoor piles for later management or sometimes buried on site. Typical tailings piles range in size from tens of thousands to over three million cubic metres [8]. In some cases tailings have been used inappropriately as construction materials [9].

The radiological hazards associated with this waste arise from the decay of naturally occurring uranium and thorium isotopes and their daughter isotopes. Beginning with ^{232}Th, ^{238}U, or ^{235}U, radioactive decay produces a series of other radioisotopes (daughters) leading to the eventual formation of stable (non-radioactive) isotopes. The half-lives of the thorium and uranium parent isotopes are extremely long, so that the radioactivity associated with waste containing these isotopes is low but persistent. Radon-222, a daughter product of ^{238}U, is of particular concern because it is gaseous and can diffuse from tailings piles unless they are properly capped.

Uranium and thorium processing waste is defined as by-product material in section 11e.(2) of the AEA. In 1978, the Uranium Mill Tailings Radiation Control Act (UMTRCA) vested the EPA with overall responsibility for establishing health and environmental cleanup standards for uranium milling sites and associated properties, the NRC with responsibility for licensing and regulating uranium production and related activities including decommissioning, and the USDOE with responsibility for remediation of inactive mill tailings sites and long term monitoring of all the decommissioned sites.

The NRC has determined that it does not have authority to regulate uranium mining and processing waste at facilities that were not under NRC licence at the time of passage of UMTRCA. Some of this waste, generated between the start of the Manhattan Project and 1978 and related to the nation's early atomic weapons programme, are managed under FUSRAP established under the AEA. FUSRAP cleanups are conducted by the Army Corps of Engineers. As noted earlier, there are different disposal options for UMTRCA and FUSRAP waste. The USDOE manages uranium contaminated waste on its sites.

4.6. NORM and TENORM waste

Naturally occurring radioactive materials (NORM) arise in many mineral extraction operations and are often discarded as waste — examples include phosphate industry residues, scale and sludge from oil and gas production, non-uranium mining tailings, and coal ash residues (see Table 1). The materials are referred to as technologically enhanced NORM (TENORM) if their concentrations of radioactive materials are increased above naturally occurring levels. Sludge or filter media from water and wastewater treatment are good examples of TENORM waste. Estimates of the NORM and TENORM inventories from US industries exceed 60 billion tonnes [10].

The radionuclides in NORM waste arise mainly from uranium and thorium series isotopes. NORM waste is therefore radiologically similar to uranium mining and milling waste, although some radioisotope concentrations may differ. Unlike uranium and thorium waste, NORM is not a by-product of the production of nuclear materials and is not controlled by the AEA. Except for Department of Transportation regulations on transportation of radioactive materials, for the most part NORM is not regulated by federal agencies but rather by states.

There is considerable variation among states, which often regulate non-AEA materials collectively as naturally occurring and accelerator produced radioactive materials (NARM). In Agreement States the same state agencies that have authority for AEA materials usually regulate NORM materials as well. States that regulate NORM specify concentrations of radium below which materials are exempt from regulation as waste, but the concentrations vary from state to state. Recognizing these disparities, the CRCPD has developed suggested state regulations for TENORM.[4]

---

[4] See <http://www.crcpd.org/SSRCRs/N_4-99.PDF>.

TABLE 1. DOMESTIC PROCESSES THAT GENERATE NORM WASTE

Process	Waste description	Radionuclide concentration (pCi/g)	Estimated waste generation (million tonnes per year)	Major generator locations
Soils in the USA	(Benchmark for typical background)	0.2–4.2		
Coal combustion	Fly ash	2–9.7	44	Midwestern and South Atlantic states
	Bottom ash and slag	1.6–7.7	17	
Geothermal energy production	Solids	10–250	0.05	California
Metal mining and processing	Slag, leachate and tailings from:			Mostly Midwestern and Western states
	Large volume industries[a]	0.7–83	1000	
	Special application metals	3.9–45	0.47	
	Rare earth metals	5.7–3200	0.002	
Municipal waste treatment	Sludge[b]	1.3–11 600 (pCi/L)	3	All, especially North Central and Atlantic Coastal Plain
Oil and natural gas production	Scale and sludge	Background to over 100 000	2.6	States where petroleum or natural gas is produced or processed
Phosphate mining and fertilizer production[c]	Ore tailings and phosphogypsum (calcium sulphate)	7–55	48	Florida, Idaho, and other states in the West and Southeast

[a] Such as iron and copper mining.
[b] Filters typically have concentrations of 40 000 pCi/g but arise in much smaller volumes.
[c] Phosphate fertilizer volumes are about one order of magnitude less, with the same concentrations of radionuclides.

Sources: Ref. [11] and <http://www.tenorm.com>.

5. FINDINGS AND CONCLUSIONS

In general, the committee concluded that there is adequate statutory and institutional authority to ensure safe management of low activity waste, but the current patchwork of regulations is complex and inconsistent—which has led to instances of inefficient management practices and perhaps in some cases increased risk overall. Existing authorities have not been exercised consistently for some waste. The system is likely to grow less efficient if the patchwork approach to regulation continues in the future. In its interim report [12] the committee developed the following findings:

5.1. Finding 1

Current statutes and regulations for low activity radioactive waste provide adequate authority for protection of workers and the public.

In its fact finding meetings, site visits, and review of relevant literature, the committee found no instances where the legal and regulatory authority of federal and state agencies was inadequate to protect human health. This finding is consistent with that of previous studies by the National Academies and the National Council on Radiation Protection and Measurements [3, 10, 13]. Some states, however, have chosen not to exercise regulatory authority over NORM and TENORM waste. The NRC has determined not to regulate certain pre-1978 uranium and thorium waste. The EPA has so far not exercised its authority under the Toxic Substance Control Act to regulate non-AEA radioactive waste. In addition, some waste has not been adequately controlled in spite of the existence of regulatory authority. The EPA estimates that some 30 000 orphan sealed radioactive sources have disappeared from regulatory control, and notes that since 1983 there have been 26 recorded meltings of sources that were inadvertently mixed with scrap steel. These incidents have been expensive, led to very conservative practices in the steel and nuclear industries, and fuelled public distrust in the regulatory system [3, 14, 15].

5.2. Finding 2

The current system of managing and regulating low activity waste is complex. It was developed under a patchwork system that has evolved based on the origins of low activity waste.

In its information gathering the committee received a clear message from agencies responsible for managing and regulating low activity waste: A more consistent, simpler, performance based and risk informed approach to regulation is needed (see Box II). Similarly, the NCRP found that the current waste classification systems "are not transparent or defensible" and that the "classification systems are becoming increasingly complex as additional waste streams are incorporated into the system" [13].

5.3. Findings 3 and 4

Certain categories of low activity waste have not received consistent regulatory oversight and management.

Current regulations for low activity waste are not based on a systematic consideration of risks.

Regulations focused on the origin of waste have led to inconsistencies relative to their likely radiological risks. NORM and TENORM are not regulated by federal agencies because they do not fall under the Atomic Energy Act. State regulation of this waste is inconsistent. Nevertheless, this waste may have significant concentrations of radioactive materials compared to some highly regulated waste streams. For example, NORM waste routinely accepted at a landfill triggered a radiation monitor intended to ensure that rubble from a decommissioned nuclear reactor meets very strict limits on its radioactivity (see Box I).

Uranium mining and processing waste, which is radiologically similar to NORM waste, is regulated under federal authority by their status at the time

BOX II. COMMENTS FROM REGULATORS AND MANAGERS

Radiation is radiation. Make decisions based on the radiation in the material and not based on the regulatory box of the material. **Southeast Compact Commission**

USDOE would benefit from a more uniform approach to waste management, particularly when USDOE uses commercial treatment and disposal. **USDOE**

Suggest improvements in management and oversight activities to achieve the greatest risk reductions with available resources. **EPA**

Consistent, national standards for classifying radioactive materials such as pre-1978 ore processing residuals, oil and gas drilling waste, and other NORM or TENORM, independent of pedigree... **Army Corps of Engineers**

Address more consistent and harmonized regulation of like materials that fall under different regulatory regimes; identify and address opportunities for more risk informed disposal of low activity waste. **NRC**

These comments were made by sponsors of this study at the first committee meeting.

UMTRCA was enacted. There are no federal regulations that prohibit ore processing residuals at facilities that were not under licence by the NRC in 1978 or thereafter from being disposed of in hazardous waste facilities, but mill tailings regulated by the NRC under UMTRCA, which may be radiologically identical to pre-1978 residuals, are prohibited from being disposed of in such facilities.

In addition to inconsistencies in regulating the radiological risks, current low activity waste regulations generally overlook trade-offs between radiological and non-radiological risks. Hundred thousand cubic metre volumes of slightly contaminated soil and debris and very heavy reactor components are being transported long distances for disposal [16]. In developing current requirements for how low activity waste is managed or disposed of, worker risks in excavating, loading, and unloading large volume waste; risks of transportation accidents; and environmental risks and costs (e.g. consuming large amounts of fossil fuel) have not been analysed and compared in a systematic way with radiological risks.

6. PUBLIC CONCERNS ABOUT LOW ACTIVITY WASTE: AN ISSUE FOR THE FINAL REPORT

On beginning this study, the committee was aware that there is persistent and widespread public concern with all aspects of radioactive waste management and disposal [3, 17–20]. During the committee's open sessions, members of the attending public expressed considerable lack of trust in the low activity waste regulatory system due to its complexity, inflexibility, and inconsistency. These factors have apparently raised doubts about the system's capability for protecting public health. The key concerns raised in the open sessions — distrust of regulatory institutions and processes, the complexity of the problem, apprehension about risks, and the desire for greater stakeholder and public involvement — is consistent with a large and growing literature on public views of radioactive waste and how to manage it [17, 21–24].

The task of the study committee in developing this interim report was to critically review the current regulatory and management practices for low activity waste, and thus set the stage for the committee's final report, which will assess policy and technical options for improving the current practices. The assessments will include risk informed options, and the committee strongly believes that issues of public trust and risk perception will be important considerations in the final report.

ACKNOWLEDGEMENTS

The following members of National Academies' Committee on Improving Practices for Regulating and Managing Low Activity Radioactive Waste and staff of the Board on Radioactive Waste Management (BRWM) developed the interim report [12] from which this paper was excerpted:

David H. Leroy, Chair, Leroy Law Offices, Boise, Idaho
Michael T. Ryan, Vice-Chair, Charleston Southern University, Kiawah Island, South Carolina
Edward L. Albenesius, Westinghouse Savannah River Company, Aiken, South Carolina
WM. Howard Arnold, Westinghouse Electric, Coronado, California
François Besnus, Institut de Radioprotection et de Sûreté Nucléaire, France
Perry H. Charley, Diné College, Shiprock Campus, New Mexico
Gail Charnley, Health Risk Strategies, Washington, District of Columbia
Sanford Cohen, SC&A, Inc., McLean, Virginia
F. Stanley Echols, Echols Consulting Group, Washington, District of Columbia
Sharon M. Friedman, Lehigh University, Bethlehem, Pennsylvania
Maurice C. Fuerstenau, University of Nevada, Reno
James Hamilton, Duke University, Durham, North Carolina
Ann Rappaport, Tufts University, Medford, Massachusetts
D. Kip Solomon, University of Utah, Salt Lake City
Kimberly W. Thomas, Los Alamos National Laboratory, New Mexico

BRWM Liaison
Robert M. Bernero, NRC (retired), Gaithersburg, Maryland

BRWM Staff
John R. Wiley, Study Director
Darla J. Thompson, Research Assistant
Angela R. Taylor, Senior Project Assistant
Latricia C. Bailey, Senior Project Assistant
Financial support for this National Academies' study was provided by the following:
Army Corps of Engineers
USDOE
EPA
NRC
Southeast Compact Commission.

REFERENCES

[1] CENTRAL INTERNET DATABASE, A database that describes Department of Energy waste and site cleanup programs. Available at: http://cid.em.usdoe.gov (2003).

[2] DEPARTMENT OF ENERGY, Summary Data on the Radioactive Waste, Spent Nuclear Fuel, and Contaminated Media Managed by the U.S. Department of Energy. Washington, D.C.: Office of Environmental Management (2001).

[3] NATIONAL RESEARCH COUNCIL, The Disposition Dilemma: Controlling the Release of Solid Materials from Nuclear Regulatory Commission-Licensed Facilities. Washington, D.C.: National Academy Press (2002).

[4] MANIFEST INFORMATION MANAGEMENT SYSTEM, A database of low level waste shipments to commercial disposal facilities. Available at <http://mims.apps.em.usdoe.gov> (2003).

[5] NATIONAL RESEARCH COUNCIL, A Review of Decontamination and Decommissioning Technology Development Programs at the Department of Energy. Washington, D.C.: National Academy Press (1998).

[6] NUCLEAR REGULATORY COMMISSION, Radioactive Waste: Production, Storage, Disposal. NUREG/BR-0216, Rev. 2. Washington, D.C: Office of Public Affairs. May (2002).

[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Code of Conduct on the Safety and Security of Radioactive Sources, IAEA/CODEOC/2001, IAEA, Vienna, Austria (2001).

[8] DEPARTMENT OF ENERGY, United States of America National Report: Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. USDOE/EM-0654. Washington, D.C.: Office of Environmental Management. May (2003).

[9] NATIONAL RESEARCH COUNCIL, Scientific Basis for Risk Assessment and Management of Uranium Mill Tailings. Washington, D.C.: National Academy Press (1986).

[10] NATIONAL RESEARCH COUNCIL, Evaluation of Guidelines for Exposures to Technologically Enhanced Naturally Occurring Radioactive Materials. Washington, D.C.: National Academy Press (1999).

[11] DEPARTMENT OF ENERGY, Integrated Data Base Report—1996: U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections, and Characteristics. USDOE/RW-0006, Rev. 13. Washington, D.C.: Office of Environmental Management. December (1997).

[12] NATIONAL RESEARCH COUNCIL, Improving the Regulation and Management of Low activity Radioactive Wastes: Interim Report on Current Regulations, Inventories, and Practices. Washington, D.C.: National Academy Press (2003).

[13] NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENT, Risk-Based Classification of Radioactive and Hazardous Chemical Wastes. NCRP Report No. 139. Bethesda, Maryland: NCRP (2002).

[14] HEALTH PHYSICS SOCIETY, State and Federal Action is Needed for Better Control of Orphan Sources. A position statement of the Health Physics Society. Available at http://www.hps.org (2002).

[15] TURNER, R, The Metal Industry's View on Unrestricted and/or Limited Metal Recycle/Release into the Commercial Market. Presented at the 18th Annual International Radioactive Exchange LLRW Decisionmakers' Forum and Technical Symposium. Park City, Utah. June 17-20 (2003).

[16] [16] ST. ONGE, R., Operating and Decommissioning LLRW: Power Generators' Perspective. Presented at the 18th Annual International Radioactive Exchange LLRW Decision makers' Forum and Technical Symposium. Park City, Utah June 17-20 (2003).

[17] DUNLAP, RILEY, E., KRAFT, M.E. AND ROSA, E.A., (eds.), Public Reactions to Nuclear Waste: Citizens' Views of Repository Siting. Durham, NC: Duke University Press (1993).

[18] GENERAL ACCOUNTING OFFICE, Low Level Radioactive Wastes: States are not developing disposal facilities. GAO/RCED-99-238. Washington, D.C.: GAO (1999).

[19] NATIONAL RESEARCH COUNCIL, Disposition of High Level Waste and Spent Nuclear Fuel: The Continuing Societal and Technical Challenges. Washington, D.C.: National Academy Press (2001).

[20] NATIONAL RESEARCH COUNCIL, Review of New York State Low level Radioactive Waste Siting Process. Washington, D.C.: National Academy Press (1996).

[21] CVETKOVICH, G., SIEGRIST, M., MURRAY, R. AND TRAGESSER, S., New Information and Social Trust: Asymmetry and Perseverance of Attributions about Hazard Managers. Risk Analysis 22:359-367 (2002).

[22] DEPARTMENT OF ENERGY, Earning Public Trust and Confidence: Requisites for Managing Radioactive Wastes. Final Report of the Secretary of Energy Advisory Board Task Force on Radioactive Waste Management. Washington, D.C.: Office of Environmental Management. November (1993).

[23] ROSA, E.A. AND CLARK, D.L., Jr., Historical Roots to Technological Gridlock: Nuclear Technology as Prototypical Vehicle. Research in Social Problems and Public Policy 7:21-57 (1999).

[24] SLOVIC, Paul, Perceived Risk, Trust, and Democracy. Risk Analysis 13:675-682 (1993).

DISCUSSION

J.R. COCHRAN (United States of America): The term ‘risk informed’ means different things to different people. What does it mean to you?

D. LEROY (United States of America): I have not studied all the definitions of risk informed, or of ‘risk based’, but as a politician sensitive to public concerns and perceptions I believe the terms should be used as follows:

— risk based should be used for a regulation or statute that contains specific numbers expressing a level of public or environmental hazard that is unacceptable and, when the specific numbers are exceeded, an action is taken;
— risk informed should be used for a regulation or statute that has taken into account specific numbers or concepts or systems for describing public or environment hazard levels, has prescribed action to be taken generally consistent with avoiding the hazard, but uses words — not numbers — to describe when action is taken.

P.J. O’SULLIVAN (Netherlands): Has the concept of ‘clearance’ featured in the deliberations of your committee?

D. LEROY (United States of America): We have not considered the concept of clearance. Nor have we suggested definitions of, for example, ‘very low level waste’ and ‘exempt materials’. We have simply attempted to broadly define the term ‘low activity waste’, and in our final report we may encourage the consistent management of nuclear waste on the basis of its radionuclide content.

ISSUES FOR THE DISPOSITION OF LONG LIVED LOW ACTIVITY WASTE

J.P. MINON, A. DIERCKX, P. DE PRETER
NIRAS/ONDRAF,
Brussels, Belgium
Email: jp.minon@nirond.be

Abstract

In Belgium large quantities of waste with a very low concentrations of long lived radionuclides were generated from radium extraction activities in the past, and are being generated by ongoing industrial practices in which naturally radioactive materials are used. The planned remediation activities in the vicinity of the former radium refinery of the Union Minière (nowadays UMICORE) plant in Olen, will generate waste which NIRAS/ONDRAF (the Belgian Agency for radioactive waste and enriched fissile materials) will have to manage. Consequently, NIRAS/ONDRAF has introduced the long term management of the long lived low and very low activity waste into its global long term management scheme for all waste categories and types. One of the major objectives of this global scheme is to present a consistent strategy as a basis for discussions with the regulatory authorities on the issues of long lived low and very low activity waste management.

1. DIVERSITY OF RADIOACTIVE WASTE STREAMS IN BELGIUM

The current paper highlights some issues regarding the final disposal of long lived low activity waste. The general waste classification system of ONDRAF/NIRAS is consistent with the international recommendations by the IAEA and the European Commission on radioactive waste classification. The Belgian classification system distinguishes three main waste categories (A, B and C), with category A corresponding to short lived low and intermediate level waste, category B to long lived low and intermediate level waste and category C to high level waste:

(1) Category A waste contains radionuclides at specific activities such as to permit surface disposal.
(2) Category B waste does not meet the above criterion for category A, but does not generate enough heat to belong to category C.

(3) Category C waste contains very high concentrations of α and β emitters and generates a thermal power of over 20 W·m^{-3}, a figure that marks the limit between categories B and C for disposal into clay. It must, therefore, be allowed to cool down during a period of interim storage. Its residual thermal power at the time of disposal requires either limiting the number of packages per linear metre of disposal gallery, or increasing the distance between galleries.

The above mentioned waste streams are produced within the nuclear field, i.e. the nuclear electricity industry and nuclear applications in industry, research and medicine. Apart from these waste streams, other streams will have to be managed arising from applications outside the nuclear field:

(a) Waste streams from site remediations.
(b) Waste streams generated in industrial practices in which naturally radioactive materials are used, but not for the purpose of their radioactive properties. This waste is generally referred to as NORM and TENORM waste, but the topic is not treated in this paper.

Finally, a special category has been introduced, category R waste. It is the only category where long term management is not the determining factor in the classification. Instead, the origin and the location of the waste streams are the determining factors. Category R waste includes the radium contaminated waste stored on the site of the old Olen refinery of the Union Minière (nowadays UMICORE) in the UMTRAP facility. The topic is not treated in this paper.

2. LONG LIVED RADIONUCLIDES IN LOW ACTIVITY WASTE DISPOSABLE ON THE SURFACE

2.1. Category A waste

The maximum acceptable activity concentration of long lived radionuclides in low level short lived waste to be disposed in a surface repository according to the international recommendations of IAEA and EC is 400 Bq/g of long lived α activity, as a mean value for the disposal facility, and up to 4000 Bq/g for individual waste packages. This is a generic recommended value; for a specific surface disposal system ONDRAF/NIRAS defines category A waste by quantitative waste acceptance criteria expressed in terms of maximum radionuclide activity levels in individual waste packages (Bq/m^3) and in the facility (becquerels) for a series of 20 important radionuclides. These activity levels are derived from long term safety assessments for a specific facility and site. The scenarios to be considered in these safety assessments are still under discussion with the regulatory authorities, especially the intrusion scenarios. The following three elements will be being analysed and/or treated in the following discussion:

(1) The conservative or pessimistic approach versus the realistic approach in scenario description;
(2) The compliance criteria (dose, risk, probability);
(3) The safety role or contribution of passive institutional control measurements, such as, markers and land use restrictions.

It is obvious that these elements cannot be treated independently; the outcome of a very conservative approach in scenario description, leading to unlikely scenarios, will, most likely, be judged against a risk compliance criterion.

The lower limit for β/γ and α activity concentrations in radioactive waste is determined by clearance and exemption levels [1]. The following clearance levels apply for the relevant long lived α activity in category A waste:

(a) ^{234}U, ^{235}U and ^{238}U: 1 Bq/g;
(b) ^{237}Np, ^{238}Pu, ^{239}Pu, ^{240}Pu and ^{241}Am: 0.1 Bq/g;
(c) ^{226}Ra: 0.01 Bq/g.

If we leave aside the specific case of ^{226}Ra (which is virtually absent in category A waste arising from the operation or decommissioning of nuclear power plants), category A waste covers about 3 orders of magnitude of α activity levels.

The estimated total volume of category A waste in Belgium amounts to around 70 500 m^3 and comprises the operational and decommissioning waste arising from the seven nuclear power plants (40 years of operation is assumed) and a great diversity of waste streams arising from other producers, such as hospitals, research institutes and industries.

2.2. Waste streams arising from site remediation

A second waste stream for which the envisaged long term management option is surface disposal, is waste coming from the planned site remediation activities at the UMICORE site in Olen (a radium contaminated site as a result of past radium production by extraction). This remediation will give rise to the removal of radioactive materials with very low radium specific activity levels, with a mean estimated value just below 10 Bq/g, as based on a first series of on-site measurements. The expected volumes are relatively large (several 100 000 m^3).

The Federal Agency for Nuclear Control, FANC, responsible for nuclear regulatory matters, and ONDRAF/NIRAS as the responsible radioactive waste management body, issued in 2001 a common position on this remediation plan. To accommodate the waste management situation in this context, a new waste category was introduced, namely very low level waste (VLLW). The nature of the waste is as follows:

(a) It comprises radioactive substances (mainly radium and its progeny) with an average long lived α activity that is significantly lower (by more than one order of magnitude) than the upper limit for long lived α activity in category A waste.
(b) Unlike category A waste, there is no dominant short lived β/γ activity.
(c) The radioactive substances arise from an intervention (remediation), and not from a practice.

In their common position, ONDRAF/NIRAS and FANC stipulate 40 Bq/g (average value over repository) and 400 Bq/g for volumes of 1–10 m^3 as the upper limits for the long lived α activity in VLLW. The activity concentrations cited above are, however, indicative, and it has been stated that the precise concentration levels are dependent on the outcome of a site and repository specific safety evaluation during the licensing procedure. Material arising from remediation that might have a considerably higher specific activity level cannot be categorized as VLLW, and it therefore falls under waste category A (or possibly B or C).

Comparable to these materials in terms of specific activity levels, are the large amounts of NORM and TENORM from different origins present in Belgium (e.g. the phosphate industry), also with very low levels of long lived radionuclides (mean α activity concentrations ranging between 1 and 10 Bq/g).

3. MANAGEMENT OPTIONS FOR LONG LIVED LOW AND VERY LOW ACTIVITY WASTE

Recently, NIRAS/ONDRAF introduced the long term management of the long lived low activity waste into its global long term management scheme for all waste categories and types (see Fig. 1). One of the major objectives of this step was to establish a consistent strategy as a basis for starting a discussion

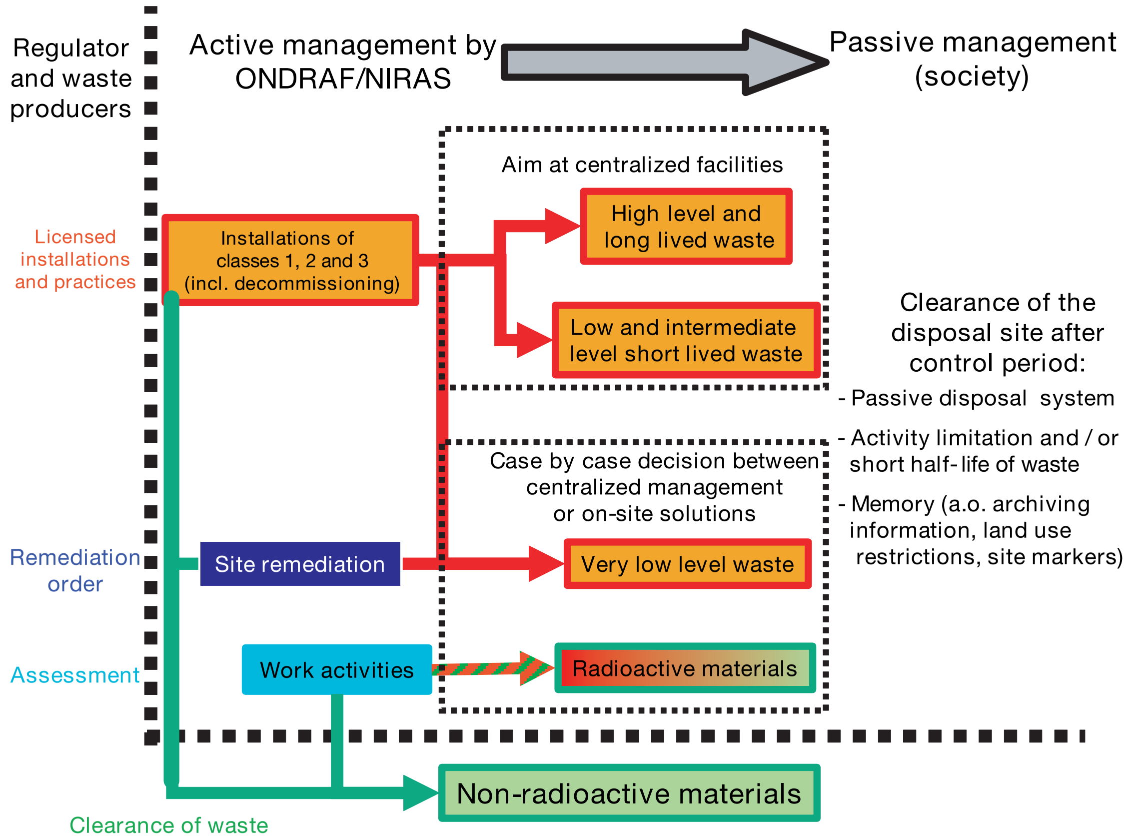

FIG. 1. Global management scheme for all waste types as currently proposed by NIRAS/ONDRAF.

with the regulatory authorities on the issues of long lived low activity waste management.

For the short and long term management of the waste of categories A, B and C, ONDRAF/NIRAS aims at management in centralized installations (treatment and conditioning, interim storage and disposal). The most important arguments for centralized management are set out below:

(a) The intrinsic risks associated with these waste streams are the highest because they have the highest activity levels and, for this reason, the number of sites with such waste should be kept to a strict minimum.
(b) The waste volumes remain relatively limited. Consequently, the transport of this waste does not present a fundamental problem as regards safety and environmental impact or as regards socioeconomic cost.
(c) The overall management costs can be reduced by restricting the number of installations. The relatively low waste volumes do not justify the construction and operation of several similar installations.

For the other waste streams (VLLW and radioactive material arising from work activities), it should be considered on a case-by-case basis whether a centralized solution or an on-site solution is the most appropriate. This consideration should take place for the following reasons:

(a) It involves materials with activity levels that are significantly lower than those of the waste in category A, so that the intrinsic risks posed by the waste are also significantly lower, especially when compared with the waste in categories B and C;
(b) In many cases, the volumes are so large that their transport to another location presents serious problems of environmental impact and cost; and
(c) The diversity of situations (i.e. the characteristics of the site and the radioactive material) precludes a single approach that would offer a satisfactory solution for each of these situations.

In the management scheme, it is proposed to keep the radioactive materials arising from work activities separate from radioactive waste streams arising from licensed nuclear power plants and from the remediation of sites that have been contaminated as a result of licensed or non-licensed nuclear activities. Because it appears necessary, for the above mentioned reasons, to assess these work activities case by case just like site remediations, there is little point in combining these cases, which are to be assessed individually.

This scheme also introduces the terms ‘active management’ (by ONDRAF/NIRAS) and ‘passive management’ (by society).

Active management refers to the whole of management activities that are concerned with the making of the waste inventory — the collection, transport, processing and conditioning and the interim storage of the waste, as well as the period of disposal before the repository site is released.

Passive management refers to the situation after the clearance of the repository site; from that moment, the site is no longer under supervision, and safety and protection therefore rely on the following ‘pillars’:

(a) The safety functions of the disposal system, which are fulfilled by passive and robust barriers;
(b) The restriction of the amount of radioactivity in the installation in the case of surface disposal sites;
(c) The information transferred to future generations about the presence of the installation (by means of archiving of information and the placing of markers on and around the site);
(d) The information transferred to future generations concerning the restriction of land use on the site.

There is a broad consensus that long term passive safety and protection must be borne, as much as possible, by the first two pillars. In well-defined cases, the last two pillars can offer additional safety for a situation that is not necessarily optimal from a safety standpoint, but which must already be acceptable from a societal viewpoint.

The fact that every case should be assessed separately is not inconsistent with the employment of a common assessment framework, based on the general principles of radiological protection. However, the case-by-case character becomes more pronounced because optimization requires that socio-economic factors be taken into account, and because these factors gain in importance if the intrinsic risks are smaller and the societal costs are greater.

4. CONCLUDING REMARKS

As mentioned above, the maximum allowable α activity concentrations in low level and short lived waste depend on the outcome of the safety assessments for a given site and disposal facility. However, no site has yet been selected in the Belgium programme. Concerning the low level and short lived waste category, NIRAS/ONDRAF is in the process of involving the local communities (population and authorities) in the development of a pre-project. The discussion with the regulatory authorities on the safety assessment scenarios, especially the intrusion scenarios are well advanced, but have not yet reached a conclusion. Some elements of the discussion are:

(a) Conservative/pessimistic versus realistic in the scenario description.
(b) Compliance criteria (dose, risk, probability).
(c) The safety role, or contribution, of passive institutional control measures such as markers and land use restrictions; fully coherent with the long term management of the low level and short lived radioactive waste, the long term management of the long lived very low level waste from site remediation activities (UMICORE site) is also based on a maximum allowable α activity concentration (^{226}Ra) that can be accepted. It is the wish of NIRAS/ONDRAF that the derivation of these levels will also be based on a sound safety evaluation. Besides the issues mentioned above for the low level and short lived waste, some specific points rose during a first safety evaluation of the remedial solution, which was essentially the construction of a multibarrier disposal site, as used for the disposal of chemotoxic waste.
(d) What will be the duration of the active institutional control period?
(e) How should the progressive degradation of the multicover be evaluated, especially with respect to the long half-life of ^{226}Ra (1600 years)? (This question is also related to the compliance period for the implementer.)
(f) How to deal with possible intrusions?

Radioactive decay for ^{226}Ra bearing waste is insignificant over the periods which are considered as a reasonable maximum to guarantee institutional control. The eternal presence on the site of a control and surveillance body cannot be assumed. So, it seems that long term safety can only be reinforced by enhancing the passive measures to be taken at a societal level to diminish the risks of inadvertent intrusion and system disturbance. Important measures that can be taken are land use restrictions and the passing of the memory of the site to the next generation (including archiving of information and installation of markers on the site). How this can be achieved over very long periods of time has to be looked at very carefully. The outcome of these discussions has financial consequences that should not be underestimated. The socioeconomic dimension of the radiation protection optimization exercise will be an important factor.

In case of very low level waste and (TE)NORM, the chemical component of the waste can dominate the potential long term impact on humans and the environment. This can bring up the question of the relevant competent authority and the question of compliance with both nuclear regulations and environmental regulations, which are often developed in distinct legal frameworks.

REFERENCE

[1] ARBIS, Royal Decree, "Koninklijk besluit van 20 juli 2001 houdende algemeen reglement op de bescherming van de bevolking, van de werknemers en het leefmilieu tegen het gevaar van ioniserende stralingen."

DISCUSSION

R.H. LITTLE (United Kingdom): Could you give examples of what you consider to be 'conservative' and 'realistic' human intrusion scenarios?

I believe that 'conservative' and 'realistic' should be used with extreme care — an issue being considered within the framework of the IAEA's ASAM programme.

At best, I consider that every human intrusion scenario should be regarded as stylized owing to the long time scales involved and the inherent difficulties of trying to 'predict' future human activities.

J.P. MINON (Belgium): We are aware of the discussion which you have in mind, and we are not opposed to it.

I raised the issue in my presentation because of the concerns of the general public and the dialogue with these stakeholders in the overall licensing process.

We consider this aspect to be as important as the discussion on stylized scenarios within a safety evaluation, in the context of the licensing process.

HISTORIC WASTE MANAGEMENT IN CANADA: THE POLICY CONTEXT AND RECENT PROGRESS

P.B. BROWN, D.M. McCAULEY
Natural Resources Canada,
Ottawa, Ontario, Canada
Email: bbrown@nrcan.gc.ca

Presented by R.L. Zelmer

Abstract

Canada has developed a policy structure and established an organization, the Low level Radioactive Waste Management Office, for the management of historic waste. This is low level radioactive waste, that is managed in an inappropriate manner, and for which the current owner cannot reasonably be held responsible. The volume of the material is approximately 1.5 million cubic metres. Most of the material resulted from industrial operations in the 1930s and the early days of the nuclear industry. The paper provides a description of the Government of Canada's policy approach to the management of historic waste; a case study of the Port Hope Area Initiative; the conditions for success in moving the Port Hope project forward and the lessons learned to date in the implementation of the process.

1. BACKGROUND

In 1931, a company known as Eldorado Gold Mines Limited discovered pitchblende ore along Great Bear Lake in the Northwest Territories of Canada. In the following year, the company established the Port Radium Mine on the northeast coast of the lake to extract the ore for its radium content, which was a valuable commodity at the time for treating cancer patients. The ore was shipped by barge 2200 km across the lake and up the McKenzie River to the town of Fort McMurray in Alberta, Canada. The material was then taken by train to Eldorado's refinery in Port Hope, Ontario where radium was extracted from the ore. In time, the strategic importance of the uranium content of the ore was realized and the refining process at the Port Hope plant was altered to extract uranium.

One of the legacies of Eldorado's operations was the discovery in the mid-1970s of radioactive waste contamination in the Port Hope area. Much later, similar, but considerably less, contamination was discovered along the transportation route from the Port Radium Mine to Fort McMurray. The original mining company, Eldorado Gold Mines Limited, no longer existed, having been reorganized, nationalized, and later privatized and, thus, the Government had an important role to play in the management of the waste.

2. THE GOVERNMENT RESPONSE

Recognizing the extent of the contamination not only in Port Hope, but in other uranium mining communities, the Government established, in 1976, a task force to manage the waste. The task force was chaired by the Canadian nuclear regulator, the Atomic Energy Control Board — now known as the Canadian Nuclear Safety Commission (CSNC). Its primary role was to establish cleanup criteria and to carry out remedial work at properties where the criteria were exceeded.

The task force established criteria for the cleanup of contaminated properties and organized the removal of the worst of the contamination to the Chalk River Nuclear Laboratories site in Ontario. However, a significant volume of material remained in the local communities pending the development of a long term management facility for the waste.

In 1982, the Government established the Low level Radioactive Waste Management Office (LLRWMO) to take over the responsibilities of the task force. The primary responsibility of the LLRWMO is to manage what is termed 'historic waste'. This is low level radioactive waste managed in a manner inappropriate to today's standards for which the current owner cannot reasonably be held responsible and for which the Government has accepted responsibility. The volume of this material in Canada amounts to approximately 1.5 million cubic metres. By far the majority of the material is located in the Port Hope area.

Funding and staffing of the LLRWMO varies according to the level of programme activity on historic waste. The current staffing level of the LLRWMO comprises 30 persons and the funding for the current fiscal year is $10 million.

The federal Government takes a 'hands-on' approach to the management of historic waste. The Department of Natural Resources provides the LLRWMO with the funding and policy direction necessary to manage the waste. This differs considerably from the Government's general policy on radioactive waste management. Under the Government's 1986 Policy Framework for Radioactive Waste Management, it is the waste owners that are responsible for the proper management and funding of their radioactive waste. Thus, the management of radioactive waste currently being produced in

Canada — be it uranium mine and mill tailings, low level radioactive waste, or used nuclear fuel — is the responsibility of the owner of the waste.

Regardless of whether radioactive waste is historic or is currently being produced, it is all regulated in the same manner by Canada's nuclear regulator, the CNSC.

3. THE PORT HOPE AREA INITIATIVE

The bulk of Canada's historic waste is located in the Port Hope area of southeastern Ontario, roughly 150 km east of the City of Toronto. The waste is located in two communities; the Municipality of Port Hope and the Municipality of Clarington.

Roughly 75% of the waste is presently stored at two waste management facilities constructed in 1955 and 1960, one in each of the two municipalities. Key contaminants are uranium isotopes and ^{226}Ra, with concentrations that can exceed 30 000 ppm of uranium and 200 Bq/g of ^{226}Ra.

The remaining material is located on public and private properties (some licensed, some not) in the Municipality of Port Hope. Here the concentrations of the key contaminants are site specific but, overall, somewhat lower than in the waste management facilities. A municipal landfill, where almost half of the material is located, has concentrations of key contaminants as follows: uranium — 1000 ppm; ^{226}Ra — 100 Bq/g; arsenic — 500 ppm. Technical studies have concluded that the waste poses no immediate health and safety risks. Nevertheless, there is public concern regarding the health impacts of the contamination, the long term acceptability of the current waste facilities, and the impact that the contamination problem has on the local economy. Furthermore, the CNSC does not consider the present situation appropriate in the long term.

Efforts to determine an appropriate long term management strategy for the waste that is environmentally safe, and economically sound, and also supported by the public have spanned two and a half decades. Strategies have evolved from the traditional 'decide, announce, defend' approach to siting, which was unsuccessful, to an approach that is 'community driven'.

The community driven approach resulted from an earlier attempt by the Government to find a volunteer community to host the Port Hope area waste. That process, resulted in the identification of a single community — located 400 km from the Port Hope area — that would be willing to host a long term management facility for the waste. The Government proceeded to negotiate a legal agreement with the volunteer community, but was unsuccessful. Simultaneous to the conclusion of that process, the communities where the waste was located came forward to the Government with their own proposals for the management of the waste locally. Their action may have been taken because of concern that the Government would not be successful in its attempt to obtain an agreement with the volunteer community or because they decided that they could manage their own waste themselves. Each of the two communities came forward with its own local solution for its own waste.

The municipalities' proposals were conceptual in nature. They involved the construction of two above ground bulk waste storage facilities that would accommodate the waste from within Port Hope — roughly 950 000 cubic metres — and, in the case of Clarington, the re-engineering of an existing waste management facility containing 425 000 cubic metres of material to minimize water infiltration and to isolate certain key contaminants in an above ground mound.

An earlier proposal to manage the waste in an underground mined cavern facility to be constructed 80–90 metres below the surface on the waterfront in Port Hope had been vehemently opposed and was not considered further by the municipalities in this round of discussions. In relation to that proposal, there were public concerns regarding impacts of the facility on Lake Ontario, concerns about the capability to monitor the facility in the long term, and socioeconomic concerns about the impact of the location of the facility on the lakefront of the community.

The key design principles for the Port Hope facilities proposed by the municipalities were that the new waste management sites should be sufficiently robust for long term management, built above ground such that they were easily monitored, and that the design of the facilities should be such that the surface could be adapted for passive or active recreational purposes. In the case of the Clarington facility, the municipalities' conceptual proposal focused on the objective of minimizing the disturbance of the existing waste by managing the waste 'in situ' — providing adequate cover, diverting groundwater around the facility, and heavily protecting the facility from the wave action of the lake.

The conceptual designs were incorporated into a legal agreement between the municipalities and the Government on the understanding that the designs would undergo an environmental assessment that would include the consideration of alternative long term management concepts. The legal agreement provides that the municipalities have an effective veto on any alternative proposal submitted for licensing subsequent to the environmental assessment of the communities' own concepts. Other key elements of the agreement were that grants be provided at the outset to the municipalities to address the impacts of the presence of long term radioactive waste management facilities within their communities, that funding be provided to the municipalities for the assessment of the work of the proponent, and that a programme be implemented to mitigate any financial impacts on property values.

The Port Hope Area Initiative is now in its fourth year of implementation. The main activity to date has been the rigorous environmental assessment of the municipalities' conceptual approaches to long term management. This assessment has involved significant municipal and public input and resulted in modifications to the original proposals. In Port Hope, the preferred concepts emerging from the environmental evaluation involves the consolidation of the two proposed waste management facilities into a single above ground mound. In Clarington, rather than the originally proposed concept of in situ management, the preferred concept, at this time, involves the removal of all waste from the current lakeside waste management facility and the relocation of the waste to a newly constructed facility further inland. These preferred options will undergo further detailed environmental assessment. They are also subject to the municipalities' ultimate approval prior to being submitted to the Government for consideration in early to mid-2005. Subject to the Government's consideration of the environmental effects of the proposals, licensing would begin in 2006. Cleanup and construction is not likely to commence prior to 2007.

4. LESSONS LEARNED

Canada's experience over the years in historic waste management has yielded a number of important lessons. Two key lessons are: the importance of a clear commitment to take responsibility for implementing a solution; and, the importance of a community driven approach.

The Government of Canada has taken a hands-on approach to the management of historic waste. This has involved the establishment of a federal agent responsible for the management of historic waste and federal policy involvement in the development of waste management strategies, direct liaison with affected stakeholders, the provision of funding, and ongoing policy direction and oversight.

Federal involvement and a commitment by the Government to resolve historic waste issues are seen as key to the resolution of historic waste management issues. In the case of the Port Hope Area Initiative, a clear commitment by the Government to take on the responsibility for the remediation was seen as integral to obtaining municipal support for the project initiative. Commitment in the legal agreement to ownership of the new facilities, to the establishment of offices in the local community staffed at the most senior levels by competent local citizens, to ongoing monitoring of the facilities, and to maintaining communication between the Government negotiators and the local Mayors, are integral to the success achieved to date.

The experience has also demonstrated that solutions must be community driven and provide explicitly for community involvement. The community must take ownership of the solution in order for the solution to be successful. Solutions generated outside the community and sold locally are typically met with suspicion and scepticism.

In the Port Hope situation, there is a commitment to a community driven approach. The municipal councils volunteered to enter into discussions with the federal Government. The subsequent proposals were generated by local citizen committees, reflecting principles that were important to them. They were subsequently endorsed by the municipal councils. The legal agreement reflects a continued commitment to the approach by Government and the municipalities. The municipalities are funded to be active participants in the process. They have an effective veto on the final preferred approach submitted to Government, and there is explicit recognition that the parties will work together and take such actions as may be necessary to maintain good communication and a professional working relationship throughout the life of the project.

5. CONCLUSION

The policy approach of the Government of Canada to deal with historic waste has evolved over time. Initial efforts were driven by health and safety concerns and were responded to by the federal provincial task force cleanup and the decision of the Government to establish the LLRWMO as a single purpose agency to manage historic wastes. After the initial cleanup, efforts to site a long term management facility for the remaining waste failed because they were based on the traditional approach to siting — decide, announce, defend. Recognizing the futility of this approach, the Government established an independent siting process to implement a cooperative siting process based on the principles of openness, cooperation, and voluntarism. The Government has since adopted a new approach to the issue that is based on a clear statement of responsibility by the Government to address the contamination problem and a commitment to community driven solutions where the municipality is responsible for developing solutions, partnering in the evaluation of those solutions, and empowered to continue its participation throughout the implementation of the project. This focus on community advocacy is the basis of the Port Hope Area Initiative and the key reason for its success.

DISCUSSION

M. FEDERLINE (United States of America — Chairperson): What, in your view, was the most important factor in the success of the Port Hope project?

R.L. ZELMER (Canada): The mood swing that has taken place in Canada, after decades of unsuccessful efforts to find long term solutions to the problem of low level radioactive waste, and that was exemplified by a shop owner in Port Hope who said "Let's just get on with it !" I believe he was expressing, not resignation, but a desire to move forward and confidence that such solutions could be found.

MANAGEMENT OF LONG LIVED LOW ACTIVITY RADIOACTIVE WASTE IN INDIA

K.B. LAL
Bhabha Atomic Research Centre,
Kalpakkam, India
Email: kblal@igcar.ernet.in

Abstract

Long lived radioactive waste is waste containing radionuclides having half-lives of more than 30 years and is primarily dominated by alpha-emitting radionuclides. In India, waste containing alpha-emitters in concentrations of more than 4000 Bq/g are classified as long lived waste and categorized as Category IV solid waste. This waste is generated during fuel fabrication, reprocessing of spent fuels and research and development activities. The paper covers waste generation, treatment, conditioning and interim storage of long lived low active waste in India.

1. INTRODUCTION

Radioactive waste has to be managed in such a way that facility operators and members of the public are not exposed to the deleterious effects of ionizing radiation. It has to be concentrated, conditioned, stored and then disposed of. One important aspect in the management of radioactive waste is that radionuclides decay to safe levels in the course of time. However, certain radionuclides have very long half-lives (more than 30 years); these are mainly alpha emitters and long lived beta emitters. The Atomic Energy Regulatory Board of India requires that any waste having more than 4000 Bq/g of alpha activity should be classified as long lived waste and categorized as Category IV waste.

2. SOURCES OF LONG LIVED LOW ACTIVITY RADIOACTIVE WASTE

In India long lived low activity waste is generated from the mining and milling of uranium and thorium bearing ores, nuclear fuel fabrication facilities, and spent fuel reprocessing plants. Small amounts of similar waste are generated from the processing of copper minerals, phosphates and the use of radionuclides in medicine, research and industry.

3. SEGREGATION AND CLASSIFICATION

The waste is produced in liquid and solid form. The liquid waste is categorized in five categories, based on the activity content as shown in Table 1. The waste is further categorized based on the presence of chemical constituents.

Solid waste is categorized in four categories, based on the contact radiation dose as shown in Table 2.

The long lived low activity waste falls under Categories II and III of liquid waste and Category IV of solid waste.

TABLE 1. CATEGORIZATION OF LIQUID WASTE

Low activity waste	Category I	$< 3.7 \times 10^{-2}$ MBq/m^3
Low activity waste	Category II	3.7×10^{-2}–37 MBq/m^3
Intermediate activity waste	Category III	37–3.7×10^3 MBq/m^3
Medium activity waste	Category IV	3.7×10^3–37×10^4 MBq/m^3
High activity waste	Category V	$> 37 \times 10^4$ MBq/m^3

TABLE 2. CATEGORIZATION OF SOLID WASTE

Low active waste	Category I	< 2 mGy/h
Medium activity waste	Category II	2–20 mGy/h
High activity waste	Category III	> 20 mGy/h
Long lived waste	Category IV	> 4000 Bq/g of alpha emitters and other long lived beta emitters

4. TREATMENT

4.1. Liquid waste

The liquid effluents from sumps, laboratories and the decontamination of active areas and equipment are treated using chemical precipitation methods based on the coagulation, flocculation, and separation approach. This strategy is mostly used for the treatment of liquid effluent from research establishments and reprocessing plants. Most of the long lived radionuclides are co-precipitated as hydroxides, carbonates and phosphates. The precipitated particles are settled in clarifiers. The precipitates are separated using sedimentation, filtration and centrifugation. This approach can be used in combination with other more efficient methods. Laboratory tests are carried out to establish the correct conditions for operation and chemical dosing using samples of the real radioactive waste to be treated.

4.2. Solid waste

One of the important aims in the treatment of solid waste is to reduce the waste volumes as much as possible for further storage or disposal and to concentrate and immobilize the radionuclides contained in the waste. The volume of low activity long lived waste is reduced by compaction, size reduction, decontamination and acid digestion.

4.2.1. Compaction

Volume reduction of low level solid waste by compaction achieves an increase in the overall density of the material. This mechanical volume reduction method is widely used in waste treatment. Volume reduction factors obtained depend largely on the waste material and the pressured applied, but in general are between 3 and 10.

On the basis of economics and practice, compaction can be divided into two main categories, i.e. low pressure and high pressure units. The force applied can vary between 4.5 and 1500 MT. Pressures vary normally between 2 and 800 kg/cm^2.

4.2.2. Size reduction and decontamination of bulk solid waste

More complicated and more expensive techniques are applied for the management of large and bulky equipment. Gloveboxes, master–slave manipulators and other process equipment, that are often contaminated with plutonium, are dismantled and decontaminated in special treatment facilities.

4.2.3. Acid digestion

Low active long lived solid waste, requires special treatment due its to high toxicity and a tendency to become airborne. Acid digestion processes for cellulose and plastic waste, comprise: H_2SO_4 + HNO_3 and H_2O_2 + H_2SO_4 digestion in the presence and absence of catalysts such as iron and selenium.

4.3. Immobilization of concentrates

The chemical sludge from effluent treatment must be transformed into solid products for final disposal. Immobilization processes involve the conversion of concentrates to chemically and physically stable forms that reduce the potential for migration or dispersion of radionuclides from the waste during storage, transport and disposal. From the different waste treatment processes, the waste concentrates are in the form of sludges and volume reduced solid waste.

Various techniques have been developed for transforming aqueous concentrates into a solid form. Solidification of concentrates and filter sludge in a matrix is necessary for final storage because the potential contamination of ground water due to leaching of the waste cannot be completely excluded if simple packaging is used.

Many matrix materials are used for incorporation of concentrates arising from nuclear power plants and other nuclear facilities.

Low activity long lived wastes are usually fixed in a cement matrix. The main reasons for using cement are:

(a) Relative simplicity of handling;
(b) Extensive experience available in civil engineering operations;
(c) Availability of raw materials;
(d) Relatively low cost;
(e) High density(shielding effect) and the mechanical strength of cement products;
(f) Compatibility of water with the matrix material.

To improve the specific properties of the waste form, compatible additives can be used. Cementation processes for nuclear waste immobilization, with and without additives, have been used on an industrial scale for several years all over the world. In India, an in-drum mixing process is used. In this process, cement, liquid concentrates and any additives, if required, are fed into a drum/container, which is also the final shipping container. In the container, the components are mixed using retrievable or disposable stirrers until a homogeneous mixture is obtained. After mixing, the cement composite is allowed to set. In the case of solids, premixed cement grout is added.

The flow diagram of the facility for the treatment of long lived alpha waste under construction at Kalpakkam is shown in Fig. 1.

5. INTERIM STORAGE FACILITY

The long lived waste is generally stored before it is treated. Also the long lived waste is stored after fixation before being transferred for final disposal. Unconditioned waste is stored in double containment and the interspaces are ventilated. The activity of the air in the workplace is monitored regularly. The facility is also used for the interim storage of conditioned waste. Figure 2 shows the layout of the facility at Bhaba Atomic Research Centre (BARC), Trombay.

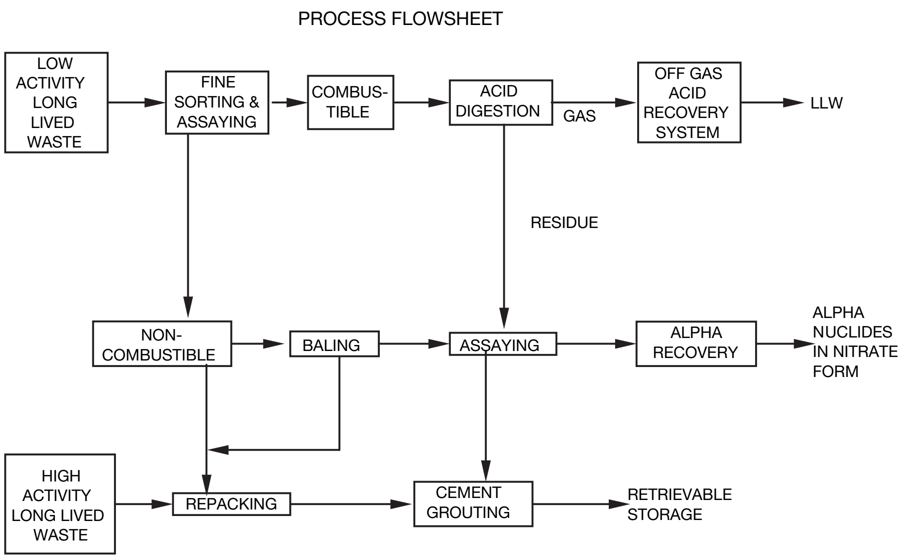

FIG. 1. Management of long lived radioactive solid waste at Kalpakkam.

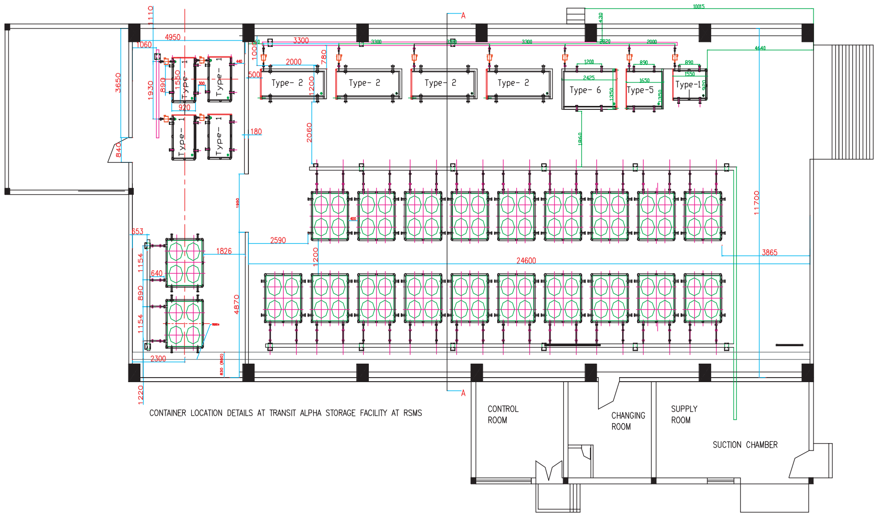

FIG. 2. Layout of interim storage for long lived solid waste.

6. DISPOSAL OF WASTE

The basic principle followed in the disposal of conditioned long lived radioactive waste after its treatment is that the radionuclides contained in the waste should not enter biosphere until they decay to safe levels. The philosophy for discharges, based on the recommendations of the International Commission on Radiological Protection, is that at no time should the discharge of effluent result in public exposures of more than 1 mSv/a.

6.1. Disposal into the aquatic environment

In planning the discharge of treated radioactive waste into water bodies or the marine environment, an elaborate pre-operational survey is conducted to find the critical radionuclide, the critical path through which it can reach man and the allowable body burden. On the basis of all of the above parameters, the site specific maximum permissible concentration (MPC) limits are derived. For example, at the Kalpakkam site, the discharge limit for short lived waste, which contains beta emitters, is 0.74 MBq/m^3, while for long lived waste, which contains alpha emitters, the limit is 29.6 kBq/m^3.

The important aspect to be noted with respect to the disposal of radioactive waste into the aquatic environment is that the MPC limits recommended for radionuclides are very stringent as compared to those for their inactive isotopes. The MPC limits are applied to the effluents in the discharge and no allowance is made for the dilution of the effluent by the water bodies.

6.2. Disposal into the ground environment

While short lived radioactive waste is disposed of in shallow land disposal facilities, long lived waste is currently stored in a retrievable form for ultimate disposal in a deep underground repository.

6.2.1. Shallow land disposal facilities

Ground disposal and interim storage facilities are located in specially chosen areas and are completely surrounded by a security fence. Some of the typical ground disposal facilities are described below.

(a) Earth trenches: These are excavations made in the disposal site with suitable slope. The dimensions are fixed according to subsurface conditions and operational convenience. Only potentially active waste having surface dose rates of less than 20 mR/hr is disposed of in these trenches.

(b) Reinforced concrete trenches: These trenches are reinforced cement concrete constructions and are usually 2 m deep, 1 m wide and 50 m long. Additional waterproofing to the outside concrete walls has been found necessary. Higher active immobilized solids and sludge are disposed of in these trenches. When full, the trench compartments are concreted on top giving enough shielding to reduce sufficiently the radiation dose rate on the surface. Waste having long lived activity concentrations of less than 4000 Bq/g is disposed of in the trenches. Further details are shown in Fig. 3.

(c) Tile holes: Tile-holes are generally 1m diameter concrete pipes with a steel lining driven to a depth of 3 m below the ground surface. All the external surfaces of the tile holes are provided with additional waterproofing. They are used for the disposal of long lived low activity waste as well as high active solid waste in retrievable form. Figure 4 shows the details of the tile holes.

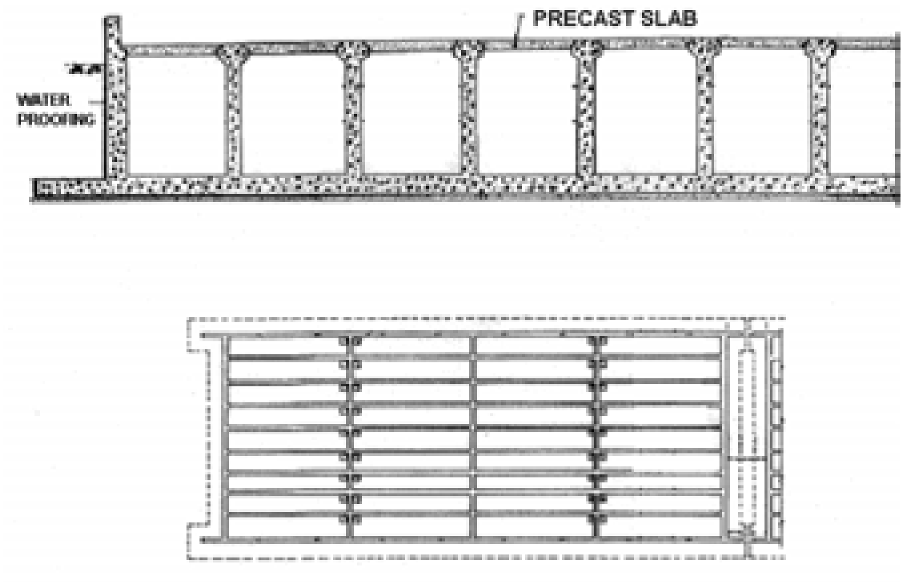

FIG. 3. Layout and plan (one battery) of reinforced concrete trenches.

7. ENVIRONMENTAL ASPECTS

Even though steps are taken to evaluate the suitability of a disposal site before its selection, the surveillance of the biosphere and the study of the potential impact of radioactive waste on the environment are essential. For monitoring of the environment a series of bore wells are drilled around the disposal site and water samples are collected for periodic analysis. This enables the moving fronts of any leaking pollutants to be located and prompts the implementation of remedial measures to prevent the radionuclides entering sources of underground water. In addition to the water samples, soil samples are also collected in and around the disposal site.

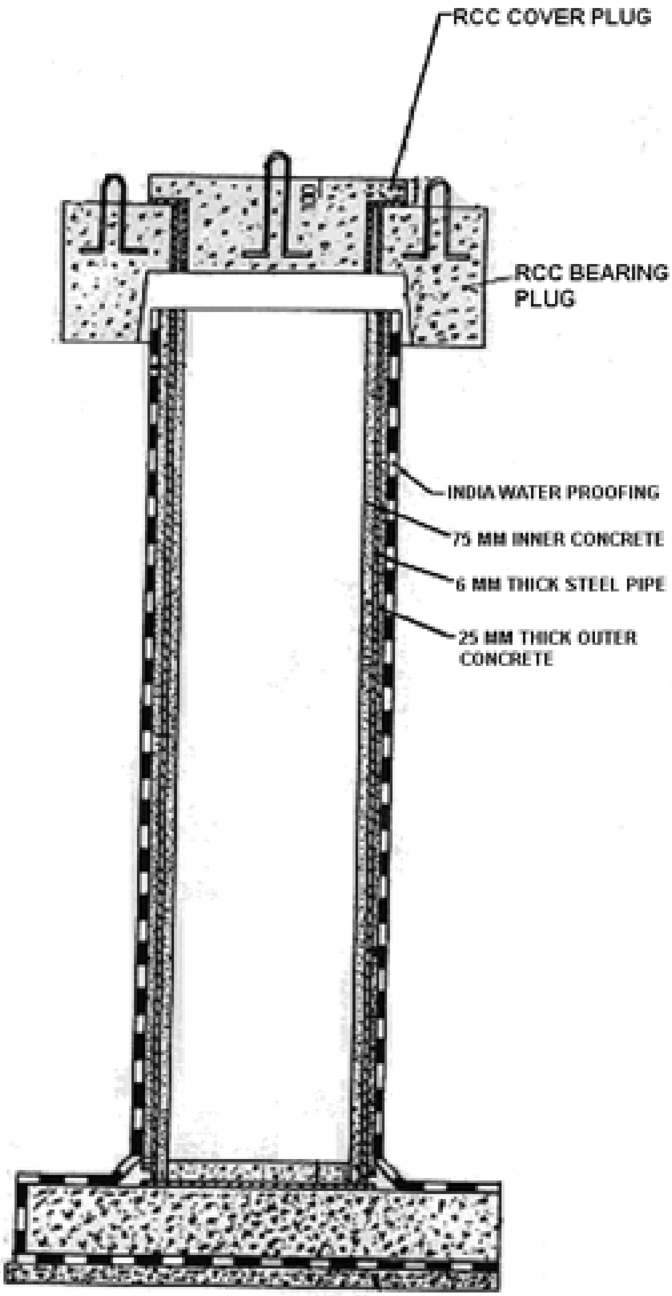

FIG. 4. Layout and plan (one battery) of tile holes.

DISCUSSION

G. JACK (Canada): Does the Atomic Energy Regulatory Board of India regulate natural long lived low level waste and artificial long lived low level waste to the same standard?

K.B. LAL (India): At present, yes. However, it is in the process of formulating new guidelines.

Personally, I feel that the toxicity of radioisotopes depends on their physical properties and not on their origin — that is to say, on whether they are natural or artificial. In my view, the same standard of safety has to be maintained.

MANAGEMENT OF NORM WASTE AT THE SILMET PLANT IN ESTONIA

M. LUST
Estonian Radiation Protection Centre,
Tallinn, Estonia
Email: merle.lust@ekk.envir.ee

Abstract

The paper gives an overview of the development the management system for the waste containing naturally occurring radioactive materials (NORM) arising from the production of the rare earth and rare metals in the Silmet plant at Sillamäe, in northeast Estonia. This development has taken several years and it provides an example of the changes in management approach due to the changes in circumstances and regulatory requirements. It is also example of good dialogue between the operators and regulators.

1. BACKGROUND OF THE PROBLEM

The Sillamäe Metallurgical Plant is located at Sillamäe, in northeast Estonia, about 190 km from Tallinn (Fig. 1). The plant was built in the late 1940s. The target product was uranium, to be used for needs of Soviet nuclear programme. From the launch of the plant until the early 1950s, local Estonian alum shale was used, but the plant then switched to the processing of ores of a higher uranium content from other central and eastern European countries, because the local ore was no longer competitive. Uranium ore processing was continued until 1977, after that, until 1990, the plant refined nuclear fuel (enriched uranium), produced in Russian plants. Waste arising from uranium production was stored in a depository located near the Sillamäe plant, 20–50 m from the waterline of the Baltic Sea.

From the early 1970s a new production line was introduced at the plant. Rare earths, niobium and tantalum were produced from loparite and ore containing naturally occurring radioactive materials (NORM). Later, (until the present) rare earths were produced from a rare earth chloride mix [1]. The composition of the raw materials varies depending on the deposit. Niobium and tantalum are usually combined with iron, tin, titanium, manganese, and radioactive elements (uranium, thorium) and their decay products. The composition and amount of the waste from the processing depends on the

FIG. 1. Location of the Silmet plant.

share of each raw material type in the total amount of raw material being processed. As the waste contained small amounts of thorium and uranium as well as the products of their decay, it was dumped together with other waste on the uranium tailings pile near the plant (Fig. 2). Since 1990, the main activity of the plant has been the continuation of the production of niobium and tantalum metals and light rare earth metals as well as compounds from various imported ores, e.g. columbite.

Until 2004, all radioactive waste from the rare earth and the rare metal production was dumped in the tailings pond. In 1999, the European Union's PHARE project was started in order to remediate the tailings. The Sillamäe Tailings Pond Remediation Project [2] required the discontinuation of the discharge of any waste, including dry radioactive waste, to the tailings pond after 2004. This means that tailings pond is no longer available for dumping the radioactive waste produced by the plant. It followed that there was a need to develop new waste management options for the waste.

Any future radioactive waste arising will be caused exclusively by the production process of Silmet [3]. The volume and activity of radioactive waste for storage and disposal depend on:

FIG. 2. Sillamäe depository for radioactive tailings at the beginning of 2000 [2].

(a) The content of radionuclides in the raw materials;
(b) The amount of processed raw materials;
(c) The waste management system.

The Board of the AS Silmet Group decided to develop a new waste management system based on international radiation protection and radioactive waste management principles. The most important problem for radioactive waste management in Estonia is that there is no existing storage facility or repository suitable for the kind of radioactive waste generated at Sillamäe. Solutions based on the Dutch experience have been considered. The Estonian Radiation Protection Center has also been an active player in the development of suitable radioactive waste management concept.

2. SITUATION IN 2001–2003

The radioactive waste management system developed during this period included radioactive waste separation at an early stage of the process. All radioactive waste was to have been treated and conditioned together; it was to have been washed to remove water soluble impurities, dried to the required moisture content, packed and stored in an interim storage facility of a modular type. Construction of the interim storage facility was planned to be located at the Silmet site. The waste was to be stored in dry conditions at the interim storage facility for 50–100 years in immobilized form. It was expected that after the expiration of this period, the waste would have been used as a feedstock for further processing or disposed of in a final repository [4]. For the final disposal stage, the vitrification option was considered for the waste.

The volume of the radioactive waste was estimated to be, at a maximum, 2000 t/a, before vitrification. The specific activity of non-vitrified radioactive waste was estimated to be about 7000 Bq/g. The vitrified radioactive waste would have been disposed of in the existing oil-shale ash storage pile of the local power plant located at the western side of the tailings pond dam. This solution would have represented, in practical terms, a final near surface disposal of vitrified long lived radioactive waste but it needed detailed specific investigations and, first of all, investigations of the long term radiological safety.

However, after the 11 September 2001 events and due to the changes in the world market for rare earth metals, the vitrification option was abandoned for economical reasons. Also, the introduction, in 2001, of the Environmental Impact Assessment (EIA) [5] process also influenced the proposal for a new waste management system. The proposed waste management system was accepted but with a condition by the Ministry of the Environment that NORM waste management should be covered more thoroughly in the EIA. The first EIA did not provide enough information about the proposed management system and, also, there were no proposed guarantees for financing the work [6]. This EIA process was a good lesson for both sides and, since the end of 2002, there have been active discussions between the operators and the regulators.

3. CHANGES IN 2003–2004

In the spring of 2003, the Silmet plant implemented the new EIA process; this time it covered only the NORM waste management system. In order to help the process, the regulator provided the plant with the proposed topics and questions that should be included in the preliminary EIA programme or be answered during the EIA process. According to Estonian legislation, this programme had to be discussed with the local community. The concern of the community was mostly connected to the future, “What are the guarantees that the waste will not stay in interim storage indefinitely and become the actual final disposal option?” To meet the public concerns, the EIA programme was amended and the future waste management aspects were addressed more deeply. This EIA process was completed in June 2004 and the proposed NORM waste management system was accepted.

TABLE 1. DATA ON THE ESTIMATED WASTE PRODUCED

Production line	Average amount of waste produced from reprocessing of 1 t of raw material (kg)	Average activities of the waste (Bq/g)	Annual estimation of the waste amounts (t)
Rare earth metals	300–350	4300	1400
Rare metals	170–200	2300	600

The starting point for the process was as follows: up to 2000 t of NORM waste, with the activity concentrations in the range 3000–4000 Bq/g, were produced annually. Data on the waste are given in the Table 1. This waste was planned to be stored temporarily outdoors in drums before the interim storage was completed. It would then be kept in the storage for about 50 years, during which time there would be enough material collected such that it might be of some interest to the reprocessing companies in the Russian Federation. According to the Silmet company, the process for finding a solution for waste disposal should start only after 50 years, if, and when, it is clear that there is no possibility of selling this material for reprocessing.

During the process there were active discussions between involved groups and there have been resulting changes in the management plans. The Board of Silmet realized the seriousness of the problems concerned with the management of the waste. In order to minimize the amount of waste produced, the plant started to use raw materials with lower concentrations of radionuclides and this has resulted the decrease of the radioactive waste produced annually by more than 10 times. For the production of rare earth metals, the raw material used contains natural radionuclides at concentrations below exemption levels. For the production of rare metals some radioactive raw material is still used and this causes the production of the NORM waste. The estimated amount of the waste produced is now about 60 t/a [7]. This waste is produced from reprocessing raw material containing columbite and tantalum and the activity concentration can be up to 300 Bq/g.

Three different storage packages were investigated:

(1) Concrete containers with the measurements of 1.63 m × 1.63 m × 1.35 m, which could contain up to 2.1 t of solidified NORM waste. If there were 4 layers of the containers, it would be possible to store 3.15 t of waste on an area of 1 m^2.

(2) Containers used in sea transportation, where the waste would be stored in plastic bags.
(3) Metal drums, which have a plastic layer inside. The volume of the drum is 0.43 m^3.

After several assessments and practical experiments, it was decided to adopt the last option. Because the waste contains ^{235}U and ^{232}Th and their decay products, the radon problem was identified as one of the most important factors in deciding on the most suitable storage option and defining the conditions for the drums and the storage. In the process of finding the solutions to the radon question, Silmet made several investigations and came to conclusion that the best solution would be to use a double package, which should avoid the leakage of radon for at least 10 years. Radon gas is one of the biggest contributing components of the dose to radiation workers. However, the drums that were to be used for the waste were not corrosion tight, so they had to be reprocessed by Silmet to improve their quality.

The first stage of the EIA resulted in the estimation of very high doses for the radiation workers, with several estimated doses over 20 mSv per year. Based on these results, all input data was checked and several additional measurements were made to obtain more realistic information about the situation. At the beginning of the assessment process, not too much data were available, so in the assessments many default values and conservative estimates were used, which caused a significant overestimation. One of the main issues discussed during the EIA process was the actual inventory of the radioactive substances in the raw materials and their movement into the NORM waste through the refining process. In the second stage, actual measured data were used as much as possible and also some additional protective measures were introduced. As a result, the dose estimations in the second stage showed a significant decrease, the average annual doses for the radiation workers were under 4 mSv. The maximum annual estimated doses (around 15 mSv) were for the workers in the packing facility. To avoid accumulating significant doses, the workers would stay in the area for limited periods and they would be used in the other processes of the plant.

During the safety assessment, several accident scenarios were considered:

(a) The falling and breaking of the drum containing the solidified NORM waste in the packaging area or during the transportation;
(b) The falling and breaking of the drum containing the solidified NORM waste in the interim storage area;

(c) A fire during the storage of raw material or during the interim storage of NORM waste;
(d) The release of the material in the production process.

The new waste treatment facility was finished at the end of 2003 (Fig. 3). The waste is heated to around 500°C in order to make it insoluble and after cooling it is packed into 430 L drums. The conditions for the waste packages are as follows:

(a) The activity concentrations in NORM waste should be less than 1.4% for uranium and 2.5% for thorium;
(b) Maximum dose rate close to the container is 50 μSv/h;
(c) α contamination on the surface of the container has to be less than 10 particles/min/cm^2 for removable contamination and 5 particles/min/cm^2 for fixed contamination.

The closed airtight drums will be transported to the interim storage facility, where they can be stored for a maximum of 5 years. The building for interim storage was completed in October 2004; it can hold up to 5000 drums of waste. Until then, the drums were stored out of doors in sea containers.

4. RADIATION LICENCE FOR THE SILMET PLANT IN 2004

In the Spring of 2004, the Silmet plant applied for a new radiation practice licence, which was received in July 2004. A major part of the raw material imported contains such low radionuclide levels that it can exempted

FIG. 3. Renewed processing lines in the Silmet plant and the cutting of the pipes used for transportation of NORM waste to the tailings (2003) [8].

TABLE 2. CONDITIONS IN THE RADIATION LICENCE FOR THE PRODUCTION OF RARE METALS

Production line	Annual maximum amount allowed according to the licence (t)	Maximum activity concentration (kBq/kg)
Rare metals	48	300

from the Radiation Act [9]. The production process was therefore divided into two parts: production of the rare earth metals and rare metals using the raw material under exemption levels and production of the rare metals using the radioactive raw material. The first production line is still under regulatory control because the plant uses the old technological lines which have not been fully cleaned. The plant has intention to clean these parts so as to be able to release of the total production line from regulatory control. The waste produced through this process can be released after some additional studies have been made, as it does not cause significant impacts on the environment. The first measurements have been made and according to the conditions set out in the radiation practice licence, the plant has to present the plan for the release of the production line in 2005. For the production of the rare metals from radioactive materials, the conditions in the licence are shown in Table 2.

The plant has a functioning power plant, which uses local oil-shale for producing energy. The estimated annual production of the oil-shale ash is around 100 000 t and it is disposed of in the local storage. The wastes produced from exempted raw materials will be mixed with the oil-shale ash, which was produced in the local power plant, and then dumped into the existing oil-shale ash storage. The oil-shale ash contains several radionuclides (Table 3). The storage is separated from the sea by a watertight dam.

TABLE 3. AVERAGE ACTIVITY CONCENTRATION IN THE LOCAL OIL-SHALE ASH [10, 11]

Radionuclide	Activity concentrations (Bq/kg)
Ra-226	48–78
U-238	48–64
U-235	2.2–3.0
Th-232	23–30
K-40	530–1100

By the end of 2005, the plant has to present a finalized plan for the future management of the waste produced from the radioactive raw material. The preliminary options, given in the EIA, now need more thorough investigations. One of the options is preparation of a near surface disposal facility for the waste currently in the oil-shale ash storage.

5. CONCLUSIONS

The outcome of active discussions involving local stakeholders and dialogue between the operator and regulator has been the development of the waste management system. The Silmet plant, which came from the Soviet system, has changed its views about environmental issues and has shown goodwill in developing the new management system. There is still a need to find a solution for final waste disposal, but the options have already been listed and the relevant studies have started.

REFERENCES

[1] Company History, Silmet group homepage http://www.silmetgroup.com/allframe_assilmet.htm (in English).

[2] The depository for radioactive tailings, Ecosil homepage http://www.ecosil.ee/?page=46 (in English).

[3] CASSIOPEE, Draft Report of project: Drawing up and evaluating management strategies for radioactive waste in Estonia (DG Environment Contract B7-032/2000/287052/MAR/C2) (2002).

[4] BEHRE DOLBEAR & COMPANY, INC, Feasibility Evaluation For Conceptual Determination of Waste Managment Alternatives at AS Silmet, 2002.

[5] Environmental Impact Assessment and Environmental Auditing Act, entered into force 1 January 2001, http://www.legaltext.ee (in English).

[6] E-Konsult, EIA Final Report for Waste Managment System at AS Silmet, 2002.

[7] E-Konsult, EIA Final Report for NORM Waste Managment System at AS Silmet, 2004.

[8] KAASIK, T., SIINMA, A., Sillamäe Uranium Process Site, SIUS follow-up seminar, Twelve years of co-operation in the field of radiation protection, November 2004.

[9] Radiation Act, entered into force 1 May 2004, http://www.legaltext.ee (in English).

[10] REALO, E., REALO, K. AND JÕGI, J., Releases of natural radionuclides from oil-shale-fired power plants in Estonia. - *J. Environ. Radioactivity* **33,** 77–89 (1996).

[11] REASO, K. AND REALO, E., Radionuclides in Estonian oil-shales and oil-shale ashes.-In *Proceedings of the IRPA Regional Symposium on Radiation Protection in Neighbouring Countries of Central Europe,* Ed. J. Sabol, Prague, 1997. p. 161–164.

DISCUSSION

J. LORENZEN (Sweden): What is the reason for heating the material to 500°C before closing it for airtightness?

M. LUST (Estonia): The waste is heated before being put into the drums in order to dry it and to make it insoluble in the later phases.

PANEL

(Session 4)

DO WE HAVE ADEQUATE SOLUTIONS FOR THE DISPOSAL OF LONG LIVED LOW ACTIVITY WASTE?

Chairperson: **M.V. Federline** (United States of America)

Members: **W. Goldammer** (Germany)
B. Cessac (France)
P. Varskog (Norway)
T. Eng (OECD Nuclear Energy Agency)

Statement

W. Goldammer
Köln, Germany
Email: w.goldammer@epost.de

I would like to summarize the thoughts which the questions raised by the IAEA for this panel have provoked in me. I will be doing that from my German perspective.

The first point is that from a radiation protection viewpoint there is no difference between exposure to natural radionuclides and exposure to artificial radionuclides. A dose is a dose, and that is the basis on which we consider the NORM issue; we don't distinguish between doses from artificial radionuclides and doses from natural ones. Of course, in terms of practicability there are differences, and they have been touched upon in many presentations this week. The activity levels of NORM are different from (very much lower in general) and the volumes are mostly very much higher than those of waste from nuclear installations. There are also differences in terms of what people do with the materials; a lot of NORM and TENORM waste is reused or recycled — for example, as building materials — which has to be taken into consideration when one is designing regulatory approaches to NORM. Then there are economic constraints, which are generally more stringent for NORM and TENORM waste than for waste from nuclear installations; we usually have more funds available for managing nuclear waste. And, of course, there is the public perception issue; people are less afraid of something natural than of something artificial coming from nuclear reactors, which are considered dangerous.

Accordingly, in Germany we have developed an approach for managing NORM and TENORM waste which is risk or dose based; it is not based just on the concentration of radionuclides in the waste and, in that respect, it is somewhat different from the approach presented in the famous IAEA Safety Guide RS-G-1.7. That IAEA document uses, for natural radionuclides, concentration limits derived from the UNSCEAR data on concentrations in natural soils. Our risk based approach is much closer to what Mr. Janssens described as the EU approach to clearance and exemption for natural radionuclides.

However, in order to address the special issues that NORM waste poses, we use optimization of radiation protection as a very important principle, to provide flexibility. That is why the regulations we are using for NORM waste are somewhat different from those for the nuclear fuel cycle.

I will give a very brief overview of our regulatory approach to NORM and TENORM. We use a dose criterion of 1 mSv/a. We cannot use 10 μSv for clearance or exemption — that would not be possible for NORM, as we all know, because the doses received from these radionuclides as part of natural background radiation are higher. On the other hand, we didn't think we could use a higher criterion than 1 mSv/a, because it wouldn't be prudent to say that the public should not be exposed to more than 1 mSv/a from reactors but then to allow them to receive more from NORM waste.

This criterion applies to TENORM which is newly arising, so it applies to, for example, the iron and steel industry and the phosphate industry, but it also applies to legacy waste, and in Germany we have very large amounts of legacy waste from uranium mining. The third largest uranium producer in the world was located in the former Germany Democratic Republic, and we have hundreds of millions of cubic metres of mining wastes from that source.

In order to take account of the special problems that NORM poses, we strongly believe that dose assessments have to be as realistic as possible; we can't afford the luxury — which one can afford in the nuclear context — of being very conservative in order to convince people that everything is really safe. We can't do that because the margin is too small. Doses to the public from NORM are often already of the order of 1 mSv/a, and so we have to be as realistic as possible in order to have practicable and economically reasonable regulations.

In our regulations we try to be very flexible, prescribing activity levels for different types of disposal that depend on, for example, the volume of the material to be disposed of and activity levels for different types of recycling. The prescribed levels are as low as 0.2 Bq/g, which may sound very low, but I can assure you, based on many measurements we have made in our east German mining area, that, if you have large enough volumes, levels above 0.2 Bq/g can give rise to exposures of 1 mSv/a and above. The prescribed value of 0.2 Bq/g isn't the total activity; it is the maximum activity of any of the radionuclides in the natural decay chains.

As an aside, many of you know that some new ICRP recommendations are being drafted for publication in 2005, and ICRP gives a level of 1 Bq/g as a general exemption level for natural radionuclides. We don't think that that it is quite appropriate, because, if you have large volumes of material the associated public dose will be too high and it will be necessary to go even lower to control doses appropriately.

We put strong emphasis on optimization. We not only prescribe levels but also give people plenty of optimization 'degrees of freedom' in order to really take into account the costs and benefits of what is being done, because we want our regulations to be as practicable and as economically reasonable as possible.

In conclusion, I should like to make three points. The first relates mainly to the new TENORM regulations we have. As I indicated, they provide quite flexible criteria for disposal or recycling plus optimization. This allows us to regulate TENORM without unjustifiable economic consequences. Of course, in the beginning, when these regulations were drafted, our nuclear industry wasn't too happy about them, but after an extensive discussion process it said that the costs arising from them were acceptable.

My second point is that, if you have hundreds of millions of cubic metres of low activity or very low activity mining waste on the surface of the earth, you simply can't get rid of it by putting it underground, so it has to stay above ground. The radioactive half-lives are extremely long and long term stewardship is therefore inevitable. We shall have to provide for such stewardship, passing on information to future societies, introducing passive controls such as land use restrictions and organizing active surveillance and maintenance. Otherwise it will not be possible to protect people.

Thirdly, I think TENORM can be managed within a risk based framework like the one we use for other radioactive waste. However, in order to take account of the specific problems that TENORM waste poses we have to optimize radiation protection as allowed for in the basic radiation protection principles.

Statement

B. Cessac
Institut de Protection et de Sûreté Nucléaire,
Fontenay-aux-Roses, France
Email: bruno.cessac@irsn.fr

The different papers presented this morning highlighted the fact that the management of naturally radioactive waste was a source of discrepancies and inconsistencies regarding disposal routes and regulations.

I shall take as an example the French situation and explain what is, to my mind, the principal problem with the management of this waste type and its acceptance by the public.

In France we have three categories of naturally radioactive waste: (1) uranium mill tailings, (2) radium and thorium bearing waste, and (3) NORM and TENORM. The three categories differ as regards specific activity, amounts and disposal routes.

To my mind, the principal problem is not really the inconsistencies between the different regulations or the competent authorities. If I take the example of France, at present, the management operations are reasonably under control, even if some problems are still arising — as everywhere.

The main issue to my mind is the long term impact assessment, which in France is still under investigation. For uranium mill tailings, we are just at the stage of thinking about the scenarios that we have to take into account. The long term management of this waste relies only on land use restrictions for the moment.

The case of NORM and TENORM is probably the worst. In France, the management of this waste type is based on the principle that it can be handled like conventional waste, without any radiation protection precautions, and so for long term management we have complete rejection of the concept of disposal facilities as a means of long term management.

So for me it is a big problem. Maybe it's a pessimistic view, but I think we have to focus our efforts on the long term aspects of management if we want to have the acceptance of the whole population for the management of this waste type.

Statement

P. Varskog
Norse Decom, Institute for Energy Technology,
Kjeller, Norway
Email: per.varskog@norse-decom.no

In oil production we have a type of TENORM which is usually called low specific activity (LSA) scale. It arises from the co-precipitation of radium with barium and strontium to form sulphates inside the production equipment — particularly the production tubes and valves and oil–water separators.

The oil industry recognized this as a problem in the early 1990s, and, since then, the problem has been addressed in the normal health and safety procedures of the industry. There is a set of procedures to identify, handle and transport the material. Everything that is done in the oil industry is procedure-driven, so the main way of regulating this activity is to write down proper procedures.

In Norway, we have an exemption limit for LSA scale that is set at 10 Bq/g for each of the radionuclides ^{226}Ra, ^{228}Ra and ^{210}Pb, and the crucial question is always "Is it above or is it below?" If it's above, it's handled as radioactive material; if it's below, it's classified as free of radioactivity, but then it is classified as hazardous waste because of its content of oil and heavy metals. So it is not unregulated; it will go to a different type of repository or storage facility.

Today, there is no final solution for the LSA scale in Norway. We have no repository. There are two commercial vendors offering a repository solution, and I think that at the end of next year there may be an LSA scale repository in Norway.

The typical activity concentration of the Norwegian LSA scale is 10–100 Bq/g of ^{226}Ra; the average is around 20 Bq/g. The typical doses to workers are 0.1 mSv/a for an offshore worker and 0.8 mSv/a for an onshore worker.

Statement

T. Eng
OECD Nuclear Energy Agency,
Issy-les-Moulineaux, France
Email: torsten.eng@oecd.org

I will first address the question "Are we actually dealing with the long term hazards associated with the disposal of long lived radionuclides?" For the disposal systems that we all now have in mind, we are considering state of the art technical barriers adapted to the radionuclide content in question. So, for very many types of waste, I would say that we have adequate solutions.

We are also doing safety assessments showing the safety margins of these different systems to the public, to the authorities and to the world in general.

What more can be done? How can we transfer information about what we are doing today to future generations so that they can take their own conscious decisions?

Stewardship means all the activities necessary to maintain long term protection. But will this stewardship work? For a while — probably yes, but there are no guarantees for the long term future, and with high probability it will fail sooner or later. But, if it fails, will the waste pose a health hazard? That is hard to say. Probably not. So what can we do? The best we can do today is simply to do our best.

As to the question of storage versus disposal, it always comes down to the fact that, for long term storage, something has to be done in the future — we will have to transfer responsibility to future generations. Active surveillance will be needed, and the sustainability of this option will depend on future generations and their actions. On the other hand, with disposal, if done in the right way, there would be no need for active, long term surveillance; there would be no legacy requiring actions by future generations. There are lots of other factors, but these are the basic ones when we consider the question of storage versus disposal.

DISCUSSION

DO WE HAVE ADEQUATE SOLUTIONS FOR THE DISPOSAL OF LONG LIVED LOW ACTIVITY WASTE?

Session 4

M. FEDERLINE (United States of America – Chairperson): I would like us to focus on the questions which we have been asked, leaving the main question — "Do we have adequate solutions?" — until the end. Let us start with "How do the technical and regulatory approaches compare for NORM waste versus the nuclear fuel cycle, and should they be consistent?" I would mention what I have heard — the rebuttable response — "There are very different regulatory and technical approaches, but the public seems to be quite happy with that." As waste management experts, do we accept that? What is the feeling of the panellists and the audience? Are we comfortable with the differences that we see in the way NORM is treated?

M.I.F. PAIVA (Portugal): I don't think we should be pleased with the present lack of harmonization. During the poster session, I saw two posters from two different EU countries where NORM waste was classified quite differently. In one case, uranium mining and milling waste was classified as NORM waste and in the other it was classified as uranium mining and milling waste. Different classifications imply different technical procedures and different management schemes, and I don't think that is a good thing.

M. FEDERLINE (United States of America — Chairperson): I understand Ms. Paiva to be calling for harmonization for radiation protection reasons. From other participants I have heard that the public, which would prefer to dictate solutions, is not so interested in the harmonization of standards in, say, the United States and France.

J. COCHRAN (United States of America): My personal experience is that the public believes there to be good radiation (for example, the radiation used in medicine) and bad radiation (from nuclear weapons and nuclear power generation and possibly from uranium mining) and that the public has different perceptions of risk when it considers them. We technical people (as indicated by Mr. Goldammer) believe that radiation is radiation and that technically harmonization makes a lot of sense, but that's not how the public sees it.

J. LORENZEN (Sweden): Mr. Goldammer indicated that he say no difference between the artificial and the natural sources of radiation. However, we have 10 μSv/a as a regulatory value for artificial radionuclides and 1 mSv/a for natural radionuclides. I don't understand this difference.

Ms. Federline talked about the public seeming to be quite happy with the existence of very different regulatory and technical approaches. I don't know where that view comes from, because, when we at Studsvik offered to treat LSA scale, our offer was rejected by the oil industry representatives, who didn't want any connection between their industry and the nuclear sector to be seen by the public, as that would be bad for business.

W. GOLDAMMER (Germany): Like many other countries, Germany is clearing radionuclides from nuclear facilities on the basis of 10 μSv/a and NORM on the basis of 1 mSv/a. I fully appreciate that there is a contradiction, but for me it is simply a matter of practicality, because it is quite impossible to regulate NORM on the basis of 10 μSv/a. With all the money in the world you could not do it.

One could argue that, if we can't do better with NORM, we should not be so strict with radionuclides from nuclear facilities. But I think that what we do can be justified in terms of optimization — in terms of costs and benefits. Regulating the radionuclides from nuclear facilities on the basis of 10 μSv/year is expensive, but the cost is bearable and, of course, there is the issue of the public acceptance of nuclear power generation.

In the case of NORM, we find that regulating on the basis of 1 mSv/a, we can achieve a reasonable level of protection by spending a large but bearable amount of money.

So, it is not complete harmony, but I think the approach is consistent — a risk based approach with some optimization in terms of the costs and benefits of what we are doing.

M. FEDERLINE (United States of America — Chairperson): Perhaps, at these very low levels, we should be focusing on optimization rather than on doses limits.

G. SMITH (United Kingdom): Earlier, Mr. Leroy explained the difference between risk based and risk informed decisions and spoke about the extent to which stakeholders can understand technical things like the difference between a sievert and a gray. For them much things are very complicated, but we need to involve stakeholders and gain their acceptance of what is proposed by the technocrats.

To that end, I think we should separate the management objectives of waste management programmes from the protection objectives and from the technical standards. Stakeholders could be invited to join in consideration of the management objectives, and they could be allowed to exert some influence on the protection objectives. Then, when they had gained some practical experience and trusted the process, I think they would accept the technical standards without asking too many questions. I would support any IAEA initiative along those lines.

V. ŠTEFULA (Slovakia): Regarding Mr. Cochran's comment about good and bad radiation, I would mention that in the Czech Republic there is a town, Jachimov, which is a famous spa because of the high level of natural radioactivity there. People visit Jachimov in order to be exposed to the radiation, but those people would be scared if they were told that they were living in houses with high levels of natural radioactivity due to radon.

W. GOLDAMMER (Germany): Jachimov is near the Czech–German border, on the German side of which uranium used to be mined. The German taxpayers are paying some half a billion euros for the remediation of the millions of cubic metres of mining waste, in the midst of which is a small town, Schlema, that has a long tradition as a radon spa, and the radon bath in Schlema was recently reopened.

As a technical expert, I believe that it is the responsibility of technical people to tell people who enjoy radon baths that it's their decision, but also to warn them about the hazards.

Stakeholders should be involved, but, as stakeholders sometimes have rather irrational views, I think that they should be provided at least with a sound technical basis and that we are responsible for developing that it.

M. FEDERLINE (United States of America — Chairperson): Let us now focus on the question "How can we deal with the hazards of long lived waste in a cost effective manner while ensuring the protection of the public and the environment?" What I have heard is that the most cost effective way to deal with those hazards is institutional controls. But how much reliance should we place on institutional controls?

V. ŠTEFULA (SLOVAKIA): I should like to ask a related question. We have a near surface repository in Slovakia, and the waste acceptance criteria have been derived from a safety analysis. The operators want to accept sludges loaded with alpha contaminants for disposal into the repository, their argument being that the waste acceptance criteria will not be exceeded. However, I have my doubts and ask myself "Should we deliberately introduce long lived radionuclides into the near surface repository knowing that it is not intended to last forever and the long lived radionuclides will outlive it? Should we not rather wait until there is a deep disposal facility?"

W. GOLDAMMER (Germany): Coming from a country having to deal with lots of long lived radionuclides that are on the surface, I would say that, if you have a choice, you should wait for the deep disposal facility to become available, because the long term stabilization of long lived waste on the surface is very costly — and institutional controls are essential. In Germany we shall not be able to avoid institutional controls.

M. FEDERLINE (United States of America — Chairperson): There are situations where natural analogues have shown that effective isolation over a long time is possible, so that decisions depend on the environment into which disposal is to take place as well as any supplementary engineering.

P. CARBONERAS (Spain): I would remind you that radiation protection is much more than fixing a numerical limit — 10 μSv/a, 1 mSv/a or whatever.

When I was working on the establishment of a common framework at the IAEA, there was a lot of discussion on this issue. It looks difficult, but it is possible to establish a common framework by using the existing radiation protection system — the one recommended by ICRP and endorsed by a number of international organizations.

When we were establishing the requirements for radioactive waste management, 15–20 years ago, we made a lot of mistakes, because what we ultimately want to do is to set objectives, assess the safety of repositories against those objectives and demonstrate compliance. That is much more than just fixing a number, doing calculations and comparing. We have today some guidance on the proper use of the radiation protection system in radioactive waste disposal. ICRP publications 77 and 81 provide to us, on the basis of the radiation protection system, with a lot of flexibility in using different numbers and different approaches to set the objectives and to achieve compliance. And with that system, the disposal of some long lived waste on the surface is allowed, depending on the kind of waste, the radionuclide content and the objectives set.

So, we should look for a common framework even if the technological solution differs from one country to another.

A.L. RODNA (Romania): I agree with Mr. Carboneras. Of course, it is a question of optimization. If you can put your long lived radionuclides into a geological disposal facility, you should optimize your solution. However, it is wrong to think of a long lived radionuclide as lasting forever. If you have waste acceptance criteria based on an assumed period of institutional controls of, say, 200–300 years and the criteria were derived properly, you do not need to rely on indefinite institutional controls for that long lived radionuclide. We should be careful when considering what the waste acceptance criteria mean.

M. FEDERLINE (United States of America — Chairperson): What I understand from the comments of Mr. Carboneras and Mr. Rodna is that there exists a common framework which will permit the harmonization we are looking for and yet allow for different technological solutions.

R.H. LITTLE (United Kingdom): Regarding the institutional control period, I should like to recall Ontario Power Generation’s proposals for a repository at the Bruce site. We undertook a safety assessment relating to this site and considered four concepts — two near surface facility concepts and two concepts for deeper facilities, one at 460 m and one at 660 m. For both of the near surface facility concepts it was demonstrated that there could be an adequate level of safety in terms of following ICRP guidance and complying with Canadian regulations, in one case by 3–4 orders of magnitude.

However, in Kincardine, the local municipality is pressing for the 660 m deep facility, and it would be interesting if someone from the municipality were here to explain its reasons for doing so. Undoubtedly, the deeper option provides for greater isolation of the waste; even with stylized human intrusion scenarios, you are at least five orders of magnitude below the ICRP 81 levels, and you remove the thorny issue of an institutional control period. With the shallow facilities, even a 100 year instiutional control period would provide adequate safety, but people probably felt rather uncomfortable about any period of institutional controls having to be administered by the municipality.

A further point — the consultation process instituted by Ontario Power Generation is a very good illustration of stakeholder involvement in the taking of decisions about options. The safety assessment approach used was the IAEA’s ISAM approach, which the stakeholders found very transparent and easily understandable and which helped to build stakeholder confidence in the safety assessment and also in the geotechnical work that had been done.

A final point — the people in the municipality have been living with a nuclear power plant in the vicinity for the past 30–40 years and are therefore familiar with the risks posed by radionuclides, so that their risk perception is more balanced.

M. FEDERLINE (United States of America — Chairperson): I would now like to crystallize our thinking about the question “Do we have adequate solutions for the disposal of long lived low activity waste and, if not, what are the gaps that we need to address?”

G. SMITH (United Kingdom): As regards gaps, questions have been raised this week about human intrusion scenarios and terrorism, but it seems to me that most safety assessments ignore malicious intent intrusion scenarios. The argument has been used that such scenarios should not be analysed because we cannot protect people against themselves. But that is not the issue. We may not be able to protect the intruder, but we should be designing facilities in such a way as to minimize the consequences of intentional intrusion for third parties.

In my view, the consideration of malicious intent intrusion scenarios might trigger new ideas about institutional controls and the advantages and disadvantages of going deep.

B. CESSAC (France): I think that in France we are coping reasonably well with the situation as regards uranium mining and mill tailings and NORM and TENORM, but we have not yet started considering the long term. So we have much work to do.

M. FEDERLINE (United States of America — Chairperson): I believe that in the United States we have adequate solutions, but — as Mr. Leroy said — they constitute a patchwork which is not very understandable for stakeholders. I think that, in the United States, we would benefit from having a systematic framework that enables stakeholders to look at the whole nuclear cycle and understand how issues are going to be dealt with.

L. NACHMILNER (IAEA): A year ago, the IAEA initiated a project on disposal approaches for long lived radioactive waste. After two meetings held within the framework of this project, I would say that there are a number of technical solutions for the disposal of long lived low level waste ranging from trenches, through near surface facilities, boreholes and subsurface facilities to geological facilities. It is only a question of the cost of such solutions.

W. GOLDAMMER (Germany): I also think that technical solutions are there, and in my view the approaches that we have taken in Germany for NORM are not too bad and work in practice. So I think there is reason for optimism.

The most important thing needed now (and that brings us back to the patchwork issue) is some kind of international consensus on how NORM should be managed, because the approaches are very different both between and within countries. The IAEA is starting to work on this issue more intensively, and I hope that its efforts lead to an international consensus in the not too distant future.

K. BÉRCI (Hungary): In answer to Ms. Federline's question I would say that in Hungary we have adequate solutions. However, I would also like to make two comments.

First, the nuclear community is a rather closed community, and you cannot sell solutions to society as a whole by talking in the way we are talking here.

Second, for large amounts of long lived waste such as NORM and TENORM, and even for much decommissioning waste, we shall have to rely on permanent controls at the disposal sites and permanent active maintenance. Our mistake was that, due to a desire for perfection, we were too ambitious.

J. COCHRAN (United States of America): In my view, if you believe that stewardship can be maintained indefinitely, you will believe that we have adequate solutions. Otherwise, you will believe that we probably don't have adequate solutions.

In this connection, perhaps we should think a little about intergenerational equity. Are we burdening future generations with risks that would be unacceptable to the current generation?

S.M. WOOLLETT (Australia): A complicating factor that has not been discussed is background dose rates. The reason why there are uranium mines in particular areas is the existence of high uranium reserves in those areas, and in Australia, for example, we have radiation doses of 9 mSv/a in areas surrounding uranium mines. Is it reasonable to regulate down to 1 mSv/a for waste facilities in such areas?

M.I.F. PAIVA (Portugal): I agree with Mr. Woollett. In some parts of northern Portugal the background radioactivity is much higher than in the controlled areas around the uranium mining and mill tailings.

In my view, however, the problem with uranium mining and mill tailings is one of public perception. What is needed is a different approach to the public, which should be told that the major danger from uranium mining and mill tailings and other NORM and TERNORM waste is due not so much to their radiological properties as to their chemical properties.

UNIQUE LOW ACTIVITY WASTE

(Session 5)

Chairperson

D. BENNETT
United Kingdom

MANAGEMENT OF UKAEA LOW ACTIVITY GRAPHITE WASTE

K. LANGLEY, A. GOLDSMITH, J. BUFFERY, M. WISE
UK Atomic Energy Authority,
Didcot, United Kingdom
Email: kevin.langley@ukaea.org.uk

Abstract

The current mission of the UK Atomic Energy Authority (UKAEA) is the restoration of sites used historically for the research and development of nuclear power. Many of the research and development reactors incorporate graphite waste, which require disposal as part of reactor decommissioning. This paper describes the graphite liabilities, and the options and requirements for their disposal, with emphasis on those that potentially fall under the UK definition of low level waste. The UKAEA is currently investigating the possible use of calcination to reduce the tritium and ^{14}C content of graphite.

1. INTRODUCTION

Since the late 1940s, the United Kingdom Atomic Energy Authority (UKAEA) has built and operated a wide range of nuclear facilities for the development of all aspects of atomic energy; they include reactor systems and fuel and reprocessing technology. These facilities, located on sites at Culham, Dounreay, Harwell, Windscale and Winfrith, are varied and complex.

The UKAEA's current mission is the restoration of these sites, including the decommissioning of research and development reactors incorporating graphite, and the management of the resultant waste. In total, UKAEA reactors contain approximately 6000 t of graphite. To put this in context, a 250 MW(e) Magnox reactor contains 2000–2500 t, and a 600 MW(e) Advanced Gas Cooled Reactor (AGR) around 1200 t.

Under the UK system of waste classification, which will be outlined briefly in this paper, most of this waste is intermediate ievel (ILW), although under other, dose based classifications it might be considered as low activity waste. However, some is within the total activity limits for low level waste (LLW), or would be if it were not for the tritium and ^{14}C content. The UK has a single national LLW disposal facility at Drigg in Cumbria, which has specific limits on ^{14}C and tritium that may prevent the disposal of LLW graphite by this route. Reduction of the ^{14}C and tritium content could bring the waste within the Drigg limits or make the waste acceptable for disposal by other routes. The UKAEA is therefore exploring the options for the treatment and disposal of this waste, including calcination of bulk graphite to remove volatile radionuclides.

This paper describes UKAEA's graphite containing reactors, and the status of the associated management and decommissioning programmes. It describes the activity levels of the waste, and the processing requirements for packaging and disposal. The disposal options for the graphite waste are outlined, and the UKAEA's investigations into calcination as a means of reducing volatile radionuclides are described.

2. UKAEA's GRAPHITE LIABILITIES

The UKAEA's main graphite containing reactors are located on the Windscale, Harwell and Dounreay sites, with only small volumes at Winfrith. These reactors will be described briefly in turn, with emphasis on the forms of the graphite, and issues associated with its disposal.

2.1. WAGR

The Windscale Advanced Gas Cooled Reactor (WAGR) was a pilot project for the advanced gas cooled power reactor system. Its purpose was to prove the in-service performance of fuel suitable for a commercial reactor; to serve as a test bed for further development of the fuel and other components; and to provide operational experience of power production [1].

WAGR was a carbon dioxide cooled, graphite moderated and reflected reactor using uranium dioxide fuel in stainless steel cans. The core contained 210 t of graphite in approximately 3000 bricks. The reactor was designed to operate isothermally at a temperature of 350°C, with a power output of 105 MW(th), 33 MW(e).

Stage 1 decommissioning, involving fuel removal operations, commenced immediately after shutdown in 1981. Stage 2/3 decommissioning, involving removal of all significantly contaminated and activated components, is now nearing completion. All in-reactor components, including the graphite, have been removed, and primary vessel dismantling is under way.

Special tools had to be developed for the remote retrieval of the graphite blocks. These included a ball grab for removal of the core graphite, and a self-tapping device for removal of the neutron shield.

The graphite waste is all categorized under the UK system as ILW, and has been prepared for long term storage by encapsulation within concrete boxes. These operations demonstrated the high integrity of the blocks post-irradiation, giving confidence for other decommissioning plans.

2.2. Windscale Piles

The two Windscale Piles (Pile 1 and Pile 2) were air-cooled, graphite moderated and reflected reactors built in the late 1940s for the production of plutonium. Each pile consisted of a 1966 t graphite core, roughly in the shape of a horizontal cylinder, 15.32 m diameter by 7.43 m deep [1].

The Windscale Piles (180 MW(th) each) operated from October 1950 to October 1957, at which time a fire occurred in Pile 1 during a routine Wigner energy release. Following the successful extinguishing of the fire, both piles were shut down and the natural uranium metal fuel and isotope cartridges that could be readily removed were cleared. Some fuel and isotope cartridges remain within the fire affected zone in Pile 1 and some isotope cartridges remain in Pile 2. The UKAEA is currently evaluating and developing options for decommissioning Pile 1 and for removing the Pile 2 cartridges. All of the graphite in the Piles is classified as ILW.

2.3. GLEEP

The Graphite Low Energy Experimental Pile (GLEEP) was built at Harwell in the mid-1940s for research purposes; it was operated between August 1947 and September 1990. GLEEP was a thermal heterogeneous reactor; graphite moderated and reflected, and air-cooled [1]; it used natural uranium metal fuel similar to that in the Windscale piles. The reactor was formed from 13 500 graphite blocks, each 184 mm square and most 737 mm long (nominally 41 kg) stacked in 40 layers.

GLEEP operated at an average temperature of 18°C and a minimum temperature, near to the charge face of the reactor, of 15°C. GLEEP's maximum output was 80 kW(th), but it normally operated at ~3kW.

The power levels of this reactor were very much lower than those of the UKAEA's other remaining reactors, and, as a consequence, the graphite activity is within the limits for categorization as LLW. Calculations have shown that, although Wigner energy may have accumulated, the levels would not be of concern in a storage environment, even if the energy were released.

During the past year, the graphite from GLEEP has been removed block by block, using both the self-tapping device developed for WAGR and a vacuum suction device [2]. Levels of contamination were monitored and were consistently very low. The graphite is currently stored in drums, awaiting confirmation of the disposal route, as discussed later in this paper. In the meantime, the biological shield has been demolished and it too awaits disposal.

2.4. BEPO

Following the construction of GLEEP, a second heterogeneous thermal reactor known as British Experimental Pile 0 (BEPO) was built at Harwell in the 1940s; it operated from July 1948 until December 1968. BEPO was also uranium metal fuelled, graphite moderated and reflected, and air-cooled. The reactor was made from interlocking graphite blocks to form a 7.9 m cube, with 888 horizontal fuel channels on a 184 mm square pitch. The BEPO core contains 766 t of graphite [1].

BEPO operated at a power output of 6 MW(th) for most of its 20 year service. During its operational life, stored Wigner energy was annealed out, but residual energy is still considered to be a potential issue for disposal. Calculations indicate that the graphite is all ILW.

2.5. Materials test reactors

The UKAEA manages three redundant materials testing reactors, all of essentially the same design; they are DIDO and PLUTO at Harwell, and DMTR at Dounreay. All of these reactors were built and started operation in the late 1950s. DMTR was shut down in 1969 and DIDO and PLUTO were shut down in 1990. They were heavy water moderated and cooled thermal reactors with a graphite reflector. The reactors operated at a power output of 10 MW(th), maximum 26 MW(th) (for DIDO and PLUTO) [1].

There is 17 t of graphite associated with the reflectors in each reactor, all of which is ILW.

2.6. Dounreay Fast Reactor

The Dounreay Fast Reactor was built at Dounreay starting in 1955; it operated between 1959 and 1977. The outside of the reactor tank is surrounded by a 1.2 m thick jacket, which acted as a neutron reflector and thermal shield. This jacket contains approximately 200 t of material, which is a mixture of borated carbon and graphite.

Calculations indicate that this jacket would be ILW. The borated carbon has higher impurity levels, and hence activity content, than graphite. It is not clear what temperature the jacket routinely reached and therefore there is some uncertainty about whether Wigner energy is a concern for the graphite; it would not be for the carbon. Similarly, analogies with WAGR indicate that the graphite would still be monolithic, but physical deterioration of the carbon may be more likely. Any boron in the graphite would disrupt the lattice and may make that more friable.

2.7. PFR

The 600 MW(th) Prototype Fast Reactor (PFR) was built at Dounreay in the 1960–1970s to obtain information to support the design of commercial fast reactors. It operated between March 1974 and March 1994. Graphite is present in the neutron shield, which comprises seven rows of shield rods consisting of stainless steel tubes filled with mild steel or graphite cores of varying diameters and lengths. Activation calculations show that efficient shielding by the inner rows has resulted in the activity levels in the outer 1–2 rows being within the limits for LLW by the time of disposal.

3. UK WASTE CLASSIFICATION AND DISPOSAL ROUTES

The UK's system of waste classification is different from other systems in Europe, so it is considered appropriate to outline it briefly. The disposal routes for radioactive waste are also outlined, with emphasis on considerations pertinent to graphite waste.

3.1. Exempt waste

Exempt waste is waste that is excluded from the requirements of the Radioactive Substances Act because its activity or activity concentration is below limits proscribed in either the Act, or the associated Exemption Orders.

The SoLA (substances of low activity) Order exempts solid waste where the material is essentially insoluble and the anthropogenic (human-made) activity concentration does not exceed 0.4 Bq/g; this value is normally taken to be additional to background levels. Other exemptions are provided for naturally occurring radionuclides. None of UKAEA's reactor graphite is within this limit, nor can it be made so.

3.2. VLLW

Very Low Level Waste (VLLW) is defined in Cm 2919, which sets out UK Government policy on waste classification and disposal [3]. It is waste that "can be safely disposed of with ordinary refuse (dustbin disposal), each 0.1 m^3 of material containing less than 400 kBq beta/gamma activity or single items containing less than 40 kBq beta/gamma activity”.

The VLLW category is primarily for organizations, such as hospitals and educational establishments, which are relatively small producers of waste. UKAEA does not currently have any authorizations to use this route directly.

3.3. LLW

Cm 2919 defines LLW as “containing radioactive materials other than those acceptable for disposal with ordinary refuse, but not exceeding 4 GBq/t alpha or 12 GBq/t beta/gamma activity”. There is no distinction between short and long lived isotopes, or consideration of dose coefficients for individual radionuclides, unlike systems in other countries. The activity is taken to be at the time of consignment, so decay storage can, in some cases, be used to reduce the classification of the waste to be within LLW limits.

There is currently only one site licensed to accept UKAEA’s LLW for disposal. It is BNFL’s site at Drigg, near Windscale/Sellafield, which has been operating since 1958. LLW that cannot be disposed to Drigg must be managed as ILW.

Drigg has a rather complicated set of limiting conditions on the radioactive content of waste. These conditions are based the site’s ultimate capacity for key radionuclides, as defined in BNFL’s Post-closure Safety Case, and are further modified in the contracts that waste producers agree with Drigg.

Originally, the Drigg repository was envisaged to last for 30 years, so the annual disposal limits are the total radiological capacity divided by 30. These annual activity limits (shown in Table 1) are divided out between the waste producers based on their expected generation and contract ‘bids’. Drigg charges more for the nuclides with smaller annual limits and less for nuclides with larger annual limits. Consequently, the cost of disposal of 1 GBq of tritium is a few pounds sterling whereas the cost for radium or thorium is nearly £50 000. In the contract negotiation process, each consignor bids for a volume allocation and an activity allocation. The volume allocation has no limit, but activity is allocated as a proportion of the annual limit.

Further limits are effectively set by what are termed ‘trigger levels’. Waste is grouped into ‘streams’, in which physical and radiological characteristics are similar. For specified isotopes and groups of isotopes, the total activity of each waste stream must not exceed 1% of the total capacity of Drigg for that isotope or group. Similarly, the implied specific activity limit for a radionuclide is the capacity divided by the total volume of the repository. The waste stream

TABLE 1. DRIGG ANNUAL LIMITS AND TRIGGER LEVELS

	Site limit (GBq/a)	Trigger (GBq/t)	Stream limit (GBq)
Uranium	300	0.09	90
Ra-226/Th-232	30	0.009	9
Other α	300	0.09	90
C-14	50	0.015	15
I-129	50	0.015	15
Tritium	10 000	3	3000
Other β/γ (including Co-60)	15 000	4.5	4500
Co-60	2000	0.6	600

is triggered when its specific activity is 10 times this implied site specific activity, and can only be accepted by special arrangements.

It should be noted that there are no specific limits for ^{36}Cl. Thus, for UK graphite, it is the ^{14}C content, in particular, that decides whether or not the waste can be accepted at Drigg.

3.3.1. Controlled burial

Under the Radioactive Substances Act, authorizations may be issued for the burial of some low level waste (which has radioactivity at the lower end of the low level waste range) at suitable landfill sites used mainly for other wastes, or — more rarely — at the site where the waste is produced. In either case, the ground must have good containment characteristics, and a specific assessment must be made and appropriate conditions placed on the disposals.

Currently only two nuclear sites have authorizations to use the controlled burial route. Current Government policy [3] is that “greater use is not encouraged, but the route should remain available particularly to small users”. However, waste producers have pointed out the vast savings that could be made by judicious use of this route in preference to Drigg, with accompanying environmental and safety benefits, and it may prove possible, in future, to open this route for some large volume decommissioning waste. None of UKAEA’s graphite waste is being considered for disposal by this route.

3.4. ILW

ILW is defined in Cm 2919 as waste "with radioactivity levels exceeding the upper boundaries for low level waste, but which does not require heat generation to be taken into account in the design of storage or disposal facilities". Again, there is no distinction between short and long lived isotopes, fissile and non-fissile material, and there is no fixed limit on heat output.

The UK Government is currently consulting the public on options for the long term management and disposal of ILW. Original planning applications to investigate land close to Sellafield with a view to building a deep waste repository (DWR) were rejected, although this is still considered by many to be the most likely disposal option. In the meantime, site operators must accumulate ILW on their sites for a period assumed, conservatively, to be 100 years.

Regulatory requirements dictate that waste must be placed in a passively safe state, which in practice means that most waste types are being packaged and conditioned in accordance with Nirex's Waste Package Specifications [4]. These specifications detail the requirements that would be expected to apply to waste consigned to a DWR, though meeting them does not guarantee ultimate acceptance.

4. CLASSIFICATION OF UKAEA GRAPHITE

The activity levels of key UKAEA graphites are shown in Table 2.

Comparing the values in Tables 1 and 2, it is clear that almost all the graphite exceeds the defining total beta/gamma limit for LLW. At the present time, only the GLEEP graphite is well within 12 GBq/t limit, however, it marginally exceeds the ^{14}C stream concentration trigger level, although the total content is below the stream limit. Thus, it should be possible for the UKAEA to negotiate the acceptance of this waste at Drigg. Nevertheless, at these levels, disposal would be very expensive and would have to be managed over at least five years.

For these reasons, the UKAEA has been considering options for reducing the tritium and ^{14}C content of GLEEP graphite, in particular. One of these options is incineration, which is more accurately termed 'calcination', as graphite does not undergo self-sustained oxidation, except in very special circumstances. This is discussed below.

The PFR Row 1 NSRs will be within Drigg limits by the time the waste is packaged (2010 onwards). By 2040, the earliest date an ILW disposal route

TABLE 2. ACTIVITY LEVELS OF UKAEA GRAPHITE

	Total β/γ (GBq/t)	C-14 (GBq/t)	H-3 (GBq/t)	Class
GLEEP	0.33 (0.06–1.8)	0.0175	0.29	LLW
Total GBq	167	9	150	
BEPO Core	88	17	68.5	ILW
Reflector	23	4.4	18	ILW
MTRs	140	7.5	110	ILW
Piles	41	4.25	21	ILW
PFR Row 1 NSRs at 2002/2040[a]	630 0.09	5.1E-3 5.0E-3	0.17 0.02	ILW LLW

[a] Includes steel, hence the decrease from 2002 to 2040 is primarily due to Co-60.

might be available, the Row 2 rods will be within LLW limits, but would significantly exceed Drigg ^{14}C trigger levels.

4.1. Calcination of graphite

The radioactivity of GLEEP graphite is principally due to tritium (87%). Thus, if it were possible to volatilize this tritium, alternatives to Drigg disposal might be considered for the solid residue.

Graphite, by itself, is almost impossible to burn. Therefore, consideration is being given to obtaining an authorization for sending graphite to a commercial waste incinerator that has appropriate discharge authorizations for gaseous radionuclides. In this way, the graphite would be heated to high temperatures by combustion of the waste with which it was treated.

This is a standard disposal route for radioactive waste from small users such as hospitals.The resulting atmospheric discharges due to the GLEEP graphite would be well within the operator's current authorization.

To demonstrate the process, three intact GLEEP graphite blocks were sent to such an incinerator. They were calcined at a temperature of 1100°C for 3 hours with domestic wastes. On removal, the surface of the blocks was no longer shiny, and one corner was chipped. Radioanalysis indicated that 88% of the ^{3}H and 64% of the ^{14}C had been released from the blocks.

Given the promising results to date, UKAEA proposes to go to the next stage, which is calcining GLEEP graphite that has been crushed to pieces of <5 cm dimensions using a modified industrial paper shredder.

4.1.1. Potential application to ILW graphite

As Table 2 shows, the BEPO reflector graphite would be within the beta/gamma limit for LLW if a similar proportion of the ^{14}C and ^{3}H could be removed. Since Drigg disposal is expected to be considerably cheaper than Nirex disposal, and the graphite has, in any case, to be annealed to remove Wigner energy , this could be a valuable route. However, even if 99% of the ^{14}C were volatilized, the residual activity would still exceed the concentration trigger level significantly. Such levels would be difficult to agree with Drigg, but might be possible if the regulator were supportive.

Activity levels of other graphites are such that, unless UK definitions of LLW change substantially, removal of ^{14}C and ^{3}H would not bring them within the LLW category.

5. SUMMARY

The UKAEA has developed methodologies for removing graphite blocks from reactors that have enabled it to disassemble two of its redundant research reactors, WAGR and GLEEP. GLEEP graphite is within limits for Drigg disposal as LLW. However, the ^{14}C content remains an issue. Calcination in an authorized commercial incinerator is being investigated as an alternative to long term storage as ILW. This has been demonstrated to remove most of the ^{14}C and tritium, and is being pursued further. While this could be applied to BEPO reflector graphite to bring it within LLW total activity limits, it would not be sufficient to allow Drigg to accept it under its current ^{14}C limits. Some PFR neutron shield rods will also be LLW by the time of waste packaging, and should be acceptable to Drigg, however, all other graphites will require preparation for long term storage as ILW.

UKAEA has developed reference decommissioning strategies for all of its reactors, most of which involve decommissioning to green-field status on an accelerated timescale. As a result, storage facilities will have to be constructed for the ILW graphite. Options for the Windscale Piles, which are currently at Stage 3 of decommissioning, are being re-evaluated.

It should be noted that the UK commercial reactors will generate considerably more ILW graphite than UKAEA's. However, it is planned to place these in 'safestore', so that the waste will not arise until a disposal route is available.

REFERENCES

[1] UNITED KINGDOM ATOMIC ENERGY AUTHORITY, Reactors UK, Fourth Edition, January 1969.
[2] Removal and Handling of Graphite from the GLEEP Reactor, IBC International Conference on Decommissioning Experience, London 2004.
[3] Review of Radioactive Waste Management Policy, Cm2919, HMSO 1995.
[4] UK NIREX, Nirex Waste Package Specifications and Guidance Documentation, T/WPS.

DISCUSSION

M. BRAECKEVELDT (Belgium): Assuming that graphite was radiologically acceptable for the Drigg facility, what would be the packaging requirements?

K. LANGLEY (United Kingdom): They would be in line with those for other types of low level waste — the graphite blocks would be packed with standard half-height ISO freight containers. Any voids left after packing would need to be filled with cement grout. The containers would be stacked in the Drigg disposal vault.

THE DISPOSAL OF IRRADIATED GRAPHITE IN FRANCE

A. GRÉVOZ
Agence nationale pour la gestion des déchets radioactifs,
Châtenay-Malabry, France
Email: arnaud.grevoz@andra.fr

Abstract

The paper deals with the options being investigated in France for the long term management of graphite waste. After providing a brief overview of the waste inventory involved, the proposed solutions are presented together with a status report on the project.

1. WASTE INVENTORY

Graphite waste results from the former gas–graphite (GGR) reactor system in which graphite was used to moderate neutrons and to regulate reactor cores. The first generation reactors were used from the beginning of the 1960s to the end of the 1980s. The nuclear power reactors belonging to Électricité de France (EDF), located at Chinon, Bugey and Saint-Laurent-des-Eaux, as well as those owned by the French Atomic Energy Commission (Commissariat à l'énergie atomique — CEA) are currently undergoing dismantling.

The graphite is in the form of hexagonal or square prisms (piles and reflectors) or of cylindrical sheaths surrounding the uranium fuel element.

The radioactive content consists mainly of short lived radionuclides (^{60}Co and tritium), but also long lived radionuclides (^{14}C and ^{36}Cl). The quantity of graphite generated by the reactors mentioned above amounts to about 23 000 t or a volume of approximately 100 000 m^3.

Graphite waste is currently stored at the sites of the nuclear power plants (NPPs) where it was produced, pending the dismantling of the facilities, or in dedicated storage facilities on the sites of processing plants.

EDF waste represents 80% of the total volume of waste produced. Estimations show that the activity levels for ^{60}Co do not generally exceed 2000 Bq/g, except for the piles at the Bugey NPP and the sheaths at the Saint-Laurent-des-Eaux NPP; the maximum activity level in these cases being estimated at 500 000 Bq/g. With regard to long lived radionuclides, the most significant nuclide for the safety of a potential repository is ^{36}Cl. According to EDF and CEA assessments, the overall inventory is 32 TBq. However, taking account of the small number of samples on which the assessment is based and of the difficulty in determining the activity of ^{36}Cl based on the historical use of the graphite elements, this inventory estimate is probably rather uncertain.

2. POSSIBLE OPTIONS FOR THE DISPOSAL OF GRAPHITE WASTE

Owing mainly to the presence of ^{36}Cl, but also of ^{14}C, the French Nuclear Safety Authority has restricted the surface disposal of the graphite sheaths to those originating from the Bugey NPP. Those sheaths are currently being conveyed to the Centre de l'Aube Surface Disposal Facility. The 0.4 TBq maximum capacity of that facility for ^{36}Cl does not allow for the surface disposal of the remaining inventory at that site.

At the request of the public authorities, ANDRA has therefore studied several other possible management solutions and has selected a reference solution. It consists of disposal in a subsurface disposal facility located at a depth of approximately 15 m within a stable clay or marl formation.

The reference solution:

(a) Protects the waste by isolating it from human activities and from human, animal or plant intrusions over a timescale of a few tens of thousands of years; the depth also protects the waste against erosion over a period of approximately 100 000 years;
(b) Contains the waste and also controls the migration of radionuclides thereby limiting their impact on human beings and the environment to an acceptable level.

Disposing of graphite waste in existing cavities, such as former open pit or slope mines or underground mines not exceeding a depth of about 100 m, was also investigated as an alternative solution. Such a solution certainly appears to be interesting from the viewpoint of controlling the impact over the long term, but it also raises some specific issues. The possibility of reusing a rehabilitated site may be affected by the conditions of the original operation (rock damage, availability of access points). There may be other issues, possibly of a legal nature. Consequently, the option is not considered as a reference solution.

3. SUBSURFACE DISPOSAL CONCEPT

Graphite waste is conditioned in concrete containers which would then be placed inside concrete structures. Those structures would protect workers during operations from the radiation emitted by the waste to ensure that their radiation doses did not exceed 5 mSv/a. They would also contribute to the chemical and mechanical protection of the packages over the long term. At the end of the operational lifetime of the repository, a cover made of reworked clay would be placed over the waste packages in order to restore the initial topographic level (Fig. 1).

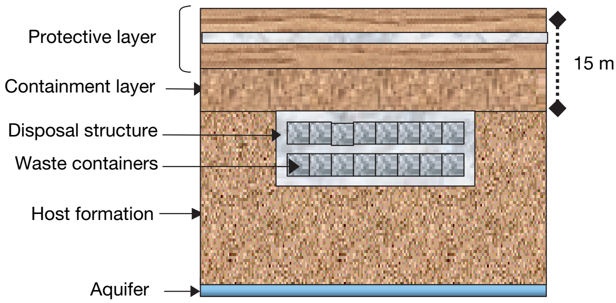

FIG. 1. Disposal facility for graphite waste.

ANDRA and the waste producers have launched an important study programme for the purpose of refining the design options. Those options will be influenced by the results of preliminary safety assessments which showed that:

(a) Although the long term impact associated with ^{14}C seems acceptable (i.e. consistent with ANDRA's objective not to exceed 0.25 mSv/a to members of the public), the impact of ^{36}Cl appears to be sensitive to the geometry of the land (thickness and permeability of the formation under the disposal facility);

(b) The long term impact of the disposal facility is directly proportional to the ^{36}Cl inventory and it is important to determine the inventory as precisely as possible;

(c) The role of the package is important as a complement to the site properties. Studies are therefore being oriented towards developing a specific package with good durability. Options, including the use of fibrous concrete for ensuring a good mechanical resistance over the long term or the use of reinforced concrete, are being investigated.

4. STUDY OF A SUBSURFACE DISPOSAL FACILITY

Preliminary design studies are under way and are addressing the possibility of coupling the disposal of graphite waste with a subsurface disposal project for radium bearing waste. The disposal facility would be divided into several areas, as follows (Fig. 2):

(a) Separate disposal areas for radium bearing and graphite waste, each consisting of excavated trenches at a depth of approximately 15 m and of disposal cells; disposal areas would be designed in modular form in order to ensure a stepwise implementation to optimize the operation of the facility with the rate of waste arising;
(b) Industrial installations, including the waste and container storage buildings and administration buildings;
(c) The excavated soil dump;
(d) The water management area, including a basin designed to collect rainwater.

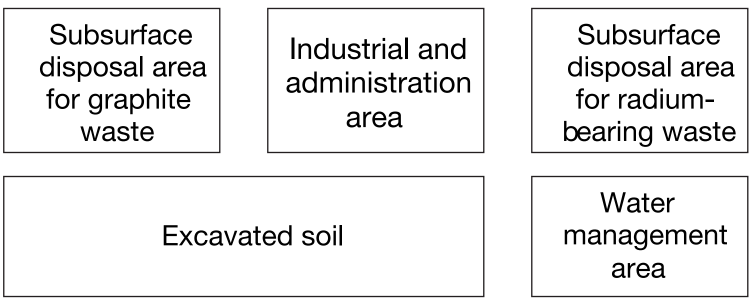

FIG. 2. Basic layout of the disposal facility.

The total surface of the facility would be in the order of 100–150 ha. The specific architecture and design of the facility will need to be adapted to the actual site at which the facility is implemented.

Safety assessments are continuing and are addressing both the normal operation of the facility and various possible types of accident situations, such as:

(a) During operation: package drop, fire (it should be noted that the graphite contained in French reactors is not influenced, in principle, by the Wigner effect);

(b) Over the long term: package deficiencies, structural failures, intrusive boreholes, etc.

5. OPERATION OF THE FACILITY

Based on the current estimations of future waste arisings, the facility should remain in operation for between 20 and 30 years. During that period, it would be monitored in order to verify the sound operation of the installations and the control of the environmental impact. This approach would also help to develop an understanding of the behaviour of the disposal facility over the long term. Ultimately, after the cover is put in place, the site would recover its original appearance — that existed before the implementation of the disposal facility.

After the operational phase, an environmental monitoring programme would probably be maintained for several decades.

6. PROSPECTS

The Nuclear Safety Authority has approved the overall design of the disposal facility for radium bearing waste. A similar report for graphite waste, highlighting the advantages of coupling both projects, was submitted at the beginning of 2004. On that basis, a programme was launched to seek a suitable site for the implementation of a common disposal facility for both radium bearing and graphite waste in consultation with the relevant government departments. In parallel, design studies for the facility are being carried out.

According to the current schedule for the project, the disposal facility should be commissioned in 2010 in order to satisfy the waste producers' needs and to meet EDF's decommissioning plans.

DISCUSSION

K. LANGLEY (United Kingdom): The long term safety case assumes that ^{36}Cl is labile and will ultimately leach out of the repository. If the ^{36}Cl is securely locked within the graphite crystal structure, however, it should not leach out. What account has been taken of the stability of the source term in the safety assessment?

A. GRÉVOZ (France): In French graphite waste, ^{36}Cl is generated through the activation of impurities that were not systematically part of the graphite structure — for example, cleaning solutions. Experiments by CEA on some samples had a high uncertainty level and showed a large variability from one sample to another. In the absence of conclusive data, ANDRA had to make a conservative assumption.

GREATER CONFINEMENT DISPOSAL OF RADIOACTIVE WASTE IN BOREHOLE FACILITIES

J.R. COCHRAN, A. HASAN
Sandia National Laboratories,
Albuquerque, New Mexico, United States of America
Email: jcochr@sandia.gov

Abstract

Security experts are now very concerned that a sealed radioactive source (SRS) could be used in a radiological dispersion device to terrorize and disrupt society. The most vulnerable SRSs are the unwanted SRSs that owners must hold indefinitely because there are no disposal facilities. Near surface facilities are not safe for long lived wastes and deep geological repositories will never be available in most countries. Sandia National Laboratories recently demonstrated that intermediate depth greater confinement disposal boreholes sited in thick arid alluvium can safely isolate long lived radioactive waste. The Egyptian Atomic Energy Authority, with Sandia National Laboratories, is conducting a preliminary safety assessment of intermediate depth borehole disposal in thick arid alluvium in Egypt based on experience with greater confinement disposal boreholes in the United States of America. Such intermediate depth boreholes can be used to remove unwanted SRSs from the biosphere, thus eliminating both the security and safety hazards associated with unwanted and highly radioactive materials.

1. INTRODUCTION

Millions of sealed radioactive sources (SRSs) are being used globally for a wide variety of beneficial purposes, ranging from medical cancer treatments to consumer smoke detectors. On the basis of an analysis of accidents and numerical simulations, security experts are now very concerned that a SRS could be used in a radiological dispersion device (RDD) to terrorize and disrupt society. The most vulnerable SRSs are the unwanted SRSs that owners must hold indefinitely because there are no disposal facilities. Near surface facilities are not safe for long lived waste and deep geological repositories will never be available in most countries. Given these facts, several countries are now considering borehole disposal at intermediate depths. Sandia National Laboratories recently demonstrated that intermediate depth greater confinement disposal (GCD) boreholes sited in thick arid alluvium can safely isolate long lived radioactive wastes.

The GCD boreholes were used to dispose of low level radioactive waste and classified, long lived transuranic waste that could not be disposed of elsewhere. The GCD boreholes are about 36 m deep; the bottom 15 m of the borehole was used for waste disposal and the upper 21 m part was backfilled with native alluvium. In 2002, after an independent peer review, Sandia's safety assessment was accepted — thus demonstrating that intermediate depth disposal in thick arid alluvium provides 'geological isolation' similar to that provided by a mined geological repository, but at a fraction of the cost.

Utilizing more than a decade of experience with the GCD boreholes, Sandia is working with the Egyptian Atomic Energy Authority and the IAEA to assess the safety of disposing of disused and long lived SRSs in intermediate depth boreholes in thick arid alluvium in Egypt. This joint initiative in Egypt is part of a large project titled Integrated Management Program for Radioactive Sealed Sources.

2. SEALED RADIOACTIVE SOURCES AND THE SECURITY THREAT

SRSs are being used daily and worldwide in medicine, manufacturing, consumer products, construction, oil and gas exploration, research, space exploration, teaching, and military applications. In many cases, SRSs are used as beneficial tools for tasks that would otherwise be difficult or impossible. In medicine, radiation is an indispensable tool used to treat about half of all cancer patients [1]. Millions of SRSs have been manufactured and disseminated [2].

Sealed radioactive sources can have activities ranging from less than 1 MBq (27 μCi) to several PBq (several kCi), and they may emit neutrons and/or alpha, beta, or gamma radiation, depending on the isotopes used. Half-lives of commonly used isotopes range from 74 days for ^{192}Ir to 1600 years for ^{226}Ra.

The concerns of security experts are exemplified by an incident in Goiânia, Brazil, in 1987 where a 50 TBq (1300 Ci) ^{137}Cs SRS was stolen from a closed medical clinic and cut open. The resulting hazard was both invisible and frightening. Four people died, several hundred suffered health effects, acute anxiety ensued and 112 000 people sought medical attention [3]. Several years were required to decontaminate or demolish buildings and remove contaminated soils, generating thousands of cubic metres of radioactive waste and costing millions of dollars. Figure 1 shows portions of the 3500 m^3 of radioactive wastes generated from the release of less than 15 cm^3 of ^{137}Cs in Goiânia, Brazil. Figure 2 shows typical ^{137}Cs and ^{60}Co SRSs.

FIG. 1. Portions of the 3500 m^3 of radioactive wastes generated from the release of less than 15 cm^3 of ^{137}Cs in Goiânia, Brazil.

FIG. 2. Typical ^{60}Co and ^{137}Cs SRSs from medical applications. The largest SRS shown here is ~2 cm in diameter and the volume is less than 15 cm^3 (Source: www.iaea.org).

The Goiânia incident provides one possible analogue of the consequences of an RDD event. Experts at the Nuclear Regulatory Commission (NRC), the US Department of Energy (USDOE), the US General Accounting Office, the non-governmental Center for Nonproliferation Studies and the IAEA are also very concerned that the economic and psychological consequences of a RDD or ‘dirty bomb’ would be quite significant [4–6].

2.1. Dangerous and vulnerable sealed radioactive sources

A dangerous SRS is defined as an SRS that could cause death after exposure to the unshielded radioactive material for a few minutes to a day, and the IAEA classifies these as Category 1 and Category 2 SRSs [7]. The present authors define a vulnerable SRS as an unwanted SRS that is not under government control, because unwanted, privately owned SRSs are a burden to their owners and are potentially subject to less rigorous controls. The contamination incident in Goiânia, Brazil involved a dangerous and vulnerable SRS (i.e. an unwanted Category 1 SRS).

In some cases, a dangerous and vulnerable SRS can be returned to the manufacturer for reuse or recycling. Although this is always the preferred option, such opportunities are limited for a variety of reasons: older SRSs may not meet current encapsulation standards, manufacturers may have gone out of business, there may be no 'special form' shipping certification, shipping may be too costly, or it may be less expensive to manufacture new materials than to recycle old materials [8]. Without a reuse/recycle option, dangerous and vulnerable SRSs must be either stored for hundreds to thousands of years or disposed of.

2.2. Disposal is the sensible path

Maintaining inventories and properly storing dangerous and vulnerable SRSs are critical first steps in properly managing unwanted SRSs. However, proper storage requires long lived government controls, and many regions of the world have lacked long lived government controls; especially in the timeframes of thousands of years.

Only proper disposal completely eliminates the safety and security risks caused by unwanted SRSs. Most unwanted SRSs could be safely disposed of in properly engineered and sited near surface facilities less than 10 m deep. However, significant numbers of unwanted SRSs will not decay to background levels in 100–300 years, and these SRSs are not appropriate for near surface disposal [9]. Such sources contain long lived radionuclides such as ^{241}Am and ^{226}Ra or high activities of nuclides with intermediate half-lives such as ^{137}Cs and ^{90}Sr. The half-lives of these radionuclides are 432 years, 1600 years, 30 years and 29 years, respectively.

Deep geological repositories have long been proposed for such dangerous long lived SRSs. Deep geological repositories would be constructed in isolated and stable portions of the lithosphere at depths greater than 300 m. They would enable radioactive waste to e removed from the biosphere for thousands to millions of years. Although conceptually simple, development costs can exceed a billion U.S. dollars, and only one deep geological repository in the world has been licensed; the Waste Isolation Pilot Plant (WIPP) in the United States of America [10]. For various legal and political reasons, neither the WIPP nor the proposed geological repository at Yucca Mountain in Nevada can accept the vast majority of unwanted, long lived Category 1 and 2 SRSs for disposal. Globally, only a few of the world's countries have the technical and financial resources to pursue development of deep geological repositories, thus exacerbating the international threat that a SRS could be easily acquired and deployed in an RDD. Intermediate depth borehole disposal has been highlighted by the IAEA and others as providing a possible solution for disposing of long lived SRSs. The following section reviews the use of intermediate depth GCD boreholes for the disposal of long lived and unwanted radioactive materials in the USA.

3. INTERMEDIATE DEPTH BOREHOLE DISPOSAL

3.1. Borehole disposal testing and utilization

Intermediate depth GCD boreholes were used to dispose of unwanted SRSs, and long lived classified transuranic (TRU) wastes. The unlined GCD boreholes are about 3 m in diameter and 36 m deep; the bottom 15 m was used for waste disposal and the upper 21 m was backfilled with native alluvium (Fig. 3). Figure 4 shows a photograph of the drilling of a GCD borehole. Such drilling equipment is used globally for constructing deep foundations for bridges and buildings.

Prior to operations, the intermediate depth disposal concept was evaluated using an instrumented GCD test borehole. The GCD test borehole was remotely loaded with unwanted SRSs containing 13 PBq (345 000 Ci) of ^{90}Sr and other SRSs containing ^{137}Cs and ^{60}Co. Subsequent waste placed in the GCD test borehole included over 26 PBq (690 000 Ci) of ^{3}H and over 1.5 PBq (40 000 Ci) of ^{90}Sr SRSs from decommissioned radioisotope thermoelectric generators [11]. Figure 5 is a photograph of the placement of three sets of instrumented monitoring lines in the GCD test borehole.

On the basis of the successful results from the GCD test borehole and other studies, 12 operational GCD boreholes were created in Frenchman Flat of the USDOE's Nevada Test Site. Four of the 12 boreholes were used to emplace TRU waste consisting of debris from nuclear weapons accidents and materials from nuclear weapons production or disassembly.

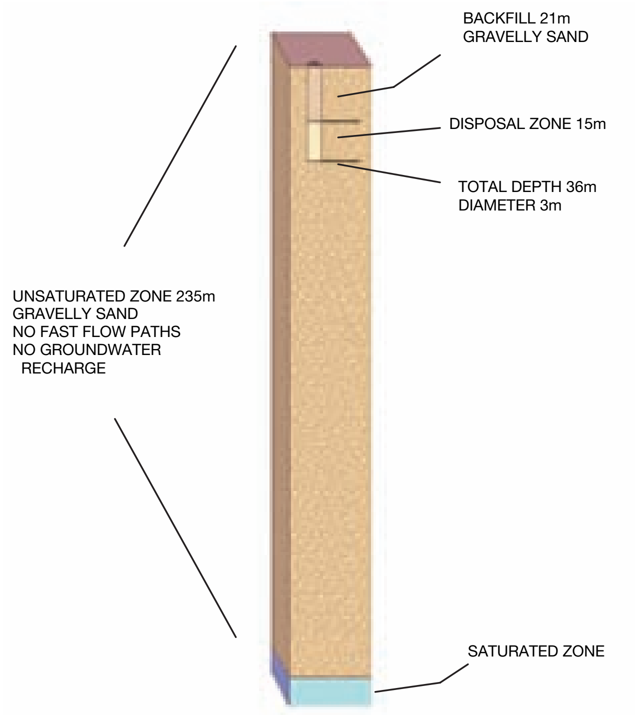

FIG. 3. Schematic of a GCD borehole.

FIG. 4. Photograph of the drilling of a GCD borehole. Note the gravelly sand in the borehole cuttings.

FIG. 5. Placement of monitoring equipment in the GCD test borehole.

This TRU waste was classified for national security reasons and thus could not be disposed of in the WIPP, which does not accept classified TRU waste. The four boreholes in total contain less than 6 kg of ^{239}Pu and less than 64 kg of ^{235}U. The average specific activity of the transuranic element ^{239}Pu is greater than 200 KBq/g (5000 nCi/g) of material, and the half-life of ^{239}Pu is 24 000 years. Because of the concerns of the State of Nevada, waste has not been placed in the GCD boreholes since 1989.

3.2. Safety standard

In 1989 Sandia National Laboratories was asked by the USDOE to complete a performance assessment or safety assessment to help determine whether or not the TRU waste in the GCD boreholes will endanger human health. The Environmental Protection Agency (EPA) in its 40 CFR 191 regulation [12] defines the requirements for protection of human health from TRU waste. The EPA's 40 CFR 191 includes four sets of requirements. The containment requirements set probabilistic limits on cumulative releases to the accessible environment for the next 10 000 years. The groundwater protection requirements, the individual protection requirements and the assurance requirements set additional quantitative and qualitative standards for long term performance of the disposal system. 40 CFR 191 is the standard applied to the WIPP deep geological repository, although there are differences between the version applied to the GCD boreholes and that applied to the WIPP [13].

3.3. Safety assessment methodology

For the purposes of assessing compliance with the EPA's 40 CFR 191 probabilistic 10 000 year standards for the disposal of TRU waste, Sandia National Laboratories developed a safety assessment methodology for the NRC. This iterative methodology is documented in a number of late 1980s and early 1990s publications, including the NRC's NUREG/CR-5521, "Use of Performance Assessment in Assessing Compliance with the Containment Requirements in 40 CFR 191" [14] and NUREG/CR-5256, "Components of an Overall Performance Assessment Methodology" [15].

This iterative methodology provides a framework for managing uncertainties and focusing work on uncertainty reduction in a cost effective fashion. A schematic of the iterative methodology is presented in Fig. 6. The first step of the ten step iterative methodology is to define the regulatory performance objectives. The second step requires cataloging all features, events, and processes (FEPs) that could affect the release of waste over the next 10 000 years. FEPs are based on the waste form, the disposal system and the site characteristics.

3.4. Site characteristics

The intermediate depth GCD boreholes are situated in a thick sequence of arid alluvium, composed of weakly stratified, gravelly sand in the Frenchman Flat basin of the USDOE's Nevada Test Site. Groundwater is approximately 236 m below the land surface. The average precipitation is 130 mm per year.

Significant efforts have gone into measuring concentrations of chemical species (mostly natural isotopes) that track the movement of pore water in the vadose zone and in measuring hydraulic properties of the vadose zone pore water. Results of the isotopic analyses are presented first, followed by a summary of the hydraulic properties.

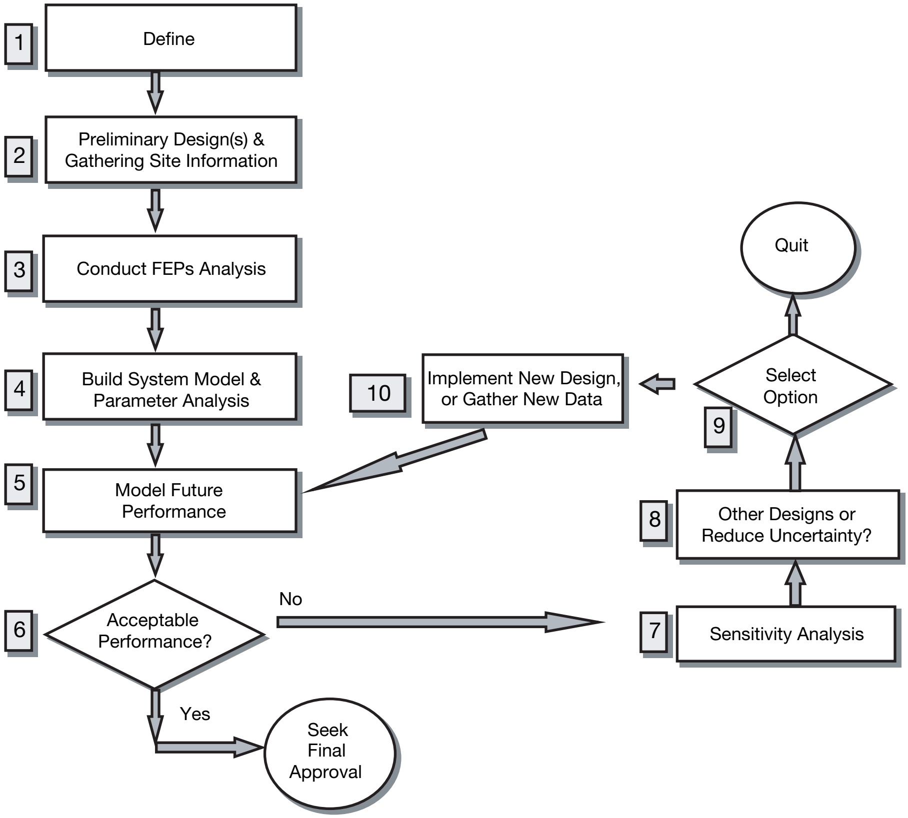

FIG. 6. Schematic of the iterative methodology for safety assessment.

Numerous studies of the concentrations of isotopes in pore water were conducted to infer recharge rates. These isotopic studies were based on chloride mass balance, stable isotopes of water (^{1}H, ^{2}H, ^{16}O and ^{18}O), cosmogenic ^{36}Cl and nuclear weapons testing 'bomb pulse' ^{36}Cl. Tyler et al. [16] provide an excellent summary and analysis of the movement of Frenchman Flat pore waters.

All the tracer studies indicate that no recharge is occurring in the vicinity of the GCD boreholes under the current climate. For example, analysis of bomb pulse ^{36}Cl from near surface soils in the GCD vicinity has shown ^{36}Cl from atmospheric nuclear weapons testing to be restricted to the upper 2 m of the soil profile. In the past 60 years no waters have infiltrated deeper than 2 m because of the strong upward gradients and because there are no 'fast flow paths' in the hydrologically homogeneous sand. The importance of fast flow paths is illustrated at the nearby Yucca Mountain facility where fracture flow paths in the bedrock have allowed waters containing bomb pulse ^{36}Cl to move to depths greater than 300 m in 60 years [17].

On the basis of a number of field studies, the matric potential and volumetric moisture content of the upper 2 m are dynamic, with the very, very dry average volumetric moisture content ranging from 1% to 3%. In this zone, hydraulic gradients are upward and very strong under the influence of plant root uptake and high evaporative demand at the surface. Only the upper 2 m is hydrologically dynamic, and aerially distributed infiltration never infiltrates deeper than about 2 m in the interfluvial regions around the GCD borehole.

Between 2 m and approximately 35 m, the alluvium shows negative matric potential decreasing with depth (for example, 10 bars at 35 m depth and 75 bars at 5 m depth), indicating an upward gradient in the pore water (i.e. if the pore water moves, it moves upward and there is no groundwater recharge).

The upward movement of pore water from 35 m deep has been studied extensively and is the result of a system in transition, where the transition times are of the order of thousands of years. In the geological past, the climate was cooler and wetter. A more xeric environment now exists, and the drying of the land surface is pulling moisture from depth, resulting in the very slow upward flux of pore water evidenced by the soil matric potentials.

The hydraulic properties for permeability and moisture retention have been shown to vary spatially as a function of textural variation from one lithological unit to the next. However, these properties can be considered homogeneous, because there appear to be no significant trends either laterally or with depth within a local region.

In summary, a variety of independent isotopic tracer and matric potential studies were used to characterize the occurrence and movement of pore water and the results of these studies are corroborative and not contradictory — only the upper 2 m of the gravelly sand is hydrologically active and there is no evidence of groundwater recharge.

3.5. Preliminary safety assessment

The characteristics of the site and other information were catalogued as FEPs, which were then screened for applicability to the GCD safety assessment. Conceptual models of the transport processes were developed for both the base case and the disruptive scenarios that survived the FEPs screening process. Because it was not known a priori what types of site characterization data would be needed, a preliminary safety assessment [18] was conducted using the Sandia National Laboratories' iterative methodology. By properly treating uncertainties in the preliminary safety assessment, the most important site characterization activities were identified through sensitivity and uncertainty analysis, thus assuring the most cost effective site characterization programme.

In the preliminary safety assessment, several techniques were used to assess the sensitivity of the outcome to the uncertain input parameters and key conceptual model assumptions. On the basis of the sensitivity analysis, the priorities for site characterization were found to be: (1) recharge rate, (2) plutonium solubility and (3) retardation, (4) hydraulic conductivity of the saturated zone, and (5) gradient in the saturated zone. On the basis of the results of the preliminary safety assessment, it was determined that compliance with the EPA's 40 CFR 191 standards was likely, and a final safety assessment of the TRU wastes in the GCD boreholes was initiated.

3.6. Final safety assessment

Initiation of the final safety assessment did not require a re-evaluation of the performance objectives; however, the preliminary safety assessment had not included a full FEPs analysis. Therefore, a rigorous assessment and screening of FEPs was initiated. As a result of the FEPs analysis, much of the final safety assessment revolved around four issues: a return to a cooler, wetter climate; subsidence caused by voids in waste packages; radionuclide uptake by plant roots; and inadvertent human intrusion. After much study and analysis, it was assumed in the the safety assessment that a cooler, wetter climate returned and subsidence occurred, both resulting in deeper infiltration of moisture (but no recharge), higher plant densities and plants with deeper roots.

The NEFTRAN code that was used in the preliminary safety assessment could not accommodate upward advection and more sophisticated plant and bioturbation models were needed. No 'off the shelf' code could accommodate upward advection coupled with plant uptake and bioturbation and a GCD specific code was written in visual basic and implemented in an access database.

3.7. Final safety assessment results (pre-review)

A total of 5000 realizations of sampled uncertain parameters were completed for assessing compliance with the 10 000 year containment requirements. The resulting complementary cumulative probability distribution function (CCDF) easily met the limits specified in 40 CFR 191. Probability distributions were estimated for the individual protection requirements for two exposure conditions: an off-site resident farmer and an on-site home builder. Dose was estimated, conservatively, at the end of the performance period. The calculated doses were far below the limits of 25 mrem for whole body dose and 75 mrem for critical organ dose specified in 40 CFR 191.

3.8. Peer review of the final safety assessment

The final safety assessment was subject of an independent peer review by a Federal Review Team that included technical specialists from other USDOE facilities, private industry and the EPA. The Federal Review Team wrote a Review Plan for the Compliance Assessment Document for the Transuranic Wastes in the Greater Confinement Disposal Boreholes at the Nevada Test Site which detailed the 49 review criteria for the containment requirements, the 26 review criteria for the assurance requirements, the 61 criteria for the individual protection requirements, and the 65 review criteria for the ground water protection requirements.

The majority of review criteria were satisfied by information in the final safety assessment. However, the Federal Review Team identified multiple criteria that were not satisfied. For example, the final safety assessment did not contain sufficient documentation on the engineered barriers or sufficient documentation on the 'classification' of the underlying groundwater.

To resolve differing interpretations on how to address releases of radionuclides in drill cuttings from inadvertent human intrusion, Sandia calculated and presented an additional CCDF that included the radiological releases from the drilling scenario. With and without the inclusion of releases in drill cuttings, the CCDFs do not violate the probabilistic containment requirements established in 40 CFR 191. Finally, a series of benchmarking exercises were completed that compare the results of the GCD model with documented and reviewed computer codes that could replicate the GCD model calculations to improve the verification of mathematical models.

It is also important to highlight items for which there were no findings:

(a) Safety assessment methodology: The Review Team did not disagree with the use of the iterative methodology.
(b) FEPs screening: The FEP screening process began with a comprehensive list of 760 processes and events. Through the screening process, all FEPS were either included in the quantitative safety assessment or screened out. The Review Team did not identify a single FEP that was mishandled in the safety assessment. There was a difference of opinion about the regulatory interpretation of releases in drill cuttings, but the human intrusion FEPs were all properly binned.
(c) Conceptual and numerical models: The Review Team did not question the conceptual and numerical models used in the safety assessment to simulate cumulative releases and doses.
(d) Input parameters: The final safety assessment presents and defends a very large number of certain and uncertain input parameters — ranging from

root depth distributions to solubilities to dose parameters — the Review Team did not identify any findings related to input parameter quantification.

(e) Transparency and traceability: The links between the underlying scientific data and the conceptual models, the numerical models, and the input parameters were not found to be deficient.

The safety assessment was revised in response to peer review comments and published [19]. Revisions in the final safety assessment led to a conditional approval of the safety assessment by the USDOE. Conditional approval means that all quantitative safety requirements in 40 CFR 191 were fully met and compliance with certain closure requirements was deferred until the closure of the larger USDOE disposal facility in Frenchman Flat basin.

3.9. Significance

The approved safety assessment of the TRU wastes in the GCD boreholes follows the WIPP as only the second disposal system to meet the safety requirements of 40 CFR 191 for disposal of TRU waste [20], thus demonstrating that intermediate depth burial in thick arid alluvium provides the same degree of isolation as a deep geological repository and will isolate radioactive wastes from the biosphere for over 10 000 years.

4. BOREHOLE DISPOSAL IN EGYPT

4.1. Introduction

Sealed radioactive sources have been used in Egypt for over 50 years in a wide range of peaceful applications. Oil exploration and medicine are the largest users of SRSs. At the end of their useful lives, the SRSs are defined as disused or unwanted. Currently, the Egyptian Atomic Energy Authority (EAEA) holds hundreds of unwanted SRSs in long term storage.

Many of these unwanted sources contain long lived radionuclides that will not decay to background or dismissal levels in 100–300 years and these SRSs are not normally acceptable for near surface disposal. Such SRSs contain long lived ^{241}Am and ^{226}Ra or high activities of nuclides with intermediate half-lives such as ^{137}Cs and ^{90}Sr.

The Integrated Management Program for Radioactive Sealed Sources (IMPRSS) is a joint project between Sandia National Laboratories, and the Government of Egypt, funded by the US Agency for International

Development [21]. The broad objectives of IMPRSS are to improve the cradle-to-grave management of SRSs in Egypt.

Utilizing more than a decade of experience with the GCD boreholes, the EAEA and Sandia National Laboratories are assessing the site specific safety of disposing of disused SRSs in Egypt. Specifically, the goal of this portion of IMPRSS is to conduct a preliminary safety assessment of intermediate depth borehole disposal in thick arid alluvium in Egypt based on experience with GCD borehole disposal. The results of the preliminary safety assessment will then be used by the Government of Egypt to decide of such a system will be implemented. The safety assessment will also utilize the experiences of the IAEA, AFRA (African Regional Co-operative Agreement for Research, Development and Training related to Nuclear Science and Technology) and South Africa in their generic assessment of intermediate depth boreholes for the disposal of disused radiation sources [22].

4.2. Borehole disposal facility development

The strategy is to use an integrated, step wise safety assessment methodology that builds on many years of GCD borehole experience in the USA and IAEA experience with AFRA. Development of a disposal facility for SRSs can be divided into five phases:

(1) Pre-site selection;
(2) Site selection;
(3) Pre-operation;
(4) Construction and operation;
(5) Closure and monitoring.

The pre-site selection phase addresses those actions necessary to undertake a site search and to develop a preliminary design. The pre-site selection phase includes three steps: (1) definition of inventory, (2) development of quantitative performance objectives from the disposal regulations and (3) 'mapping' of the licensing process. To implement these steps, there will also be project management activities, the management of records and the implementation of a quality assurance programme.

The site selection phase includes four steps:

(1) Site search;
(2) Preliminary site characterization;
(3) Preliminary facility design;
(4) Preliminary safety assessment.

For this project, the site search criteria are based on the characteristics of the GCD site and the preliminary site selection criteria are:

(a) Arid climate, <130 mm per year precipitation;
(b) Thick deposits of sand and gravel (alluvium), >150 m thick;
(c) Deep water table, >150 m below land surface;
(d) No potential for surface flooding.

The secondary characteristics of a GCD disposal site are:

(a) No dwelling within 1 km;
(b) Land owned by the government;
(c) No volcanic activity in the geologically recent past;
(d) No valuable subsurface resources such as oil, gas and gold.

Simple geological settings and homogeneous materials are preferable to complex geological settings and materials, as simple settings and materials are easier and less expensive to characterize and easier and less expensive to model, providing greater confidence in the safety assessment.

4.3. Current status

Project activities are ongoing in the areas of (a) defining the inventory, (b) development of quantitative performance objectives from the disposal regulations and (c) initiating management activities, records management and quality assurance. Using the site selection criteria listed above, EAEA scientists are searching the country for candidate disposal sites. From a preliminary review, areas of the Western Desert of Egypt may meet the site selection criteria (Figs 7 and 8).

FIG. 7. Western Desert of Egypt.

FIG. 8. Western Desert of Egypt.

5. SUMMARY

Security experts are concerned that dangerous and vulnerable SRSs could be used in a RDD to terrorize and disrupt society. The most vulnerable SRSs are the unwanted SRSs that owners must hold indefinitely because there are no disposal facilities.

Recent work by Sandia National Laboratories has demonstrated that intermediate depth disposal in thick arid alluvium can safely isolate long lived radioactive waste from the biosphere for thousands of years. Such intermediate depth boreholes are conceptually simple and have relatively low associated costs. The EAEA, with Sandia National Laboratories, is conducting a preliminary safety assessment of an intermediate depth borehole in thick arid alluvium in Egypt based on experience with GCD.

ACKNOWLEDGEMENTS

Preparation of this article was internally funded by Sandia National Laboratories Waste Legacy Program and IMPRSS.

REFERENCES

[1] GARCIA-BARROS, B., et al., Science 300, 1155 (May 2003).
[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Press Release, “Inadequate Control of World’s Radioactive Sources” (PR 2002/09 25, June 2002; www.iaea.org/worldatom/Press/P_release/2002/prn0209.shtml).
[3] NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS, Management of Terrorists Events Involving Radioactive Material (NCRP Report No. 138, 2001).
[4] U.S. GENERAL ACCOUNTING OFFICE, Nuclear Nonproliferation – U.S. and International Assistance Efforts to Control Sealed Radioactive Sources Need Strengthening (GAO-03-638, Washington DC, 2003; www.gao.gov/cgi-bin/getrpt?GAO-03-638).
[5] U.S. DEPARTMENT OF ENERGY and U.S. NUCLEAR REGULATORY COMMISSION Interagency Working Group, Radiological Dispersal Devices: An Initial Study to Identify Radioactive Materials of Greatest Concern and Approaches to Their Tracking, Tagging, and Disposition (DOE/NRC, 2003).
[6] FERGUSON, C. D., KAZI, T. and PERERA, J., Commercial Radioactive Sources: Surveying the Security Risk (Center of Nonproliferation Studies, Monterey Institute of International Studies, Monterey CA, 2003).

[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Categorization of Radioactive Sources (IAEA-TECDOC-1344, IAEA, Vienna, Austria. 2003).

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, Management of spent high activity radioactive sources (SHARS) (IAEA-TECDOC-1301, IAEA, Vienna, Austria, 2002).

[9] INTERNATIONAL COUNCIL ON RADIATION PROTECTION, Annals of ICRP, Publication 81 "Radiation Protection Recommendations as Applied to the Disposal of Long lived Solid Radioactive Waste," Volume 28, No.4, 1998, Pergamon Press.

[10] KERR, R.A., Science 283, 1626 (1999).

[11] BOLAND, E.J. and DICKMAN, P.T., "High-Specific-Activity Waste Handling for Greater Confinement Disposal", Abstract for Waste Management '86 (Proceedings of the Symposium on Waste Management at Tucson, AZ, 1986).

[12] U.S. ENVIRONMENTAL PROTECTION AGENCY, "40 CFR 191: Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes; Final Rule" (Federal Register, Vol. 50, no. 182, 38066–38089, 1985).

[13] U.S. ENVIRONMENTAL PROTECTION AGENCY, "40 CFR 191: Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Rule" (Federal Register, Monday, December 20, 1993).

[14] BONANO, E.J., and WAHI, K.K., Use of Performance Assessment in Assessing Compliance With the Containment Requirements in 40 CFR 191 (NUREG/CR-5521, SAND90-0127, U.S. Nuclear Regulatory Commission, Washington, DC, 1990).

[15] DAVIS, P.A., et al., Components of an Overall Performance Assessment Methodology (NUREG/CR-5256, SAND88-3020, U.S. Nuclear Regulatory Commission, Washington, DC, 1990).

[16] TYLER, S.W., et al., Water Resources Research **32**, 1481 (1996).

[17] EWING, R.C. and MACFARLANE, A., Science **296**, 659.

[18] PRICE, L.L., et al., Preliminary Performance Assessment of the Greater Confinement Disposal Facility at the Nevada Test Site — Volume 1: Executive Summary, (SAND91-0047, Sandia National Laboratories, Albuquerque, NM, 1993).

[19] COCHRAN, J.R., et al., Compliance Assessment Document for the Transuranic Wastes in the Greater Confinement Disposal Boreholes at the Nevada Test Site, Volume 2: Performance Assessment (SAND2001-2977, Sandia National Laboratories, Albuquerque, NM, 2001). A 72 MB e-copy of this safety assessment is available at http://infoserve.sandia.gov/sand_doc/2001/012977.pdf .

[20] COLARUSSO, A., CROWE, B.M., COCHRAN, J.R., "Completion of the Transuranic Greater Confinement Borehole Performance Assessment for the Nevada Test Site," Proceedings from Waste Management '03 (Waste Management Symposia, Inc., Tucson, AZ, 2003).

[21] HASAN, A., et al., "Integrated Management Program for Radioactive Sealed Sources in Egypt," Proceedings from Waste Management '03 (Waste Management Symposia, Inc., Tucson, AZ, 2003).

[22] SOUTH AFRICAN NUCLEAR ENERGY CORPORATION (NECSA), The Borehole Disposal Concept for Spent Sources, Vol. I: Development and Evaluation of the Concept (NECSA Report GEA-1353, NWS-RPT-00\013, NECSA, Pretoria, South Africa, 2000).

DISCUSSION

J. LORENZEN (Sweden): We have had great difficulties in deciphering Egyptian hieroglyphs. That being so, how do we ensure that in — say — 1000 years' time people will be able to decipher radioactivity warning signs left by us?

J.R. COCHRAN (United States of America): There has been a Waste Isolation Pilot Plant (WIPP) study of this issue. It is not clear whether such signs would deter or invite human intrusion.

A. GRÉVOZ (France): How did you address concerns about inadvertent human intrusion?

J.R. COCHRAN (United States of America): Addressing such concerns was difficult. Two answers were presented in the final safety assessment. One is based on regulation, which excludes the assessment of doses from transuranic waste. The other is based on the probability of inadvertent human intrusion, which was derived from an expert elicitation conditioned on current society.

M.W. KOZAK (United States of America): The need for borehole facilities is dependent on the assertion that certain radiation sources are inappropriate for near surface disposal. However, that assertion is based on waste acceptance criteria derived from inadvertent human intrusion scenarios. For NORM waste, indefinite institutional control periods — to manage risk — have been advocated. It is only with such institutional control periods that near surface NORM waste disposal is possible.

If we applied the same philosophy in the situation described by you, we could accept the sources in question for shallow land burial. This illustrates the difference in regulatory philosophy between NORM and low level waste. Within our present regulatory construct, boreholes are a good idea.

J.R. COCHRAN (United States of America): I agree.

MANAGEMENT OF RADIOACTIVE WASTE IN BELARUS

N.M. SHIRYAEVA, V.V. SKURAT, M.L. ZHEMZHUROV,
N.K. MYSHKINA, R.A. SHATERNIK, S.N. YATSKO
Joint Institute of Power and Nuclear Research,
Minsk, Belarus
Email: irep@sosny.bas-net.by

Abstract

The paper summarizes the present situation in Belarus with regard to the management of radioactive waste. Important and non-typical radioactive waste types exist in the country due to the former military activities of the former Soviet Union and as a result of the recovery and decontamination activities after the Chernobyl nuclear power plant accident. The current status of the management plans for the resulting wide range of waste types are described, including the different types of existing storage and disposal arrangements.

1. INTRODUCTION

In Belarus, the main sources of radioactive waste are:

(a) About 300 industrial organizations, more than 40 medical institutions, about 60 scientific laboratories;
(b) The Joint Institute of Power and Nuclear Research, which has a decommissioned research reactor;
(c) Military industrial organizations;
(d) Materials and land contaminated as a result of the Chernobyl nuclear power plant (NPP) accident;
(e) Radioactively contaminated ash from the use of firewood in settlements located in the contaminated areas.

The current arrangements for storing and disposing of the radioactive waste in Belarus can be categorized as follows:

(a) Radioactive waste from small users containing low and intermediate activity levels (industry, medicine, and research) — in repositories of the ‘Radon’ type;

(b) Disused military radioactive sources — in well-type repositories;
(c) Decontamination waste from the area of Belarus contaminated after the Chernobyl NPP accident — repositories using natural depressions, trenches, pits, ravines, etc.;
(d) Domestic ash waste — methods still under development.

2. INDUSTRIAL RADIOACTIVE WASTE

Radioactive waste resulting from the use of radioactive sources in industry, medicine and research is disposed of in a near surface repository at the Ecores facility near Minsk. The Ecores facility is a state facility for the disposal of low and intermediate level radioactive waste. The Ecores facility has been operating since 1963. At the Ecores facility, from 1963 to 1977, radioactive waste was stored in two reinforced concrete trenches, without prior treatment. An approximate inventory of the isotopic composition and activity level of the waste in the trenches of the old repository has now been established. The volume of the old repository is 450 m^3; it contains waste with a total activity of 4.7×10^3 GBq. The greatest part of the volume consists of construction materials, wadding, rags, papers, radium compresses, spent sources containing ^{125}I, ^{170}Tm, ^{75}Se, gauges containing radioactive sources, and medically prescribed sources. Toxic materials such as arsenic, phosphorus, etc. were also stored in the trenches. This part has been isolated from the rest of the repository.

In 1977, after reconstruction, the facility was put back into operation. The refurbished repository includes two solid waste disposal areas together with four wells for storage of the disused radioactive sources. Each disposal area contains eight vaults made of solidified reinforced concrete. The first disposal area has now been filled and isolated; the second is now nearly 80% full. The total activity of solid waste accumulated in the operational repository over 25 years is 7.55×10^4 GBq. The main characteristics of the old and new repositories are presented in Table 1.

The wells for storage of the disused sealed sources are fitted with S-tubes, with diameters of 100 mm, to provide shielding of the sources. At present one well is full, one is being used for the disposal of neutron sources, and two wells are being used for spent gamma and beta sources. The Ecores facility accepts 6–10 t of low and intermediate activity level wastes per year and 3000–6000 t of disused radioactive sources of different types. It has been estimated that, during the next 10 years, the total activity of disused radioactive sources for disposal will exceed 18.5 PBq. This value considerably exceeds the Ecores facility capacity.

In 1989, ten containers filled with experimental fuel containing uranium with different enrichments were buried in the first disposal area. It is clear that this action is not consistent with international standards on safe radioactive waste disposal.

Safety analysis of the storage and operating conditions at the Ecores repository have indicated that waste is not being stored in compliance with international principles and recommendations for safe storage and disposal [1]. The main scenario of the safety assessment assumed migration of radionuclides from repositories into groundwater due to failure of the engineered barrier. The annual effective individual dose from consumption of drinking water contaminated with radionuclides was used as the primary criterion of safety. Additional criteria and indicators of safety have also been used.

The calculations have shown that, within the sanitary protection zone, the permissible concentration of radionuclides in groundwater may be exceeded for the following radioisotopes:

(a) ^{14}C, ^{16}Cl, ^{60}Co, ^{90}Sr, ^{239}Pu, ^{226}Ra, ^{232}Th, as a result of migration from the closed trenches;
(b) ^{3}H, ^{90}Sr, ^{238}U, ^{239}Pu, ^{226}Ra, as a result of their migration from vaults being filled.

Conservative assessments show that within the sanitary protection zone, the maximum permissible individual dose (1 mSv/a) may be temporarily exceeded by a factor of 10 to 10^3 if the water contaminated with radionuclides were used for drinking purposes. Beyond the boundaries of the zone this could become possible within 2000 to 20 000 years. The radioisotopes ^{14}C, ^{36}Cl, ^{90}Sr, ^{238}U and ^{3}H are weakly absorbed by geological media and they are, therefore, the most dangerous within the period of 20 to 1000 years. Their high migration ability can result in contamination of the lower aquifers used for the municipal water supply. The radionuclides ^{239}Pu, ^{241}Am, ^{226}Ra, and ^{232}Th are potentially hazardous for future generations because of the possibility that they may contaminate the aquifer in the distant future.

In 1997, a resolution to reconstruct the Ecores facility was accepted by the Council of Ministers of the Republic of Belarus. The reconstruction of the Ecores facility is intended to include the following:

(a) An increased capacity and new technologies for processing all the accumulated waste, including that in the old repositories;
(b) Technology for extracting and conditioning the waste in the old repositories;
(c) An additional repository with a capacity of 3000 m^3.

TABLE 1. SPECIFICATIONS FOR THE OLD AND NEW REPOSITORIES OF THE ECORES FACILITY

Characteristics	The old repository (closed)		New repository
	Trench No.1	Trench No. 2	
Sizes (m):			
Length	15.0	15.0	6.0 [a]
Width	5.0	5.0	6.0 [a]
Depth	3.0	3.0	3.25 [a]
Activity inventory, GBq	8.214×10^3	3.885×10^4	7.548×10^4
Number of isotopes	15	24	28
Isotopic composition:			
$T_{1/2}$ <1 year	^{45}Ca, ^{192}Ir, ^{210}Po, ^{75}Se, ^{170}Tm	^{110m}Ag, ^{57}Co, ^{192}Ir, ^{32}P, ^{210}Po, ^{35}S, ^{124}Sb, ^{75}Se, ^{119}Sn, ^{170m}Tm, ^{65}Zn, ^{133}Ba	^{45}Ca, ^{57}Co, ^{125}I, ^{192}Ir, ^{54}Mn, ^{99}Mo, ^{32}P, ^{210}Po, ^{119m}Sn, ^{88}Y, ^{65}Zn
$T_{1/2}$ = 1–100 years	^{60}Co, ^{137}Cs, ^{3}H, ^{147}Pm, ^{90}Sr, ^{204}Tl	^{133}Ba, ^{60}Co, ^{134}Cs, ^{137}Cs, ^{3}H, ^{147}Pm, ^{238}Pu, ^{90}Sr, ^{204}Tl	^{109}Cd, ^{60}Co, ^{137}Cs, ^{152}Eu, ^{55}Fe, ^{3}H, ^{63}Ni, ^{147}Pm, ^{239}Pu, ^{106}Ru, ^{90}Sr, ^{204}Tl
$T_{1/2}$ = 10^3–10^{10} years	^{14}C, ^{36}Cl, ^{239}Pu, ^{226}Ra	^{14}C, ^{239}Pu, ^{226}Ra, ^{232}Th	^{241}Am, ^{14}C, ^{239}Pu, ^{226}Ra, ^{238}U
Isotopic content:			
1.	^{60}Co: 75.0%	^{60}Co: 41.0%	^{137}Cs: 72.6%
2.	^{137}Cs: 13.6%	^{137}Cs: 40.4%	^{3}H: 25.7%
3.	^{226}Ra: 6.0%	^{192}Ir: 8.9%	^{90}Sr: 0.4%
4.	^{90}Sr: 1.69%	^{3}H: 4.3%	^{239}Pu: 0.3%
5.	^{239}Pu: 1.37%	^{75}Se: 2.5%	
6.	Others: 2.34%	Others: 3.0%	Others: 1%

[a] The dimensions of one vault.

The main purpose of the reconstruction of the Ecores facility is to guarantee the long term safety of the whole disposal site and to make arrangements for the movement of the most dangerous waste into a new storage facility. The reconstruction project provides new technologies for waste sorting and conditioning. The first part of the work has been completed. It comprises a new repository for disused radioactive sources and a system of control boreholes for monitoring groundwater.

The second part will include a waste processing building with modern methods for waste sorting, cementing and compacting. These methods will be used not only for incoming new waste, but also for waste from the old closed repository. The third part will provide for the extraction, identification, processing and conditioning of waste in order to make it suitable for long term storage or transportation.

These measures allow the management of both new and old radioactive waste in accordance with international recommendations. At the present time, a programme is being developed for the selection of a disposal site for a new waste disposal facility because the Ecores facility has limited possibility for extension. Furthermore, it is located near to a city of two million people.

3. DISUSED RADIOACTIVE SOURCES FROM MILITARY BASES

After the break-up of the Soviet Union, the repositories for radioactive waste were abandoned in places vacated by the Russian Federation military.

The repositories, which contain ^{60}Co, ^{137}Cs and ^{90}Sr sources, are concrete wells filled with layers of disused sources and isolated with concrete or sand. The causes of concern with regard to these repositories are:

(a) High radiation dose rates on the upper surface of the wells (300–2500 μR/h);
(b) Absence of technical documentation of the well design, radionuclide inventory, and means of waste isolation;
(c) Lack of any records or registration of the sources.

About 20 such repositories have been found in Belarus. It is clear that the facilities do not meet international standards of safety. In accordance with a resolution of the Council of Ministers of the Republic of Belarus in 2002–2003, the Institute of Radioecological Problems of the National Academy of Sciences of Belarus (NASB) and the Republican Scientific Geological Unitary Belgeo Facility of NASB have carried out radioecological, geological and hydrogeological research at two of the disposal sites (Gomel-30 and Kolosovo) located in the former military areas. The experimental and calculational investigations allowed the following conclusions to be drawn:

(a) The depths of wells are approximately 6 m; the waste in the Gomel-30 repository was immobilized in a concrete matrix; in the Kolosovo repository the waste was mixed up with sand.

(b) Both repositories contain ^{60}Co, ^{137}Cs and ^{90}Sr radioisotopes; the inventories amount to at least 160 GBq (Gomel-30) and 530 GBq (Kolosovo).
(c) The repositories are located in similar geological conditions; the groundwater tables are at depths of about 7 m (Gomel-30) and 11 m (Kolosovo), below the well bases.
(d) ^{137}Cs and ^{90}Sr radionuclides were found in soil and groundwater samples taken near the wells.
(e) The potential danger period due to the waste extends to nearly 1000 years.
(f) Both repositories present a hazard for ecosystems and humans, considering both the normal evolution scenario and alternative ones.

This situation requires that decisions are made to reduce the hazard and to provide for the radiation protection of the population.

4. DECONTAMINATION WASTE OF CHERNOBYL ORIGIN

After the Chernobyl NPP accident, about a quarter of the territory of Belarus was contaminated with ^{137}Cs to more than 37 kBq/m^2. In the first years after the Chernobyl accident, decontamination activities resulted in a large amount of radioactive waste in the exclusion and resettled zones of the Gomel, Mogilev and Brest regions [2]. The waste has the following features, which allow it to be considered as a separate category:

(a) The main radionuclides in this waste are ^{137}Cs and ^{90}Sr;
(b) It can be considered low and very low level radioactive waste;
(c) It exists in large volumes and its processing is not practicable;
(d) It is stored in the resettled areas where the contamination levels of soil are comparable with the specific activities of the disposed waste.

In 1990, on the basis of the State Programme of the Republic of Belarus on Reduction of Consequences of the Chernobyl NPP accident, the decision was taken to define the decommissioning waste disposal sites and their inventories. As a result, the locations of 92 disposal sites were identified; 13 of these are in the exclusion zone, where residence and any economic activity are forbidden; the rest are located in the resettled zone, where any farm activities are restricted. The repositories have a total area of more than 800 000 m^2. Almost 400 000 m^3 of decontamination waste, with specific activities of ^{137}Cs of 1–110 kBq/kg, ^{90}Sr of 40–900 Bq/kg, and ^{239,240}Pu of 0.2–48 Bq/kg were disposed of in these repositories. Eleven of the waste repositories have systems for the continuous monitoring of ground and groundwater. As a result, a great amount of experimental data has been accumulated regarding the situation at these repositories. This information was used for the safety assessment of the repositories.

At present, the residential properties are being decontaminated and contaminated industrial equipment is being dismantled and buried. For these purposes, and also for the control and maintenance of the repositories, Belarus allocates 1.6 million dollars annually.

The decontamination waste management activity is regulated through the document "Sanitary Rules on Decontamination Waste Management" (SRDWM-98). According to the Belarus classification, the disposal sites are named 'point of storing decontamination waste' (PSDW). There are three categories: PSDW–I, PSDW–II and PSDW–III.

PSDW–I is a special engineered structure for storing decontamination waste with specific activity more than 96 kBq/kg. PSDW–I ensures reliable waste isolation, using special engineered barriers for preventing radionuclide leakage. The sole representative of PSDW–I is the Khatki disposal site. It is a repository, of the near surface type, containing 8 trenches with 360 reinforced concrete cells. Some 3088 t of radioactive meat of total activity 745.5 GBq were disposed of in 300 cells of the repository. Analysis of geological features of the 'Khatki' disposal site showed that its vadose zone is composed of fine sands between beds of mid-sized sands, loam, and clay. The groundwater table is at a depth of 9.0 m to 14.0 m. The favourable hydrogeological conditions of this disposal site justified its use as a PSDW–I type repository. An expert team from IAEA approved this decision.

PSDW–II are near surface repositories with volumes of up to 50 000 m^3, in the base of which is placed a hydroisolating clay layer, of 0.5 m thickness, functioning as a simple engineered barrier. These repositories are assigned to decontamination waste with specific activities of less than 96 kBq/kg. There are ten such repositories in Belarus. They are still operating because the decontamination waste is still being created and about 30 000 t of waste arises annually. Decontamination waste mainly consists of soil, domestic waste, wood, roofing materials, waste from stockbreeding farms, etc. After the PSDW–II type repositories are full, they are isolated with layers of clays and local soil and sown with grass. Eight of the ten repositories of this type are currently being operated.

The PSDW–III type was created during the first stage of the post-Chernobyl decontamination activity in extreme conditions, often without detailed account being taken of the hydrogeological situation at the sites. As a result, decontamination waste was placed in 26 quarries, 17 pits, 16 trenches, 3 ravines and 19 repositories of the heap type. The areas, occupied by waste in these repositories, vary from 30 m^2 to 13 000 m^2. Analysis of the hydrogeological situations at these disposal sites has shown that, from 81 repositories of this type, 27 may be periodically flooded and 13 become saturated when seasonal fluctuations of the groundwater table occur. Safety analysis has been conducted at 22 facilities. The long term observations showed that as a result of seasonal fluctuations of the groundwater table, four repositories from 22 may become flooded and 10 may become saturated with groundwater. As a result radioactive contamination inevitably enters the aquifer. However, the influence zones of the repositories are limited to areas within 100–330 m of the repository. In the influence zones, the dose rates due to consumption of water do not exceed 10 mSv/a. Outside the influence zones, the dose rates from consuming drinking water will not exceed 0.1 mSv/a and will depend on the contamination of the surrounding territory.

In accordance with the State Programme of Republic of Belarus to mitigate and overcome the consequences of the Chernobyl NPP accident, a database of decontamination waste disposal sites has been created for supporting decision making on the radiation protection of the population.

Up to now, 62 PSDWs are isolated, i.e. covered with local ground layers and grasses; 3 are in the process of being isolated; 32 are being operated; and 4 require decision making on waste reburial because of the small volumes of waste. As stated earlier, the disposal sites are mainly located in the resettled zone that will be rehabilitated in the next 10–20 years.

5. RADIOACTIVE DOMESTIC ASH WASTE OF THE CHERNOBYL ORIGIN

Inspection of the Belarus forests showed that, after the Chernobyl NPP accident, about 26% of wood resources were contaminated with radionuclides. Analysis of wood and firewood samples showed that the maximum levels of contamination with ^{137}Cs were 1184 Bq/kg for wood, 444 Bq/kg for firewood, while permissible levels are 3700 Bq/kg and 740 Bq/kg respectively [3].

It was established that application of contaminated wood for stove heating leads to formation of ash waste that may be categorized as radioactive waste because of its high specific activity of ^{137}Cs. The specific activities of ash are 60–140 times higher than wood; in some cases its value is more than 50 kBq/kg. Moreover, 72% of ash waste is above the permissible limit of radioactive waste, i.e. more than 9.6 kBq/kg. At present 43% of houses in Belarus are equipped with stove heating. As a result, about 18 000 t (4.1×10^4 m^3) of radioactive ash waste are produced annually in the Republic, including about 13 000 t (3×10^4 m^3) of such waste in village settlements. The radioactive ash waste contains ^{137}Cs with specific activity up to 550 kBg/kg, ^{90}Sr — up to 22.6 kBq/kg, and $^{239,240}Pu$ — up to 126 Bq/kg.

In ash, about 10–15% of ^{137}Cs and 16–25% of ^{90}Sr is in exchangeable form. Less than 30–40% of radionuclides can be extracted by processing ash samples by mineral acid solutions. Therefore, the chemical processing of domestic ash waste before its utilization is not advisable. When using ash as a fertilizer, the secondary contamination of natural media and agricultural production is possible as a result of the air and water transfer of radionuclides [3]. Consequently, the development and introduction of technologies for the safe storage of radioactive ash waste are of real importance for Belarus. Different technologies have been considered for immobilizing radioactive ash waste — based on the application of fixing materials, such as cement, low temperature coagulating additives, for example, clay, etc.

In parallel with these developments, the possibility of ash waste disposal in near surface repositories of the PSDW–II type without preliminary processing has been studied. The conclusions were as follows:

(a) ^{137}Cs can be retained by the clay engineered barrier during the potentially dangerous period of the waste.
(b) ^{90}Sr, which is more mobile than ^{137}Cs, can reach the aquifer with a specific activity more than national limits; the influence zone of repository, where specific activity of ^{90}Sr is reduced to a safe level, was assessed to be about 400 m in the worst case; in the case of a small density of local contamination, ^{90}Sr is completely absorbed within engineered and natural barriers.
(c) On the whole, the application of PSDW–II for disposal of radioactive ash waste is permissible when a reliable outer isolation of the repository exists. But when disposing of waste with a high content of ^{90}Sr, it is advisable to use a means of fixing the radionuclide in the waste.

6. CONCLUSIONS

The analysis of waste types, waste streams, the conditions and safety of waste disposal revealed the following key points of strategy for radioactive waste management in Belarus.

(a) In the next 10–20 years, the amount of radioactive waste will increase due to decommissioning. Therefore, in the next decades it is necessary to:
    (i) Complete the reconstruction of the Ecores facility in accordance with international standards of radiation safety;

   (ii) Begin implementing the national resolution on the siting, selection and building of a new national radioactive waste repository.

(b) At present, about 20 repositories of the well type with disused military radioactive sources have been found. Apparently, this list is not complete. Therefore, the important strategic task is to find all such facilities in Belarus. They must be investigated, their safety assessed and decisions made on the need for their restoration and, possibly, for alternative arrangements for disposal.

(c) In Belarus, 92 repositories containing decontamination waste of the Chernobyl origin have been investigated and most of them have been isolated. The repositories are continuously observed and controlled by the regulatory organizations. Because most of these repositories are located in the resettled zone, it is necessary to estimate the extent of potential danger to local populations, to ensure the proper maintenance of the repositories and to define criteria for their release from regulatory control in future.

(d) Radioactive domestic ash waste is not yet well regulated. The strategy for the management of such waste must include:
   (i) Investigation of methods for conditioning and disposing of this waste;
   (ii) Development and approval of documents defining methods for managing such waste.

ACKNOWLEDGEMENTS

The authors are grateful to the Ministry on Emergency, the State Committee on Elimination of the Consequences of the Chernobyl NPP accident of the Republic of Belarus and the International Atomic Energy Agency for interest and support of the work performed.

REFERENCES

[1] SHIRYAEVA, N.M., ET. AL., “The State and Safety Assessment of the Low Level Waste Repositories in the Territory of Belarus”. Waste Management’00 Conference (Proc. Conf. Tucson, Arizona, USA, 2000, http://www.wmsym.org/wm2000/home.htm).

[2] SKURAT, V.V., ET. AL., Analysis of the Safety of the Burial Ground of Decontamination Waste of Chernobyl Origin in the Territory of Belarus., Journal of Engineering Physics and Termophysics. **75** 5 (2002) 158–164.

[3] BASHARIN, A.V. ET. AL., Investigations for Substantiation on Management with Communal-Domestic Waste of Low Level Activity. Preprint JIPNR–2. Minsk (2002) (in Russian).

DISPOSAL STRATEGY FOR NORM WASTE GENERATED BY THE SYRIAN OIL INDUSTRY

I. OTHMAN, M.S. AL-MASRI
Atomic Energy Commission of Syria,
Damascus, Syrian Arab Republic
Email: atomic@aec.org.sy

Abstract

The paper describes a strategy for the disposal of naturally occurring radioactive materials (NORM) waste generated by the Syrian oil industry. Three main categories of NORM waste have been identified, viz. hard scales from decontamination of contaminated equipment and tubes, sludge waste and NORM contaminated soil. Disposal solutions for each type of NORM waste have been proposed and implemented.

1. INTRODUCTION

Naturally occurring radionuclides originating from the ^{232}Th and ^{238}U series can be concentrated and accumulated in tubing and surface equipment in the form of scales and sludge during the production of oil and gas. Scales or sludges containing technologically enhanced naturally occurring radionuclide concentrations are known as low specific activity (LSA) scale/sludge or as naturally occurring radioactive material (NORM). LSA scale formation is due to the precipitation of stable alkaline earth metal (Mg, Ca, Sr, and/or Ba and Ra) sulphates and/or carbonates caused by solubility changes. Variations of sulphate and carbonate solubilities are connected to temperature variations, pressure changes, evaporation in the gas extraction pipes and injection of incompatible waters; injected water into the reservoirs to maintain the pressure has been reported to be the main cause for scale formation.

Scales may cause problems in the operations of installations by plugging perforations, clogging tubes and valves, thereby restricting flow. Therefore, plants or equipment have to be refurbished prior to reuse. In order to avoid classification as either radioactive waste or as surface contaminated objects, plant or equipment must be decontaminated. Various decontamination methods can be applied on-site and off-site, such as, chemical dissolution, dry and wet abrasive methods and melting of metallic compounds contaminated with NORM [10]. High pressure (1500–2500 bar) water jetting has been shown to be a very effective method for decontamination of components from the oil industry. Decontamination processes give rise to a different type of waste such as hard scales, cleaning liquids or even contaminated personal protective equipment. NORM waste in the oil industry was not recognized as a waste management issue, however, until the mid-1980s.

The Syrian oil fields are situated approximately 700 km to the northeast of Damascus and near to the city of Der Ezzor. Oil and gas with production water are routed to various central processing facilities for separation and processing. Three main categories of NORM waste can be identified; i.e. hard scales from decontamination of contaminated equipment and tubes, sludge waste containing low levels of radium isotopes and contaminated soil with NORM as a result of uncontrolled disposal of production water.

The main objective of this paper is to describe a strategy developed by the Atomic Energy Commission of Syria (AECS) for the disposal of NORM waste generated by the Syrian oil industry. This strategy includes NORM waste characterization, cleanup, disposal and the monitoring of the selected disposal routes.

2. NORM WASTE CHARACTERIZATION

2.1. Hard scales

Hard scales formation occurs in all parts of the Syrian oil installations. This problem has prompted one of the largest oil companies (Al-Furat Petroleum Company (AFPC)) to have a NORM Decontamination Facility (NDF) constructed. The NDF was designed and built by the UK Atomic Energy Authority Technology and has been operated by the AECS since 2000. Hard scales removed from contaminated equipment and tubes by high pressure water (around 55 t of scales up till now) are stored as wet materials in standard storage barrels in a controlled storage area. For comparison purposes, the US Environment Protection Agency estimates that about 25 000 t of NORM contaminated scales and 255 000 t of NORM contaminated sludge are generated annually by the petroleum industry. Maintenance operations on natural gas power stations produce tens of tonnes of scales containing radon progeny, ^{210}Pb and ^{210}Po, at relatively high concentrations.

The characterization process is carried out for these scale materials as a preliminary step to final disposal [2]. Hundreds of scale samples have been collected and analyzed for radioactivity, elemental and mineralogical compositions at the AECS. The average ^{226}Ra, ^{228}Ra and ^{224}Ra concentrations in the collected scales are about 174 Bq/g, 67 Bq/g and 91 Bq/g respectively; the highest value found was 1520 Bq/g, which is well within the worldwide range, 0.1–15 000 Bq/g [12]. X ray diffraction analysis of scale samples has indicated that the scales consist of aragonite, galena (PbS), calcite, baryte, monohydrate and anhydrate sulphate and halite. In addition, trace elements, such as Pb, Hg, Ni, Cu, Cd, Hg, are also found in the collected scale samples. High levels of Hg in the analysed scales were observed; Hg concentrations range from 78 mg/kg to 1072 mg/kg and the average value is 383 mg/kg. Similar levels have been found in other parts of the world; Hg concentrations varied between 18 mg/kg and 1600 mg/kg in scales collected from the oil production lines in the Netherlands. This additional contamination has to be considered during the selection phase of the disposal options.

2.2. Sludge containing NORM waste

Sludge, oily sediment that is produced during the cleaning of oil separators, storage tanks and other surface equipment, is considered as NORM waste. This waste is found to contain less activity than the hard scale; the highest value observed for ^{226}Ra is about 1000 Bq/kg. Some Syrian oil companies have disposed of this waste into unlined pits; resulting in large areas becoming contaminated. Other companies implementing NORM management systems are currently using plastic lined disposal pits that are constructed in each area for temporary storage. Regulatory approval has been given to oil companies to dispose of this waste by mixing it with NORM contaminated soil and emplacing it in regulated disposal pits.

2.3. NORM contaminated soil

The third main NORM waste produced by the Syrian oil and gas industry is contaminated soil. Over 200 000 m^3 of contaminated soil have been recognized and characterized as a part of a national remediation project. The main radionuclides present are the isotopes of radium. The distributions of radionuclides in surface and subsurface soil have been determined; the soil contaminated with NORM that needs treatment as radioactive waste, according to the Syrian criteria for cleanup and disposal, has been determined. Depth profiles of radioactivity have been established and laboratory leaching experiments have been performed. In addition, radium isotopes were also measured in the water of observation wells drilled at the contaminated sites; the levels were found to be very low. Radon, arising from ^{226}Ra contaminated soil, and which is considered to present a potential risk, has been measured in ambient air and subsurface soil.

2.4. Other NORM waste in Syrian oil fields

Two other important waste types observed in the Syrian oil fields are contaminated equipment and production water. Contaminated equipment is stored in the NORM yards of each oilfield until it is decontaminated and cleaned; controlled areas have been defined in each oilfield and they are inspected periodically by the Regulatory Office. Production water is usually separated from oil and disposed of by various means, such as, discharge into an injection well or disposal well. Radium-226 concentrations may reach a value of 100 Bq/L in production water. These levels can be considered high in comparison with other reported values in the world. All operating companies in the Syrian Arab Republic are currently disposing of production water into disposal wells.

3. CLEANUP AND DISPOSAL CRITERIA FOR NORM WASTE

A scientific committee was established in 1998 to determine criteria for cleanup and disposal of NORM waste generated by the Syrian oil industry. Several worldwide recommendations and regulations for NORM waste disposal were reviewed. However, only one set of criteria related to the disposal and cleanup of contaminated soil has been established. These criteria were based on a risk assessment study and are defined as follows:

(a) Soil containing specific activities of ^{226}Ra less than 0.15 Bq/g does not need any treatment.
(b) Soil having specific activity of ^{226}Ra higher than 5.2 Bq/g needs to be managed as radioactive waste.
(c) Contaminated areas containing ^{226}Ra with soil specific activities between 0.15 Bq/g and 5.2 Bq/g need a special treatment to reduce the radiation exposure to a value below 100 μSv/a.

No criteria for disposal of hard or soft scales and contaminated equipment have been set.

4. NORM WASTE STABILIZATION AND LONG TERM STORAGE

NORM contaminated materials (scales and sludges) and equipment are stored in segregated areas with access limited to personnel who have been instructed on the safety precautions associated with NORM at all national oil companies adopting NORM management systems (such as AFPC, DEZPC). Scales produced by the decontamination processes are currently stored without stabilization; stabilization is required when the landfill option is used for the final disposal of the waste. However, there is no landfill site in the Syrian Arab Republic and no cementation facility for stabilization. There is a disposal area and treatment facility at one of the AECS sites; it is believed to be for the stabilization and treatment of small volumes of liquid radioactive waste generated by research and medical activities. It is, therefore, not likely to be suitable for NORM waste (tonnes of materials). Moreover, the transportation of NORM waste to Damascus, where this facility is situated, would not be an acceptable practice from the regulatory and public opinion point of view.

5. NORM WASTE VOLUME REDUCTION TECHNIQUES

The amount of scales currently generated by the decontamination processes at the Syrian oilfields can be considered small in comparison to the situations in other countries. NORM waste volume reduction techniques are not considered to be required at this stage. Nevertheless, external radiation measurements have been used to classify the barrels containing scales into low and high exposure rate barrels.

Techniques for waste volume reduction consist of physical separation and chemical treatment. Mechanical sorting and separation of waste by particle size and dewatering can be used for NORM contaminated soils, tank bottoms, pit sludges, produced sands and sludges from production vessels.

6. NORM DISPOSAL OPTIONS

Several final disposal options for NORM waste generated (mainly scales) by the oil industry have been extensively discussed in the literature. These include land spreading with, and without, dilution, burial with restricted, and unrestricted, site use, disposal in low level radioactive waste facilities, burial in former surface mines, and disposal in deep geological facilities, e.g. abandoned wells, well injection under fractured, and non-fractured, conditions and in salt domes. The most applicable options to the Syrian case are discussed below.

6.1. Land spreading

Disposal by land spreading in hot arid climates (sometimes also called sludge farming) involves minimal precautions, and simply consists of spreading sludge and scales on the surface of open lands in a prescribed area. It is not a labour intensive process and requires little more than a suitable tract of land and some basic earth moving equipment. This option has been used by one company (DEZPC); sludge samples are usually collected and analysed for approval by the Regulatory Office before carrying out the land spreading. Land spreading with dilution involves mixing the applied waste thoroughly within the top 20 cm layer of soil.

6.2. Burial with unrestricted site use

Land based burial with unrestricted site reuse may be applied in any available land area which has minimal or no groundwater flow. These practices have been observed in AFPC sites where waste containing NORM is collected in lined pits. After burial, the trenches or pits are generally capped with clay or other low permeability cover material, gravel drainage layers and a topsoil layer. The burial at shallow depths of pipes containing scales and/or sludge may be considered as a special case and may require restrictions on site use. This has been practised at one of AFPC site where a licence has been issued to the company to implement this approach.

6.3. Burial in surface mines

A related option is burial of NORM sludge and scale in surface mines such as surface pits of phosphate mines; in this case, some pretreatment of NORM waste may be required. In the Syrian Arab Republic, the old phosphate mine pits near Palmyra could be used as a disposal site, but risk assessment studies would have to be carried out. Transportation in this case is also an issue.

6.4. Filling and plugging an abandoned well

This process consists of disposing of NORM (or other) waste inside the casing of a well that is about to be plugged and abandoned. The waste is sealed inside one or more strings of tubing that are placed in the well bore; NORM waste may be placed in the well bore in bulk. The well should be capped to prevent accessibility from the surface. This option might be applicable to the Syrian case.

6.5. Disposal wells

Disposal into a well may be carried out by injection at pressures lower than the formation's fracture pressure (subfracture injection), and by injection at pressures exceeding the fracture pressure (slurry injection). This process provides greater environmental security than alternatives such as disposal in surface pits or landfills, and is less costly than off-site transport and disposal. Slurry injection is carried out by processing the waste stream into an injectable slurry by crushing/grinding, milling, adding carrier fluid and pumping this mixture into a well with a sufficiently high pressure to create a fracture in the selected formation. This process can be considered for the NORM scales produced by the NDF. This choice requires, firstly, the selection of a suitable well and then, the implementation of strict health and safety rules during project execution.

7. CONCLUSION

A strategy for managing NORM waste generated by the Syrian oil industry has been established. In relation to achieving safe NORM disposal methods, both parties involved, that is, the competent Regulatory Authority and the NORM waste producers (gas/oil producers), should accept their responsibilities. The tasks for the competent Regulatory Authority to implement this strategy are as follows:

(a) Set up guidelines for the application of a risk based approval approach to NORM waste disposal. These guidelines should assist in the decision making process and provide guidance to both government regulatory and operators on documentation requirements.
(b) Set up unconditional release limits for NORM waste. These limits should be risk based generic values, taking into account all potential NORM waste uses, applications and dispositions within the Syrian Arab Republic and the Syrian environment.
(c) Define conditional release limits by means of risk based studies for the type of NORM waste under consideration (e.g. NORM disposal into wells by fracture injection). These limits should be risked based, taking into account all peculiarities of the NORM disposal method under concern (e.g. for NORM disposal into wells by fracture injection).

Recommendations for the oil industry:

(a) Identify and select the most appropriate NORM waste disposal options. Consult with the competent Regulatory Authority.
(b) Apply all possible waste volume reduction processes.

BIBLIOGRAPHY

[1] AL-MASRI, M.S. AND SUMAN, H., NORM Waste Management in the Oil and Gas Industry: The Syrian Experience, J. Radioanal Nucl. Chem. 256, 2003, 150–162.

[2] AL-MASRI, M.S. AND ABA, A., Characterization of Radioactive Scales from Different Parts of Oil Installations, J. Applied Geochemistry, 2004, In Press.

[3] AL-MASRI, M.S., ABA, A., AL-HAMWI, A., MUKALLATI, H., Characterization of NORM Contaminated sites at the Syrian Oil filed: Depth profiles and Leaching Processes, Paper presented at 9th International conference on Radioactive Waste Management and Environmental Remediation, September 21–25, 2003, Oxford, England.

[4] BAKER, B.D., ENGLEHARDT, J.M. AND REID, J.D., Large Scale NOW/NORM Disposal through Slurry Waste Injection, SPE paper 53821 presented at the 1999 Latin American and Caribbean Petroleum Engineering Conference, Caracas, Venezuela.

[5] BLUNT, D.L. AND SMITH, K.P., Dose Assessment for Management Alternatives for NORM-Contaminated Equipment within the Petroleum Industry, paper presented at Beneficial Reuse '95, 3rd Annual Conference on the Recycle and Reuse of Radioactive Scrap Metal, 1995, Knoxville, TN, US.

[6] EL-HATTAB, M.I., Scale Deposition in Surface and Subsurface Production Equipment in the Gulf of Suez, Journal of Petroleum Technology 9, 1985, 1640–1652.

[7] GESELL, T.F. AND PRICHARD, H.M., The Technologically Enhanced Naturally Radiation Environment, Health Physics 28, 1975, 361–366.

[8] GRAY, P., Radioactive Materials Could Pose Problems for the Gas Industry, Oil and Gas Journal June, 1990, 45–48.

[9] HARDY, G.H. AND KHATIB, Z.I., Treatment and Disposal Options for NORM Oil Field Waste, SPE Paper 36586, 1996 (c.f. also Journal of Petroleum Technology March 1997, 272).

[10] INTERNATIONAL ATOMIC ENERGY AGENCY, Radiation and Waste Safety in the Oil and Gas Industry, IAEA Safety Report, NO. 34. 2003, Vienna.

[11] JONKERS, G., HARTOG, F.A., KNAEPEN, W.A.I. AND LANCEE, P.F.J., Characterization of NORM in the Oil and Gas Production Industry, Paper presented at Workshop on Pollutants in Oil Industry, Damascus, 27–30 April, 1998.

[12] JONKERS, G. AND HARTOG, F.A., Review on the State of Art of NORM Volume Reduction Techniques and Waste Disposal Routes, internal Shell report, 1998, Shell Research and Technology Centre, Amsterdam, CA. 98.20633.

[13] JONKERS, G., Exposure Scenario for a Sludge Farm Worker in an Arid Climate, internal Shell results, 2002.

[14] KOLB, W.A. AND WOIJICK, M., Enhanced Radioactivity Due to Naturally Oil and Gas Production and Related Radiological Problems, Science of the Total Environment, 1985, 45, 77–84.

[15] ORUM, J.D., BAUDOIN, D. AND BRISCOE, O., Remediation of Naturally Occurring Radioactive Material (NORM): a Field Trial, SPE Paper 30701, 1995.

[16] OTHMAN, I., AL-MASRI, M.S., Characterization of NORM Contaminated sites at the Syrian Oil filed Sampling, Analysis and Data Management, Paper presented at the Waste Management 2 Conference, February 24–28, 2002, USA. Published in the Proceedings.

[17] MÜSSIG, S. AND FREE, M., Environmentally Friendly Disposal of Mercury and NORM-Contaminated Waste in the Exploration and Production Industry, Proceedings of the 2nd International Symposium on the Treatment of Naturally Occurring Radioactive Materials, 1998, 142, Krefeld, Germany.

[18] REABURN, G.T., FINAZZ, P., LUISE, G., TJESSEN, K., OORTGIESEN, A.J., HEATON, B., WERNER, K., KEAD, A.D., Low Specific Activity Scale, Origin, Treatment and Disposal, E & P Forum, Report No. 6.6/127, London, January 1988.

[19] REED, A.C., MATTHEWS, J.L., BRUNO, M.S. AND OLMSTEADT, S.E., Chevron Safely Disposes One Million Barrels of NORM in Louisiana through Slurry Fracture Injection, SPE paper 71434 presented at the 2001 SPE Annual Technical Conference and Exhibition, New Orleans, LA, US.

[20] SMITH, A. L., Radioactive Scales Formation, J. Petroleum Technology, 1987, 697–706.

[21] SMITH, K.P., BLUNT, D.L., WILLIAMS, G.P., ARNISH, J.J, PFINGSTON, M., HERBERT, J. AND HAFFENDEN, R.A., an Assessment of the Disposal of Petroleum Industry NORM in Non-Hazardous Landfills, Argonne National Laboratory, October 1999, Lakewood, CO, US.

[22] STRAND, T. AND LYSEBO, I., NORM in Oil and Gas Production Waste Management and Disposal Alternatives, 1998, Proceedings of the 2nd International Symposium on the Treatment of Naturally Occurring Radioactive Materials, Krefeld, Germany , Nov 10–13, 1998.

[23] VEIL, J.A., SMITH, K.P., TOMASKO, D., ELCOCK, D., BLUNT, D.L. AND WILLIAMS, G.P., Disposal of NORM Contaminated Oil Field Wastes in Salt Caverns, Environmental Assessment Division, Argonne National Laboratory, August 1998, Lakewood, Colorado, United States.

[24] VEIL, J.A. AND SMITH, K.P., NORM Disposal Options, Costs Vary, Oil & Gas J., January, 1999, 37–43.

[25] VEIL, J.A. AND DUSSEAULT, M.B., Evaluation of Slurry Injection Technology for Management of Drilling Wastes, Environmental Assessment Division, Argonne National Laboratory, May 2003, Lakewood, Colorado, United States.

[26] VETTER, O.J., An Evaluation of Scale Inhibitors, Journal of Petroleum Technology, 1972, 992.

[27] VETTER, O.J., Oil field Scale - Can We Handle It?, Journal of Petroleum Technology, December 1976, 1402–1408.

[28] VETTER, O.J., KANDRPA, V., HAROUAKA, A., Predication of Scale Problems due to Injection of Incompatible Waters, J. Petroleum Technology February, 1982, 273–284.

[29] VETTER, O. J. AND PHILLIPS, R.C., Prediction and Deposition of Calcium Sulphate Scale under Down-hole Conditions, J. Petroleum Technology October, 1970, 1299–1308.

[30] WOITTIEZ, J.R.W. AND SLOOP, J.E., The Mercury Content in Tubes from Gas and Oil Production, ECN Energy Innovation, ECN-CX-95-060, December 1995.

DISCUSSION

C. TENREIRO LEIVA (Chile): The situation regarding oil extraction in the Syrian Arab Republic reminds me very much of the situation with regard to the mining industry in Chile. Did stakeholders become involved in the question of decontaminating tubes and water?

I. OTHMAN (Syrian Arab Republic): Yes, it was public pressure which led to the expenditure of money on decontamination.

At the same time, I would emphasize that AFPC — the local partner of Shell Syria — acts on the basis of 'safety first', which helped in reaching the decision to build and operate the facility that I described.

J. LORENZEN (Sweden): Are tubes reused after water jet decontamination?

I. OTHMAN (Syrian Arab Republic): It depends on the level of decontamination achieved. We recommend their reuse in oil production. If it is a question of municipalities wishing to use decontaminated tubes for — say — carrying sewage, they must obtain authorization from the regulatory authority. Of course, there is no question of decontaminated tubes being used for carrying drinking water.

J. LORENZEN (Sweden): As water is scarce in your part of the world, have you tried any decontamination methods besides high pressure water jetting? At Studsvik, we use grit blasting.

I. OTHMAN (Syrian Arab Republic): No, we have not. The main advantage of using water rather than — say — grit is that there are no residues which might affect valves and other components.

S.A. SYED HAKIMI SAKUMA (Malaysia): What is done with the water used for descaling the tubes?

I. OTHMAN (Syrian Arab Republic): The water is collected in special settling tanks, from which it is drawn off and filtered — a very effective process — for reuse. The sludge in the tanks, which is radioactive, is transferred to barrels for storage awaiting final disposal.

PANEL

(Session 5)

REMAINING GAPS AND ISSUES RELATED TO THE DISPOSAL OF LOW ACTIVITY RADIOACTIVE WASTE

Chairperson: **D. Bennett** (United Kingdom)

Members: **J.-M. Potier** (IAEA)
A. Morales (Spain)
A. Grévoz (France)
H.M. Fernandes (Brazil)

Statement

J.-M. Potier
International Atomic Energy Agency,
Vienna
Email: j-m.potier@iaea.org

As you know, there are several tens of facilities in operation worldwide for the disposal of low level waste (LLW). However, a number of countries still do not have such facilities. I think there are two main reasons. First, in a number of countries with developed nuclear power programmes (such as Belgium, Switzerland, the Republic of Korea, the Russian Federation and even Germany and Canada), a lack of sociopolitical acceptance has made the siting of LLW disposal facilities quite difficult. Second, many other countries — mainly developing ones — simply lack the necessary human and financial resources. The IAEA is trying to help these countries, and I would like to see them getting together in an effort to find solutions.

Another issue the IAEA is addressing relates to existing LLW disposal facilities which — as shown by performance assessments and safety analyses carried out under IAEA guidance using the ASAM methodology — do not comply with current safety requirements and need to be upgraded. There are different ways of upgrading these facilities. One is to retrieve the waste packages and characterize, recondition and repackage the waste. Another is to reinforce the containment barriers that are inadequate for the containment of radioactive waste. The IAEA is helping a number of countries with LLW disposal facility upgrading through its technical cooperation programme.

Then there is the issue of the operating costs of existing disposal facilities. In a number of countries, where the facilities are being operated safely, there is great pressure on the operators to minimize their operating costs and also their future post-operational costs. The IAEA is proposing to arrange for an exchange of information between operators, and a meeting is due to take place at the IAEA's Headquarters in May 2005.

The issue of decommissioning waste disposal was discussed in Session 3, but the focus was on dedicated facilities in countries such as France, Spain, Japan, Sweden and the United States of America. A possible way of minimizing the costs of decommissioning waste disposal might be co-location — that is to say, disposal in facilities at sites where low and intermediate level waste repositories already exist.

Finally, the absence of disposal routes for disused sealed sources is an important issue, as several millions of such sources worldwide are awaiting proper disposal but most operating disposal facilities do not accept them. Many of the IAEA's developing Member States are facing disused sealed source disposal problems, which is why the IAEA is promoting the borehole disposal concept. The IAEA has received letters of interest in the concept from Africa (Ghana, Morocco and Egypt), Latin America (Chile and Brazil), Asia (the Philippines and Malaysia) and the Middle East. It is trying to help those countries through its technical cooperation programme. Also, the IAEA is sponsoring a project in Africa whose purpose is to demonstrate the safety and cost effectiveness of an approach designed by the South African organization NECSA. In April 2005 there will be an international peer review of the approach, which has been designed for a generic site and could, with very minor adaptations, be applied in a number of countries.

Statement

A. Morales
ENRESA,
Madrid, Spain
Email: amol@enresa.es

In countries that already have low and intermediate level waste disposal facilities in operation, one should avoid concluding that everything necessary has been done. I will talk about three gaps that we have at the El Cabril facility, which has been in operation now for 12 years.

First, sealed sources may be disposed of at El Cabril only if they have been conditioned and do not contain radionuclides with half-lives longer than that of ^{60}Co. For sealed sources containing radionuclides with half-lives ranging from that of ^{60}Co to that of ^{137}Cs, we have to prepare a safety assessment and present it to the authorities for evaluation.

Second, large items of equipment such as steam generators, reactor vessel heads and heat exchangers may not be disposed of at El Cabril without first being cut up. We intend to make proposals to the authorities with a view to obtaining approval for the disposal of such items without cutting.

Third, the disposal of metallic components with high specific activities of ^{60}Co and ^{63}Ni is not allowed at El Cabril, and this also can be considered a gap.

Statement

A. Grévoz
ANDRA,
Châtenay-Malabry, France
Email: arnaud.grevoz@andra.fr

France, like Spain, has an operating disposal facility for low and intermediate level short lived waste, and we have made some progress in the management of high activity waste. Also, we are developing a concept for subsurface disposal, so we have quite a large number of options available to us. We recently estimated that we have operational solutions for 75%, by volume, of the radioactive waste in France. That is not to say that there are no gaps. Some disused sealed sources still do not have any final destination, although the safety authority recently authorized us to dispose of short lived sealed sources at the Centre de l'Aube — quite a step forward. For long lived waste, we were recently authorized to construct a central storage facility, which will help in dealing with emergencies.

When we developed the concept for a subsurface repository, our idea was to accommodate radium bearing waste, graphite waste and all other types of low activity waste not accepted at the Centre de l'Aube — and we think that this concept is a promising one for some disused sealed sources (although I think we must be very cautious about this). But then we made a big mistake — we gave a name to the waste that would be going to the subsurface repositories. We called it 'low activity long lived waste' — 'low activity' because it is not high activity waste and 'long lived' because it is not accepted at the Centre de l'Aube. Then the troubles began. Those waste generators whose waste is at the lower end of the spectrum began saying "My waste is not low activity — it is closer to 'very low activity', so I do not think that I should send it to your repository." At the other end of the spectrum, waste generators with intermediate level waste began to say "My waste is very close to 'low level waste'; I would like to send it to a subsurface repository instead of an underground one."

So we are in a bit of a quandary regarding the expected inventory of the repository, and this is a problem in estimating the operating costs, since, as everybody knows, the first thing you need when estimating such costs is a stable expected inventory.

So, when dealing with types of waste which are outside the main stream, one should not call them low activity, intermediate activity, high activity or whatever. One should simply characterize them correctly and find pragmatic solutions to the management problems. That is what we are trying to do with the subsurface concept.

Statement

H.M. Fernandes
Comissao Nacional de Energia Nuclear,
Rio de Janeiro, Brazil
Email: hmf@ird.gov.br

In addressing the question put to the panel, I shall focus on NORM waste, about the management and regulation of which there is not a great deal of agreement between countries.

Exemption and clearance are key concepts when one is determining whether or not NORM needs to be regulated. The absence of consensus here represents an important gap. However, I think some of the discussion has been fruitful. In particular, the idea that the emphasis should be on optimizing protection, rather than on the individual dose reference levels, is in my view helpful in explaining the apparent discrepancy between the way we treat material from the nuclear fuel cycle on one hand and NORM on the other.

As regards the disposal of NORM, various technical approaches are possible, but for most of them guaranteeing safety in the long term is an issue that is not easy to resolve. This too, therefore, represents a gap — or a flaw in our approach. Of course, it applies to all long lived radioactive waste, unless it is to be disposed of deep underground.

DISCUSSION

REMAINING GAPS AND ISSUES RELATED TO THE DISPOSAL OF LOW ACTIVITY RADIOACTIVE WASTE

Session 5

K. LANGLEY (United Kingdom): If we accept that 1 mSv/a is a reasonable target for controlling NORM and that it is not feasible to go below it, why should we expect anthropogenic sources of waste to be controlled to 10 μSv/a?

Secondly, at what point in the past ten years did 10 μSv/a stop being a lower limit below which doses were not of regulatory concern and become an upper limit above which one should not go?

H.M. FERNANDES (Brazil): We are talking not about a limit but about some kind of reference level. I think that, in line with the approach described by Mr. Goldammer, the emphasis should be on the optimization of radiation protection in the prevailing circumstances rather than on reference levels.

D. LOUVAT (IAEA): I should like to make a point of clarification regarding the Basic Safety Standards. If NORM waste management is considered a practice, then the annual dose limit for public protection for a single source within a given practice is not 10 μSv but 0.3 mSv, unless you consider that NORM activities represent multiple sources of exposure — then you have to regulate at 1 mSv/a.

But I think we are, in a way, mixing different things.

P. CARBONERAS (Spain): I have the same feeling. I think we are mixing numbers, and numbers mean nothing unless you put boundary conditions on the application of those numbers.

D. CANCIO (Spain): In this particular area there is another important concept — amenability to control, which is referred to in the Basic Safety Standards. The problem is that this concept is not universally applied. I think that there is a need for international action to deal with the apparent inhomogeneity of the radiation protection system as regards natural radioactivity.

J. LORENZEN (Sweden): I think we got the answer from Mr. Goldammer. To my understanding, the 10 μSv philosophy is statistically related to the number of cancer cases per million persons. In the case of NORM and TENORM, as Mr. Goldammer said, it is not economically feasible to bring doses down to 10 μSv/a. So we are dealing with economics versus safety.

G. JACK (Canada): That is a gap in my opinion, albeit not a technical one. Many times we claim to have the technical solutions, but we have difficulty implementing them for social or political reasons.

On a slightly different aspect — in Canada, our ability to control NORM is very different from our ability to control nuclear waste, because Canada is a confederation, and nuclear waste is controlled by the federal government and NORM is controlled by the ten provincial governments. The likelihood of achieving regulatory uniformity among the ten provincial governments is very small, and that of achieving regulatory uniformity between them and the federal government is even smaller. There is, therefore, a practical problem in controlling NORM to anything like the degree to which nuclear waste is controlled.

H.M. FERNANDES (Brazil): I completely agree with Mr. Jack. When you are licensing a nuclear installation, you know at the very outset that it is a nuclear installation. When you are licensing an oil platform or a phosphate plant, nobody cares if it is radioactive, because it is not nuclear, and you therefore have a completely different legal framework.

L. JOVA SED (IAEA): Further to what was said by Mr. Potier, I would mention that the IAEA and many of its Member States attach great importance to the borehole concept as a means of solving the problem of disused sealed sources. The IAEA is preparing a safety guide on this concept. The draft was recently approved by the IAEA's Waste Safety Standards Committee (WASSC) and will soon be distributed to all Member States for comment. I invite all of you to look at it and send your comments to the IAEA.

C. TENREIRO LEIVA (Chile): I know exactly who is producing the radioactive waste in certain countries and I know exactly how many requests Chile receives from those countries — which I won't name — for permission to dump radioactive waste in Chile, and I would like to see the waste producers in question, which comply with the relevant IAEA regulations in their own countries, complying with them also in countries like Chile.

In my view, there is a gap here.

J.-M. POTIER (IAEA): In a number of cases, there is a clear advantage in countries getting together and trying to find a common solution — a shared disposal facility. After all, the safety requirements would be the same for international facilities as for national ones.

The IAEA stands ready to assist Member States in finding common solutions.

J.R. COCHRAN (United States of America): With regard to the comment made by Mr. Tenreiro Leiva, multinational companies see sovereign nations each with its own regulations and its own definition of 'safety', and, to be honest, there are few broad international truths. For example, 1 mSv/a is a guideline — it is not an 'international truth'.

D. LOUVAT (IAEA): The Joint Convention — an international binding agreement — offers countries a basis for dealing with multinational companies. In addition, there is the import and export guidance supplementary to the Code of Conduct or the Safety and Security of Radioactive Sources.

The only problem with the Joint Convention in this context relates to NORM waste. Under the Joint Convention, reporting on the management of NORM waste is voluntary — that is to say, a country can choose whether or not to report on how its NORM is managed.

In my view this is an area where evolution of the Joint Convention is necessary.

L. JOVA SED (IAEA): At the first Review Meeting of Contracting Parties to the Joint Convention, an issue arose regarding two particular countries, one of which had not provided the other with information that it had requested many times. When challenged at the Review Meeting, the former country immediately agreed to provide the latter country with the requested information. The Joint Convention process really worked.

J.-M. POTIER ((IAEA): A month ago the IAEA published a technical document regarding multinational repositories, and I encourage those who are interested in the subject to examine it. Its purpose is to make clear what conditions must be met for the establishment and operation of multinational repositories.

D. BENNETT (United Kingdom — Chairperson): I think it would be interesting to consider the situation of small countries with no nuclear industry.

M.I.F. PAIVA (Portugal): Such countries have two particular problems; not having a nuclear industry, they have difficulty in raising the financial resources necessary for NORM problems, and being small they have difficulty in finding suitable sites for — say — boreholes (quite apart from meeting the high costs of safety assessments).

D. LOUVAT (IAEA): Regarding the important point of amenability to control raised by Mr. Cancio (and considered by ICRP and taken into account in the Basic Safety Standards), when you cannot control the radioactivity there is very little useful action that you can take. You should certainly not displace populations because they are living in Kerala or the north of Portugal. On the other hand, when you can control the radioactivity, you must — as a regulator or an operator — act within the framework defined by the Basic Safety Standards.

J.-M. POTIER (IAEA): In my statement, I referred to an April 2005 international peer review of the borehole disposal approach designed by

NECSA. If all goes well, the approach will be validated, after which the technology will be licensed for use in various countries.

I think the approach is safe and cost effective, but I have concerns about intrusion — both deliberate and inadvertent. One reason for making the borehole deeper, 50 m or so, is to minimize the risk of intrusion. Even if the footprint is small on the surface, the deeper the borehole the lower the risk will be.

Regarding deliberate intrusion, if the waste was at a depth of 300 m in the middle of the desert, intrusion would be more difficult than if the waste was on the surface. But we have tens of millions of radioactive sources which are currently stored on the surface in many places worldwide, and we are comparing this situation with boreholes with the sources placed at 50 m from the surface. The latter is infinitely preferable.

As to inadvertent intrusion, if the borehole were — say — 300 mm (1 foot) wide, it is very unlikely that somebody would come to the middle of the desert and drill a hole precisely at the location of the borehole.

A. GRÉVOZ (France): I do not think that any repository, however deep, will be completely safe as regards human intrusion. One cannot exclude the possibility of someone, at some time, identifying the repository as something special and drilling a hole in order to see what is there.

In my view, we should think in terms of relative safety rather than absolute safety. Sources in storage at facilities from which one can readily imagine their being stolen should be transferred to a repository, even if the repository is not 100% safe.

G. SMITH (United Kingdom): It may be recalled that, during an earlier topical session, I raised the issue of malicious intent human intrusion. I did so because I believe that such intrusion should be covered in waste management risk assessments, not in order to make it difficult to justify disposal. In fact, I believe that the possibility of malicious intent human intrusion strengthens the case for disposal. That being so, I find it strange that the people advocating disposal object to the inclusion of malicious intent intrusion scenarious among the scenarious covered in risk assessments. I do not understand why they object.

We do not know in detail all the possible forms of malicious intent human intrusion, but we need only consider the possibilities of damaging the integrity of the disposal system and devise ways of minimizing them — and of mitigating the consequences of intrusion if it occurs.

We do not need to be able to guess what sociopolitical situation will exist in a thousand years' time, but we do need to consider whether there are obvious things we can do in order to improve long term management.

J. LORENZEN (Sweden): We do not know what will happen either in the remote future or even in the near future. A few generations ago, people had no conception of nuclear power, and, in three to four generations' time, people may believe that some nuclear waste is a fantastic source of energy. So perhaps retrievable disposal is the best option.

G. JACK (Canada): It appears that several developing countries would love to use the borehole disposal technique. The difficulty lies in finding a safe site at which to drill the borehole. That requires a great deal of expertise and money.

J.R. COCHRAN (United States of America): You can obviate that difficulty by moving away from the idea of geological isolation to that of engineered isolation. Many countries have made that shift.

If you have a canister for the sources that will not leak for a long time, you eliminate the environmental pathways, and if you put the canister deep enough (30–50 m), you eliminate all human intrusion scenarios except drilling. Your safety analysis will be an analysis of the safety of the canister, not of the safety of the site, and it can be done generically.

If you are worried about drilling, you can place a granite deflector on top of the canister so that the drill stem is deflected. Alternatively, you can assess the probability of intrusion through drilling, and, if the target — the canister — is one foot in diameter, the probability will be vanishingly small (say less than one in ten million in 10 000 years), so you can dismiss it.

R.H. LITTLE (United Kingdom): I should like to mention two relevant reports regarding the feasibility of borehole disposal for a range of geosphere and biosphere conditions.

The first one relates to the NECSA approach which Mr. Potier mentioned. It describes work done for a range of different geologies and biospheres. It shows that for most combinations of conditions borehole disposal offers sufficient safety. This work, carried out for NECSA with IAEA funding, is to be followed up by an IAEA safety guide on the subject.

The second report, a draft IAEA safety report, deals with the key issues which you have to consider in a borehole safety assessment — issues such as the groundwater travel times, the absorption characteristics of the geosphere, the chloride concentrations, the sulphate concentrations and the amount of dilution at the geosphere–biosphere interface. The idea is to provide an envelope of suitable conditions whereby you can say, with a relatively small amount of site characterization, "Yes, my site fits within this envelope. Therefore, it would be possible to dispose of a particular inventory of disused sealed sources at that site."

J. ROWAT (IAEA): I am surprised that nobody has raised the issue of making long term storage passively safe in order to deal with the eventuality of active controls becoming impossible owing to a lack of financial resources.

R.H. LITTLE (United Kingdom): Some people argue that the subsurface storage of low level waste at depths down to — say — 100 m, which potentially eliminates some problems associated with surface storage, is rather like the 50 year surface storage of high level waste in that both involve passing the responsibility on to future generations. To them I would say that some of the low level waste problems I am dealing with now are the legacy of my father's generation, but I don't mind dealing with them.

P. CARBONERAS (Spain): We are looking ahead to the long term future in a much more discerning manner today than 10–15 years ago, when we were still saying that we could predict the future, including future human behaviour — which is nonsense. Accordingly, and having listened to Mr. Smith's comments about malicious intent human intrusion, I would not like to be involved in calculating the per-year probability of a terrorist attack!

D. BENNETT (United Kingdom): There are quite a lot of things we have not covered in this session and no doubt there are gaps in what we have covered, but I think we have had a good discussion of subjects such as borehole disposal, NORM waste and human intrusion.

CLOSING SESSION

Chairperson

J.C. LENTIJO
Spain

SUMMARY OF SESSION 1

POLICIES AND STRATEGIES FOR LOW ACTIVITY RADIOACTIVE WASTE MANAGEMENT AND DISPOSAL

Chairperson

P. CARBONERAS
Spain

The first session of the Symposium started with a 'scene setting' paper from the IAEA outlining the aims of the symposium and describing the activities of the IAEA most relevant to the topics of the Symposium.

It was followed by national presentations from Spain, the United States of America, France, Japan, the Russian Federation and Portugal outlining their national policies and strategies for low activity radioactive waste management.

From these national presentations it was clear that several countries have well-established arrangements for managing the low level waste from the normal operation of their regulated facilities. The presentations revealed that new additional low level waste streams have been identified that require the development of innovative management approaches. They include the large volume low level waste from decommissioning (for example, graphite waste and large metal and concrete components) and the large volume long lived waste from industries using natural materials and from the former processing and use of radium. Progress has been made in some countries towards developing appropriate disposal solutions for these waste streams. In some countries, solutions are already in place. It is evident that there is a need for further consideration of this subject, at the international level, so that generally accepted and scientifically justified solutions can be agreed upon, and applied worldwide, where needed.

These new additional low level waste streams are generally not yet included in existing waste classification schemes. In this context, it is clear that it would be appropriate for the IAEA to revise its radioactive waste classification scheme and other relevant safety standards so as to take account of the additional waste streams, indicating preferred disposal solutions and giving consideration to security concerns. The category 'very low level radioactive waste' should be included in the revised scheme.

A report on the relevance of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (the

Joint Convention) to the safety of low activity radioactive waste management was presented. The Joint Convention is recognized as an important mechanism for promoting the safety of radioactive waste management in the world. The benefits for countries that are Contracting Parties to the Convention were elaborated. However, many countries with significant quantities of radioactive waste have yet to become Contracting Parties.

The session was concluded with a panel of experts discussing the question "How can existing radioactive waste management strategies better address the needs of countries with limited resources?" The following is a summary of the main points of the discussion.

Developing countries usually have comparatively small amounts of radioactive waste making the normal methods used for waste management in countries with nuclear power plants very costly in terms of cost per waste volume. Economies of scale can be achieved through regional solutions and countries within a region were encouraged to consider such approaches. The subject can be politically sensitive but progress might be made by means of a step by step approach, starting, for example, with regional waste processing facilities before moving eventually to the more difficult area of disposal.

Concern was expressed by several participants that some governments do not take their responsibilities for managing radioactive waste sufficiently seriously. In the discussion that followed, it was suggested that an important first step towards indicating that a country has a serious commitment to managing its radioactive waste safely is to have an established national waste management strategy setting out priorities, plans and responsibilities. A further comment was that the lack of such a national policy might discourage otherwise sound initiatives in the country.

The importance of involving the waste producers in the national and international debates related to waste management, as a way of involving them in efforts to establish proper waste management strategies and activities was raised as an issue in the discussion.

Another point concerned the need to avoid unnecessary duplication of effort (mostly in international organizations) and to redirect the resources saved towards activities in countries having insufficient levels of development in radioactive waste management infrastructure.

It was finally recommended that international organizations should consider the following actions in the context of helping developing countries:

(a) Establishment of a clear approach for assessing the adequacy of national arrangements for safe radioactive waste management

(b) Production of more practically useful projects for developing countries, such as the 'borehole disposal project', as well as practical guidance and 'ready to use' assessment and management tools.

SUMMARY OF SESSION 2

VERY LOW LEVEL RADIOACTIVE WASTE (VLLW)

Chairperson

J. AVÉROUS
France

The session was started with a presentation explaining the history of the successive IAEA waste categorization schemes. It has been recognized that some important waste streams are not included in the most recent scheme, including the category of very low level waste. This, and the publication in 2004 of the new Safety Guide on Application of the Concepts of Exclusion, Exemption and Clearance (RS-G-1.7) indicate the need for the revision of the IAEA categorization. A revised IAEA classification scheme should be more closely linked to an overall scheme for managing all types of radioactive waste in which each waste type is identified with a suitable disposal route; such a scheme is under development at the IAEA under the title "A Common Framework for Radioactive Waste Management".

Presentations from France and Spain described national progress in establishing disposal facilities for very low level waste (VLLW). The French VLLW disposal facility at Morvilliers has been operational since mid-2003 while, in Spain, a technically similar facility, planned to be sited at El Cabril, is currently undergoing regulatory review. One difference in approach is that the Spanish facility will be regulated as a nuclear facility, while the French facility is regulated in relation to conventional hazardous waste disposal regulations.

A third presentation focused on the current strategic review of LLW management in the United Kingdom, under the aegis of the new Nuclear Decommissioning Authority. Preliminary assessments have shown that the remaining capacity of the Drigg surface disposal facility will be insufficient when account is taken of the expected waste volumes from future cleanup and decommissioning operations. The participation of stakeholders and the public in the definition of the strategy are stressed as being essential, and for that reason, the range of possible management options being considered is very broad.

The last presentation described the efforts of the EC in developing clearance levels for application to different materials. The presentation reviewed the various approaches to the management of VLLW in EU countries and assessed the merits of the different approaches, e.g. recycling, landfill and VLLW repositories.

Following these presentations, a panel session was held with the title "Clearance and VLLW disposal: Competing or complementary approaches?"

Most participants considered that the clearance concept and VLLW disposal can be complementary but that further clarification and elaboration of how the concepts can be applied separately and together is needed.

A VLLW waste category was considered by most participants to be useful, however, one view was that it may complicate unnecessarily the overall waste management scheme, especially for countries with small amounts of waste or with exclusively NORM waste.

Clearance is a logical and well-based scientific concept with the potential for avoiding costly and unnecessary regulation. While it is clear that the adoption of policies such as clearance in countries is affected by public acceptance, the role of the scientific and technical community is to provide clear and scientifically based advice (decision aiding rather than decision making).

Whether or not clearance policies are adopted in a country, it is valuable to have the capacity for waste disposal, be it a LILW repository, a VLLW repository, or both. There is a need for flexibility in defining acceptable management solutions for VLLW, whatever the solutions considered may be (clearance, disposal, etc.). Some reasons are:

(a) Different management solutions (including different clearance policies) may be justified depending on the circumstances, for example, for small amounts of material or for particular materials for which the final destination is known.
(b) The costs and difficulties associated with transporting large amounts of radioactive waste to distant sites may provide an argument for relaxations in disposal arrangements at the site of origin.
(c) Different disposal arrangements may be decided upon depending on the origin of the waste, for example, if it is from operational practices or from intervention situations involving the cleanup of contaminated areas.

However, the requirement for flexibility does not remove the need for a well-defined regulatory framework that will ensure consistency.

At the international level, there is a need for more guidance on the practical application of the clearance concept (and of the new document (RS-G-1.7)), on approaches for demonstrating compliance with clearance criteria, on an operational framework for transboundary trade in material, and on the safety requirements for VLLW surface disposal facilities.

SUMMARY OF SESSION 3

LOW ACTIVITY RADIOACTIVE WASTE FROM DECOMMISSIONING

Chairperson

L. VALENCIA
Germany

The session started with a presentation from the NEA giving a global overview on estimates of the radioactive waste produced as a result of the decommissioning of NPPs. However, the exercise revealed that such data are sparse and, although available for some common reactors types, the estimated amounts are variable, and so it is concluded that it is currently difficult to provide reliable global estimates.

It was followed by a presentation describing the system in France for managing the waste from decommissioning operations. It is characterized by a 'defence in depth' approach with a leading role for 'zoning' as a means of distinguishing conventional from nuclear waste at nuclear facilities. It is supplemented by checking and measurement procedures as additional safety steps. The advantages of the approach were described from both technical and socio-political perspectives.

The third presentation described the experience of decommissioning nuclear fuel production facilities in South Africa. Metal scrap from the facilities has been successfully decontaminated and recycled. However, radioactive waste has yet to be disposed of. It awaits the establishment of a national policy for radioactive waste management in South Africa. In its absence, approved waste disposal routes are lacking, although a potential site exists at the existing LLW disposal facility at Vaalputs.

Two presentations described the plans for managing decommissioning waste in Japan. A large number of facilities will eventually have to be decommissioned and considerable efforts have gone into making plans for the disposition of the resulting waste. Progress towards establishing a comprehensive scheme for managing and disposing of radioactive waste from decommissioning was described, ranging from clearance policies, at one extreme, to geological disposal, at the other.

The final presentation covered plans for decommissioning the Ignalina NPP in Lithuania. An assessment performed to estimate the expected waste amounts from decommissioning was described; it includes a categorization scheme based on the predicted external radiation doses from the various waste streams.

A panel session addressed the question "Radioactive waste disposal routes: A bottleneck for decommissioning?"

For the countries represented on the panel there is no bottleneck effect so far. This is because three of them (Sweden, Belgium and Lithuania) are at a fairly early stage of decommissioning; they each anticipate that near surface radioactive waste repositories will become available at the appropriate time to deal with the low and intermediate level waste from decommissioning. In the case of the other country, the United States of America, there are various near surface disposal options available at present and these are being utilized to the full by decommissioning companies.

Even without the availability of a near surface disposal facility at the time when radioactive waste is being produced from decommissioning, the implementation of decommissioning is not necessarily excluded. If a clearance (or zoning) policy is in place and being implemented in the country, only a comparatively small volume of radioactive waste has to be managed and this can be achieved through the on-site interim storage of suitably conditioned and packaged waste.

IAEA Safety Standards place emphasis on the need to plan for decommissioning at the design stage of nuclear facilities. Such planning was generally not done for the generation of facilities now being decommissioned. However, in response to a question concerning lessons learned to prevent bottlenecks, it was revealed that the designers in Finland are giving consideration to these aspects in the context of planning for their new NPP.

Concern was expressed over the availability in countries of the expertise necessary to carry out decommissioning. This consideration is one of the arguments for early or immediate dismantling — so that advantage can be taken of the expertise of the existing workforce. Participants also described schemes in their own countries to engage young people in their organizations, as another way of addressing the problem.

SUMMARY OF SESSION 4

LONG LIVED LOW ACTIVITY WASTE/ OTHER MATERIALS

Chairperson

M.V. FEDERLINE
United States of America

This session was mainly devoted to the issues arising from the need to manage long lived low activity waste for very long times into the future. However, the session was started with a presentation summarising a study which has reviewed arrangements in the United States of America for the management of low activity radioactive waste. One of the main conclusions is that while the the regulatory framework that has evolved provides adequate authority for the safe management of low activity radioactive waste, it is based on the origin of the waste rather than the radiological hazard that it presents. Probably as a consequence, the regulatory system was found to contain certain inconsistencies and gaps. Presentations from Belgium, Canada and Estonia described the arrangements that have been made for the management of historic long lived waste from nuclear and non-nuclear industries, while a presentation from India described the national arrangements for managing long lived low level waste from the nuclear fuel cycle.

A panel session addressed the question “Do we have adequate solutions for the disposal of long lived low activity waste?”

The focus of discussion tended to be on NORM materials and their long term management, often in the context of how risks from these materials are managed in comparison with risks from nuclear fuel cycle waste. Some of the major points that arose in the discussion are summarized in the following paragraphs.

Nuclear fuel cycle waste is of extreme concern to the general public (often in contrast to their attitudes to NORM). The lack of definitions, or the use of definitions that are difficult to understand, for terms such as low activity waste or low level waste, can be frustrating for the public, and the development of more understandable definitions by countries and international organizations would be helpful in building public confidence.

There is a strong need for risk informed management of low activity radioactive waste. Where the risk is equal from different radioactive waste types, there should be equal treatment of those waste types in managing the associated risks.

Where the amounts of waste material are very large, for example, in the case of NORM waste, institutional controls and the use of greater realism and less conservatism in the assessment of potential radiation exposures may be required as part of rational and practical solutions for managing these waste types.

There is continued debate about the effectiveness of institutional controls, and additional guidance and examples of their use would be of benefit to countries that have to rely on them. One issue concerns the amount of reliance to be placed on passive controls, such as markers, as compared with active controls, such as monitoring. Both points of view were given in the session. In any case, it seems inevitable that institutional controls will be used, but that steps will have to be taken to ensure that they are effective, and better understood. It was noted that the consequences of their failure need to be considered, for example, as part of a safety assessment, because they can range from very large, if a highly radioactive sealed source is dug up, to very small, if a fence is breached and an unplanned land use occurs on land contaminated with relatively low concentrations of radioactive material.

In addition to focusing on risk, and defining terms clearly, there are other significant steps that countries can take to build public confidence. They include having a clear commitment from governments to solve particular problems, both in words and deeds. This may entail having direct involvement in dealing with those affected, making financial contributions to resolve the problems, and having an ongoing participation and oversight of the solutions that are negotiated.

The session provided information on different ways in which NORM and fuel cycle materials are being managed. At least one country has a systematic framework in place for addressing NORM management that may provide insights for other countries. It is based on risk (or more specifically dose), and makes use of optimization to determine what is practically achievable below a certain radiation dose limit. It also relies on the use of more realistic exposure scenarios than those often employed for radiological assessments of nuclear fuel cycle waste.

The technical community responsible for managing NORM waste is often different from that having responsibilities for managing nuclear fuel cycle waste. In this session there was encouragement for the communities to work more closely together towards finding consistent solutions that properly satisfy international safety requirements.

SUMMARY OF SESSION 5

UNIQUE LOW ACTIVITY WASTE

Chairperson

D. BENNETT
United Kingdom

Presentations were made by invited speakers from the United Kingdom, France, the United States of America, Belarus and the Syrian Arab Republic addressing work being undertaken to solve a range of problems concerning: situations where there are relatively high activities of long lived radionuclides in waste, the management of disused sealed sources, the problem of limited resources for waste management in some countries and the issue of historic disposal sites which do not meet modern standards.

Two of the presentations concerned graphite waste from gas cooled reactors, which contain significant amounts of long lived radionuclides. Both were given on behalf of countries with capabilities for dealing with these waste types. One was given by an operator of research and development reactors and described an innovative technique for reducing the waste inventory in order to meet waste acceptance conditions for an existing near surface disposal facility. The other paper was given by a waste disposal organization and described the proposed development of a subsurface disposal facility to deal with this waste type.

The next presentation described work undertaken to demonstrate the potential for boreholes, sunk to intermediate depth in thick alluvial deposits, to safely isolate disused sealed sources. This is a conceptually simple, low cost, option, potentially of interest to countries having small amounts of waste and limited resources to deal with the problem. Work under way to explore the potential for employing the technique for the safe disposal of spent sealed sources in Egypt is a good example of cooperative activity between organizations and countries.

The next presentation described important work in one country to identify and assess a range of historical radioactive waste disposal practices. Some them fall short of modern safety standards and could give rise to significant risks to the public in the short term. A considerable amount of work will be required to upgrade the existing disposal facilities, or to retrieve waste for subsequent treatment and disposal in facilities built to modern standards.

The final paper addressed the management of NORM waste from the oil and gas industries. It described the development of a national strategy for dealing with different categories of waste and made recommendations to industry and to national regulators in order to implement the strategy.

A panel of experts then discussed with symposium participants the question "What are the remaining gaps and issues related to the disposal of low activity radioactive waste?"

The panel discussion led to the identification of a list of gaps and issues, which included:

(a) Gaps:
   (i) Lack of disposal routes in some countries, particularly for sealed sources;
   (ii) Historic disposals which fall short of modern standards.

(b) Issues:
   (i) The pressure to minimize disposal costs;
   (ii) The different levels of regulation across Member States;
   (iii) The inadequate knowledge of some national waste inventories;
   (iv) The poor understanding of radiation doses associated with NORM;
   (v) The inadequate level of support available to countries with limited resources;
   (vi) The exploitation of countries with lower standards by unscrupulous commercial interests;
   (vii) The option of long term storage as an alternative to disposal.

A number of possible ways of resolving the identified gaps and issues were discussed by the panel and the participants. The implementation of the borehole disposal concept was one of these. The borehole concept is of interest to many Member States, especially those with small waste inventories and limited resources. The organizations involved in developing the borehole concept are to be encouraged to promote understanding of the potential benefits of this option.

There was a discussion regarding the short and long term safety of disposed waste in boreholes. This included consideration of the following points: the chance of inadvertent and deliberate/malicious intrusion, the level of safety provided by the borehole compared with levels of safety of the many unwanted spent sources presently in surface storage, the application of the borehole concept in different geosphere/biosphere locations (arid versus temperate, low versus high population, etc.), and the potential for engineering design to improve safety.

A strong message emerged from the discussion that signing up to the Joint Convention is a means of avoiding exploitation for countries with existing lower standards.

It is desirable for there to be increased support to countries with limited resources in the provision of: training, advice and guidance on regulatory frameworks, assessment tools and guidance on best available practices and techniques. There is much advice and guidance already available or under development by the IAEA and similar organizations that will facilitate this support.

Remarks by Chairperson of Closing Session

J.C. LENTIJO

Spain

This Symposium was very timely because it responded to the need for countries to address the issues associated with low activity radioactive waste management; issues which have often not received sufficient attention in the past. It has included the increasingly important subject of the management of waste from the decommissioning of nuclear facilities and the management of other important low level waste streams.

The Symposium has provided evidence of the progress being made in many countries towards the safe management and disposal of low and intermediate level waste from nuclear power plants. This contrasts with the generally slow progress globally in establishing geological repositories. However, it is also clear that not all countries are being successful in managing low and intermediate level waste, mainly because of problems in siting near surface repositories or because of a lack of resources to develop repositories.

The Symposium has drawn attention to important aspects where more consideration is still needed, for example, in the application of the clearance concept and arrangements for very low level radioactive waste disposal.

It has drawn attention to important low level waste streams for which there is, as yet, no consensus on how they should be managed. Examples are the large volume and bulky waste from decommissioning, the long lived and large volume waste from other industries and from past events and accidents. For these waste types there is a need to balance safety considerations and economics and to find solutions that are demonstrably safe but affordable.

The problems of developing countries with small but significant amounts of waste were discussed and, in particular, the problems of limited resources and of unfavourable economics of scale, especially in the context of waste disposal.

In many of these areas there have been proposals from the Symposium on how to improve the situation — sometimes through bilateral action and sometimes through recommendations to international organizations to establish new programmes or projects.

This has been a technical meeting; its focus has been on how to solve problems by means of scientific and engineering solutions. In real life, politics and public opinion are often major factors influencing decision making. Nevertheless, there will always be a need for sound science and workable technical solutions. The Symposium recognized that it is the role of the technical community to ensure that decision makers are always provided with such solutions.

One of the main functions of international symposia such as this one is in facilitating the exchange of information between countries. This Symposium has, in addition, been valuable in,

(a) Reaching common views on important subjects — through panel sessions and the involvement of the participants;
(b) Identifying international solutions to common problems;
(c) Advising the international organizations on priority items for their programmes.

It is clear that the Symposium has made an important contribution to resolving the problems of low activity radioactive waste disposal and that the published proceedings will make a useful addition to the international literature. The subject is very important for Spain and it was appropriate that the Government of Spain was able to host the Symposium.

CLOSING ADDRESS

T. Taniguchi
Deputy Director General
Department of Nuclear Safety and Security,
International Atomic Energy Agency,
Vienna

The programme of the IAEA on the management of radioactive waste that is included in the IAEA's Major Programme on Safety and Security has been constantly revised and adjusted as a result of the Conferences and Symposia that have been organized in these last years; in particular, the 2000 IAEA Conference on Safety of Radioactive Waste Management, held in Córdoba, and the 2002 IAEA Conference on Issues and Trends in Radioactive Waste Management, held in Vienna. The IAEA's programme on radioactive waste management has been influenced and structured by Action Plans derived from the findings of these international meetings. From the present Symposium again, I see several important findings that can influence the existing Waste Safety Action Plan and, in particular, the three related actions of the Action Plan that have been the basis for this Symposium.

The first action (Action 4), which I think will be influenced by the Symposium results, is the action to develop an internationally accepted and harmonized approach for controlling the removal of materials and sites from regulatory control. The Symposium has made it clear that the IAEA's waste classification and its clearance policy should be coherent with each other. The IAEA had planned to start the reassessment of its waste classification in 2005; it will take due account of the specific conclusions of the Córdoba Symposium in this development. The clearance document, the Safety Guide RS-G-1.7, was issued this year. As a result, there is now an internationally endorsed set of levels for clearance that apply to bulk quantities of materials. This is seen by the IAEA's Member States as a great achievement and is reflected in a resolution of this year's IAEA General Conference. The specific discussions on this topic at the Symposium made it clear that practical guidance is now needed on how to apply the Safety Guide recommendations, specifically, how to verify compliance with clearance levels and how to implement the 'graded approach' to regulation at low levels of risk. As a general policy, it has already been decided that more technical documents in support of the Safety Standards will be developed. This will certainly help us to provide more clarity in the application of these Standards.

The two topics of waste classification and clearance are elements of what has been called the “common framework for radioactive waste management”, and lead to the second action (Action 1) of the Waste Safety Action Plan, that is, to develop a common framework for the management and disposal of different types of radioactive waste that sets out optimum management and disposal routes for the various waste types, taking particular account of the hazard that they present. This is a major effort at the IAEA. We have had, throughout the Symposium sessions, illustrations of the different problems and concerns of our Member States in managing their waste and evidence of how much these concerns can vary from one country to another depending on the nature of the respective nuclear programmes, on the volume and inventory of the waste and on the availability of financial resources. This common framework is relevant to all types of waste but is crucial for low activity radioactive waste where the diversity in management options is the greatest. The IAEA must, together with other relevant international bodies, work out a framework that will offer safe and appropriate disposal routes for each of these diverse waste types. In preparing this framework, we must pay attention to all existing situations, in particular, situations where the amount of waste is small and where there are very limited financial resources.

This effort combined with the IAEA’s methodological projects on safety assessment which bring together countries with different safety cultures and practices, is the basis of a knowledge management network for our Member States. The essence of knowledge management is treating knowledge as a capital asset. Therefore, introducing methods to better manage waste safety knowledge is of key importance for providing Member States with solutions for radioactive waste management problems. This mechanism can be used to promote the sharing of experience among our Member States and to create new knowledge.

The last action (Action 9) of the existing Waste Safety Action Plan to be influenced by this Symposium requires the Secretariat “to explore international mechanisms for facilitating the management of spent sealed radioactive sources and, in particular, for the disposal of such sources”. This issue, of importance in terms of both safety and security, was actively discussed during the Symposium. We will take the discussions of the Symposium on this subject into account in the further development of our current project aimed at finding adequate solutions for the disposal of disused sealed sources, starting with our African Member States.

This part of the Waste Safety Action Plan is particularly relevant the Technical Cooperation programme of the IAEA. Given the IAEA’s mandate to establish Safety Standards and to provide for their application, there is no better way to provide for their application than by supporting our less advanced Member States by training their professionals and enhancing their regulatory infrastructures.

I cannot conclude without mentioning the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. The Joint Convention envelopes all of the issues related to the management of low activity radioactive waste that have been discussed during this Symposium and is relevant to all countries — because every country has at least some low activity radioactive waste to manage. Countries must not see the Joint Convention only as a peer review process, but also as a way for them to improve their waste management programmes through international cooperation.

I wish to remind all participants of the forthcoming International Conference on the Safety of Radioactive Waste Disposal that will be held in Tokyo, Japan from 3 to 7 October 2005. The results of this present Symposium will surely support the development of the programme of the Tokyo Conference.

Before finishing, I wish to thank all those who worked to make this Symposium a great success. I hereby declare the 2004 Córdoba Symposium closed.

CLOSING ADDRESS

J.A. Pina
President
Empresa Nacional de Residuos Radioactivos (ENRESA),
Madrid, Spain

It is an honour for me to close this International Symposium on the Disposal of Low Activity Radioactive Waste, which reaches its conclusion today after an intensive and fruitful week of work that has seen the participation of more than 250 experts and representatives from national programmes and regulatory organizations from some 60 countries and international organizations. It has also been a source of pride that this important international event has been held in this wonderful and historic city of Córdoba. As you are all aware, this city is the capital of the province in which our El Cabril low and intermediate level waste disposal facility is located, in the municipal area of Hornachuelos; it is a facility of which we are all very proud.

The Symposium has been organized by the IAEA in cooperation with the OECD Nuclear Energy Agency (NEA), under the auspices of the Government of Spain, through the Nuclear Safety Council (CSN) and the Spanish Radioactive Waste Management Agency (ENRESA), in collaboration with the French National Radioactive Waste Management Agency (ANDRA).

Throughout this week we have had an opportunity to gain insight into, and debate in depth, the current approaches being adopted for the management of low activity radioactive waste, the problems associated with managing the different streams of this type of waste and the current international challenges and initiatives in this area. In particular, the following issues were debated:

(a) Currently existing management policies and strategies and their suitability for countries with limited resources;
(b) Solutions for the management of ‘very low level’ waste and especially considerations regarding its final disposal and practices for its removal from regulatory control;
(c) Management routes for low level waste arising from the dismantling of nuclear facilities and their influence on dismantling strategies;
(d) Management practices for materials having unique characteristics, such as graphite or disused spent sealed sources.

The session chairpersons have already reported on the main conclusions of the symposium and have underlined those aspects that, in view of their unique management implications, still warrant special attention in international cooperation programmes.

I should like to highlight just one or two aspects. Most of the radioactive waste generated during the different stages of the nuclear fuel cycle and in industrial, medical or research activities are, indeed, low and intermediate level wastes for which there are industrial solutions based on a wide and varied body of experience. However, while the waste from the dismantling of nuclear facilities will represent the largest amount, by volume, from the nuclear fuel cycle, the greatest part of it contains very low levels of radioactivity. In my opinion, this fact should be taken very much into account when designing and establishing requirements for the installations that are to house such waste. The protection measures should be in keeping with the risks posed by the waste to be managed. The application of this general principle is, to my way of thinking, a very important basis for the optimization of the overall management of radioactive waste. It cannot be forgotten that the economic resources available are limited and that they should, therefore, be used efficiently in management practices. This has been understood by the Spanish House of Congress, which has underlined the need for the country's low and intermediate level waste management system to be optimized, through various Resolutions of its Industry and Energy Commission. With this aim in mind, we have developed the project for complementary installations at the El Cabril site to house very low level waste. This project is currently being reviewed by CSN.

The other point that I wanted to touch on briefly relates to social aspects, and very specifically to public information, which, although not the subject of this Symposium, is critical when trying to achieve socially acceptable solutions. Radioactive waste management encompasses a number of complex scientific and technical disciplines and, like any other such specialized subject, uses a highly specialized language that is generally not easily understood by the public. The public's concern regarding nuclear issues in general, and radioactive waste in particular, although constructed on perceptions that are not based on scientific evidence, is a fact that must necessarily be taken into account when attempting to create the climate of trust necessary to allow us to implement suitable solutions. In this respect, in my opinion, there is a need not only for transparency but also for effort in disseminating information, such that the issue can be understood by the general public.

In concluding, I should first like to thank the IAEA for having organized this important international Symposium in Spain, in cooperation with the NEA, and to thank also ANDRA for its collaboration.

I should also like to express my gratitude to all those who have made this Symposium possible: the members of the Programme Committee, the Chairpersons and Rapporteurs of the Technical Sessions, the participants in the discussion panels, the authors of the papers and posters and those who have attended the Symposium.

CHAIRPERSONS OF SESSIONS

Opening Session	A. BECEIRO	Spain
Session 1	P. CARBONERAS	Spain
Session 2	J. AVÉROUS	France
Session 3	L. VALENCIA	Germany
Session 4	M.V. FEDERLINE	United States of America
Session 5	D. BENNETT	United Kingdom
Closing Session	J.C. LENTIJO	Spain

PRESIDENT OF THE SYMPOSIUM

M.-T. ESTEVAN BOLEA Spain

PROGRAMME COMMITTEE

Chairperson:	K. Bérci	Hungary
Members:	J. Tamborini	France
	T. Eng	OECD/NEA
	A. Beceiro	Spain
	E. Vico	Spain
	P. Zuloaga	Spain
	J. López de la Higuera	Spain
	C. Torres Vidal	Spain
	D. Graham	United Kingdom
	J. Kennedy	United States of America
	J.-M. Potier	IAEA
	J. Rowat	IAEA

SECRETARIAT OF THE SYMPOSIUM

J.-M. POTIER	Scientific Secretary (IAEA)
J. ROWAT	Scientific Secretary (IAEA)
K. MORRISON	Conference Organizer (IAEA)
H. SCHMID	Conference Organizer (IAEA)
A. GALASINSKI	Conference Secretary (IAEA)
M. DAVIES	Records Officer (IAEA)
G. LINSLEY	Proceedings Editor
R.J. BENBOW	Coordination Editor (IAEA)

SUMMARY LIST OF PARTICIPANTS

Note: detailed address information provided by the participants at the Symposium is provided on the CD-ROM at the back of this publication.

ALBANIA
- Qafmolla, L.

ARGENTINA
- Perri, M.S.

AUSTRALIA
- Fernando, K.
- Woollett, S.M.

AUSTRIA
- Puchhammer, V.

BELARUS
- Shiryaeva, N.

BELGIUM
- Baekelandt, L.
- Boyazis, J.P.
- Braeckeveldt, M.
- Dardenne, P.
- Dierckx, A.
- Doneux, J.D.U.I.
- Grosfils, O.
- Lemmens, A.
- Minon, J.P.
- Steinkuhler, C.C.F.
- Van Cotthem, A.
- Vanwildemeersch, J.
- Verwaest, I.R.A.

BRAZIL
- de Almeida Gomes, C.
- Diniz, C.
- Faria Esposito, F.
- Fernandes, H.M.
- Lauria, D.
- Pires do Rio, M.A.

CANADA
- Ben Belfadhel, M.
- Case, G.G.
- Jack, G.
- Lojk, R.
- Zelmer, R.L.

CHILE
- Tenreiro Leiva, C.

CROATIA
- Grgic, S.
- Kubelka, D.

CUBA
- Tomás Zerquera, J.

CZECH REPUBLIC
- Kulovany, J.

DENMARK
- Carugati, M.S.
- Dyekjaer-Hansen, T.
- Nielsen, C.
- Ostergaard, M.

EGYPT
- El-Kamash, A.M.
- Zaki, A.A.

ESTONIA
- Lust, M.

FINLAND
- Sjöblom, K.-L.

FRANCE
- Avérous, J.
- Barescut, J.-C.

Bertrand, C.
Cazala, C.
Cessac, B.
Chapalain, E.
Dutzer, M.
Grévoz, A.
Jacq, F.
Jarret-Laurend, D.
Palut-Laurent, O.
Pellegrini, D.
Tamborini, J.

GERMANY
Borrmann, F.
Goldammer, W.
Oppermann, U.
Valencia, L.

HUNGARY
Berci, K.
Czoch, I.
Juhász, L.
Ormai, P.
Szanto, Z.
Vegvari, I.

INDIA
Lal, K.B.

IRAN, ISLAMIC REPUBLIC OF
Darban, A.K.

ISRAEL
Ambar, D.
Dickstein, P.M.
Hirshfeld, H.
Makover, I.
Peles, D.H.
Sarusi, R.
Schwartz, I.
Torgeman, S.

ITALY
Demofonti, C.
Resta, E.
Rizzo, S.
Zorzoli, F.

JAPAN
Karigome, S.
Kashiwagi, M.
Kawakami, H.
Kawakami, Y.
Kawatsuma, S.
Sakai, A.

KAZAKHSTAN
Shiganakov, S.B.

KOREA, REPUBLIC OF
Cheong, Jae Hak
Im, Man-bin
Kang, Sang Yeol
Lee, Nam-yong
Park, Sang Hoon
Suk, Tae Won
Yun, Si-tae

LITHUANIA
Janenas, D.
Poskas, P.

MALAYSIA
Gan, Pek Yen
Hasmadi, H.
Razali, H.
Syed Hakimi Sakuma, S.A.

MEXICO
Mejia Lopez, M.
Paredes Gutierrez, L.

NETHERLANDS
O'Sullivan, P.J.

NORWAY
Davids, C.
Sneve, M.

Varskog, P.

PORTUGAL
Muñoz, J.I.
Paiva, M.I.F.
Rezio, M.T.
Trindade, R.

ROMANIA
Raducea, D.
Rodna, A.L.
Vieru, G.

RUSSIAN FEDERATION
Neretin, V.A.
Polkanov, M.
Sukhanov, L.
Tourlak, E.A.
Tourlak, V.
Yakovleva, E.

SERBIA AND MONTENEGRO
Jovanovic, S.
Plecas, I.
Raicevic, J.

SLOVAKIA
Stefula, V.

SLOVENIA
Veselic, M.

SOUTH AFRICA
Bredell, P.
Pretorius, G.F.A.
Tselane, T.

SPAIN
Alvarez, M.A.
Beceiro, A.R.
Blázquez Arroyo, E.
Cancio, D.
Carboneras, P.
Carretero, L.
Correa, C.
Duro, L.
Enríquez, C.
Espejo, J.M.
Estevan Bolea, M.T. *(President)*
Garcí Márquez, J.A.
García Neri, E.
Grávalos, J.M.
Guerra-Librero, A.
Lang-Lenton, J.
Lentijo, J.C.
Lopez de la Higuera, J.
López, I.
Morales, A.
Navarro, M.
Pina Barrio, J.A.
Ramos, L.
Redondo García, J.M.
Rodríguez, A.
Sánchez, G.
Simón, M.I.
Torres Vidal, C.
Vico, E.
Zuloaga, P.

SWEDEN
Efraimsson, H.
Frise, E.O.L.
Keyser, P.B.
Lorenzen, J.
Skogsberg, M.L.
Sundström, B.E.
Torstenfelt, N.B.
Wiebert, A.

SYRIAN ARAB REPUBLIC
Othman, I.

TURKEY
Özdemir, T.

UKRAINE
Bilyk, A.
Savin, A.

UNITED ARAB EMIRATES
Dib, M.

UNITED KINGDOM
Bennett, D.
Bennett, D.G.
Brown, K.
Dutton, L.M.C.
Goldschmidt, A.
Graham, D.
Jackson, R.L.
Langley, K.
Little, R.H.
Longley, P.
Meehan, A.R.
Selby, T.
Smith, G.
Streatfield, I.J.
Williams, T.
Wisby, S.
Wise, M.

UNITED REPUBLIC OF TANZANIA
Shao, D.

UNITED STATES OF AMERICA
Bailey, E.
Benda, G.
Cochran, J.R.
Farley, D.R.
Federline, M.
Hasan, A.
Kennedy, J.E.
Kozak, M.W.
Leroy, D.

VIETNAM
Pham, Van Lam

EC
Hilden, W.
Janssens, A.
Murphy, S.

IAEA
Jova Sed, L.
Louvat, D.
Metcalf, P.
Nachmilner, L.
Potier, J.-M.
Rowat, J.
Sokolov, Y.
Taniguchi, T.

OECD NUCLEAR ENERGY AGENCY
Echávarri, L.
Eng, T.

WANO
Tailliez, B.L.G

AUTHOR INDEX

Low activity radioactive waste constitutes the largest proportion, by mass and volume, of all such waste types. Management solutions exist for some but not all of these wastes. A new urgency exists in many countries to develop and extend existing waste management practices owing to the ongoing or imminent decommissioning of their nuclear power plants. This symposium was convened in order to facilitate exchange of information on this topic and to seek common approaches to the problems identified.

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA
ISBN 92–0–102905–5
ISSN 0074–1884