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FOREWORD

In response to the needs of its Member States, and for dealing with the problems of radioactive contamination in the environment, the IAEA has established an Environmental Restoration Project. The principal aspects of current IAEA efforts in this area include (1) gathering information and data, performing analyses, and publishing technical summaries, guides, reports and publications on key technical aspects of environmental restoration; (2) conducting a co-ordinated research project in environmental restoration; and (3) contributing expert assistance and co-ordinating technical activities for the IAEA's technical co-operation projects for the rehabilitation of radioactively contaminated sites. Included in the information and data gathering effort is a survey of radioactively contaminated sites in the current membership of the IAEA and development of an international registry of such sites.

This publication focusses on factors which are important for formulating a strategy for environmental restoration. In parallel to this effort, the IAEA has conducted activities in related areas which have been reported in companion reports dealing with (1) the characterization of radioactively contaminated sites for remediation purposes and (2) available technology for cleanup and remediation of radioactively contaminated sites. Additionally, follow-up activities will focus on two other areas, viz. planning and management options for cleanup of contaminated groundwater, and post-restoration monitoring of decommissioned sites.

In a separate initiative the IAEA has developed preliminary guidance on radiological criteria for determining when cleanup action is needed and for deciding on when areas have been cleaned up to a sufficient extent.

This publication is concerned with radioactive contamination of soils, groundwaters, structures and biota which may have the potential for harm to people. It is intended that it will serve as an important source of information and data on the key factors to be considered in the formulation of an environmental restoration strategy.

The initial draft of this report was prepared at a consultants meeting held in Vienna in November 1995, with the assistance of R. Pollock (Canada), A. Jouve (France), V. Projaev (Russian Federation), S. Claughton (United Kingdom), and J. Vrouwes (United States of America). J. Vrouwes, whose graduate thesis at Denver University, USA, was used as a basis for the initial draft, served as chairman of this meeting. D.E. Clark of the IAEA's Division of Nuclear Fuel Cycle and Waste Technology served as Scientific Secretary at this and subsequent meetings. An Advisory Group meeting (AGM) was convened in Vienna in June 1996 for the purpose of reviewing the draft report and providing a broader coverage of views on this important subject. Eleven specialists, representing Belgium, Canada, Croatia, France, Germany, India, Italy, the Russian Federation, Slovakia, the United Kingdom and the United States of America, participated in this AGM. L. Fellingham of the United Kingdom served as chairman for the AGM. Lastly, a consultants meeting was held in Vienna in December 1996 for final review and revision of the text. Participants were R. Pollock (Canada), V. Projaev (Russian Federation), L. Fellingham (United Kingdom), and S. Warren (United States of America). L. Fellingham also served as chairman of this consultants meeting. G. Gnugnoli of the IAEA provided important assistance and advice to the Scientific Secretary throughout the implementation and completion of this task.

EDITORIAL NOTE

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1. INTRODUCTION

There are a very large number of sites around the world where radioactive materials, human made or natural, have been or are being used. Each of these has the potential for becoming a source of environmental contamination. Some of these sites have become contaminated as a result of past waste management practices or due to nuclear accidents. In recent years, public and political awareness of the potential problems associated with radioactively contaminated sites has risen considerably. It was the result of an increased public interest in all aspects of the safety of nuclear power and particularly radioactive waste management and disposal. The interest increased significantly following the Chernobyl accident in 1986. It has recently been raised further as information has been released on the environmental problems both in eastern Europe and the former Soviet Union and on the state of nuclear weapons production facilities in the Russian Federation and the United States of America [1–4].

To address these growing concerns, the IAEA has initiated an environmental restoration project, with the objective to collect information on, and support development of, (1) management techniques for planning and implementing environmental restoration activities; and (2) reviewing available technology for remediation of radioactively contaminated sites. In the near term (through 1999), these objectives will be met through performing the following tasks:

- Publishing technical summaries, guides, reports and documents on characterization and remediation technologies applied to radioactively contaminated sites.

- Conducting a co-ordinated research project focusing on site characterization techniques.

- Co-ordinating and assisting in technical co-operation projects relating to environmental restoration.

- Developing an international registry of radioactively contaminated sites.

Given the potential number and extent of radioactively contaminated sites, it is appropriate that each country should have its own strategy for identifying, characterizing and potentially remediating such sites according to their own national priorities and needs. To develop this strategy, responsibility will need to be given to an appropriate national agency. This report addresses the important factors to be considered in development of such a strategy.

Further work under the project will provide general information on the characterization of radioactively contaminated sites for remediation purposes. It will present technical approaches (e.g. sampling, radiation measurements, laboratory testing, etc.) used to determine the extent of contamination and its chemical/physical form, nuclear properties, distribution, etc. primarily in order to support the remediation (cleanup) of radioactive contamination.

A third part of the project will be concerned with technology information, guidance on criteria for selecting technologies, resources for further technology information, trends in technology developments, and case examples of environmental characterization and remediation.

In a separate initiative, the IAEA has established preliminary radiological criteria for aiding decision making on the cleanup of contaminated areas [5].

2. OBJECTIVE AND SCOPE

The objective of this report is to provide information to Member States for use in formulating and implementing strategies at the national and local level for the environmental restoration of radioactively contaminated sites. The scope covers sites contaminated from all types of activity, except uranium mining/milling and decommissioning of nuclear facilities which are treated elsewhere [6, 7].

Many of these sites require environmental restoration in order to reduce the levels of risk to the workers, general public and the environment. Environmental restoration encompasses:

(i) cleanup and decommissioning of redundant or disused structures on the site;

(ii) remediation of any contaminated soil and groundwater;

(iii) restoration of the site to a level appropriate to its planned future use; and

(iv) management of any resulting wastes.

In ideal circumstances, the environmental restoration process aims to restore a contaminated site to a condition where no restrictions are necessary. In practice, the site cleanup process can involve varying degrees of cleanup and hence levels of exposure. The cleanup level may be sufficient to permit unrestricted use of the site, or it may be more limited, necessitating certain restrictions remain on its use and access.

There are many factors which must be considered in developing a strategy for environmental restoration, not all of which are discussed in this report. The relative importance of the different factors will vary depending on the type and extent of radioactive contamination; the site's characteristics and surroundings; the affected populations; the perceived priorities at the local, regional, and national levels; and so on. However, in all cases, a range of factors will be considered and selections made by decision makers in development of strategy and planning for remediation. The following list, not intended to be exhaustive, indicates the variety of factors which may affect the strategy adopted for any particular situation involving environmental contamination:

- national policies on waste management, worker and public safety, etc.;
- legal framework;
- international agreements and relations;
- national (and international) criteria and standards;
- regulatory framework at the national and local levels;
- public attitudes and perceptions;
- cultural and ethnic traditions;
- organizational structures and responsibilities;
- problem site identification and characterization;
- safety and human health regulations, etc.;
- ecological impacts;
- human health impacts;
- economic and social impacts;
- implementation resources (economic, technical, etc.);
- management of wastes;

- programme and project management; and
- post-restoration activities.

To meet the stated objectives, this report first describes typical situations that have resulted in sites becoming contaminated. Descriptions are then given of how Member States may organize internally to deal with their specific situations. A discussion is given of the factors to be considered, at the national, regional and local levels. The report then discusses how these factors can be considered at a site, as well as, how decisions would be made, based on these potential considerations. It is concluded by a description of how the resulting decisions may be implemented at the site level and of follow-up actions that can be taken to ensure that all appropriate factors are addressed.

Examples are given in the Annexes of various approaches which have been adopted at both the national and local levels by selected countries. The treatment is not meant to be exhaustive, nor is it representative of all approaches being made throughout the world. For example, major environmental restoration programmes are underway in the USA in response to contamination of weapons production and testing sites. These are covered in many other publications which are readily available to interested parties, and so, they are not included in the Annexes of this report. It is intended that the Annexes provide a sampling of environmental restoration programmes along with discussion of the applicable strategies which have been adopted, so as to expand upon and to complement the information presented in the main body of the report.

3. RADIOACTIVELY CONTAMINATED SITES AND SOURCES OF CONTAMINATION

The use of radioactive materials for a variety of purposes has resulted in contamination of sites throughout the world. The radionuclides involved may have been derived from; nuclear fuel cycle, use of radioisotopes in scientific research; industry; medicine; or military applications. They may also result from enhanced concentration of naturally occurring radioactive elements. The affected sites can range from localized areas in urban environments to larger areas encompassing many tens or hundreds of square kilometres.

The source of the contamination may be from a known operation activity at the site. Records may give information about the radionuclides involved and their likely disposition and chemical state. Alternatively, contamination may be revealed by chance with little other information being available. In general, all sites suspected or known to be contaminated will need some level of evaluation (characterization). However, if the site is populated, immediate steps may be necessary to reduce actual or potential exposures to radiation prior to undertaking investigations.

The nature and extent of the contamination varies substantially amongst sites, and is strongly dependent on how the contaminants were released [3, 4]. Radionuclides released into the air will be deposited onto surfaces by dry or wet deposition processes (dry deposition, or wash-out). Dry deposition results in contamination which is spread out, decreasing with distance from the source, as determined by wind direction and velocity, and atmospheric stability. Sharply higher contamination levels will be associated with areas where wash-out from the contaminant plume occurs due to precipitation. A different process occurs at many old waste storage sites, where leaching, and subsequent transport of contaminants by groundwater is the main mechanism. This will depend on both the site hydrogeology and waste characteristics, with substantial variations in transport behaviour for different radionuclides. Although they differ substantially, both of these natural transport processes result in distribution which are continuous, although not necessarily monotonic. By comparison, contamination resulting from human action has (e.g. dumping of wastes or spread of contamination by soil moving associated with property development) frequently results in much more random distribution.

Some examples of contamination that might be encountered are given below. The list is not exhaustive but is intended to show the wide range of problems that might be found; they can vary in size from relatively small manufacturing facilities to large land areas.

(a) Nuclear power production and the nuclear fuel cycle [8–15]

The various stages of the nuclear fuel cycle and the operation and decommissioning of nuclear reactors all have the potential to create contaminated sites. The contamination may include mill tailings; spillage of ore and product at the mine and in transport; waste from enrichment and fuel fabrication operations; fission product and actinide waste streams from reprocessing of fuel elements, and wastes produced during operation and decommissioning of reactors.

(b) Production and use of radioactive substances for medical, research or industrial purposes [16–18]

Radioactive materials have been used widely since their discovery for a variety of scientific, medical and industrial uses. In some cases sites have been left contaminated with residues of the operations. Such sites include factories where radium was used in luminescent paint and thorium was used in thorium-coated gas mantles.

(c) Mining and processing of ores containing significant natural radioactivity [12, 19–22]

Uranium and thorium are present in many ores. The mining of these and their processing to recover materials such as copper, niobium, rare earths, noble metals and phosphates will generally produce waste streams containing significant amounts of natural radioactivity. In addition, combustion of coal concentrates the natural radioactivity in the resulting residues (e.g. fly ash). These have the potential to result in contaminated sites.

(d) Military activities and the production, and testing of nuclear weapons [2, 13, 23, 24]

The manufacture of nuclear weapons involves the handling, transport and storage of large quantities of radioactive materials. The testing of weapons may involve the release of fission products and activation products, or may involve the deliberate dispersal of radioactive materials in the environment. Some military use is made of depleted uranium, in non-nuclear activities. All of these activities have, in the past, resulted in contamination to the environment, many of very large areas [24].

(e) Accidents and incidents [13, 25–27]

Examples are the waste tank explosion at Chelyabinsk, Russia; the Windscale Pile fire event in the United Kingdom; and the more recent Chernobyl Reactor accident in Ukraine. Other examples of accidental releases include those associated with military plane crashes at Palomares, Spain and Thule, Greenland, or nuclear submarine incidents such as accidental release during refuelling in Chazhma Bay, Russia.

Another example of accidental release is when radiation sources have been lost, stolen, or misused. Since 1962, reported accidents with sealed radiation sources have resulted in 21 fatalities among members of the general public. Moreover, significant expenditure has been involved for the monitoring and cleanup costs associated with these type of incidents (e.g. 1987 accident in Goiâna, Brazil associated with ^{137}Cs radiotherapy source).

4. FACTORS FOR NATIONAL CONSIDERATION

The scope and extent of the environmental problem will influence the complexity of the necessary regulatory and organizational infrastructure for a member country. This can range from solutions devised in an informal manner for problems of limited scope and duration to a formal national programme. Both of these approaches may be equally acceptable based on local conditions and priorities.

At the national level, the decision making for environmental restoration may be driven by a number factors. Not all of these factors may be relevant to each country and some factors for certain countries may have specific and overwhelming importance. In many countries where contamination problems have existed and have been recognized for a long time, mature remedial action programmes already exist. Determination of national priorities with respect to remediation of sites involves factors which may be technical but also, significantly and overwhelmingly, socio-economic or socio-political in nature.

4.1. ORGANIZATIONAL CONSIDERATIONS

Organizational considerations are important for the satisfactory completion of environmental restoration projects.

4.1.1. National policy, regulatory and legal framework

Contamination of soil or water has taken place in the environment at many locations in the world in the past, due to human activities involving radioactive materials of natural or human made origin. The type, severity and extent of contamination can vary quite widely. Though lessons learned from the past help appreciably in reducing the severity of such events, they will not eliminate them completely. It is therefore, important that a country's national strategy be developed accordingly and that an adequate regulatory framework exists to ensure that environmental restoration actions can be undertaken as appropriate to the problems at hand.

It is recognized that radioactive waste management has a very important role in any environmental restoration operation. As such, the strategy and regulatory framework for environmental restoration should be consistent with that for radioactive waste management. Furthermore, it is advisable the strategies be consistent with international agreements.

National strategies on environmental restoration normally take into consideration the various government and private organizations involved, what are or will likely be their interrelationships, the resource required, the standards to be achieved and the mechanism for ensuring compliance. National laws and regulations on environmental protection, radiation safety, occupational safety, and human health will need to be considered. The degree of the regulatory framework required will vary from country to country. Where a detailed regulatory framework is lacking, the national government may wish to refer to the guidelines from international agencies such as the IAEA and the International Commission on Radiological Protection.

4.1.2. Organizational and structural framework

Environmental restoration projects may be simple or highly complex depending on site conditions. Such projects may involve a number of discreet stages which could be carried out by different organizations. The projects will be multidisciplinary and will require substantial interactions between different organizations. Therefore, for the smooth completion of the projects, it is important to have clearly defined responsibilities and effective communications among the various organizations involved. In this regard, the recommendations of international bodies such as the IAEA (as contained in the Basic Safety Standards [28]) can be considered for adoption, with any necessary adaptations as may be appropriate to the specific country.

4.2. NATIONAL AND INTERNATIONAL FACTORS FOR CONSIDERATION

There are a number of national and international factors that should be considered in the development of successful environmental restoration projects.

4.2.1. Nature and extent of environmental contamination problems

The nature of the response to environmental problems at the national level, and eventually at the programme or project level, will depend on the nature and extent of contamination. This includes the information on radionuclides involved, their distribution affected media, actual or potential exposures of individuals and the general public, and the potential negative effects on the environment.

Environmental contamination could arise from a number of situations or sources. These may include accidental releases from nuclear facilities, discharge practices from installations, nuclear weapons production and testing, uranium mining and milling activities, phosphate rock mining, nuclear fuel cycle wastes, or radionuclide use in research, medicine, and industry.

In countries with existing nuclear facilities and substantial uses of radionuclides, the information on contaminated sites may already exist and the actual or potential risks to human health or the environment may be well known. For many other countries however, the identification of the problem may occur indirectly. Problems can come to light by any of a number of ways; for example, as a result of scientific investigations, reporting by the news media, developing public awareness ways, or by incidental means.

4.2.2. National priorities of action

The first step should be to assess, even in a preliminary fashion, the potential exposure from the contamination to humans and the environment. After the seriousness of the problem is known the urgency for action can be determined. In general, the urgency of action will be determined by the potential exposure. Situations requiring immediate or urgent action are high priority, as the actual or perceived threat to human health and safety requires a quick response. If the environmental contamination resulted from a past or present practice about which information is mostly available, the decision making authority, has more time and flexibility to consider all relevant factors and assess their relative importance.

4.2.3. Financial responsibilities for cleanup

It is important that financial responsibility for cleanup should be defined at the national level. Where a party responsible for the contamination, a private company, for example, can be identified, the government may require that party to implement the cleanup. In those cases where no historical link to the contamination origin can be established or where the contamination resulted from governmental programmes, the national government may have to accept responsibility for conducting the cleanup. In certain instances, irrespective of the source of the contamination, it may be in the national interest for the government to assume financial responsibility for the remediation.

4.2.4. Socio-economic factors

At the national level, decisions relating to the priority of environmental restoration may have to accommodate themselves to the realities of budget and the relative importance of remediation compared with other national needs. Land use considerations may be important. Availability and allocation of other resources such as technical manpower investments in social and/or economic spheres, etc. are other important considerations.

Two scenarios to consider are: The remediation action (removal of homes and industries) will cause a significant impact on the quality of life of the local inhabitants, such that the impact to the local population could be better accommodated through better health care or education; or the cost on a national level for remediation is too large for limited national resources, such that on a national level greater impact to a nation could be accomplished by the allocation of these same resources to other priorities. The resolution of this debate between remediation and other actions will be heavily dependent on the availability of resources national as well as international that can be brought to bear.

4.2.5. International factors

The movement of environmental contaminants across national boundaries can have serious consequences for the affected countries. Worldwide fallout from nuclear weapons testing in the atmosphere was considered to be a serious problem and a moratorium on this type of testing was eventually adapted.

There are international agreements on the transboundary movement of wastes and disposal of said waste in international waters. In addition, there are international standards and conventions on waste management practices and radiation protection. An additional area where international factors can be of considerable interest is in the areas of technical or financial assistance. The ability to access technical knowledge from other countries can significantly reduce the challenges to a country with limited experience. Also, the availability of international funding can assist with environmental contamination that threatens other countries.

4.2.6. Waste management issues

Waste management issues are generally associated with environmental restoration. Wastes arise directly from the decommissioning of facilities and cleanup of contaminated soils, groundwater, and so on. In some cases, treatment of contaminated soils or groundwater will largely eliminate the original problem, however, secondary wastes may be produced. Methods which are commonly used to manage these wastes include the following:

- in situ or on-site management, using engineered containments (covers, cells) of varying degrees of complexity, or technologies such as in situ vitrification;
- reuse or recycle of uncontaminated materials, or materials which have been decontaminated or treated to meet release criteria for unrestricted use;
- reuse of recycle of contaminated materials for specified purposes, such as recycle of contaminated steel into waste disposal containers;
- classification and segregation of wastes for off-site disposal in appropriately licensed facilities.

5. FACTORS FOR REGIONAL AND LOCAL CONSIDERATION

When considering specific contaminated sites which are primarily of concern at the local level, the following factors will influence the type of remediation effort undertaken.

5.1. EXPOSURE OF THE WORKER, PUBLIC AND ENVIRONMENT

At the local and the site level, radiological exposure to public health will need to be assessed. Radiological assessments in general will provide an indication of the potential exposure to an individual or the public. Based on the nature of the radioactive contamination, the site information, and the information on the individuals at risk and the nearby population, mathematical models on exposure pathways can be used to determine the potential radiation doses to an individual. Collective dose is another parameter which may give an indication as to the total effect of the contamination on the public.

At a site with ongoing activities the exposure of workers should be considered in the evaluation. In addition, reductions in exposure to the public should be balanced with an evaluation of the exposure incurred by the worker as a result of the remediation action.

In consideration of the hazards at a particular site, the impact to the local environment may be considered as part of the site evaluation. In addition, when a remediation decision is made the impact of this approach on the local environment may be evaluated to determine the net reduction in hazards (e.g. it might not be reasonable to cause more harm as a result of the remediation than by leaving the site alone and instituting long term monitoring or restricting access).

5.2. ECONOMIC IMPACT

The economic impact to the local community can be either direct or indirect. Examples of direct impact are loss of jobs if a facility is closed and an increase in jobs if the remediation effort brings in additional work, loss of revenue from the site either because an industrial facility is closed or productive farmland is taken out of use.

Indirect impacts range from losses in taxes because of workforce restrictions which lead to underfunding of social infrastructure (e.g. schools); decreases in property values due to the association with the contaminated site, failure of local businesses that depended on the site on its workforce for income.

5.3. FUTURE LAND USE

The planned use of the affected land is a significant factor in determining a restoration decision. The future use either residential or recreational or industrial has an impact on the contamination pathways which directly influence the screening levels and subsequent cleanup levels. In addition, the future land use can impact on whether on-site disposal could be a viable option (e.g. a residential scenario is not usually compatible with an on-site disposal cell). Consideration of future land use could necessitate the involvement of local communities and planning officials in the decision making process.

5.4. LOCAL REGULATIONS

The interaction between local and national regulations, if not harmonized, can significantly increase the cost of and time for the restoration. It is of value to resolve conflicts between these regulations prior to the start of restoration, otherwise programme/project focus is lost. Negotiations should be initiated to determine the primacy of regulations for each expected situation at the start of the decision making process. It is suggested that communications between the local, regional, and national regulators and with the project managers are established and maintained throughout the life of the project. It is also important to consider the full range of regulatory regimes that could impact work at the site. For example, unless allowances are made for local building permits and restrictions (if applicable) there could be significant project delays if facility construction was not carried out in conformance with the local requirements.

5.5. CLEANUP OR RESTORATION CRITERIA

Cleanup or restoration criteria can help in the allocation of limited resources for cleanup in a cost effective manner. The criteria are generally derived from radiation protection criteria. International and national organizations and regulatory bodies have established a great variety of limits to restrict or constrain doses that might be received by man. They may, where appropriate, be adopted directly for use in evaluating the need for the restoration of a site. The IAEA has recently proposed risk based criteria specifically for guiding cleanup decisions [5]. They may be used as guides, which are used in conjunction with an assessment of the natural hazards from background radiation and other existing problems or conditions affecting the public in and around the contaminated area. Where multiple sources of exposure to a population exist and funds are limited, choices must be made between alternative areas for action.

Costs for restoration rise rapidly with the stringency of cleanup restoration criteria. Therefore there is an interest in determining the contamination levels below which there is no further concern; contamination levels below this level indicate (1) there is no need to remediate this site, or (2) the site has been sufficiently restored.

The restoration criteria can be site specific or generic.

The site specific criteria for restoration are typically based on calculated risks to humans or to the environment. This approach allows for the adaptation of cleanup levels to local site conditions. For example, the health risk at a particular site may depend on the combined effect of many factors, such as the radioactive species, its distribution and concentrations, possible pathways, climatic conditions, soil conditions, hydrology, meteorology, and demographics.

Since each site presumably has different conditions, the use of site specific criteria allows the tailoring of restoration criteria to each specific site. In other words, it is possible to assign different cleanup levels while keeping the risk at a uniform level for all sites. However, site specific criteria, typically leading to different restoration levels at different sites (the very reason for its use) may lead to social/political questions of perceived injustice and inequity. Generic criteria will usually also be based on risk consideration but are not necessarily directly related to the conditions at the site under investigation. Generic criteria are uniform for all sites in a region or country. The major advantage of generic criteria may be their greater political acceptability. As generic criteria do not give rise to different restoration levels, they avoid the appearance of providing different treatment of different population groups. Because of their clarity, generic criteria are also easier to regulate and enforce. The disadvantage of generic criteria is that they may not be universally applicable. By adhering to them, the opportunity of tailoring the expensive cleanup activity to minimum locally required levels can be lost. In some instances, this could dramatically increase the cost over what would be necessary under site specific standards.

5.6. PUBLIC CONCERNS

Public acceptance of the proposed environmental restoration can be very important for its successful implementation. This can require public input during the consideration of technology options, as well as public endorsement of the selected remediation approach. Technologies and approaches which enhance the likelihood of public acceptance are sometimes preferred since they not only perform the necessary restoration, but also build public trust and confidence.

There may be concerns about the remediation itself, there are usually public concerns about impacts to local employment. If the site is in operation when the restoration decision is made, there are usually issues about changes in the local employment base. These changes could be caused by either a changing mission (i.e. from operation to remediation) and the potential closure of that site and facility sometime in the future. Resolution of this issue is very dependent on local customs and conditions.

6. ASSESSMENTS OF EXPOSURE AND THE DECISION MAKING PROCESS

Once data are available on the nature and extent of contamination at any site, decisions can be made on the need for and extent of any remediation. The first step in this decision making process is the determination of the absolute level of exposure, posed by the site to both human health and the general environment. The level of exposure can then be judged against selected national or international criteria to determine whether it is acceptable or not. If it is judged to be unacceptable, the second part of the process is to determine how much the exposure may be reduced by the application of different remedial actions and the "cost" involved in achieving each increment of reduction. If the exposure is acceptable, the process can end at this point.

6.1. FACTORS TO CONSIDER IN DECISIONS REGARDING THE NEED FOR REMEDIATION

6.1.1. Assessment of exposure

The level of exposure posed by any site is the first factor which needs to be determined and assessed in any decision on the need for remediation. This may be interpreted as exposure to the health of living organisms or other interference with the ecological systems of which they form part and includes harm to property and facilities.

Its significance can be judged as:

(i) risk of death, serious injury, cancer or other disease, genetic mutation, birth defect or impairment of reproductive functions for human beings;

(ii) any irreversible or other substantial adverse change in the functioning of a habitat or site for any living organism or ecological system within any habitat;

(iii) risk of death, disease or other physical damage, such that there is a substantial loss in value for property in the form of livestock or other owned animals; and

(iv) structural failure or substantial damage for facilities in the form of buildings or equipment.

The assessment of the level of exposure involves consideration of all of the potentially exposed populations, be they human, flora, fauna, property or equipment, their exposure pathways and the rates and magnitudes of the exposures. Threats to the health of the workers and the general public will normally be given the highest priority in any assessment with lower weightings being given to the other exposed populations. Dependent on the complexity of the site and the distribution of contamination, the assessment of exposure may be a relatively simple process as for direct irradiation leading to radiation dose, or much more complex analyses may be required involving consideration of many different pathways and exposure components. Such analyses will also need to consider the potential impact of non-radioactive contaminants, both individually and in a synergistic mode, as well as conventional health and safety risks in order that the overall risks at any site can be fully assessed. Indeed, cases may occur where these latter hazards drive remediation requirements with the radioactive contamination serving to increase the complexity.

6.1.2. Screening criteria

After the level of exposure has been determined, it can be compared with appropriate screening levels. A number of international and national organizations and regulatory bodies have established various limits on acceptable levels of risk under different conditions, including doses that might be received by people through routine operations and discharges into the environment. These limits may be useful screening guides in conjunction with assessments of the other hazards in an area for decisions on the need or otherwise for remedial action or for further consideration of the site. What must be appreciated, however, is that environmental restoration represents a potential intervention situation. Thus the standards associated with radiation exposures to the public, etc., from routine operations and releases represent ideal limits, which may not be achievable in practice for many reasons. These include the absence of appropriate technologies, unacceptably high costs, etc. The limits associated with routine exposures may, therefore, be used directly or as the base factor in a screening limit, which may be set as some multiple of this limit. Screening limits may also be derived with reference to background levels in the area. For the other potentially exposed populations, such as the flora and fauna, there are no international and very few, limited national guidelines.

Where risks from radioactivity dominate, derived reference levels from dose constraints may be more useful in the initial screening process than direct dose constraints. As an example, Germany has derived reference levels as criteria for the cleanup of uranium mining and milling sites. These are based on the assumption that doses to man should not exceed 1mSv per year. According to this approach a site can be used without any restriction when the specific activity of total -emitters in soil is less than 0.2 Bq/g. If it is between 0.2 and 1 Bq/g, further assessment is recommended and some restriction on land use may be appropriate. As an example, a site might be acceptable for industrial purposes but not for housing. When the specific activity exceeds 1 Bq/g, remediation needs to be considered. These reference levels might be adopted for other uranium mining and milling sites. These specific activity limits would not be suitable for sites contaminated with activation and fission products, although the underlying principles behind such derived limits could be employed to determine appropriate levels.

For the more complex sites or where suitable derived reference levels are not available, a more complex assessment may be appropriate and the level of exposure will need to be estimated by other means, such as through an environmental impact assessment process. The result of the assessment can be an important element in the decision process. This process can be used to assess the impacts of contamination from multiple sources, active and inactive, and via various different pathways, such as direct irradiation, dust and vapour inhalation, soil and food ingestion and dermal contact. When the assessment indicates that the radiation exposure caused by the contaminated site is not acceptable, restoration should be planned. The assessment considers the remedial action options and their exposure reducing and creating potentials. Table I describes the possible criteria to be considered in the assessment process [29].

For the assessment of radiation effects on species other than humans, the data is currently very limited and hence adequate assessments of such effects are very much more difficult. With harm to property and facilities radioactive contamination alone is rarely sufficiently high to cause significant damage and it is usually the non-active components of the contamination, e.g. salts, which are more significant in causing corrosion, degradation, etc.

After exposure has been assessed the options and incremental costs of reducing the exposure require assessment. Some aspects can be determined directly as financial costs. Others, however, are very much more difficult to quantify in cost terms alone and alternative approaches to assessment may be required. The latter may range from simple ranking by interested parties through to various forms of multi-attribute analyses.

6.1.3. Selection of remedial action options

For restoration of any contaminated site a number of different remedial options might be applicable and it is the task of the decision makers to select the most appropriate one. In this selection several different factors have to be considered:

- the effectiveness of each technique in reducing doses and other exposures;
- its applicability under the particular site conditions;
- its regulatory approval status;
- the permanence of the results achieved;
- the completeness of the solution achieved, i.e. avoidance of the need for ongoing action;
- net present value costs for implementation;
- the nature and magnitude of risks associated with the technique;
- requirements for pre-existing infrastructure, such as waste treatment, transportation and disposal facilities;
- public acceptability.

TABLE I. POSSIBLE CRITERIA TO BE CONSIDERED IN THE ASSESSMENT PROCESS

- **Public health**: addresses potential adverse impacts on the health and safety of the surrounding or affected off-site community.
- **Environmental protection:** addresses potential adverse impacts on the environment, including physical degradation of surrounding or affected ecological systems and/or their constituents.
- **Site personnel safety**: addresses potential adverse impacts on the health and safety of site personnel working inside the site boundary, including physical injury and exposure to radioactive or chemical pollutants.
- **Public or affected parties preferences:** addresses potential adverse impacts on the level of confidence that the public and affected parties maintain in the environmental restoration programme.
- **Mission or intended goals**: addresses potential adverse impacts on the ability of responsible parties to accomplish the environmental restoration mission or intended goals.
- **Cost–effectiveness:** addresses potential adverse impacts on ability of the environmental restoration programme to avoid future costs.

Often the most difficult part of any evaluation is the comparison of its "costs" and benefits. Direct cost, which is the amount of money necessary to apply a method, can often be estimated relatively easily. More difficult is the estimation of less tangible costs, such as those which might be incurred later in time. As an example, when the remediation is carried out by removing the upper layers of soil, the fertility of soil may decrease and therefore indirect costs may be incurred through the need to provide financial support to farmers. On the other hand, if no action would be taken, the direct costs will be much lower, but the support of farmers might become unacceptably high.

Whatever restoration method is applied, there will be disadvantages, both direct and indirect. Restoration workers will receive immediate radiation exposures and wastes will be generated which may require a waste management infrastructure with authorized disposal routes. These adverse risks and disadvantages must be appropriately assessed and accounted for in the decision making process.

The final result may be that a less effective method is the best practicable environmental option for the site rather than the most effective method because of its lower cost and its better applicability. An analysis might also indicate that the demand for manpower and the costs are so high, that it cannot be afforded. Then the use of the site might be restricted. Often it may be appropriate to combine two or more countermeasures. Instead of deep ploughing, only ploughing might be recommended, which lowers direct irradiation but not plant uptake. Therefore, additionally the growth of non-agricultural products might be recommended.

6.2. THE DECISION MAKING PROCESS

On completion of the assessments of exposure and the "costs" for incremental reductions in exposure, decisions can be taken on the most appropriate remedial action. This process will need to account for the different judgements to be made in individual countries on financial or other resource values which may be expended to reduce the exposure. They will also need to consider the uncertainties in the assessments. In the latter respect, ranges of parameter values should be considered in the assessments in order to account for intrinsic uncertainties in the assessment methods, data, etc.

The nature of the decision making process will vary from country to country. It will depend on many factors including the cultural and political background, existing regulatory processes, the magnitude of the problem by comparison with national resources and priorities, and national and local political considerations. The decisions on priorities may be taken through the existing political processes or through special public consultation exercises.

6.2.1. Public consultation

The importance attached to different types and levels of risk varies significantly with the cultural values and background of individual countries and decision making groups. It is also affected by the social and economic status of the country, groups and individuals, educational levels, demographics, individual and group life experience, etc. This will affect the need for restoration and perhaps the relative acceptability of various restoration methods.

Organizations engaged in restoration activities in some countries have endeavoured to reach consensus amongst the various interested parties by providing information concerning the contaminated sites, the associated hazards, and the methods proposed for dealing with those hazards. Often, this information is provided with some general education on radiation itself, so that the concepts forming the basis of restoration decisions can be more readily discussed.

In those countries where active participation from outside governmental groups has occurred, often as a regulatory requirement, participatory or 'scoping' processes have been successfully used to facilitate interaction. Such processes, where parties outside the government and official organizations are invited to participate in the identification of issues and priorities, assist in the development of alternative actions, and contribute to the decision making process. When a participatory or scoping process is used, it is important that there is an adequate period for public review and comment on draft proposals, in order that their views may be seen to have credence. Regulatory bodies can then use these comments to identify both additional areas for consideration and the relative importance attached to individual factors prior to any final decision taking. This process can help reduce the chance of overlooking a significant issue or a reasonable restoration approach. This may result in important revisions to assessments before submission to primary decision makers. Experience suggests that the quality and particularly the acceptability of the subsequent decisions are improved by this process.

6.3. PRIORITIZATION OF SITES FOR REMEDIATION

Dependent on the scale of contamination within individual countries, sites may be prioritized following the hazard assessment and reduction process. However, it may be necessary that other factors play important role. These factors may vary from political considerations, funding considerations, logistical considerations and public input. The prioritization schemes will vary from country to country.

The regulatory authorities could follow simple screening procedures for placing sites on a national priority list. In such procedures, any potential candidate site would first receive a preliminary assessment to eliminate it from further screening. This may consist of a review of existing data. Sites surviving this elimination may then become subject to a physical site inspection and a thorough evaluation of their hazards.

7. IMPLEMENTING THE APPROACH TO RESTORATION

The assessments described in Section 6 will have generally led to a decision(s) on the scope of the programme/project, on the approximate amount of funding required, and on the desired schedule for implementation. Programmes/projects will range from relatively self-contained projects to large scale programmes involving many different projects and sites. In many cases, particularly for large scale projects, the availability of resources (financial and other) will control the rate of implementation. The following sections discuss these aspects under the general divisions of economic resources, technical resources and human resources.

7.1. LIMITATIONS ON IMPLEMENTATION

A number of limitations exist with regard to the implementation of an Environmental Restoration Programme. These are discussed below.

7.1.1. Economic resources

For a restoration project to proceed effectively it needs adequate, assured funding from the outset. The source of the funding will depend on the allocation of responsibilities for funding remediation and any prior provisions made, such as through national or industry levies, company provisions and insurance with independent financial institutions. If the responsibility rests with national or local agencies, then the availability of funding will depend on national and local priorities and the competition for funds. Such funds may be allocated on the basis of a priority list. Such lists will ideally be drawn up after the assessment and ranking of the hazards posed by each site.

Given the number of factors which often need to be considered in such assessments and the difficulty in reaching public and political consensus on the methodology and weightings to be used in assessing all factors, other allocation methods are sometimes used. These include dividing the total available budget by the funds required for the projects and funding each on a percentage basis. This approach leads to restoration progress on a broad front, but places heavy demands on regulatory and remediation resources due to the large number of projects potentially being handled. It does have the advantage of potentially broadening the pool of experienced remediation staff and contractors, but at the expense of reducing the opportunities for learning from previous work. As an approach this is much more suited to countries with large pools of resources. Another approach to allocating funding is to rely on the national Government to define the priorities for work.

If responsibility rests with the current owners of the site, as often occurs in countries where the caveat emptor ("buyer beware") principle governs property and facility sales transactions, or with the original polluters, who may or may not individually or all be traceable, then the availability of funds will depend on their current financial status and willingness to pay. For a number of sites in the latter category funding for remediation may be inadequate or non-existent and funding responsibility may, in practice, have to be assumed by local or national agencies. The latter can be the case for orphaned or abandoned sites where no previous owner or polluter can be traced.

7.1.2. Technical resources

Environmental restoration programmes require the availability at different stages of a wide range of methodologies, equipment, technologies, facilities and supporting infrastructure in appropriate numbers and quality. These technical resources typically include:

(i) methodologies for characterizing radioactivity, and site media, groundwater flow, etc., and for modelling contaminant behaviour;

(ii) characterization equipment;

(iii) radiation and environmental monitoring equipment;

(iv) personal and respiratory protective equipment;

(v) analytical equipment for field and laboratory use;

(vi) data processing equipment, hardware and software;

(vii) medical screening equipment; and

(viii) waste management infrastructure including waste storage, conditioning, transport and disposal facilities.

Some of these technical resources may be used or could be potentially available after modification and training from other environmental, medical, industrial, etc. applications within any country. However, others are more specialized and require procurement or development. Their availability at the required stages in any remediation project will be a key factor if the works are to be implemented successfully. Some of the resources, such as the required waste management infrastructure, will be major separate projects within themselves. Their development will involve long time scales, due to the needs for potential national and local government, and regulatory approvals, design, construction and commissioning.

The availability of the infrastructure necessary to support a technology is a key consideration in the evaluation of the usefulness of a technology. Infrastructure includes both the necessary trained labour to operate and control the technology, and the supporting commercial business which provide materials and supplies required by the technology. Physical resources and systems such as electric power, access roadways, rail access and disposal or storage facilities, also form part of the infrastructure. When the use of a technology requires the development of supporting infrastructure, this adds to the scope of the remediation project.

7.1.3. Human resources

The availability of appropriately trained and experienced manpower will be another key requirement for the successful and timely implementation of any environmental restoration programme. A range of qualified staff will be required including:

(i) remediation engineers and scientists;
(ii) project managers;
(iii) health physicists;
(iv) chemical specialists (e.g. analytical chemists);
(v) geologists and hydrogeologists; and
(vi) environmental science (e.g. biologists).

Availability and scheduling of qualified personnel is an important consideration, which also extends to organizational and regulatory structures. In countries with a large pool of qualified personnel having the various technical skills, the issue becomes more one of logistics than availability. However, there are also broader issues. For example, retraining and redeployment of workers from nuclear weapons protection to environmental restoration activities is an important consideration in the USA, as well as in the Russian Federation. However, there are issues relating to an ageing workforce. The facilities have been, and continue as, major employers and retraining minimizes the social dislocations resulting from major changes in work forces. Though there are difficulties in changing the priorities to environmental factors with the old weapons workforce.

In some countries, the availability of qualified personnel is a factor in the rate at which environmental restoration activities can be implemented. This is further complicated by the need to retrain and redeploy existing personnel. In these circumstances, institutional structures which respond to these broader issues may be preferable, at least in the immediate future, to those which rely on a mobile pool of existing qualified personnel.

7.1.4. Options for minimizing the constraints to implementation

Three major implementation constraints have been identified: financial, technical and human. The significance of the financial constraint will depend on the allocation of responsibilities for funding remediation and any prior provisions made, such as through national and industry levies, company provisions and insurance policies with independent financial institutions. In cases where funding is restricted, for whatever reason, a planned, phased remediation programme should be adopted and implemented. In such a programme priority should be given to tackling those tasks which reduce the most serious sources of exposure.

If there are technical resource limitations, a number of options exist for minimizing the constraints:

(i) Develop the facilities, etc. using internal resources.

(ii) Purchase services, equipment, etc. from other countries. This approach presumes that funding is not a major constraint. Even if funding is available, certain items, such as appropriate waste management infrastructures will take time to develop even if designs and key items of equipment can be purchased from foreign companies.

(iii) Seek participation in international technology collaborative projects, such as the IAEAs regional co-operation and technical assistance programmes.

In cases where there is a shortage of appropriately qualified personnel in a country for either the regulation or implementation of restoration activities, the options for minimizing the constraint are:

(i) Hire trained and experienced staff from other countries for the short or even the long term.

(ii) Prioritize staffing needs to ensure that there are sufficient staff to meet national regulatory, programme and then project management needs.

(iii) Develop a national programme to train the required technical specialists. This can involve collaboration with national and possibly overseas universities and other training establishments. It may start with training new graduates. Alternatively, experienced, technically qualified personnel may be available for retraining from other redundant fields, such as specialists from the major military–industrial complexes of the former Soviet Union.

The choice between and the applicability of the options will depend upon the urgency and scale of the problems. Thus, in situations where there are a limited number of significantly contaminated sites, it can prove to be more efficient on technical and economic grounds to supplement local resources with experienced staff and technologies from overseas, rather than devoting valuable national resources to developing the resources internally. An example of this approach is the cleanup by Australia of the former British nuclear weapons test site at Maralinga. Alternatively, if there is no urgency for action, but a large number of sites requiring remediation in the country, the option of developing a national resource for remediation may be followed effectively.

7.2. IMPLEMENTATION OF ENVIRONMENTAL RESTORATION

The implementation of the Environmental Restoration Programme will require the careful consideration of financial, technical and human resources.

7.2.1. General considerations

Although the scale varies substantially amongst different projects and programmes — from individual projects to major national programmes — there is a common need to integrate the activities performed by various organizations, companies or individuals over time.

Integration of these activities over time aids in moving from one stage of a project/programme to the next in a consistent, continuous and non-disruptive manner. Continuity of key staff is an important factor and can be crucial where institutional or corporate memory is needed to maintain overall project continuity. These activities often occur in parallel or overlapping time, and involve technical and scheduling issues. Integration over all of these activities is needed and in order to carry out this range of activities in a co-ordinated manner. The different activities will frequently be done by different companies and organizations, or thereof. In addition to the integration of the activities, there is a need for consistent contract management and the ability to deal with issues arising from organizational factors.

This integration process is an important component of project management. The ability to perform environmental restoration projects in a cost effective and timely manner requires that the responsibility for project management be clearly defined and well executed. The size of the project management organization may vary from a project manager for small projects to an organization dedicated to this function for a major programme.

The Annexes contain two examples of cleanup/environmental restoration programmes, including examples of specific projects or sites. It can be seen that the project management function can be completed in more than one way, however there is common recognition of the need for this function.

7.2.2. Developing the environmental restoration plan

Decisions to proceed with a project/programme will often have been made on the basis of approximate estimates of costs, schedules and methods. Frequently, an early step in the planning process is thus to develop a much more detailed and reliable estimate of project scope, costs and schedule. This will often involve estimates based on known technology and/or extrapolation of experience from other sites. It is not unusual, however, for information gaps to be identified as the project design and cost estimate are developed. Site characterization data may have gaps related to specific areas and/or to specific questions or issues.

There may also be gaps in available technology. It is unlikely that a decision to proceed will have been made on the basis of technology which has yet to be invented, however the status of development may be at a prototype, or smaller scale. It is also frequently the case that experience gained at one site or project will be used to improve technology for new sites or projects. This is an important consideration as there seems, at times, an automatic difference between those who wish to develop and use "the latest improvement" and those who wish to develop a design, and resulting cost estimate and schedule, on the philosophy that "if it is not broken don't fix it". Those responsible for project management need to be aware of this difference, and to understand the trade-offs between the opportunities for improved performance and for lower costs, and the risks to costs and schedules arising from unproven methods or equipment.

Regardless of whether a project involves a virtual repetition of previous experience, or an undertaking with considerable uncertainty, a reference project scope, cost estimate and schedule is a common feature. The level of uncertainty is often accommodated by the amount of contingency allowances built into the cost estimate and schedule. It is important to recognize that schedule uncertainty (for example, an increase in the amount of contaminated material which has to be excavated or processed or disposed, beyond the range of what was considered for the estimate) is important even when the technical approach/equipment is well proven.

In addition to the reference project scope, cost estimate and schedule, a project plan normally includes an organization chart and description of responsibilities for each "box" in the chart. Particular attention should be paid to the interface between "boxes", to ensure that there is neither confusion from duplication nor omission of key responsibilities. A project plan should also briefly describe, with appropriate references, the key documents, the plans for supporting activities such as quality assurance, environmental monitoring and communications.

7.2.3. Identifying and mobilizing resources

Previous sections (7.1.1–7.1.4) discussed limitations of resources, and means by which they might be overcome. This section presumes there are no fundamental inconsistencies between the resources required for the project and the resources available.

There will generally be some type of formal funding arrangement between the government departments, agencies or other organizations funding environmental restoration projects and the organizations implementing the work. Various arrangements are possible:

- a multi-year approach with periodic times for reporting and authorization of the release of further funding;
- an annual appropriation based on approval of an annual plan;
- a multi-year approach with authorization of the release of further funding based on specific milestones being achieved.

Regardless of the arrangement, it is important to recognize that it is, in effect, a contract. In exchange for having funds provided, the implementing organization commits to achieving a specific goal(s) over a specified time interval. Satisfactory performances of this contract, even when it is implied, is important both in minimizing costs to the sponsor and ensuring the longer term success of the implementing organization.

With funding identified, the organization implementing the work can then identify and mobilize the resources required to perform the work. As discussed in Section 7.1.3, resources can either be internal to an organization, or contracted. In the case of contracting, the process of requesting bids or proposals, evaluating them and placing contracts should result in the necessary resources being identified and committed to the project at a competitive cost. There are considerable merits to using a similarly rigourous approach when work is being done internally, to establish deliverables, costs and schedules.

7.2.4. Implementing the plan

Physical work can start once contracts or other arrangements are in place. Regardless of the scope of the project, it is important that the party performing the work have an appropriate system for tracking progress and cost. Depending on the scale of the project, this can range from sophisticated computer programs to simple software or manual methods. The larger programmes also assist in scheduling the availability of equipment and work forces, and in minimizing completion times through methods such as critical path scheduling.

For many projects, it is also important to maintain liaison with various stakeholders. These include both administrative bodies, such as regulatory agencies and funding sources and the public, either directly or through liaison or advisory committees.

7.2.5. Monitoring and correcting the plan

Regardless of the system, it is important to have a strong (and realistic) linkage between actual progress and costs incurred, since the latter are quantitative by definition. This linkage is necessary from the individual project level to the overall plan level. Timeliness is important, so that problems are identified and corrected as soon as possible.

In addition to financial monitoring, various types of technical monitoring and correction will occur. These can range from simple change orders to reflect minor changes in the scope of work, to major changes in methods of technical criteria are not being achieved.

7.2.6. Verification

An important part of any remediation is verifying that the desired performance has been achieved. Such verification activities can range from simple radiation surveys to assure the source material has been removed; to complex, long term monitoring of groundwater to detect plume movement. In any case, this activity usually contains many characterization elements and, its design depends on the earlier characterization of the contamination and site environment.

8. POST-REMEDIATION ACTIVITIES

Once remediation activities have been completed and verified, the post-remediation activities can begin. These activities will vary in comprehensiveness and duration according to the degree of remediation that has been achieved or is desired.

If institutional control has been seen as necessary, then post-remedial activities will occur in a controlled context. Otherwise, the activities will occur in a more open and public domain. This will influence the level of security needed for permanent environmental monitoring solutions, etc.

Post-remedial activities can include the following:

- monitoring the long term stability and performance of barriers which isolate and contain contaminated materials;
- monitoring environmental indicators within and down-gradient of the remediated site;
- prevention of intrusion if contamination is not fully removed or if the land is returned for limited use;
- adherence to licencing condition controls may have been imposed; and
- regulation and administration of administrative controls (e.g. deed restrictions).

8.1. POST-RESTORATION MONITORING PROGRAMME

For most environmental projects, a maintenance and monitoring period may be required. The sites remediated and eventually released without restrictions will not require any long term monitoring. However, the sites released with conditions, or released for restricted use will require long term monitoring and post-restoration activities. Post-restoration monitoring has to be carried out to demonstrate that restoration has been successful.

National authorities should usually be responsible for or have to initiate: the design of the programme; its implementation; the evaluation of the results with respect to exposure or dose; and documentation of the programme and results of measurements as well as dissemination of the same to the public.

Funding and responsibility for the measurements should be assigned to a single organization. To ensure the quality of the measurements the laboratories should be involved in intralaboratory calibration programmes. To guarantee impartiality it is reasonable to have a third party take confirmatory samples (usually a small percentage). The post-restoration monitoring programme can take samples on an as needed bases, but it is recommended that it has a frequency of no more than once per quarter and no less than once per year.

The monitoring programme at a minimum should: respect the object and scope of the original restoration programme; be structured to monitor the contaminants for which the restoration was undertaken; consider site specific conditions with respect to exposure pathways; allow to make a exposure or dose estimate; and take into account possible contamination which might occur later in time and/or in distances.

The extent and duration of monitoring depends on site specific problems and actions taken. For example, if a site has been restored by removing the upper part of the soil it might be sufficient to demonstrate by measurement, the reduction of radionuclides in soil has been achieved.

In some areas it might be possible that the success of restoring decreases with time, for example, when radionuclides were not removed but fixed in soil to lower migration and plant uptake rates. In this case monitoring might have to be continued over a longer period of time to make sure that radionuclides do not get mobile again. In some cases, it even might be possible that the success of countermeasures will become obvious not in the first year but later with time. For example, countermeasures to lower radionuclide activities in groundwater might only be successful after a few years. The activity will decrease slowly.

8.2. ADMINISTRATIVE CONTROLS

With some sites it will not be practicable to remove the contamination to such low levels that they are suitable for unrestricted use. With these sites some form of administrative control will have to remain in place. These controls will be required indefinitely or until such time as further remedial action is undertaken to reduce remaining contamination to levels acceptable for unrestricted use or adequate confidence is obtained from monitoring results to allow relaxation of the controls.

The administrative controls may involve direct surveillance of the site, security systems to control unauthorized access or restrictions through land use planning systems. Surveillance and security regimes will be agreed to with appropriate regulatory agencies and will vary with the level of residual hazard posed by the site. The latter will be influenced by the nature, extent and location of the residual contamination and the location of the site.

The local planning and permitting (where applicable) system is used to restrict a sites use to activities where the risk of exposure to the remaining contamination is minimized. This usually means restricting its use to activities other than public housing with children's play areas and gardens and allotments where food is grown for domestic consumption. In practice, this means industrial activities, where the potentially exposed group are adults and the duration of their potential exposure is limited to the working day. Even within this system further constraints are possible, such as restricting the use of the most contaminated areas by covering with asphalt and using as a vehicle parking areas and restricting excavations. It is also possible to place a notification on title in situations where the residual contamination has little or no impact on use of the land, but where such notification is legally required.

9. SUMMARY AND CONCLUSIONS

This report describes the key stages which Member States may undertake in developing a national strategy for the environmental restoration of radioactively contaminated sites. It identifies the types of contaminated sites which occur with their key characteristics. It considers both sites which have been gradually contaminated as a result of industrial practices and those where the contamination is a result of sudden, unplanned releases of radioactivity into the environment. It then considers the various factors which may be considered in developing a comprehensive strategy. These start at the national level with the identification of the global scale and nature of the potential problem and lead through to the more detailed local considerations and hence to the remediation of individual sites. Finally, it considers necessary post-restoration activities.

At the national level it discusses the identification of the problem; the nature and extent of potential contamination; national priorities of action; responsibilities for funding the remedial action; socio-economic and resource considerations and international factors which may be considered in prioritizing sites for remedial action.

For the regional and local level it considers: exposure of the worker, public and environment; economic impact; future land use; local regulations; restoration criteria and public concerns. The process assessing exposure and how decisions should be reached on selecting the appropriate course of action is discussed. The resources for implementing the restoration as well as the discrete steps are detailed. Finally, the key considerations for implementing the environmental remediation process are examined along with necessary post restoration activities.

The report concludes:

(1) Comprehensive strategies should be developed for dealing with the environmental restoration of potentially radioactively contaminated sites within the borders of affected countries. This strategy should be commensurate with the usage of radioactive materials and the scale for potential environmental contamination in each member state.

(2) The implementation of such strategies will require an appropriate regulatory framework and responsibilities to be in place.

(3) The implementation of such strategies will also require that adequate resources of financial, technical and human resources are available to meet both the national and individual site environmental restoration needs.

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Annex I

AUSTRALIA

I-1. INTRODUCTION

Australia is an example of a country with no current or planned nuclear power programme or its associated industrial infrastructure. However, it does have a uranium mining industry. It also has groups of small, but highly trained nuclear research and radiation protection staff. These are based, respectively, at the Australian Nuclear Science and Technology Organization (ANSTO) nuclear research centre at Lucas Heights near Sydney, where there is a research reactor, and the Australian Radiation Laboratory (ARL) in Melbourne. It was against this background and resource that Australia has developed a strategy and implemented a programme to rehabilitate the former British nuclear weapons development and testing sites at Maralinga and Emu in South Australia. The Maralinga and Emu sites are located in the state of South Australia in the region south of the Great Victorian Desert and north of the Nullarbor Plain (Figure I-1). Maralinga is 270 km north west of Ceduna. Emu Field is about 190 km northeast of Maralinga.

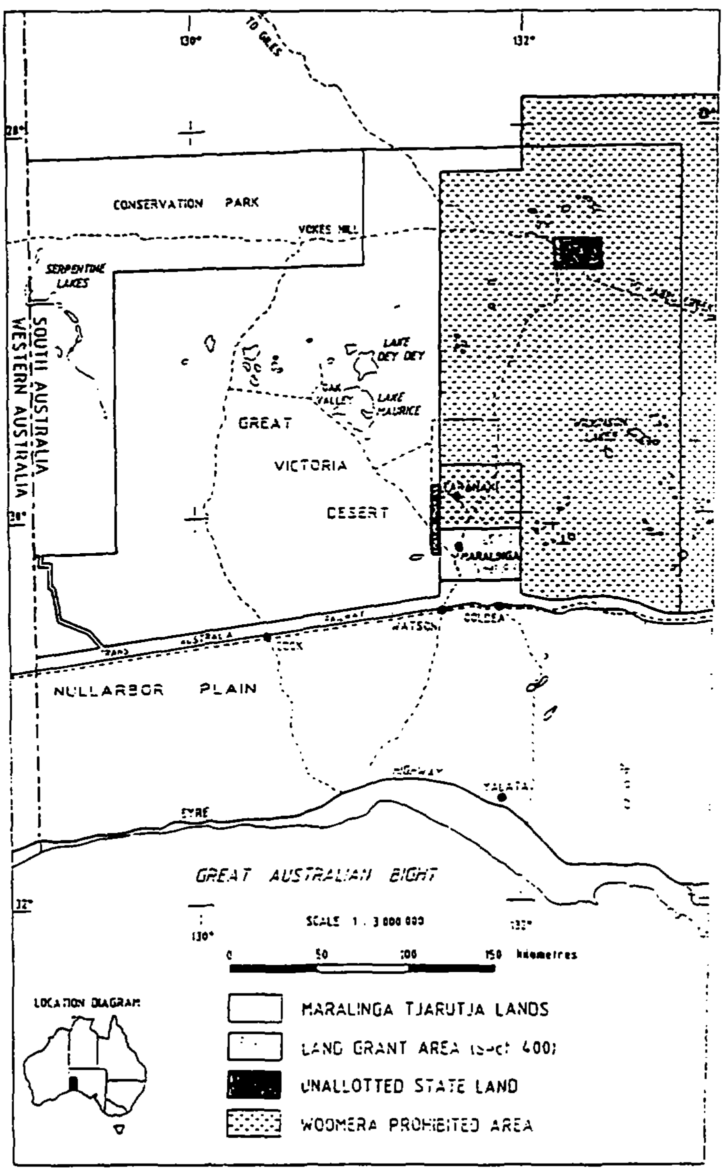

Fig. I-1. Location of the Maralinga and Emu weapons testing sites (Australia).

Between 1953 and 1963, the United Kingdom conducted several programmes of nuclear warhead development trials at Maralinga and Emu. Nine major nuclear trials involving atomic explosions, and several hundred smaller scale experiments ('minor trials'), which dispersed radioactive materials, were carried out. In addition, three major trials were carried out on the Monte Bello Islands off the northwest coast of Australia. The test sites at Maralinga and Emu are shown in Figures I-2 and I-3, respectively. A number of cleanup operations of the Maralinga and Emu sites were carried out by the British, culminating in Operation Brumby in 1967. The underlying premise behind that cleanup, which was the final and by far the most comprehensive, was that the land would be used in future as pasture for sheep and possibly cattle grazing. By implication, human occupation was expected to be intermittent and of very low density. The atomic explosions deposited radioactive fallout downwind of the ground zeros. Some explosions fused sand into 'glazing' and/or induced radioactivity in the soil. Small pellets of cobalt-60 were dispersed at the site at Tadje.

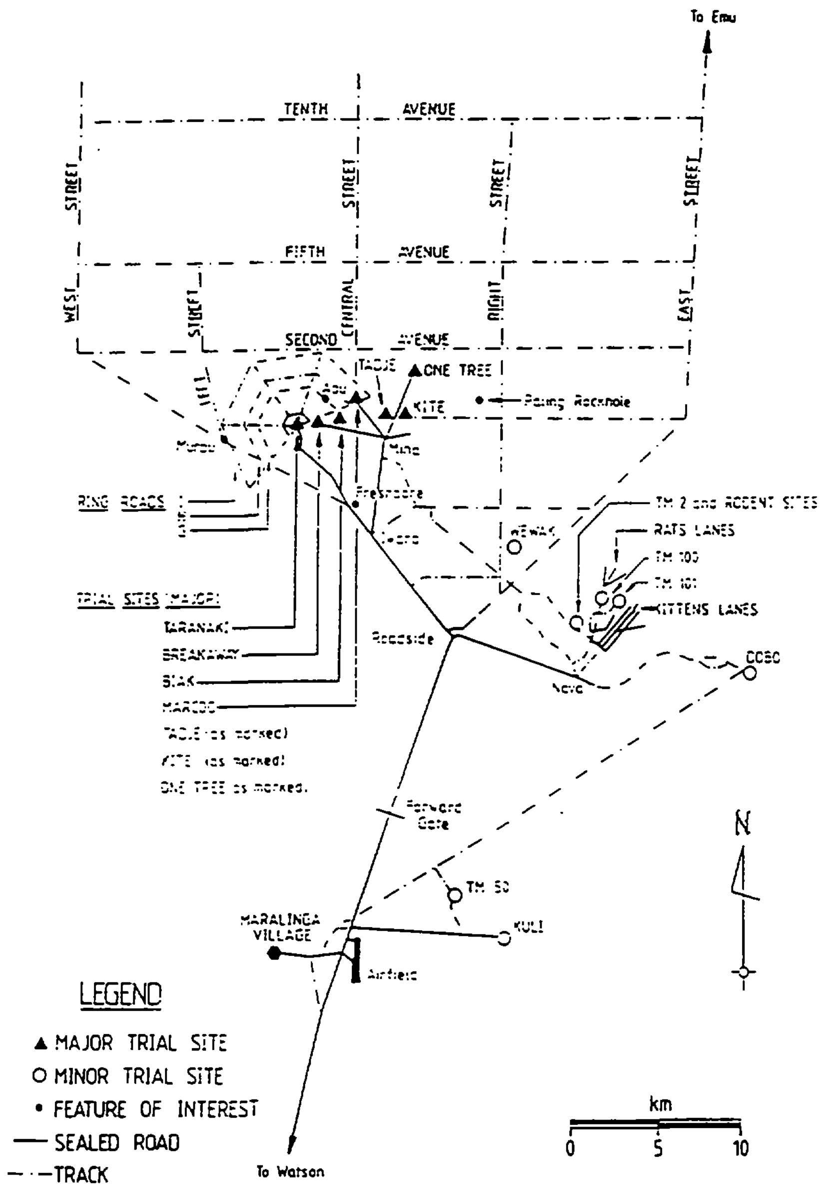

Fig. I-2. Weapons testing site at Maralinga (Australia).

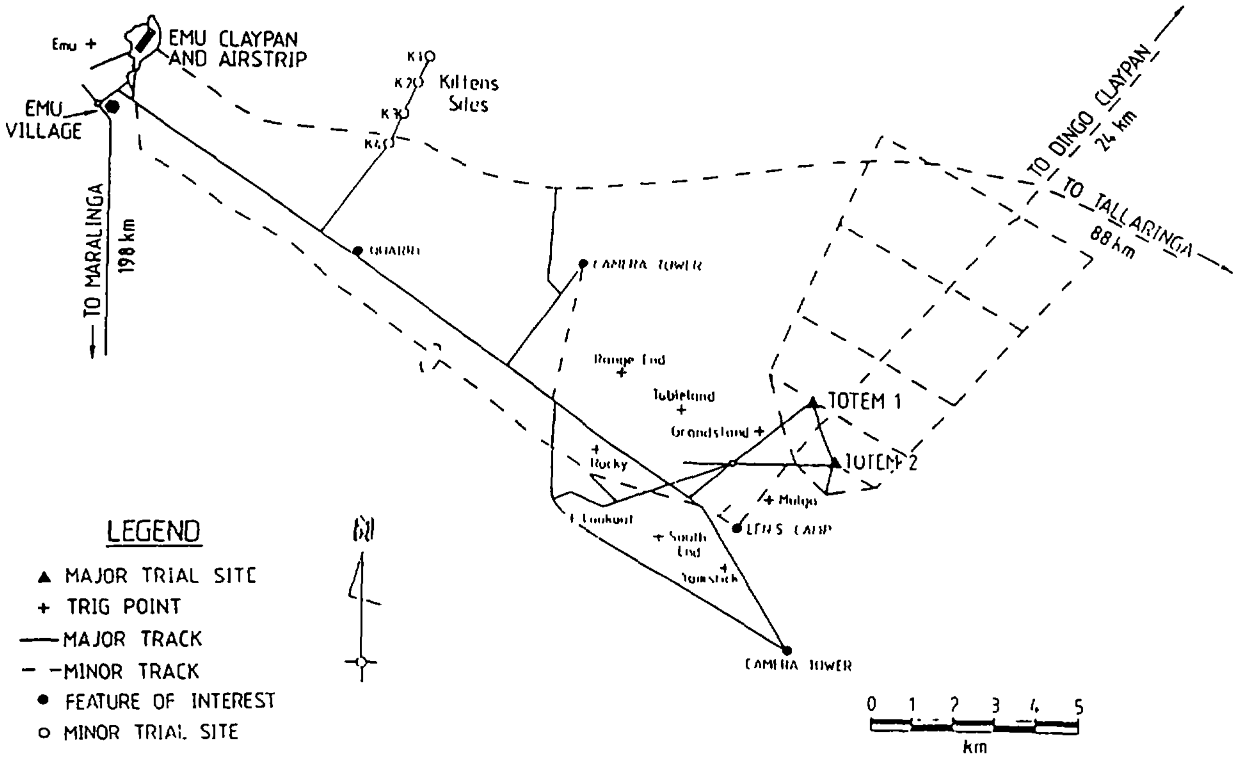

Fig. I-3. Weapons testing site at Emu (Australia).

Five minor trials at Emu and several hundred at Maralinga involved the dispersal by burning and explosion of radioactive material. In some of them, beryllium, uranium and plutonium were dispersed. About 22 kg of plutonium was dispersed explosively in narrow plumes in the Vixen B trials at Taranaki. The residual plutonium in surface layers exists as a finely divided dust, as small sub-millimeter particles, and as surface contamination on larger fragments of debris. In the central area at Taranaki, the surface soil was mixed by ploughing to a depth of 15–25 cm during Operation Brumby in an attempt to reduce surface contamination. Contaminated debris, soil, and general rubbish were buried in pits in the forward area at Maralinga. Those pits known to contain radioactivity were recorded and numbered. Twenty one numbered burial pits at Taranaki are believed to contain between two and twenty kg of plutonium associated with an estimated 830 tonnes of debris and 1120 tonnes of soil from the Vixen B trials. Four numbered pits outside of Taranaki contain about 90 g of plutonium and small quantities of other radioactive and toxic materials. Up to seven tonnes of uranium are contained in pits at Kuli. Some plutonium has been detected in five out of eighty three unnumbered pits in the Maralinga area. The latter were general refuse pits used by the British during the original tests and subsequent cleanup operations. The crater formed by the Marcoo major trial was used to bury a considerable quantity and variety of debris and soil, including some contaminated with plutonium.

I-2. HISTORICAL DEVELOPMENT OF THE CURRENT REHABILITATION PROGRAMME

The Government of Australia accepted Operation Brumby as having rehabilitated the Maralinga to an acceptable standard. There was then a period when the range was left open with the minimum of supervision. Public concern arose during the intervening years and culminated in the setting up in July 1984 of a Royal Commission (public inquiry) into British Nuclear Tests in Australia. This commission took evidence, much of which was gathered in public hearings in both Australia and the UK, from people involved in the test and earlier cleanup programmes and from other interested parties. In 1986, the Royal Commission reported its findings. It concluded, in part, that the treatment of the plutonium-contaminated areas in earlier cleanup campaigns was inadequate, based on the wrong assumptions, and had left the range in a more difficult state for any proper future cleanup.

The Royal Commission recommended a Maralinga Commission be established to determine suitable cleanup criteria, oversee the cleanup and coordinate all future test site management. It suggested membership of the Maralinga Commission should include representatives of the traditional owners, the UK and Australian Governments and the State Government of South Australia, where the range was located.

The Australian Government responded to these recommendations by forming in February 1986 two groups. The first was a Technical Assessment Group (TAG) to address the technical conclusions stemming from the Royal Commission. The second was a Consultative Group, which was to be a forum for discussion of the programme. The membership of the latter was as recommended by the Royal Commission, but with the addition of representatives of the State of Western Australia, which is adjacent to South Australia and has one boundary close to the test range.

I-3. STRATEGY USED BY THE TECHNICAL ASSESSMENT GROUP

Studies were defined to provide the necessary input data for the TAG to develop clearance criteria, engineering options and costs.

The first five studies involved the following areas:

- Anthropology
- Radioecology
- Bioavailability
- Inhalation hazard assessment

Radiochemical and chemical analysis established the base data needed to determine a level of acceptable contamination for each of the land use options. The aerial radiological survey provided contamination contours (A to E in increasing order) for the major areas at Maralinga and Emu.

A dosimetric modeling study brought together the data from these six studies and assessed the range of potential annual radiological doses from 100% occupancy of the contaminated areas.

The second set of studies involved:

- intrusive examination using a backhoe and monitoring of several unnumbered burial pits;
- estimation of the potential volume of contaminated soil at Maralinga;
- a geological/hydrological study of the Taranaki area; and
- the definition of a range of rehabilitation options.

These studies provided essential basic data for the study of potential engineering rehabilitation options and associated indicative costs. Technical procedures and costs for various land release and land use options were then formulated.

It must be emphasized that the cost data presented was of a preliminary nature and resulted from paper studies and minimal field test data. Provision was made for contingencies and the accuracy of estimates given was considered adequate for broad-based technical and administrative judgements to be made. More detailed and reliable estimates were to come from a specific Design Development Phase study on the preferred approach to be adopted.

It is the nature of this type of site reclamation that time scales and costs given at this initial stage can be expected to escalate during the design development phase.

I-4. FACTORS FOR CONSIDERATION IN REHABILITATION AND RELEASE OF LANDS AT MARALINGA AND EMU

The various studies provided the background data to allow an assessment of the potential radiological impact of residual contamination in the Maralinga and Emu areas. From these studies, it was possible to assess the dose from resuspended inhaled contaminated dust, ingestion of food stuffs and associated soil, the extent of external gamma dose and beta dose from the ground and contaminated clothing. In addition, the dose associated with wound contamination was assessed. There is a remote possibility of high tissue doses being received after a wound contamination. Except for the ploughed areas, this was assessed to be of lesser importance than the hazards from inhalation and ingestion.

It was concluded that the most significant radiological pathways were inhalation of resuspended activity for which the largest doses are received by young (~10 year old) children and ingestion of contaminated soil by infants in the first year of life. Assuming full time occupancy, estimated committed doses to such children were 4–5 mSv per year at the A contour of the Taranaki plumes; 470 mSv per year in the inner Taranaki area; 25 mSv per year at the D contour at Kuli; and 30–80 mSv per year near the ground zeros at Emu.

The development of a realistic hazard assessment and the derivation of criteria for cleanup were based upon a judgment that the risk of a human being dying prematurely from cancer as a result of exposure to ionizing radiation from the test sites should be less than 1 in 10 000 for each year over the individual's anticipated life-span. The risk for humans was considered to be below this level until the age of about 50 years if the individual was continuously exposed to 5 mSv per year from birth. Beyond the age of fifty years the projected risk increases with age. The level of soil contamination which corresponds to this risk depends markedly on life style, and changes in life-style which lead to a reduced exposure — principally through reduced dust intake — are also likely to lead to a lengthened lifespan for other reasons. The reduced exposure is then offset by a higher radiation induced cancer incidence with increasing age, so that the lifetime risk is more or less independent of increasing lifespan. It was therefore recommended that as a criterion for rehabilitation the annual risk of fatal cancer following the inhalation or ingestion of contaminated soil should not exceed 1 in 10 000 by the fiftieth year.

If the Oak Valley community is maintained at its present size for several generations and continues to live a semi-traditional life-style it is estimated that the incidence of fatal cancer will amount to one or two per century from an annual committed dose of 5 mSv.

The scale of the rehabilitation measures to control radiation dose is predominantly determined by Aboriginal life style. A substantial part of the estimated cost of rehabilitation is directly attributable to those options relating to the release of land for unrestricted entry and use.

It is considered that the contour corresponding to an annual committed dose of ~1 mSv (Fig. I-4) is the borderline between acceptability and unacceptableness of risk. It is based upon knowledge of the present life-style of the semi-traditional Aborigines, their current life expectancy and a judgment of their occupancy of areas where the dose exceeds 5 mSv per year (e.g. for hunting or transit). This is clearly an upper bound of dose in view of the likelihood that a nomadic individual will spend much more time in the areas of lower contamination. There are substantial uncertainties in quantifying the Aboriginal life style. It is considered that the acceptable level of contamination should not be reduced on this account. Rather, a trade-off is seen between these uncertainties and those related to the occupancy factor.

The Maralinga Tjarutja are a nomadic people, moving their camp over varying distances on a regular basis. Major relocations to a new site 10 to 15 km distant are made periodically. Since the Oak Valley Out-station was established there is one recording of camp movement 50 km west of Oak Valley. Camp sizes at Oak Valley have ranged from 11 to 118, with a mean population of 69, over the period of the anthropological study. Two hundred and eighty six different people were recorded as being present in the censuses.

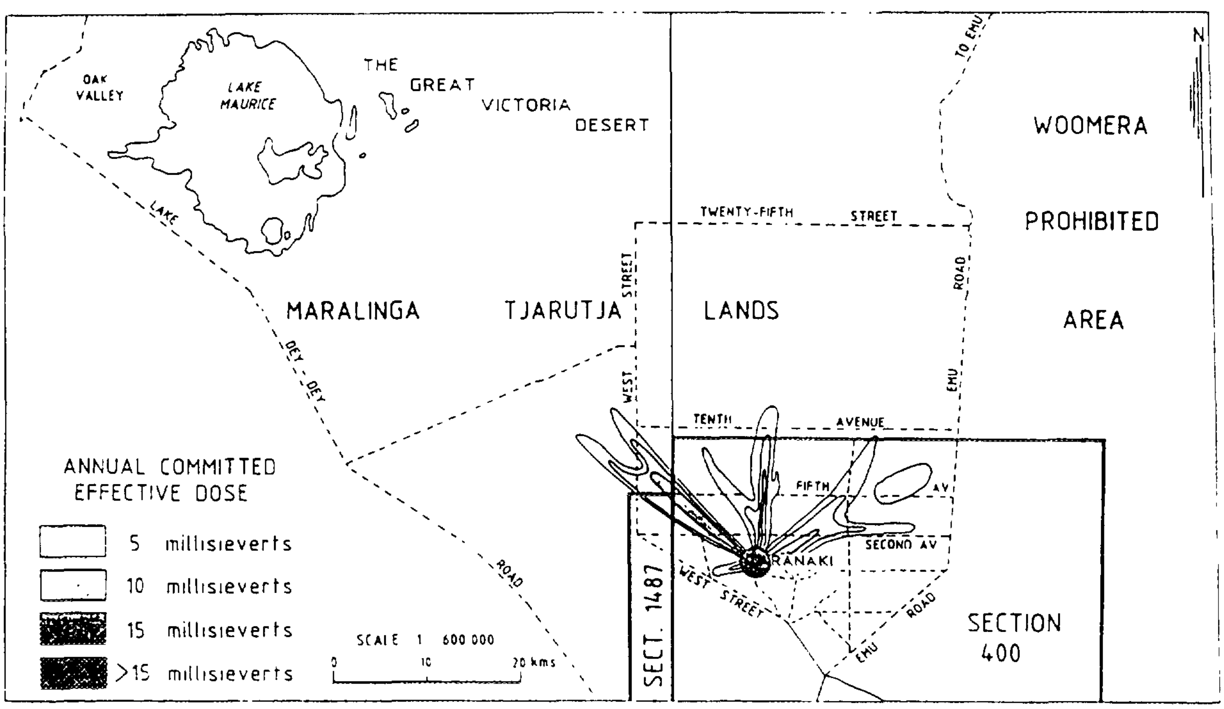

Fig. I-4. The major plumes at Maralinga with predicted doses from 100% occupancy.

Any decision on remedial action had take into the account the optimum balance between the cost of intervention and rehabilitation (including the hazards to the workers carrying out the rehabilitation) against the value of the dose averted to humans who might occupy the area. In addition, the inability to predict demographic evolution, (e.g. movements through the area) or the effect of climatic changes on land use needed to be recognized.

I-5. OPTIONS CONSIDERED FOR REHABILITATION

Rehabilitation options for contaminated areas of soil have included the following:

- *Restriction of access* by exclusion and/or warning fences.
- *Collection and burial of contaminated soil* in a specially constructed trench.
- *Decontamination of collected soil* to concentrate the radioactivity and reduce the volume for burial.
- *Mixing of contaminated soil* in the lightly contaminated with clean outer plume areas underlying soil to reduce the concentration.

Disposal of contaminated soil by landfill in a shallow engineered covered trench offers economic advantages, particularly in an arid environment where the potential for contact with ground water is remote and can further be reduced by repository design. A geological and hydrological investigation of the Taranaki area has established that a site near the plume areas is suitable for shallow ground disposal of contaminated soil. In a separate assessment, the British Geological Society concluded that "Shallow trench disposal is considered geologically feasible within the proposed site assuming the release mechanism (vertical propagation) suggested in the geological report."

Measures considered for the rehabilitation of debris pits in general are as follows: In situ stabilization by pressure grouting or in situ vitrification to immobilize the contents of the pits and provide better containment. Exhumation of the contents of the pits and disposal of the radioactivity in a specially constructed trench or borehole. The debris pit at Marcoo is a special case. This pit has a volume of some 7000 m^3 and, while provision has been made to grout the contents and to provide a concrete cap, future investigations may show that the contents should be exhumed and transferred to a prepared disposal site.

I-6. STRATEGY USED TO DEVELOP ENGINEERING OPTIONS AND COSTS

A series of engineering work packages was defined to embrace the range of established technologies that are used in contaminated land recovery operations. The technical proposals and cost estimates provided by these work packages were then used as base data to develop indicative cost estimates against a strategy for Maralinga which involved the following options.

A progressive release of land from Section 400 in South Australia moving in a northerly direction from the base of Section 400 (Options 1–6).

A release of land to the east of Right Street (Option 7) to give access to Paling Rachael. This is achieved by treatment of plumes east of Right Street, in situ stabilization of all numbered pits other than those at Taranaki and optimal fencing of the remaining contaminated areas.

Removal of contaminated soil from outside the boundaries of Section 4C'~ (Option 8). The costs for the rehabilitation of Emu (Option 9) allow for the removal of contaminated soil from the two Totem plumes and mounding it at the ground zero locations.

Although cost estimates based on established rehabilitation technologies have been used in the majority of the options, two advanced processing methods have also been included since, if proven, they could provide significant cost advantages. The first method is in situ vitrification (ISV) of the burial pit contents and the second is a soil decontamination process (TRUclean) which concentrates the activity in a smaller volume. Both of these processes have been taken beyond the experimental stage in the USA, but each process would require further development and proving for use in the Maralinga situation. Accordingly, judgments have been made of the costs of actions which involve these two techniques.

I-7. RESULTS OF THE TECHNICAL ASSESSMENT GROUP

The predominant contributor to potential radiation dose at the test sites is residual plutonium contamination of soil which may be incorporated into the body through inhalation of resuspended dust. The problem posed by plutonium contamination is not a new one. There have been several dispersals of nuclear warhead plutonium elsewhere, particularly at the US test site at Nevada, at former Soviet test sites, and as a result of accidents with nuclear weapons. These have led to levels of plutonium in the environment similar to those encountered at Maralinga and requiring cleanup. Some of the accident situations, such as at Palomares in Spain, differed through the contamination of most concern being in agricultural and village areas with a potentially high permanent population. During the period of atmospheric testing of nuclear weapons, large quantities of plutonium were dispersed into the atmosphere and have subsequently been deposited in small concentrations over the surface of the earth. However, levels have steadily declined since the peak fallout years of the early nineteen-sixties. People have been continuously exposed to plutonium from this source. The amounts incorporated are minute, but they are detectable in some tissues by radiochemical analysis.

Acceptable levels of radioactive soil contamination based upon organ doses from incorporated plutonium and the associated health detriment were proposed in a study undertaken by the Technical Assessment Group for a series of land use options ranging from:

(I) fully unrestricted habitation by Aboriginals including the case of high dependence on local plants and animals for food; to

(ii) casual access by Aboriginals assuming retained or, if necessary, extended fences.

The area of land affected and the quantity of soil and other material with more than the proposed limit of contamination have been determined for each of the land use options. A range of remedial measures for reducing contamination to a level acceptable for each of the land use options was assessed by TAG and methods were proposed for safe disposal of the contaminated materials.

The associated costs of these remedial measures and disposal methods were estimated. The need for remedial measures for burial pits containing radioactive materials was examined for each land use option. The increase in land availability for each combination of remedial measures and disposal procedures was determined. For some areas a detailed ground survey was essential before any cleanup option involving soil removal or treatment could implemented, and all areas required a ground survey before any is released. Once the preferred approach was selected, the next stage has been to undertake more detailed studies as part of a Design Development Phase which has been required before any extensive cleanup work is undertaken.

Surface contamination levels at Maralinga and Emu were measured in an aerial radiological survey covering 1550 km^2, which included the major and the minor trial sites. Detailed ground measurements have been made in limited areas of Maralinga and Emu. A generalized impression of the extent of the plumes of plutonium contamination resulting from the minor trials at Taranaki is shown in Figure I-4.

The radiation contours for an Aborigine living a semi-traditional life-style with 100% occupation in the Vixen B plutonium plumes were assessed and are shown together with a portion of the boundary of the Commonwealth Prohibited Access Zone, Section 400, and the corridor of unalotted South Australian Crown Land between Section 400 and the Maralinga Tjarutja Land Grant. The committed dose contours of 5–15 mSv per year were derived by dosimetric modelling. The land areas enclosed within the dose contours were derived from data obtained during the aerial radiological survey. The areas which relate to these several sections are as follows:

Region	**Section**	**Area (km^2)**
Maralinga	400	3120
Emu	1486	500
Maralinga Tjarutja Lands	1302 & 1485	76 420
Unalotted SA Crown Land	1487	200

A total of approximately 100 km^2 of land is contaminated to a level exceeding 5 mSv per year, of which about 34 km^2 is outside of Section 400.

I-8. SUMMARY OF COST ESTIMATES AT MARALINGA

The rehabilitation options and their indicative costs were determined. The estimates of contaminated soil volume were derived from the 'limit of detection' americium contours obtained in the aerial radiological survey, which defined a contaminated area of some 120 km^2. This area has been used as a basis for costing extremes in fencing and soil collection operations. Its boundaries correspond to an approximate annual committed dose of about 4 mSv for an Aborigine child assuming 100% occupancy; that is slightly lower than the 5 mSv per year dose which has been recommended.

For engineering and clearance monitoring purposes, the 5 mSv per year contour will be converted into an equivalent surficial activity of kBq ^{241}Am per m^3. The numeric value of this conversion varies from location to location. The three most important parameters in this derivation are the ^{239}Pu to ^{241}Am ratio (this varies from 7.8 [NW plume] to 50 [Emu, Totem II]); the enhancement factor, which varies from 1 (ground zeros, major test sites) to 20 (inner Taranaki); and the depth distribution of the ^{241}Am. The last mentioned parameter can account for a variation factor of about three.

The cost summary includes indicative costs for engineering work, necessary work in the Design Development Phase and other costs including capitalization of fence replacements and the maintenance of surveillance by the Australian Protective Service (APS). Engineering costs for Option 6 (a) to (j) include grouting of the Marcoo Crater.

Surveillance by the APS is estimated at A$8M and is common to all options which retain fencing. Satellite surveillance may offer a cost effective alternative. The estimates can be placed in broad bands:

A$13M for fencing the entire areas and including the capital investment for the maintenance of surveillance by the APS in perpetuity.

A$60 to A$70M for replacing intrusion resistant fences, providing a warning fence around the plumes and either exhuming and reburying the contents of the pits, or using a variety of treatments for in situ stabilization of the pits.

A$80M to A$120M for fencing of the plumes, collecting and burying the soil from the heavily contaminated treated areas or alternatively operating a decontamination process to remove and concentrate the contamination for burial, together with a range of treatments for the burial pits.

A$135M to A$650M to eliminate the need for fencing and surveillance by mixing of the plume areas to dilute surface contamination, or collecting and burying the contaminated soil. This cost range also incorporates previous options for the burial pits and heavily contaminated treated areas. Other specific estimates include:

The cost of collection of plume soil from outside Section 400, which is above the 5 mSv dose contour; this is estimated to be about A$66M if the soil is transported to and mounded at Taranaki, or about A$110M if the soil is buried within Section 400. The alternative of mixing the soil outside Section 400 is about A$35M.

Collection and burial of soil to the east of Right Street and treatment of all debris pits outside of Taranaki would cost about A$52M to A$82M. This option provides access to Paling rockhole, but the heavily contaminated area at Taranaki would remain fenced.

Collection and disposal of soil from the Taranaki treated area is estimated to cost between $35M and $45M depending on the result of the safety assessment of the disposal. The cost estimates involving soil removal given above are probably lower bounds since they are based on the removal of soil to an average depth of 100 mm.

I-9. SUMMARY OF COST ESTIMATES AT EMU

Preliminary estimates have been made of contours at Emu corresponding to an annual committed dose of 5 mSv. Costs of collection of contaminated soil and mounding it at the ground zero locations is about A$11M.

I-10. MARALINGA REHABILITATION PROGRAMME

Estimates have been derived of the time scales to completion for each rehabilitation option. They cover the range from 1.5 to 9.0 years. A period 0.5 to 2.5 years is included in these estimates for a Design Development Phase which needs to be completed before field operations commence. The complexity of this phase is dependent upon the selected option but generally will include safety assessments, detailed design of equipment and facilities, field studies, provision of safety and operational procedures and training of operatives. Options involving the removal of substantial quantities of soil were favoured, so sufficient resources needed to be set aside for the development of the best technical and cost effective procedures. It is also important to note that lands so treated would be at great risk from erosion and hence care has had to be taken with revegetation plans to ensure that they will be satisfactorily for use by the Aborigines.

I-11. RISKS TO REHABILITATION WORKERS

The on-site activities proposed to effect rehabilitation of the contaminated areas are in many ways typical of those employed in the construction industry. For many activities the Maralinga operatives will be burdened by radiological protection equipment but in the absence of more specific data it was deemed not unreasonable to use data from this industry to indicate the order of risk to operators.

The greatest workforce estimated for the Maralinga cleanup is in excess of 500 personnel working for over 6 years (Option 6 h). For this option the statistics suggests one fatal injury, several injuries involving permanent disability and several hundred less severe other injuries.

By comparison, 2 fatalities and 63 severe work accidents occurred during the radiological cleanup of Eniwetok atoll, which involved the removal of about 50 000 m^3 of soil and 200 000 m^3 of debris.

For a well regulated working environment, calculations indicate that one premature death from cancer might ultimately be expected due to radiation exposure from the most comprehensive cleanup option.

Annex II

BRAZIL

II-1. INTRODUCTION

In Brazil, attention has recently been focused on radiological problems at conventional mining areas. The mining and milling of ores containing significant amounts of uranium and thorium minerals may lead to the radioactive contamination of the environment. This may occur during the operational phase of the facilities, as well as after the facility closeout (unless a proper remediation is carried out). The tailings and waste dumps resulting from these operations are generally deposited in open impoundment areas, and they are constantly subjected to weathering, the runoff effects of rainwater, etc. After closeout of the mining and milling facilities, the effects of weathering and runoff in the impoundment areas may vary over time, even though they may appear externally to be unchanged. Thus, the rate of leaching of pollutants from the solid waste materials can be expected to generally change with time.

As discussed in this Annex, there are several conventional mining facilities in Brazil which may present potential radiological problems due to the presence of uranium and thorium in main ore. These include installations operated by the coal, phosphate, niobium, gold, tin, copper and lead mining industries. These industrial sites are to be found throughout the entire Brazilian territory. Regional characteristics will influence the amounts of the population's exposure to pollutants released by these industries. In addition, large areas with substantial quantities of contaminated waste materials (e.g. tailings and waste dumps) will be left following closeout of these industrial sites, and the remediation of these areas for their unrestricted future use may become necessary. In the past, these industries have not been regulated with respect to their possible radiological impacts. However, the Brazilian regulatory authorities have realized that there are some radiological problems associated with the activities of these industries. At the present time, a rather broad research programme to evaluate the extent of this problem is being developed by the Institute for Radiation Protection and Dosimetry (IRD) in conjunction with other sectors of the Brazilian Nuclear Energy Commission (CNEN).

For mining sites in which radioactive contamination already exists, the principle of intervention may be invoked, once the affected areas have been characterized and it has been established that the industrial practices were conducted without benefit of radiological regulations. In such a case, remedial actions will be required to reduce or avert chronic radiation exposures [II-1]. However, for those practices that are still in the planning stage, they may not be bound by the requirements of licensing and regulation if they meet the exemption criteria levels as proposed by the IAEA [II-1].

Taking into account the number of mining industries in Brazil, and the sheer size of the country, a pragmatic approach has been adopted to identify and characterize the sites, and then to implement remedial actions, where necessary, at those locations where there are legitimate radiological concerns.

II-2. CHARACTERIZATION ACTIVITIES — A WORKING METHODOLOGY

The adopted working methodology couples the concept of doing mass balance calculations (and making predictions of radionuclide concentrations in the environment) with a risk assessment protocol as recommended by the US Environmental Protection Agency [II-2]. The methodology consists of the following steps:

(1) Analyzing the operational process(es) of the industry.

(2) Collecting samples and determining radionuclide concentrations in selected samples which are representative of specific parts of the line process.

(3) Calculating mass balances and determining the total activity accumulated at each step of the operational process, as well as what is likely to be deposited in the waste residues. The amount of radioactivity expected in the final product is also considered.

(4) Determining and quantifying the potential mechanisms involved in the mobilization of the pollutants from the waste deposit areas (e.g. from tailings, waste dumps, etc.).

(5) Estimating the contaminant concentrations in the effluent releases,

(6) Performing risk assessments of the operational impacts of the facility and, also, those associated with the facility closeout.

(7) Examining the need for remediating the contaminated areas (e.g. waste piles) for given future land uses (e.g. unrestricted use).

The working methodology is summarized in Fig. II-1.

II-3. RADIOACTIVE CONTAMINATION AT MINING SITES IN BRAZIL

Seven mining and milling facilities have been characterized and studied so far in Brazil. They include coal, niobium, phosphate and gold industrial facilities. The contaminated sites consist of waste disposal areas (tailings and waste dumps) containing excessive levels of radioactivity.

The remedial actions selected for these sites will depend on the particular characteristics of the processing materials. The discussion below presents the most important issues and the probable remediation strategies to be adopted in each case.

II-3.1. Coal industry

In the coal industry, one of the main problems associated with the process wastes is the acid runoff and drainage due to oxidation of the pyrite. The average pyrite concentration in the waste materials is expected to be about 10% by weight. The pH values observed in acid drainage situations may range between 2.0 and 3.0. The resulting solution can leach significant amounts of pollutants (including radioactive metals) that will then be released to the environment. Values of around 50 Bq/L for ^{238}U and 10 Bq/L for ^{210}Pb were determined for the drainage waters of coal waste dumps.

The rate of "production" of U_3O_8 that would be deposited in the waste dumps of the coal industry in Brazil could reach 5 t/a.

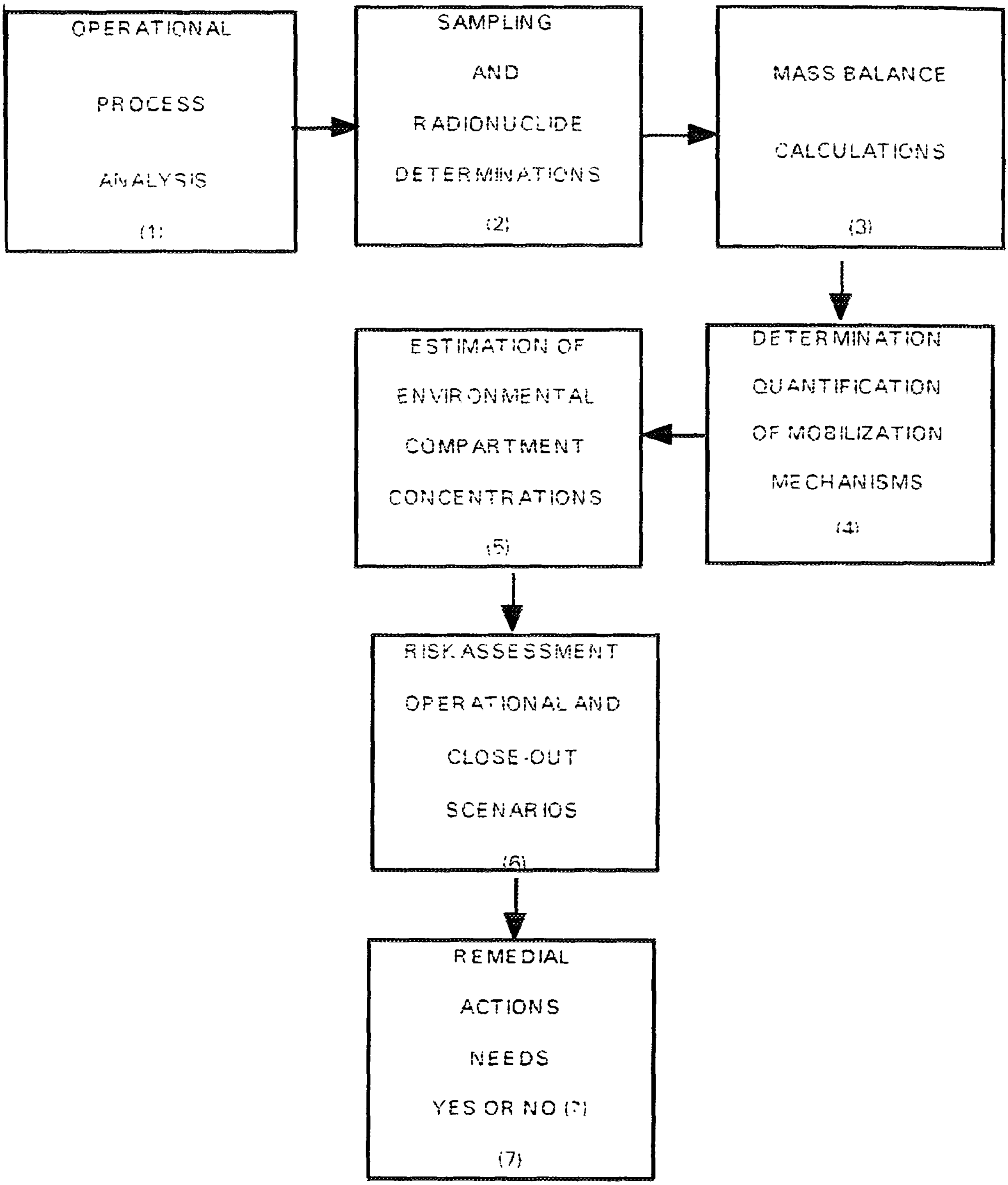

Fig. II-1. Working methodology flowchart (Brazil).

In order to remediate these areas, the levels/flow of water and oxygen in the coal wastes must be reduced. Some alternative approaches may be considered, including the following:

(1) cover the surface with a low permeability layer;

(2) apply lime to the surface so that any percolating water would be alkaline;

(3) prevent the infiltrating water from making contact with reactive material

(4) isolate the entire dump (e.g. by means of compacted clay/soil layers);

(5) keep the dumps saturated (i.e. wet) so that oxygen transport is severely restricted; and

(6) grow vegetation on the waste piles and dumps to enhance evaporation and reduce the amount of infiltrating water.

The remedial actions will also have to consider the reduction of external radiation exposures (e.g. to workers) where appropriate.

II-3.2. Niobium industry

Figures II-2 and II-3 show the activity concentrations of radionuclides from the ^{238}U and ^{232}Th series in each step of the operational process. The most relevant by-products in terms of their radioactive contents are the metallurgical wastes and the (chloric) acid leaching wastes. The first of these process steps mainly concentrates ^{232}Th and ^{238}U in the metallurgical wastes. On the other hand, the acid leaching produces wastes containing significant amounts of ^{238}U and ^{226}Ra (values ranging up to about 10^2 and 4×10^3 Bq/L, respectively). The metallurgical wastes are refractory and do not appear to contain any significant amounts of leachable material. Depending upon where the wastes are stored or disposed of, the most important doses to human populations would be received via external exposure pathways.

Uranium is generated in the leaching step at a rate of about 48 t/a. The element is precipitated after the addition of lime, and it could be recovered for the production of yellow cake. If the uranium was recovered, this would lead to an significant decrease in the total deposited radioactivity.

The tailings dam is expected to be managed by means of lining/covers with eventual revegetation.

II-3.3. Phosphate industry

In contrast to the Niobium Industry, Brazil's Phosphate Industry, which was also investigated in this project, did not employ any chemical extraction steps in their operational process. Thus, only physical processing steps are employed by the Phosphate Industry. As a consequence of this, the Phosphate Industry has not been faced with potential radiological contamination problems in the environment during their operational phase.

The highest radionuclide concentrations in the wastes and by-products were detected in the process step involving barium flotation, especially for the case of ^{210}Pb, in which the concentration reached a value of 5.6×10^3 Bq/kg (see Fig. II-4).

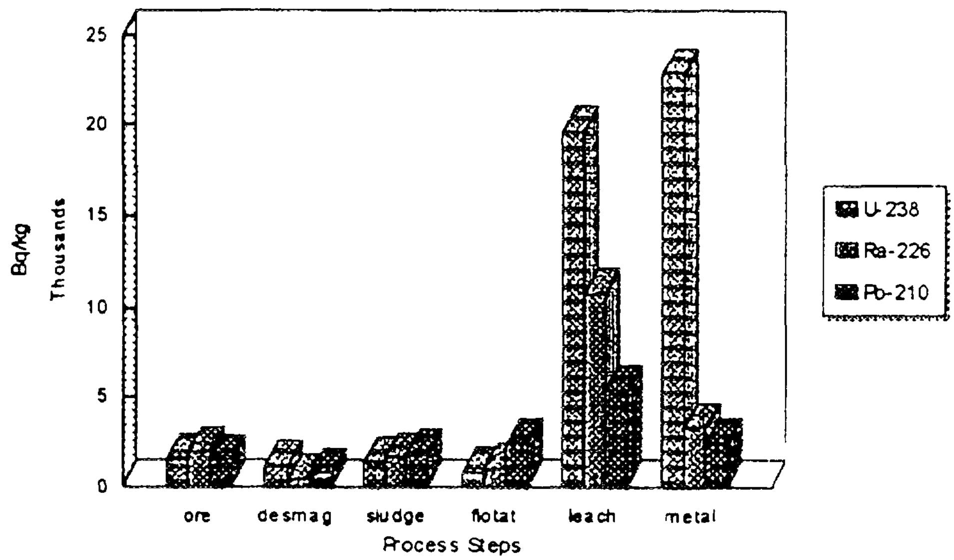

Fig. II-2. Activity concentrations radionuclides from the ^{238}U series in each step of the operational process followed by the Niobium Industry in Brazil.

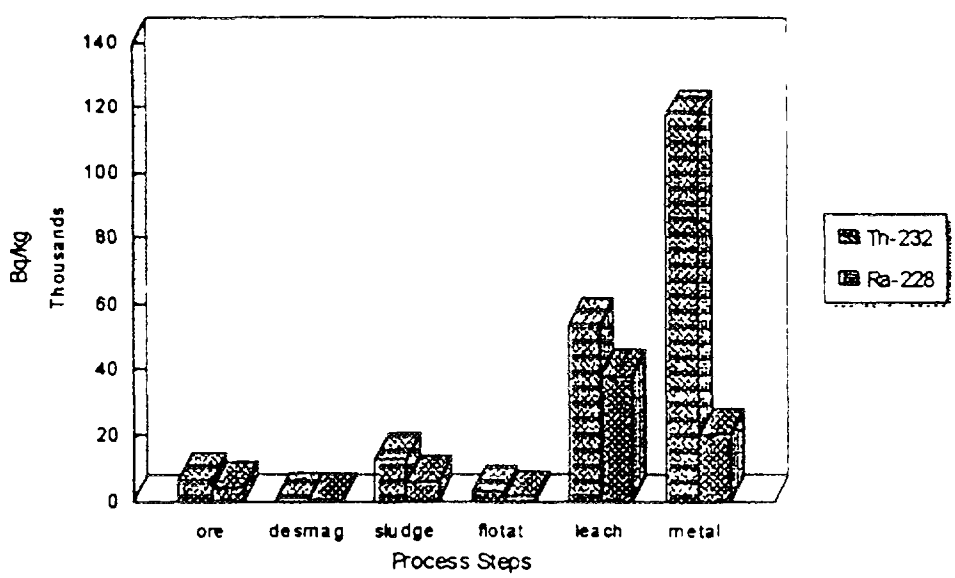

Fig. II-3. Activity concentrations of radionuclides from the ^{232}Th series in each step of the operational process followed by the Niobium Industry in Brazil.

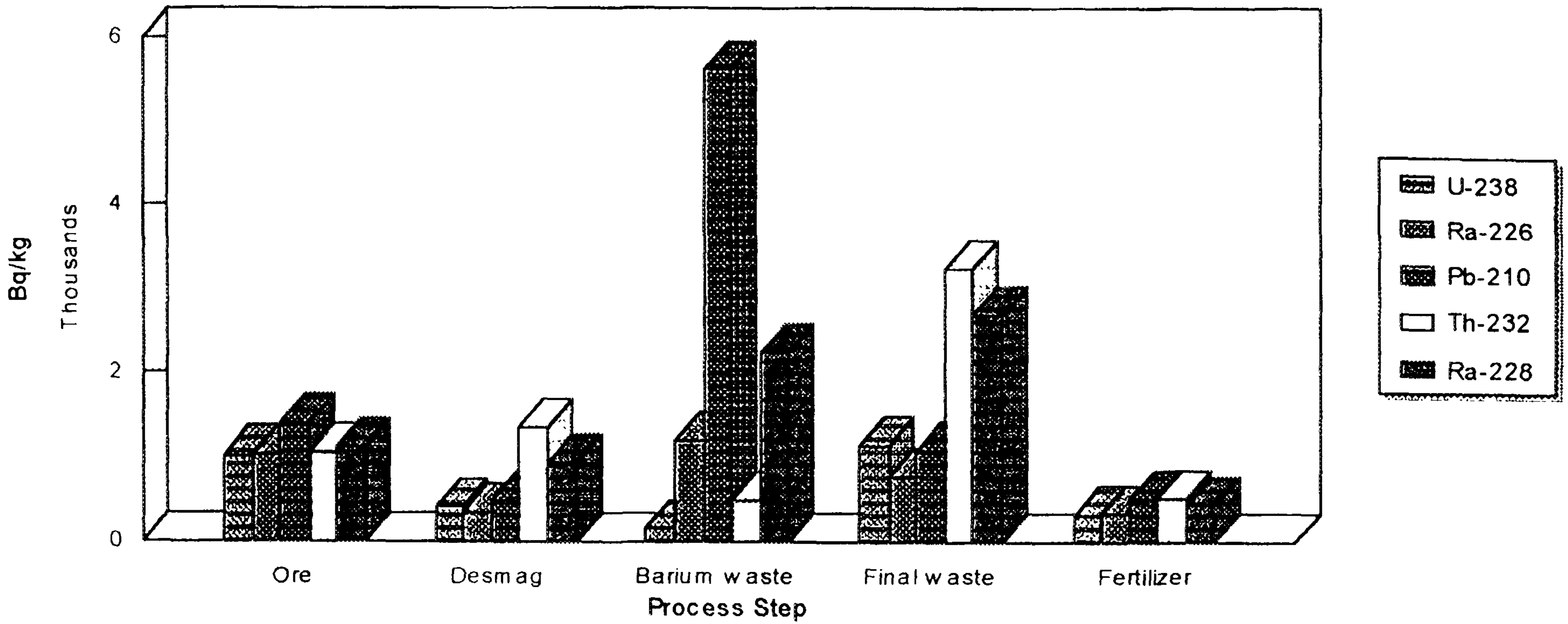

Fig. II-4. Activity concentrations of radionuclides from the ^{238}U and ^{232}Th series in each step of the operational process for the Phosphate Industry in Brazil.

In terms of the remediation to be applied to the disposal wastes areas of the Phosphate Industry in Brazil, one has to consider that phosphogypsum will be the principal by-product of concern. It could serve as an "beneficial additive" to improve the physical properties of agricultural soil, and also as a fertilizer source of sulphur and calcium. The concentrations of ^{226}Ra and ^{210}Pb in the soil, which might result from either the intentional, accidental or incidental application of phosphogypsum to the agricultural land, would be considerably less than the respective values of 1.5 kBq/kg and 0.7 kBq/kg, suggested by the U.S. National Council on Radiation Protection and Measurements (NCRP) as guides for agricultural use [II-3].

II-4. SUMMARY

A pragmatic approach to dealing with radioactively contaminated sites at conventional mining areas has been undertaken in Brazil. The working methodology which has been adopted focuses on characterization of the site, evaluation of environmental impacts (including hazards to the affected population), and consideration of remediation alternatives.

REFERENCES TO ANNEX II

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[II-2] UNITED STATES ENVIRONMENTAL PROTECTION AGENCY, Risk Assessment Guidance for Superfund, Vol. I, Human Health Evaluation Manual, OSWER Directive 9285.7-Ola, EPA Office of Emergency and Remedial Response, Washington, DC, 1989.

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Annex III
CANADA

III-1. INTRODUCTION

This Annex describes the remedial action programme for sites contaminated by historical activities associated with the production and use of radium in Canada. Historic low level radioactive wastes date back to 1933 in Canada, when a radium refinery began operation in Port Hope, Ontario. The problem of residual wastes and contaminated buildings and soils in Port Hope, resulting from the practices in the early years of radium and uranium production, was discovered in the mid-1970s, and a large scale cleanup programme carried out. This work was concentrated on developed properties. As a result, substantial quantities of contaminated materials remained in a number of large undeveloped areas. A number of additional historic waste sites have subsequently been discovered at other locations in Canada, where buildings and/or soils were contaminated with uranium ores or concentrates spilled during transport, or with processing residues, or as a result of the use of radium containing materials.

III-2. ORGANIZATIONAL FRAMEWORK

The federal department responsible for policy for energy in Canada, including nuclear energy and consequently radioactive wastes, is Natural Resources Canada (NRCan). The general approach to radioactive waste management is that the producer/owner is responsible for its radioactive waste and must ensure compliance with regulatory requirements. This extends to remediation of environmental contamination in accordance with the principle of "polluter pays", however this principle cannot be applied to historic wastes. Historic wastes are low level radioactive wastes which are managed in a manner no longer considered acceptable, but for which the original producer no longer exists or otherwise can not reasonably be held responsible. The federal government consequently assumes responsibility for remedial action, including management of wastes, at those sites where the Atomic Energy Control Board (AECB) would have been the regulator had the current regulatory system been in effect at the time of the original activity.

The regulatory agency in Canada is the Atomic Energy Control Board (AECB), established in 1946 with the Atomic Energy Control Act. The AECB is responsible for the regulation of health, safety, security and environmental aspects of the use of nuclear materials and the operation of nuclear facilities, as well as the implementation of Canada's international safeguards policy. A number of other agencies, both provincial and federal, are involved in the regulation of some activities, including environmental remediation, but the AECB retains the primary regulatory and licensing function.

In general, Canadian regulations tend to be focused on broadly based performance criteria. There is not a substantial amount of detailed prescriptive regulations. That is, the onus is on the licensee to describe to, and obtain approval from, the regulator how the performance criteria will be met and how ongoing safety will be ensured.

Legislation for a new Nuclear Safety and Control Act was passed in 1997. It addresses a number of matters not covered by the previous act. For example, with respect to contaminated sites, it explicitly provides authority for the AECB to:

- establish criteria to determine whether a site is contaminated;
- identify radioactively contaminated sites, and cause notice to be placed on the title of the property; and
- order cleanups at contaminated sites, including assignment of costs.

In addition to AECB regulatory requirements, environmental reviews are required by the federal government, in accordance with the Canadian Environmental Assessment Act. Although nuclear energy is an area of federal jurisdiction, the regulatory and environmental review processes take provincial concerns into consideration as well, in order to avoid duplication.

The Low level Radioactive Waste Management Office (LLRWMO) was established by the federal government in 1982 to carry out responsibilities of the government for LLRW management in Canada. These responsibilities extend to both historic wastes and to LLRW produced on an ongoing basis, and specifically include the resolution of historic waste problems that are a federal responsibility. The LLRWMO is operated by Atomic Energy of Canada Limited (AECL) through a cost recovery agreement with NRCan, the federal department which provides the funding and establishes national policy. AECL is a federal Crown Corporation (i.e. a company owned by the government), responsible for nuclear research and development, and the sale and supply of CANDU® nuclear power reactors. The LLRWMO operates primarily as a project management oriented organization, and contracts projects to private sector contractors and consultants, and to other divisions of AECL.

Other major federal groups are independent Siting Task Forces which have been established to locate new permanent sites for specific historic waste inventories. They use a voluntary siting process.

III-3. FACTORS FOR CONSIDERATION

Most of the factors described in the main report have required consideration in developing the remedial action program for contaminated sites associated with the past production and use of radium in Canada. These are discussed briefly in the following sections (corresponding to the structure of Sections 4 and 5 in the main report).

III-3.1. National and international factors

The factors discussed below are important considerations in Canada, as they would be in other countries. The international nature of these factors is not an issue in Canada, however, it could be important in other parts of the world, particularly where transboundary interactions would exist.

III-3.1.1. Nature and extent of the problem

There are a wide range of sites — both geographically and in terms of site and contaminant characteristics. These can be broadly grouped into several groups:

Sites along a 2200 km water transport route used in the past for transporting high grade uranium ores. Contamination of soils and buildings occurred at transfer points and storage sites.

Sites resulting from the refining and processing of ores, and waste management practices of the time. Initially, wastes from the radium industry were treated no differently from other types of industrial waste. Processing residues and other contaminated wastes from the refinery were used as fill materials during construction activities and sent to landfill sites. Contamination was spread to other locations by wind and water transport from storage sites, salvage of contaminated building materials and spillage from haul vehicles. The problem of residual wastes in Port Hope was recognized in the mid-1970s and a large scale cleanup programme carried out. This work was concentrated on developed properties. As a result, quantities of contaminated materials remain in a number of large undeveloped areas and in smaller pockets. The LLRWMO is responsible for cleanup of these historic wastes remaining in Port Hope.

As the Canadian nuclear programme developed after the second world war, the production of uranium quickly became the most important component, and radium production ceased in 1953. As understanding of the effects of radiation improved, the indiscriminate management of wastes was replaced by the use of dumping under controlled access, and then shallow land burial of wastes in dedicated and controlled facilities. Unfortunately, when the choice of sites was made in the 1940s and 1950s, leaching and contaminant transport were poorly understood, and substantial contamination of the host soils has occurred. Two major sites are involved, referred to as the Welcome and Port Granby sites. The sites are maintained by the current licensee, however, the federal government is mainly responsible for funding the remediation programme for the old sites through its prior ownership of the company.

In all, there are about 1 million cubic metres of processing residues and contaminated soils in the Port Hope area, from the waste management practices of the radium and uranium industry in the 1930s, 1940s and 1950s. At many of the old sites, for every cubic metre of waste that was originally produced, there is now about 10 cubic metres of contaminated soil, which has become part of the overall problem. The contaminants are natural uranium with radionuclides and heavy metals present in the original ores that were processed. Arsenic is the most significant in terms of amount, mobility and toxicity.

Sites where there is residual contamination of buildings and/or soils from the past use of radium paint to produce luminous dials, or from activities such as the repair of gauges and other devices containing radium dials.

III-3.1.2. Priorities for action

An initial site characterization is done to determine the following:

- the approximate scope of the problem at the site;
- whether interim remedial action is required; and
- requirements for further site characterization.

Sites are then classed into one of two general categories, depending on the volume of waste. This is a dominant consideration since there are currently no facilities licensed by the AECB for permanent disposal of radioactive wastes in Canada. Although progress is being made towards establishing such facilities, it will be some years yet before any are available.

Remedial action programmes carried out by the LLRWMO thus fall into two categories:

(1) *Small scale sites.* These are defined as historic waste sites where the waste volumes are sufficiently small that transfer to a central waste management facility is preferred to developing a local area storage or disposal site. Small volumes of waste (typically <1–20

m^3 per project) are transferred to an AECB licensed storage facility operated for the LLRWMO by Chalk River Laboratories (CRL) of AECL.

(2) *Cleanups with local area temporary storage.* Cleanup with temporary storage at, or near, the contaminated site is an interim remedial strategy. It is a standard approach now used by the LLRWMO for sites where remedial action should be undertaken, but where the volumes of contaminated soil are too large for transfer to the storage facility at CRL. Segregation of wastes into different inventories has proved to be a cost effective approach at some sites.

High priority for cleanups at small scale sites, or for interim remedial action at major sites, is given to those situations where an individual annual dose exceeding 1 mSv is estimated for the existing use of the site and/or neighbouring areas.

III-3.1.3. Responsibility for cleanups

The LLRWMO is responsible for planning and implementing cleanups, with owners of lands and buildings sharing the costs, except for private residences. Cost sharing is based on division of costs into three broad categories:

- planning and approvals;
- cleanup or other remedial action; and
- management of resulting wastes.

The LLRWMO is responsible for the first and last portions of the costs, with owners responsible for reimbursement of the LLRWMO for the costs of the cleanup or other remedial action. Legal agreements are used to specify the responsibilities of each party at a property. Owners may also assume all responsibilities if they do not wish to participate in the project planned by the LLRWMO, providing they meet regulatory requirements.

III-3.1.4. Socio-economic factors

There are adequate human and technical resources for this programme, with the rate of progress, at other than high priority sites, determined by funding levels and the date of availability of a permanent disposal facility(ies).

III-3.1.5. International factors

None of the Canadian sites have transboundary effects, although this might not be the case for some radioactive contamination situations elsewhere in the world.

III-3.1.6. Waste management issues

The development of permanent LLRW disposal facilities is a policy objective of the government. For LLRW produced on an ongoing basis, this is a responsibility of the producers, while for historic wastes, it is a responsibility of the government.

Since it will be some years until permanent LLRW disposal facilities are available, cleanups with local area temporary storage or disposal is the standard approach used by the LLRWMO for sites with large waste volumes. This approach eliminates the time consuming step of trying to find a temporary storage site at a new location well away from the location of the contaminated site. Efforts in the early 1980s, by the LLRWMO and its predecessors, to locate such temporary storage sites were unsuccessful due to opposition by residents near proposed locations. With the current approach, contaminated soil is now consolidated and held in storage either on the parcel of land where it was first encountered, or nearby. Experience has shown that a comprehensive public consultation process can be successful in establishing interim storage facilities at or near the sites where the contaminated soil and other materials are located. Agreement with the owner of the contaminated site is also more readily and quickly attainable given the potential for immediate action. Although final disposal is still required for these contaminated materials, these interim remedial actions have eliminated health risks and remedied environmental problems. There are also general benefits to the community, in terms of eliminating negative perceptions and removing constraints on land use.

The LLRWMO has used a number of interim storage approaches as part of its remedial work programme at sites in Ontario, British Columbia, and the Northwest Territories. These include: engineered mounds, concrete block walled bunkers, and drummed storage within a fenced area. Such storage sites hold a little as 50 and as many as 40 000 cubic meters of contaminated soil, but typically apply to inventories of a few thousand cubic meters.

Segregation of wastes into different inventories has proven to be a cost effective approach at some sites.

III-3.2. Regional and local factors

The regional and local factors discussed below would be generally applicable for contaminated sites anywhere in the world.

III-3.2.1. Risk to workers, public and environment

A number of factors are of interest and/or concern to communities where contaminated sites are located, and to site neighbours. These include:

- risks to people who use or access the site on a regular or occasional basis;
- offsite environmental impacts;
- risks to people from offsite environmental impacts;
- future land uses and their impacts, if any, or property values and the local economy;
- options or alternatives for remedial action;
- cleanup criteria and other restoration objectives, including any future requirements for land use control, monitoring, or maintenance activities;
- plans for managing wastes (contaminated or other) resulting from remedial action;
- risks to workers during the performance of remedial work;

- off-site environmental impacts during the performance of remedial work; and

- monitoring plans, actions levels and mitigative actions for various of the above items.

III-3.2.2. Economic impacts

Many of the Canadian sites are in urban areas, so that constraints on present or future use of lands or buildings, perceptions of risk to present or future users, and potential impacts on neighbouring property values, are important factors. These factors are also important in rural and undeveloped areas, but involve a smaller number of interested, or affected, parties.

III-3.2.3. Future land use

Future land use can both affect the remedial action plan and be affected by the remedial action plan. For example, cleanup criteria and other restoration objectives may be, in part, a function of future land use, as specified in official plans or zoning bylaws. Conversely, residual contamination levels, or in situ management of wastes or contaminated groundwater may require land use controls, monitoring or other future actions, for at least some period of time.

III-3.2.4. Provincial or local regulations

Factors which arise from regulatory requirements at the provincial or municipal level include:

- standards and guidelines for chemical contaminants are established at the provincial level;

- land use plans (official plans, site plan approvals and building permits) are established at the provincial and/or municipal level; and

- standards and guidelines for environmental parameters such as noise and dust are established at the provincial or municipal level.

These factors are dealt with in an integrated manner through the environmental assessment process and through the role of the AECB as the primary regulator. That is, there is a "one window" approach whereby the AECB coordinates regulatory agency review of licence applications, and establishes any requirements of other agencies as conditions on the licence issued by the AECB. Inspections and audits may thus also include representatives of other agencies.

III-3.2.5. Restoration criteria

Cleanup criteria are generally based on one of the following approaches:

- background levels as a basis, where this is a practical approach;

- levels specified in regulations, standards or guidelines; or

- levels developed from site specific risk assessment.

Regardless of the approach, it is important to apply the ALARA principle in considering remediation action alternatives at a site. The normal practice in Canada is also to impose a dose constraint of 1 mSv/a (incremental dose) to a critical group individual. In addition, several provinces have, or are developing, comprehensive regulatory frameworks for chemically contaminated sites, and it is important to maintain an overall consistency of approach when both radiological and chemical contaminants are present. In addition to cleanup criteria, remedial action plans also contain other restoration objectives, including the physical restoration of properties.

Formal compliance verification plans, as approved by the regulator, are implemented by the LLRWMO to confirm that cleanup criteria were achieved.

III-3.2.6. Public concern

Public consultation is an important component of developing and implementing remedial actions in Canada. It is a requirement of the Canadian Environmental Assessment Act, which applies to projects which have a federal department as the proponent, or are federally funded, or are carried out on federal lands. Most importantly, public consultation carried out before key project decisions are made has been demonstrated to be a successful approach to developing projects which are both technically sound and acceptable to those affected.

III-4. SAMPLE PROJECT: CLEANUP OF CONTAMINATED SOIL AT SCARBOROUGH, ONTARIO

This particular example is illustrative of a project requiring both extensive public consultation at the planning stage, and a project specific technical approach, soil sorting, to segregate the contaminated soil into different inventories.

III-4.1. Introduction

The Malvern Remedial Project (MRP) resulted in the removal of radium-contaminated soils from more than 60 residential and commercial properties in the Scarborough, Ontario community of Malvern. The contamination originated from the radium dial painting industry at the time of the Second World War. Farm land which was undeveloped then was subsequently developed, and contaminated soil was discovered at residential properties in Malvern in 1980. Cleanups to remove small discrete contaminated materials from surface soils, and interim actions to reduce indoor radon levels were carried out. However, several initiatives to remove the buried contaminated soil failed when residents who lived close to proposed interim storage sites objected vigorously. The MRP, a jointly funded project by the federal and provincial governments, was announced in 1992 March. The main elements of the project were to complete the cleanup of soils at the original location and at a second location subsequently discovered, to sort the soil to remove all material with licensable concentrations of radium and to store the remaining mildly contaminated soil at the sorting site until a permanent disposal site is available in Ontario. An extended radiological survey of the Malvern community, to confirm that no further areas of contamination exist, was performed in parallel with the cleanup project.

III-4.2. Organization

Three committees guided the project. The MRP Steering Committee was comprised of senior representatives from the two sponsoring governments departments, Natural Resources

Canada and the Ontario Management Board Secretariat, together with the chairpersons of the other two committees. These were the Public Liaison Committee (PLC) comprising members of the community and the Technical Advisory Committee (TAC) made up of technical experts from government departments and a PLC representative. The federal Low-Level Radioactive Waste Management Office (LLRWMO) provided administrative and technical support, including project management and contract administration, and ensuring that quality assurance and regulatory requirements were met. Project activities were performed through engineering and environmental consulting firms, and contractors, selected through competitive processes to ensure both cost effectiveness and competence.

III-4.3. Planning and approvals

The initial work was directed at identification of a technically suitable, publicly acceptable temporary site for sorting and storage of the mildly contaminated soils. A proposed site for these activities was acquired by the Government of Ontario in mid-1993, in an undeveloped part of a nearby industrial area. The proposed activities of the project were assessed, based on this site, in accordance with the provisions of the Federal Environmental Assessment Review Process Guidelines Order. The site selection and environmental assessment processes involved the preparation of draft reports by consultants hired by the MRP, an extensive public consultation process led by the PLC and final reports responding to all comments received. Environmental assessments were then carried out by Natural Resources Canada, as the initiating department responsible for the project, and by Atomic Energy of Canada (AECL), as the operator of the federal Low-Level Radioactive Waste Management Office (LLRWMO). Both of these assessments concluded that the project could proceed with appropriate measures in place for mitigation of potential environmental effects. A licence was obtained from the AECB for possession of radium-contaminated materials resulting from the project, to complete the planning and approval phase in late 1994.

III-4.4. Technical approach

Site preparation started in 1994 December. The approach of using an automated soil sorting conveyor system to remove material with licensable amounts of radium, and then to characterize and segregate the soil into clean and mildly contaminated inventories, was customized for application to the MRP. The original version of the system was developed for a partial cleanup at one of the sites in 1990.

III-4.5. Implementation

Excavation of contaminated soil at both locations began 1 June 1995. The work included removal of contaminated soil stockpiles at one site during the partial cleanup in 1990, and extension of the excavated area to a city street and a small portion of an adjacent shopping center property. Restoration of the properties was generally concluded by September. A requirement to remove additional amounts of contaminated soil from one area resulted in an extension to the planned schedule. The original project scope included about 40 properties identified during the initial surveys of the area in the early 1980s. Improvements in surveying technology resulted in the identification of 23 additional properties during the extended gamma radiation surveys being performed in parallel with the cleanup. The excavation and restoration schedule were extended into November to complete the cleanup.

Excavated soil, amounting to over 16 000 m^3, was sorted using the equipment developed specially for this purpose to segregate licensable material. These materials, which represented only about 0.3% (approximately 50 m^3) of the total amount, were transferred to the LLRWMO interim storage facility at AECL Chalk River Laboratories. Separation of clean soil, interspersed throughout the excavated material, then reduced the original volume by about half. The remaining mildly contaminated soil was placed in an engineered storage mound at the sorting site. Closure of the mound to fully encapsulate the mildly contaminated soil, and landscaping of the site for the interim storage period, were completed in the spring and summer of 1996. The storage mound will be removed when a permanent disposal facility is available to the LLRWMO.

III-4.6. Health, safety and environmental protection

The project had stringent objectives for worker safety and protection of public health and the environment. There were no lost time injuries at any project work site. Environmental monitoring data, and inspection by an independent environmental inspector, showed consistent compliance with criteria. Mitigative measures to control dust concentrations in the immediate vicinities of work areas were the only actions consistently required, and these were successfully employed when needed. Environmental monitoring and routine inspections of the site will be continued throughout the interim storage period, to demonstrate ongoing satisfactory conditions.

The extended radiological survey of the Malvern community was also completed. From 1992–1995, gamma radiation surveys were conducted at more than 1000 properties, mostly residential, and all 14 schools in the Malvern community. No additional findings of contaminated soil were made outside of the previously known or suspected areas. Surveys in the suspected area included all properties other than a small number where the owners declined, and also included indoor radon measurements.

III-4.7. Costs and benefits

Total costs since the start of the project in 1992 are about 10.3 million dollars, including about 1.3 million dollars for the radiological survey program. Soil sorting costs were about 3 million dollars, which will be more than offset by the reduction in interim storage costs and in future disposal costs resulting from segregation of clean soil. Until cleanup of the contaminated properties, land transfers and development in the affected areas were impeded. This is no longer the case and most of the residential properties which were purchased by the Province of Ontario when earlier cleanup projects failed, have already been sold, and further developments are being planned on other lands. While it is difficult to place a dollar value on all benefits, especially the sociological benefits, it is clear the overall merits of the project outweigh the costs. The success of the project is a demonstration of the advantages of a cooperative approach to problem solving amongst all levels of government, and the community, who collectively had a common interest in resolving this long-standing issue.

BIBLIOGRAPHY TO ANNEX III

The following is a general bibliography for Annex III. The referenced items provide additional details concerning the remediation activities and strategy discussed herein.

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TABLE III-1. SUMMARY OF REMEDIAL ACTION PROGRAMME RESULTING FROM PRODUCTION AND USE OF RADIUM IN CANADA

Type of Activity	Type of Site	Extent of Problem	Status of Remedial Action
Transportation of Ores/Concentrates	- Transfer points along water transportation route (Northwest Territories)	- Contaminated soils at about twenty locations in two general areas	- Three year survey program completed in 1994. Interim action at three locations. Two working groups, including local representatives, established to develop longer term remedial action plan.
	- Handling/storage areas at railhead (Fort McMurray, Alberta)	- Contaminated building materials and soil. Contaminated soil further spread over 45 hectares by industrial activities	- Cleanup completed at eight of nine sites. Licensable LLRW (about 400 m^3) segregated and transferred to LLRWMO central storage facility at CRL. Mildly contaminated soil (about 40,000 m^3) disposed as industrial waste in dedicated cell at municipal landfill. LLRWMO maintains long-term monitoring responsibility.
Refining/Processing	- Individual private properties in local community (Port Hope, Ontario)	- Contaminated fill and salvaged contaminated building materials used during property development from 1930s to 1950s	- Extensive radiological survey (3,500 properties) and cleanup, between 1977 and 1981,at approximately 400 properties exceeding cleanup criteria based on existing use of property. - Followup excavation monitoring program at new construction sites. 900 properties checked since 1988, with additional cleanup of contaminated soil at about 50 properties. - Remedial action plan developed for further work to bring all properties to criteria for future unrestricted use (ie. end construction monitoring program). Implementation dependent on availability of permanent disposal site for historic waste.
	- Areas with contaminated soil, and contaminated sediments, from waste management practices of 1930s to 1950s (Port Hope, Ontario)	- Nine areas (ravines, open areas, roadbeds) with 1,000 to 10,000 m^3 of contaminated soil each. Contaminated materials co-mingled with municipal/industrial waste at landfill (50,000 m^3). Contaminated sediment (85,000 m^3) at small craft harbour.	- Interim remedial action (waste consolidation, engineered containments) at two high priority sites, restricted access at a third. Contaminated soil below uncontaminated soil at other sites, or only marginally contaminated in surface areas. - Site inspections/environmental monitoring programs and comprehensive risk assessment to assess need for further interim action. - Remedial action plan developed, but implementation dependent on availability of permanent disposal site for historic waste.

TABLE III-1. SUMMARY OF REMEDIAL ACTION PROGRAMME RESULTING FROM PRODUCTION AND USE OF RADIUM IN CANADA (cont.)

Type of Activity	Type of Site	Extent of Problem	Status of Remedial Action
	- Old waste management sites (near Port Hope, Ontario)	- Two major sites dating back to 1940s and 1950s, with total waste volume increased to about one million cubic meters due to contamination of native soils.	- Sites are maintained by the licensee to meet AECB requirements, for interim storage prior to decommissioning, which include collection and treatment systems for contaminated groundwater. - Remedial action plans developed, but implementation dependent on availability of permanent disposal site for historic waste.
Production/Use of Radium Products	- Use of luminous paints for dials (Several locations, mostly in Toronto, Ontario)	- Buildings with residual contamination	- Approximately 20 projects completed. Wastes transferred to LLRWMO storage facility at CRL site of AECL. Ongoing administrative controls at several sites, for further monitoring at time of major renovations or eventual demolition of building.
	- Removal of radium from scrap materials (Scarborough, Ontario)	- Contaminated soil, further spread by development activities	- Cleanup at 65 residential properties, 3 commercial properties in 1995, after 3 year period for planning and approvals. 17,000 m^3 of excavated soil segregated into licensable LLRW (<50 m^3) transferred to LLRWMO storage facility, and approximately equal amounts of mildly contaminated soil, which is temporarily stored at a nearby undeveloped industrial site, and of uncontaminated soil which was initially interspersed throughout the excavated soil.
	- Repair of gauges, watches, and other devices with radium dials (Numerous locations)	- Areas within buildings, with residual contamination. Over 400 locations known where radium dials have been, or are being, repaired (many older aircraft have radium dials).	- Regulatory agency (AECB) to identify locations with old inventories of radium containing materials and/or residual contamination suspected. LLRWMO to perform surveys and implement remedial action where needed.

Annex IV

CROATIA

IV-1. INTRODUCTION

At present, a specific strategy has not yet been prepared for the environmental restoration of radioactively contaminated sites in Croatia. Therefore, the following discussion on radioactive waste management strategy is intended to provide a general description of the current situation with regard to management of radioactive wastes and other used radioactive materials. Namely, it is reasonable to expect that the environmental restoration strategy (when adopted) would be included as part of the strategy briefly presented below.

IV.2. BASIC STRATEGY FOR RADIOACTIVE WASTE MANAGEMENT

The basic strategy for radioactive waste management in Croatia was drafted by the Hazardous Waste Management Agency (APO) in 1992, but it has not yet been approved by the governmental authority. The main objectives of the strategy are the following:

- to identify in detail sources and quantities of radioactive waste and other radioactive material, as well as to create and maintain the registry on these materials;
- to define the national legal framework, i.e. the system of responsibilities;
- to establish the financing of the national radioactive waste management programme;
- to introduce the regulations on radioactive waste;
- to develop a low level/intermediate-level waste (L/ILW) repository (including site selection, technical design, safety, etc.);
- to foster the public participation related issues; and
- to provide support for other radiation safety related actions.

Since its initial drafting, the Croatian waste management strategy has been modified in accordance with recent international developments and recommendations in this area (including, for example, publications issued by the IAEA).

Most of the topics which have been integrated in the national strategy are related to the low- and intermediate level radwaste repository project in Croatia. This disposal facility is intended for half of the total L/ILW (including decommissioning wastes) generated in Nuclear Power Plant Krsko (some 18000 cubic metres) and all of the "spent" (that is, disused) radiation sources from nuclear applications in medicine, industry, research institutes, etc. in Croatia.

The national radioactive waste management programme is expected to be financially supported solely by the electricity generating facilities in the country. Two interim storage facilities for radioactive waste materials have been established at two research institutes in Zagreb; these facilities are expected to fulfill the national requirements for at least the next twenty years. In addition to the services of these two research institutes, a few small private companies have been formed to safely transport and handle radiation sources. The possible application of radioactive waste management technologies and methods to hazardous waste management is also being applied in Croatia.

The adoption of specific strategies and requirements related to radioactively contaminated sites has not yet been considered in detail. However, there is recognized need to develop a strategy on cleanup measures: (1) at sites having dumping practice of naturally occurring radioactive materials (NORM), such as coal residues, slag, ash, phosphogypsum, etc.; (2) at other sites where NORM have been identified such as at spas (rich in content of radon), oil and gas drilling locations, as well as in the cement and ceramics industries; (3) for radioactive lightning conductors (there are currently about 430 of these devices installed in Croatia); (4) for ionizing smoke detectors (it is estimated that there are about 50 000 of these operating in Croatia); and (5) for the products of nuclear applications (mostly related to the sealed radiation sources) in medicine, industry and research institutes -- this is especially needed due to damage to radiation sources in the war affected areas of the country. There is a complete and regularly updated Registry on Radiation Sources being used in Croatia (this registry is maintained by the Ministry of Health).

IV-3. INSTITUTIONAL FRAMEWORK

The regulatory authority for radioactive waste management has been organized through sections of the following government entities:

Ministry of Health —*for radiation protection (nuclear applications).*
Ministry of Economy —*for nuclear safety.*
State Directorate for Environmental Protection — *some additional environmentally related aspects of radiological safety.*

Since there is no permanent co-ordinating body among these regulatory bodies, some overlapping and gaps of responsibilities has been known to exist. There are, in addition, some other ministries responsible for specific activities related to radwaste management, as follows:

Ministry of Physical Planning, Civil Engineering and Housing —*for inclusion of preferred sites for nuclear facilities into the Physical Plan of Croatia.*
Ministry of the Interior
Ministry of Foreign Affairs
Ministry of Defence

The last three above mentioned ministries are also responsible for transportation, export/import and safety planning (especially for emergency situations) related to radioactive materials.

Other institutions dealing with nuclear safety and radiation protection in Croatia include the following:

Hazardous Waste Management Agency (APO). The APO is the national operational organization which is authorized to establish and maintain an efficient hazardous (including radioactive) waste management system, as well as to organize and perform some specific environmental restoration and health protection activities.

National research institutes: Institute "Rudjer Boskovic" and Institute for Medical Research and Occupational Health. These two institutes are authorized to perform personal dosimetry radiological monitoring programmes, as well as some other radiation safety activities. At both of the institutes, temporary storage facilities have been established for "spent" (that is, disused) radioactive materials.

EKOTEH Company. This firm has been designated for the handling and transport of radioactive materials. It is authorized to conduct specific activities, including the maintenance, transport and repair of radiation devices and sealed sources. It also plays an important role in on-site environmental cleanup actions. A special emergency intervention team has been organized at the company for some projects (e.g. remediation of damaged radiation sources in the war affected areas of Croatia).

Finally, it should be noted that there are many users of radioactive materials, including radioactive waste producers, in Croatia.

IV-4. LEGISLATION AND REGULATIONS

Legislative actions have been taken, or are in process, relative to radiation protection and nuclear safety (including the management of radioactive waste). The national radioactive waste management strategy was drafted in 1992 and subsequently updated in 1994, however, it is not yet approved by the regulatory authority. The basic law being applied is entitled "The Law on Ionizing Radiation Protection and Safety Actions in Nuclear Energy Implementation." This law was issued in 1984, and it has been temporarily taken over from ex-Yugoslavian legislation until the new Croatian law is approved (this law is expected to be approved in the near future). A total of 17 regulations and codes of practice have been derived from the above mentioned basic law, including the following:

- Code of Practice on Methods of Collecting, Account, Processing, Storing, Final Disposal and Release of Radioactive Waste Substances in the Environment (issued in 1986/88);
- Code of Practice on Conditions for Siting, Construction, Start-up and Operation of Nuclear Facilities (issued in 1988);
- Code of Practice on Standard Format of Safety Report and Other Documentation Necessary for Safety of Nuclear Facilities (issued 1986/88);
- Law on Health Protection (includes particular articles covering the handling radioactive waste and radioactive materials); and
- Law on Transport of Dangerous Substances (includes a part concerning radioactive materials).

Related legislation and regulations on environmental protection issues include the following:

- *"Strategy of Environmental Protection"*
- *"Law on Environmental Protection"*
- *"Law on Water Protection"*
- *"Law on Nature Preservation," and others*

Related legislation and regulations related to facility planning, design and construction include the following:

- *"Law on Safety and Health Protection"*
- *"Code of Practice on Working Conditions, Emissions, etc."*
- *"Law on Fire Protection"*

IV-5. IMPLEMENTATION OF RADIOACTIVE WASTE MANAGEMENT STRATEGY AND OTHER ISSUES

The implementation of a radioactive waste management strategy, as well as that for nuclear safety and radiation protection, has been slow in coming. The national institutions are in a transitional stage of their organization and realizing their role and position. While there has been great enthusiasm, a relatively low efficiency has been realized in meeting the requirements that Croatia has suddenly faced as a newly independent country. Fortunately, there is a "safety culture" in the country related to radioactive waste management activities. Among the current issues which must be dealt with are the following:

- private companies are now intruding into (or are involved in) what has for a long time been a state system for handling radiation sources;

- there has been no permanent body to co-ordinate activities of ministries involved in radiation protection and nuclear safety;

- in addition to the Ministry of Economy and the Ministry of Health, there are a few other ministries which also have responsibility for the licensing of some radioactive waste management activities;

- very limited budgetary funding is allocated for regulatory tasks;

- financial support has been mostly given by the electricity generating facilities;

- Krsko Nuclear Power Plant, as the greatest radwaste producer, is actually situated outside of Croatia (i.e. it is in the neighbouring country of Slovenia);

- the salaries in the ministries are not attractive enough for experts;

- only a few persons in each ministry involved are dealing with radiation protection and nuclear safety issues; some of these persons have dual responsibilities for issues which are not strictly related to nuclear safety and radiation protection;

- two temporary storage facilities for "spent" (disused) radioactive materials from nuclear applications in Croatia are expected to satisfy the needs for at least the next 20 years (not including radwaste from the Krsko nuclear power plant);

- the national registry of radiation sources being used in Croatia is maintained by the Ministry of Health, and it is about to be computerized (requiring a significant effort);

- with the lack of any system for hazardous (i.e. toxic but not radioactive) waste management, attempts have been made to apply technologies and methods experienced in the radioactive waste management to the management of other hazardous wastes; and

- there has been the lack of a strategy specifically directed to cleanup of sites contaminated by naturally occurring radioactive materials (e.g. dumping practice of industries, etc.).

It is necessary to further develop the national radioactive waste management strategy and to expand it to radioactively contaminated sites. As has become clear, the necessity exists to inspect and re-evaluate a few sites contaminated with naturally occurred radioactive materials (coal-slag and ash piles, as well as pools containing phosphogypsum). Croatia intends to use some of the most recent technical tools and approaches to make justified decisions on the possible cleanup/remediation of the contaminated sites, all in accordance with international criteria and recommendations (e.g. of the International Atomic Energy Agency, International Commission on Radiological Protection, World Health Organization, and other competent international organizations). The need to evaluate these sites has been arisen from the fact that there have been measured activities at such locations, although they are assumed to be just below the lower levels for radioactive waste according to Croatian legislation. There is also a growing public awareness of the possible need to clean up these sites.

IV-6. CONCLUSIONS

An efficient and "working" infrastructure in all of the related segments of environmental restoration (financing, environmental protection, planning, communication with the public, etc.) is extremely important for the practical implementation of the adopted strategy. A transparent governmental policy toward the principal nuclear and radiation effects issues will be of substantial assistance for practically implementing the remediation strategy. Thus, it is important that the following actions are carried out:

- to define the legal and regulatory system in a transparent manner;

- to establish a national system for financing of radioactive waste management and all actions related to the remediation of radioactively contaminated sites;

- to encourage and strengthen at all levels the communications with the public, including educational programmes;

- to provide full government support to other radiation safety activities; and

- to development contacts with national and international organizations dealing with radioactive waste management and environmental restoration.

Annex V

FRANCE

V-1. INTRODUCTION

The approach followed by France for the management of radioactively contaminated sites is discussed in this Annex. In France, the National Agency for Management of Radioactive Wastes (ANDRA) is in charge of waste management. It manages mainly short-lived radionuclides (half-lives of less than 300 years) of low and medium activity in the radioactive waste disposal centre of Aube.

Since 1991, ANDRA has also been responsible for the inventory and survey of radioactive wastes sites. The wastes come from nuclear industry and military activities, but also from small productors (nuclear medicine, research centers, small industry, etc.). In 1996, the inventory list included 1083 such sites, each of which was separately described by an identification sheet.

In France, there are also about ten disused or abandoned sites whose owners have vanished. These are mostly older, small-sized manufacturing sites or factories which have used radium-containing materials in the past.

V-2. PRACTICAL APPROACH TO CONTAMINATED SITES

There is no special or national rule in France for the management of very low activity contaminated sites. In practice, each site is a special case and must be the subject of a sanitary impact study.

In each "Département"[1], the Prefect is responsible for public health and issues licences for rehabilitation of radioactively contaminated land. In this regard, the Prefect takes advice from the Departemental Hygienic Comity and of OPRI (National Office for Protection Against Ionizing Radiation).

The criteria for cleanup are often comparable to the radiation levels of the surrounding background, or are derived from the recommendation of the International Commission on Radiological Protection (ICRP) for the exposure of members of the public, that is, a maximum dose of 1 mSv/year.

Concerning very low activity wastes (<100 Bq/g), studies are in progress for a national disposal facility with a capacity of 1 500 000 m^3 to be operational within about five years, and also for a specialized disposal for items containing radium.

V-3. SOME CASES OF SITE REHABILITATION

Two cases are described below for the region of Paris. Their origin was a result of outdated waste management practices, and both were widely discussed in press campaigns.

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[1] One of the 95 main administrative divisions of France.

V-3.1. Discharge from "l'Orme des merisiers" at St. Aubin (Essonne)

This site is located about 20 km south of Paris. Up until 1976, the French Atomic Energy Commission (CEA) disposed of rubble and sludges arising from the treatment of industrial waters at the "Centre d'Etudes de Saclay" in two old pits. The site had also been used to store concrete blocks containing radioactive wastes, some of which were fissured.

In 1990, some newspapers published an article about contamination by plutonium and others radioelements. The CEA then undertook a campaign to measure the activity of the site, and the following results were found :

The contaminated zone covers 7000 m^2 in area and has a depth of approximately 0.1 m, with typical values of :

^{90}Sr:	50 to 500 Bq/kg
^{137}Cs:	50 to 30 000 Bq/kg
$^{239+240}Pu$:	100 to 2 000 Bq/kg
^{241}Am:	50 to 600 Bq/kg

The Prefect of Essonne Departement established a specific committee, which was representative of all parties having an interest in the site, to study the radiological impacts and make recommendations, as appropriate. The conclusions were, briefly, that:

- There are no health hazards for the population.
- The reference value for radiological protection is 1 mSv/year.
- Two impact studies have been done by the Institute for Nuclear Safety (IPSN), and also by the National Radiological Protection Board (UK), taking into account different possible uses of the site (e.g. used for agriculture, recreation, etc.).
- The criterion for rehabilitation of this site was chosen to be equal to ten times the surrounding background (due to gamma radiation).

As a result of the study and restoration strategy, CEA was required:

- to remove 150 m^3 of the most contaminated ground containing 20 millicuries of ^{137}Cs and 2 millicuries of plutonium;
- to close the site and to restrict access;
- to measure the radioactivity after the end of rehabilitation;
- to make routine radiological surveys; and
- to keep the public informed regarding their actions.

In addition, any new construction in this area is forbidden.

V-3.2. Site of "Le bouchet at Itteville" (Essonne)

This site is located about 40 km south of Paris. CEA had treated uranium ores at the site during the period of 1949–1971. After dismantling the factory, there remained an area (approximately 1 ha) containing wastes from the treatment of ores and an old water tank with sludge. The characteristics of radioactive contamination at this site are given in TABLE V-I.

TABLE V-I. RADIOACTIVE CONTAMINATION AT THE SITES OF LE BOUCHET AT ITTEVILLE (FRANCE)

Product nature and its state at end of 1995	**^{226}Ra Activity(GBq)**	**Major radionuclide**
– Old settling tank (6000 m^2)	278	^{226}Ra
15 000 tonnes (t) sludges, 20 t U and 1 t thorium	370	^{226}Ra
5000 t rubble	37	^{226}Ra
– Solid wastes		
2500 t hydroxides	185	^{226}Ra
100 t steriles	370	^{226}Ra
–3000 t rubble	37	^{226}Ra

The radon levels at the limit of the site are higher than mean values in the region.

After an analysis of the results, the Prefect has established the provisional objectives for rehabilitation, as follows:

- cover the site with clay to obtain the same level of radon as in the surrounding country, and then finish with a cover of arable earth and grass (without any trees or deep-rooted plants);
- assume an obligation to measure the radioactivity periodically.

V-4. SUMMARY

These two examples briefly illustrate the approach followed by France for the management of radioactively contaminated sites.

Annex VI

ITALY

VI-1. INTRODUCTION

In this Annex, considerations which have been recognized by Italy in developing a strategy for environmental restoration are discussed. The general process, which is thought to be applicable to many situations is outlined, and an actual experience of applying methodology for investigating and remediating a site in Italy is discussed.

VI-2. SOME GENERALIZED INVESTIGATIVE AND REMEDIATION APPROACHES

In many countries, the environment has been contaminated by radioactivity resulting from diverse activities in relation to nuclear fuel cycle, defense-related operations, research and medical facilities, as well as from radioactive wastes arising in factories, hospitals, etc.

In the case of nuclear accidents, a typical approach to investigating and remediating radioactively contaminated sites is that the contaminated areas are first located by the local authority, which then reports them to the central authority. It is generally the latter which shares responsibilities, takes care of the project of intervention, and decides about utilization of funds necessary to characterize and restore the areas.

The first step in formulating a strategy for the environmental restoration of a radioactively contaminated site where, for example, an accident has occurred, should be to work within the appropriate regulatory framework of the country. It may be that, for a specific country, there is no single regulatory authority with responsibilities for all aspects of management for interventions on contaminated sites, and this can lead to a different demand of the priorities, and even conflicting requirements among the regulatory authorities. For a country faced with the need for environmental remediation, it is important that early agreements are reached with and among the concerned regulatory authorities on different aspects of the intervention, such as: on the standards to which any site should be cleaned up, the investigation methods to be carrying out, the remediation techniques to be used, and the methods for certifying that those standards have been achieved.

A good step in this direction might be to establish a group of experts or a specific committee representative of all the authorities with an interest in the site, at a level as high as possible and at the earliest possible stage: this group or committee may serve as focus for arranging interactions with and among all of the regulatory authorities through common meetings. The authorities' involvement from the very beginning of the intervening action, say before the site investigation stage, should enable their possible concerns to be taken into consideration in time, so as to avoid additional investigations at a later stage.

In those countries where an exhaustive regulation in this field is not yet operating, and where a clear regulatory structure which is applicable for remediation of radioactively contaminated sites is not available, the first thing that might be pursued would be to find an "effective authority." In the best case, such an authority could manage all of the different aspects of the interventions, also considering that it might be necessary to obtain substantial technical assistance, and so on.

VI-3. DEVELOPMENT OF A STRUCTURED APPROACH FOR THE INTERVENTION

Once the decision to intervene has been made, the prerequisites for remediation have been established, and the necessary resources to carry out the remedial action have been identified, the serious planning for environmental restoration can begin in accordance with an appropriate methodology. This will be followed by desk studies and field investigations to support the implementation plan for enviromental restoration.

VI-3.1. Planning for environmental restoration

Details concerning the planning and timing of the environmental restoration, as well as the remediation goals themselves, may well vary from country to country, as well as from site to site. These will depend on many factors, including the public concern, social and economic expectations, the wealth of the country, availability of technologies and equipment, climate, etc. and are certainly important factors in the strategy for any environmental restoration programme. Regardless of these differences, an intervention must start with an informed understanding of the situation being dealt with. This is derived from the site characterization, that is to say, from an understanding of the topology of the environment, the source term estimate, and a detailed determination of spatial distribution of the radioactive contaminants.

An effective methodology starts with site characterization, which is generally a multi-stage programme and includes at least the following items:

- Investigation of the site to determine the radioactive contaminants and the level and extent of the contamination. The investigation may be influenced by the nature of soil and underlying geology, and hence the next item is also required.

- Investigation of the geology and hydrogeology of the area; physical, chemical, and biological features; climate; affected populations; etc.

- On the basis of the results of the above investigations, there follows the development of a conceptual model of the spreading of the contaminants, taking into account that contaminants could have been migrating off-site as a result of the local lithology characteristics, rainfalls, dust dispersion, etc. Models of how the contamination may affect populations (e.g. health effects) are also developed.

- The identification of remediation options and rationale for their implementation is made.

It is evident that the geologic and hydrogeologic characteristics of the area will influence very considerably the dispersion of the radioactivity, including the extent and depth of contamination on the site itself, and therefore they are two of the most critical factors of any investigation. Thus, the first step of any intervention should be to develop a good understanding of the site geology and hydrogeology. An effective sampling campaign should be implemented for the characterization of the local lithology and, if necessary, a groundwater monitoring programme could be started. The proposed methodology starts with the principle that it is imperative to understand the critical elements of the site assessment before seriously planning and developing any intervention.

The conceptual lithology and hydrogeological model may be considered to be a primary mechanism for accomplishing this task, and it may be advisable to obtain as much information as possible concerning the following:

- stratigraphy (classification and extent of units);
- groundwater (groundwater flow-lines, rates of flow, physicochemical conditions, etc.); and
- potential subsurface leached migration,

to which the information on the following can be added in order to have a better understanding of the spreading of the contamination:

- climatology/meteorology;
- surface features and waters.

A structured approach to site assessment may consist of first establishing regional data and gradually identifying and refining the understanding of site characteristics as more information has been gathered through the analysis. This approach usually includes the following:

- a thorough review of existing literature, reports, and technical information;

- a preliminary site aerial and ground reconnaissance;

- construction of an initial regional and site specific geological conceptual model; and

- a design of the field investigation, based on that initial conceptual model.

In general, this initial investigation may be sufficient to establish target sampling and, in some cases, monitoring zones, as well as to plan other phased-in activities. After this, the site investigation may generally follow the pattern as indicated below.

VI-3.2. Desk studies

So-called desk studies are an important part of developing and implementing an effective strategy for remedial action. These will usually include the following:

- Define regional conceptual geographic model(s);

- Propose site specific conceptual model(s);

- Propose conceptual model(s) of the spread of the contaminant(s);

- Plan field investigation(s);

- Develop a sampling plan and select target sampling zones, if needed, for ongoing data acquisition.

It may appear obvious, but the model for the spread of a contaminant should certainly consider all of the pertinent geographic factors, including the climatological features (wind intensity and direction, rainfall, etc.).

VI-3.3. Field investigations

Field investigations are essential for obtaining site specific information and data. In general, these will include the following:

- Establish the site specific geology (at and nearby the site);
- Establish a conceptual lithological model;
- Define a conceptual hydrogeological model (uppermost aquifer, aquitard, aquifer system);
- Implement the sampling plan; characterize the essential features of the site, as needed; and conduct monitoring surveys to determine the nature and extent of the contamination.

In conclusion, the site investigation should always begin with an assessment of the regional geography and geology/hydrogeology with the existing available information, in order to realize as early as possible how the radioactive contaminants are distributed and can be expected to spread. This will permit the design of a suitable site investigation plan. Site specific information and data may be available from many sources, including published reports or previous site studies, and, in many cases, the existing information may be adequate to sufficiently characterize the site, realize how the radioactive contaminants will spread, and decide how to carry out radioactivity measurements and other data acquisition activities. Additional field investigation should only be undertaken where the existing information and data are not adequate to realize possible contaminant pathways.

In general, existing geographic data may be available to provide the following information:

- Characterization of the surface lithology;
- Characterization of the subsurface geology and geomorphology;
- Location of the uppermost aquifer and aquitard(s);
- Hydrogeological characteristics of each water-bearing formation down to the uppermost aquifer;
- Hydrogeological characterization of the area;
- Water quality characteristics of the water-bearing formations;
- Annual precipitation; and
- Wind regime.

In general, this information may be sufficient to formulate a preliminary conceptual model of the site geography and geology/hydrogeology. However, if more information is necessary to establish an adequate understanding of how the radioactive contaminants may penetrate the ground and spread in the environment, a field study designed to produce supplemental data should be undertaken. The actual techniques used in assessment, of course, will vary depending on the complexity of the site and other factors.

VI-3.4. Implementation phase

Eventually, based on an understanding of the radioactive contamination and how it is expected to spread, plus the predicted associated hazards to people and the environment, serious planning for and the implementation of environmental restoration can occur. In general, the successful remediation of a radioactively contaminated site may represent a very significant technological, economic, social, and political challenge to the decision makers and other involved parties.

VI-4. AN ACTUAL CASE OF THE STRATEGY DEVELOPED FOR ENVIRONMENTAL RESTORATION

An actual case of remedial action for a radioactively contaminated site in Italy illustrates how an appropriate strategy for environmental restoration may be developed. This example involved the intervention by the Agency for New Technologies, Energy and Environment (ENEA) to perform environmental restoration of the site. The work was conducted within the framework of an IAEA Technical Co-operation (TC) Regional Project on Environmental Restoration for Central and Eastern Europe. The programme included the investigation and remediation of a contaminated site in Italy, where previously there had been little regulatory or other experience with such a matter. Thus, it was necessary to first seek out an effective authority which would be able to share the responsibilities and support the work efforts before developing a plan for the restoration.

The intervention was begun in late 1990 and lasted for about two years, including implementation of the monitoring system. The site concerned was situated near Brescia, about 90 km east of Milan, in the northern part of Italy. It was an industrial waste disposal site, consisting of seven basins, about 50 000 m^3 each, with a total area of about 30 000 m^2 ; a total volume of about 280 000 m^3 of industrial waste had been discharged here, and the radioactive contaminant was ^{137}Cs (Fig. VI-1).

Since this appeared to be a straightforward case of nuclear contamination, a typical procedure was followed. The contaminated area had first been noted by the local sanitary authority, and then it was reported to a central authority, that is, the Lombardy Region Administration. This authority requested the ENEA, as the general authority in the nuclear field at that time, to set up a project for the intervention, however, no funding was provided for this purpose.

From the beginning, it was realized that it would be necessary to establish a mechanism (a "tool") capable of bringing together all of the authorities with an interest in the site and the different aspects of the intervention, and which could also be considered as the "reference point" for all of the investigations and remedial actions at the site, such as the work tasks, cost sharing, rationale for remedy, restoration target specifications, project management and planning, etc. Therefore, agreement was sought and eventually was reached among the regional and provincial sanitary and administrative authorities having an interest in the site. A Technical Committee ("the tool") was established under the Lombardy Region Administration's responsibility; it consisted of people responsible for certain of the sanitary, administrative and technical aspects of Lombardy Region and Brescia Province, and representatives s from ENEA. It should be noted that only a few years later, in 1994, Italian legislation did establish the National Agency for Environmental Protection (ANPA) as a regulatory body. However, at the time of this particular intervention, no effective "tool" had been established by the government to deal with such a problem.

Fig. VI-1. A view of part of the contaminated waste disposal site (Italy).

The Technical Committee's first specific task was to determine the various factors relevant to environmental restoration of that contaminated site, and then devise a strategy able to tackle all of the issues associated with the intervention (clearly, these were not limited to technical problems). Many complicated aspects of the strategy were focused on by the Committee. These included, for example, the interactions between the sanitary and administrative authorities with an interest in the site; the standards to which the site would have to be cleaned up; the investigative methods to be used; the options for the remediation; selection of the remediation techniques to be used; etc.

Two important problems which the Committee had to tackle immediately were: 1) how to give the force of command to the actions necessary for the intervention, and 2) where to find the financial resources. It was soon realized that:

- in the particular situation, the only authority that could impose actions was the local municipal council through, as strange as it might seem, the tool of formal resolutions (ordinances); and

- it was possible to reach an agreement with the owner of the waste plant, since that party was very much interested in making the facility productive again (the facility had been immediately closed by the above mentioned municipal council as soon as the radioactive contamination incident was known).

In conclusion, a general agreement was reached whereby:

- ENEA would be expected to propose the solutions and prepare the projects, including the planning and scheduling of the environmental restoration, in accordance with expectations of the local people, availability of resources and equipment, and local conditions (e.g. weather considerations, etc.).

- the Committee would function by examining and, if all were in agreement, approving the proposed targets, as well as, step by step, the project and each phase of the intervention;

- the local municipal council would co-operate by delivering resolutions to implement work activities of the specific plans, and the related procedures, as these became available from ENEA;

- the owner of the waste facility would have to provide the money and the equipment necessary for carrying out the restoration works;

- the local sanitary structure would serve to control the proper and effective execution of each step of the work; and

- ENEA would be responsible for supervision of all of the work, including each stage being carried out.

Therefore, in accordance with the agreement which was reached by all of the parties, prior to the initiation of each stage of the intervention, the action plans and the related procedures were actually submitted for approval by the local municipal council. The council then delivered formal resolutions to implement the restoration activities conducted under the supervision of ENEA.

To further illustrate this example of remediation strategy, some of the technical issues that the Committee had to deal with are briefly discussed below.

Behaviour of ^{137}Cs — it was very important to understand and be able to predict the radionuclide's behaviour in the specific setting where it had been scattered, including its mobility and degree of fixation in the materials with which it was associated.

Groundwater characteristics — particular attention was paid to the groundwater because of its great mobility in the soil and earthen materials in which it can quickly migrate, transport contaminants, and reach the underlying aquifers.

It is well known that caesium compounds have high solubilities. Thus, the first question was whether the radionuclide could migrate outside the facility and off the site by means of groundwater transport. A study of the facilities at the waste plant had shown that the underground system was very tight, with a good impermeable lining on the bottom and on the walls of every basin. Each of the basins could be considered as a well-controlled system, having a good lining and a suitable drainage, canalization, and collecting network. To take extra care, however, it was decided to construct a monitoring net around the entire waste disposal area.

Disposition of the contaminated material — this was quite challenging since the quantities were very large. One of the most important issues that the Committee had to face was whether it would be necessary to send the contaminated material (solid wastes, soil, etc.) elsewhere, or to leave it in place by providing a suitable in situ control (i.e. containment on site using engineered barriers). The decision would have to be in accord with the Italian reference regulations and hazard assessment of the radioactivity. However, the reference regulations in Italy (DPR 185/64 and DPR 1303/69) did not appear to fit very well with situations of radioactive contamination caused by accident and where the radioactivity was spreading in the environment. A more suitable reference for that situation appeared to be one addressed by the Group of Experts examining Article 31 of EURATOM Treaty (November 1988), for which they had recommended an exemption value of 1Bq/g as a concentration limit for the free re-utilization of materials coming from the decommissioning of nuclear plants.

In the case of this contaminated site, the average concentration of ^{137}Cs was much lower than that limit at all locations, except for one of the basins where it was found to be at a concentration level of about 10 Bq/g, with peaks of higher activity occurring in some of the waste blocks. Most of the radioactivity was already buried in the bulk, some meters deep (5–8 m; as had been shown by ^{137}Cs gamma activity vertical profiles) and was surrounded by a huge mass of noncontaminated material. Therefore, the final decision was for a containment on site, using engineered barriers, that is to say, with a suitable cover of clay and loam soil.

In other words, it was realized that the radionuclide ^{137}Cs should remain fixed inside the waste bulk itself, chemically attached to the clay fraction of the soil matrix, after being first mobilized due to the percolation of rainwater, and that a cover of clay and loam soil would then provide suitable containment. Given these facts, it was considered unthinkable to remove and transport such a huge quantity of material to another location; first of all, because of the prohibitive cost of such an operation; and, secondly, because that would once gain put the radioactively contaminated material in contact with the environment, and it could result in the additional dispersion of radioactivity along with increased risk and inconvenience to the local population.

VI-5. THE IMPACT OF PUBLIC OPINION ON THE REMEDIATION

The impact of the reported contamination and subsequent remediation activities on public opinion was not a minor aspect of the problem. Taking into consideration that the local newspapers had been emphasizing the accident as being "a nuclear disaster," it was necessary to give out correct information and to obtain approval from the general public for the proposed solutions before the necessary remedial actions could be carried out.

With that aim in mind, a number of public lectures were delivered, and meetings were held with the local population and administrative units, in order to make them aware of the actual risks connected with the radiological contamination at the site, and, also, to make the main characteristics of the proposed intervention known to them in advance.

One important purpose of the public meetings was to receive as many suggestions and indications of concerns as possible from the local populace, who, of course, had a good knowledge of the situation. But the principal aim of the meetings was to involve the public in the problem, as much as was possible, in order to prepare a project with which they could agree. As it turned out, the agreement was reached and the intervention was successfully carried out. Although some of the details are specific to this particular situation, the general process is thought to be generally applicable to many other situations of environmental contamination.

BIBLIOGRAPHY TO ANNEX VI

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Annex VII

RUSSIAN FEDERATION

VII-1. INTRODUCTION

The environmental restoration activities for the radioactively contaminated sites in the Russian Federation are described in this Annex. Although many of the cited primary literature sources are in Russian, secondary English sources are also referenced.

VII-2. NATURE AND EXTENT OF THE RADIOACTIVE CONTAMINATION PROBLEMS

Sites in Russia have become radioactively contaminated as a result of many factors. These include: (i) past practices of radwaste management and dumping; (ii) nuclear accidents; (iii) nuclear weapon testing and so-called "peaceful" nuclear explosions; (iv) radioactive contamination of conventional industries; (v) radioactive contamination of metropolitan areas as result of past uncontrolled uses of naturally or human made radioactive materials. Examples of contamination from these sources are discussed below.

VII-2.1. Past practices of the radwaste management and dumping

From 1949–1951, liquid radioactive wastes from the radiochemical combinat (operations) "Mayak" were pumped into the Tetcha River and into lake Kyzyltash. The total volume of the disposed waste has been estimated to be 75 millions m^3 with a total gamma activity of appriximately 1 times 10^{17} Bq [VII-1–VII-3]. In the upper Tetcha, the dose rate from gamma radiation reached levels of 50 mGy/h. After 1951, radioactive wastes from "Mayak" were accumulated in special facilities, including a system of natural and constructed ponds. The total activity of radionuclides accumulated in open reservoirs exceeds 4 times 10^{18} Bq [VII-1, VII-2]. At present, an underground lens of radioactive water with an area of about 10 km^2 and volume up to 5 million m^3 exists which could result in the contamination of a regional aquifer.

Materials containing more than 8.5 times 10^{16} Bq of radioactivity (including 16 nuclear reactors from submarines and an icebreaker) were discarded in the Arctic Seas, and about 7.2 times 10^{14} Bq were disposed of in the Far-East Seas. At present, about 130 atomic submarines with unloaded reactors are docked and waiting for dismantling and decontamination. The total activity of ^{137}Cs and ^{90}Sr in these reactors is more than 4.8 times 10^{19} Bq [VII-4].

The total quantity of the radioactive waste accumulated in Russia exceeds 1.5 billion Ci (5.6 times 10^{19} Bq) (see Table VII-.I), plus 4.5 billion Ci (~1.7 times 10^{20} Bq) of radionuclides in spent nuclear fuel are stored at the Russian enterprises of Minatom, Mintrans and Navy [VII-5].

VII-2.2. Nuclear accidents

As a consequence of the Chernobyl disaster (1986), around 56 000 km^2 of the territory of the Russian Federation have been contaminated with human made radionuclides, resulting in surface activities of ^{137}Cs up to 4 MBq/m^2 and initial dose rates in the air of up to 300 μGy/h [6]. More than 100 000 people still reside in a 2,400 km^2 controlled zone of the Bryansk region with ^{137}Cs surface activities levels exceeding 0.6 MBq/m^2.

The Ural accident of 1957 resulted in widespread contamination. An explosion occurred at the storage facility in Kyshtym near Chelyabinsk, which contained 70–80 tones of high level nitrate-acetate waste, approximately 7.5 times 10^{16} Bq of fission products were released into the atmosphere. About 23 000 km^2 in the Chelyabinsk, Sverdlovsk and Tyumen regions were contaminated with radionuclides. Initial dose rates at the frontal part of so-called "Eastern Ural Radioactive Trace" (EURT) were as high as 6 mGy/h; 217 localities with 270,000 inhabitants were found to be contaminated [7, 8]. In 1967, one of the open waste ponds of radiochemical combinat "Mayak" (the natural lake Karachaj) dried out, and around 2.2 times 10^{13} Bq of radioactive dust was dispersed by wind into the environment. The territory of the radioactive trace was about 2700 km^2 in area and included 63 localities with 41 500 inhabitants [VII-1]. The more recent accident at nuclear weapons combinat "Tomsk-7" *(1993)* [VII-9] resulted in much less radioactive contamination, however, it clearly signifies that operational safety problems still exist.

A nuclear submarine accident occurred in harbour Chazma (the Sea of Japan) on August 10, 1985, and resulted in the release of 1.9 times 10^{14} Bq of radioactive substances. Another incident involved the leakage of liquid radioactive waste from a spent fuel storage facility in the Motovsky Bay and Litza-fiord.

VII-2.3. Nuclear explosions

During the period of 1949–1962, a total of 142 atmospheric nuclear tests with the cumulative explosive yield of 358 megatonnes of TNT were conducted at the Novaya Zemlya and Semipalatinsk test sites [VII-10]. In addition to these above ground explosions and other underground nuclear tests, about 80 so-called "peaceful" nuclear explosions took place in the Russian Federation from 1963–1989. The total radioactivity resulting from these experiments was estimated to be on the order of a few million Ci [VII-4, VII-10].

VII-2.4. Radioactive contamination of conventional industries

Increased concentrations of natural radionuclides are typical for clinker-ash waste (especially after incineration of brown coal), blast-furnace clinkers, liquid and solid wastes from the rare earth metal industry, thermophosphoric clinkers, red wastes from aluminum production, wastes from tin production, and dust pollution associated with the rare metal and phosphate industries [VII-7, VII-11]. Specifically, at the oil-production enterprises "Stavropolneftegas," the dose rates from the used equipment may reach levels of 20 μGy/h; occupational doses may reach 45 mSv/a; and specific activities of the filtration field deposits approach 89 000 Bq/kg (^{226}Ra) and 34 000 Bq/kg (^{228}Ra) [VII-11].

VII-2.5. Radioactive contamination of metropolitan areas

In the cities of Moscow and St. Petersburg alone, about 3000 γ radioactivity anomalies have been detected, with the maximum dose rates being more than 2.5 Gy/h [VII-12, VII-13]. In the Moscow oblast, the total area of radioactive anomalies (mostly contaminated with ^{137}Cs, ^{226}Ra, ^{235}U, ^{239}Pu and ^{232}Th) is almost 2 million m^2 (i.e. 2 square kilometers), and the quantity of slightly contaminated soils at the dust-heaps can be estimated to be around 1.5 million tonnes [VII-13].

VII-3. THE NATIONAL FRAMEWORK IN RUSSIA FOR DEALING WITH RADIOACTIVELY CONTAMINATED SITES

All environmental restoration and waste management activities are regulated by the three level documentary scheme [VII-14]. National policies are defined at the upper level by the *"National Conception."* In a sense, these are the codes of scientifically grounded principles on which the corresponding laws and standards are based. The *"National Conception"* defines the general strategic approach to the problems of radiological protection and, also, the organization of safety-related economic activities (where and when these can be undertaken) in radioactively contaminated territories [VII-15]; the necessary medical attention, social protection and rehabilitation of population affected by accidental radiation exposure [VII-16]; and the special prophylactic systems for inhabitants living in areas which have become contaminated due to nuclear/radiation accidents [VII-17]. The *"National Conception"* includes important elements of the environmental restoration and waste management strategy, such as the following:

- medical and biological consequences of radiation exposure;
- categorization of radioactively contaminated sites;
- principles of radiation, medical, socio-economic, psychological and legal protection of the population;
- methods of medical investigation and treatment of the people exposed;
- principles of safe economic activities; and
- recommendations to the inhabitants living in contaminated areas.

Incidental to the above, roles are also assigned to indirect measures (limitation of the harmful impacts of non-radiation hazards; forming of healthy mode of life; improvements in medical service; increasing the levels of psychological and legal protection, etc.) which are intended to compensate the consequences of radioactive contamination.

The national regulatory and legal frameworks are represented at the second level of the scheme by Federal Laws and Standards, which establish and regulate the environmental restoration and waste management activities, as well as activities concerning radiation protection and the rehabilitation of populations. These apply to all government administrations, local authorities, jurisdictional persons (independently from their subordination and types of property) and other involved individuals.

VII-4. RUSSIAN ORGANIZATIONAL STRUCTURE FOR ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT

The principal Regulatory Agencies responsible for the environmental restoration and waste management at the federal level in the Russian Federation (RF) are as follows:

- RF State Committee on Supervision of Nuclear and Radiation Safety (SCSNRS),
- RF State Committee on Sanitary-Epidemiological Supervision (SCSES), and
- RF Ministry of Environment and Natural Resources (MENR).

Some important regulatory functions are assigned to RF Ministry of Health and Medical Industry (MHMI), and RF State Committee for Standardization, Metrology and Certification (SCSMC). Nineteen Ministries and State Committees are constituted in an Unified State System of Ecological Monitoring headed by the MENR. Definitions of the Agencies' responsibilities, hierarchial interconnections, rights and duties are fixed/provided by the Presidential Decrees, Governmental Orders and Federal Laws.

The main Executive Bodies responsible for practical implementation of environmental restoration programmes on the Federal level are the Ministry of Atomic Power (MAP, Minatom) and Ministry on Civilian Defense, Emergency Situation, and Liquidation of the Consequences of Natural Disasters (MCDESLCND). The system of enterprises "Radon" (16 centres all over the Russian Federation near big industrial centers) have responsibilities on the regional level. The decentralization and strengthening of regional centers for activities in environmental restoration and radioactive waste management are the main features of the Federal Programme adopted in Russia for the period of 1996–2000 [VII-5]. A number of relevant functions (monitoring, research and development, regulation and control, insurance, etc.) are entrusted to the other Agencies and institutions, including non-governmental companies. For example, radiological monitoring is carried out at 1,460 hydrometeorological stations and monitoring posts of Federal Service of Russia for Hydrometeorology and Environmental Monitoring (Roshydromet). The commercialization of environmental restoration technologies is a new phenomenon in domestic practice, and the degree of its success (or failure) on a national level should be known over the next few years.

VII-5. NATIONAL AND INTERNATIONAL PRIORITIES

In the 1992–1993 period, three State Environmental Restoration Programmes were adopted for regions which had suffered the most from accidental radiation exposure. These regions are the Eastern Ural, the Russian territories not far from the Chernobyl nuclear power plant, and regions near to the Semipalatinsk experimental region. Because of the huge scale of contaminated territories, the programmes mainly included measures of radiation protection and the social and economic rehabilitation of populations. Although the funding of these programmes was carried out irregularly, their adoption did indicate that important changes had occurred in the official attitudes regarding this problem.

It is now common practice to perform a comprehensive characterization of the ecological situation (including the radioecological one) in order to collect the data and understanding that can establish the needs for continuing or additional funding from the Federal Budget for regional environmental restoration programmes. The legal basis is given in "Criteria for Evaluation of the Ecological Situation Aimed at Revealing Zones of Extraordinary Ecological State and Zones of Ecological Calamity" [VII-19].

International considerations arise because some of the Russian radioactively contaminated sites (Chernobyl zone, Naval radwaste in the Northern and Far Eastern regions, etc.) have transboundary effects, joint projects have been developed in collaboration with Japan, Norway, USA, France, Germany, European Community ("Tacis" programme), and so on.

VII-6. CONSIDERATIONS FOR CLEANUP AND REMEDIATION

Ministries, the owners of radioactive wastes and contaminated sites (see TABLE VII-I), are responsible for initiating and implementation of cleanup and remediation activities. As a rule, the environmental restoration programmes will include a number of responsible Ministries, Agencies and other Institutes.

TABLE VII-I. QUANTITATIVE DISTRIBUTION OF RADIOACTIVE WASTE IN THE RUSSIAN FEDERATION AS OF 1996 [a)]

	Ministry, Agency	Accumulated RW		Solidified RW	
		Quantity, m^3	Activity, Ci	Quantity, m^3	Activity, Ci
1	MINATOM of RF'	6.3×10^8	1.5×10^9	2.6×10^4	2.0×10^8
2	Ministry of Defense of RF	2.7×10^4	9.8×10^2	2.0×10^2	0.2×10^2
3	Ministry of Transport of RF	1.9×10^3	2.0×10^4	–	–
4	State Committee of Defense Industry	4.0×10^3	6.0×10^2	–	–
5	Ministry of Construction Industry	2.0×10^5	2.0×10^6	6.0×10^3	1.2×10^2
	Total	$\sim 6.4 \times 10^8$	$\sim 1.5 \times 10^9$	3.2×10^4	2.0×10^8

a) See Ref. [VII-5].

The development of a radioactive waste management infrastructure is a policy objective of RF Government (see Fig. VII-1). Local regulation is carried out with regional and sectorial norms standards and guides which comprise the third level of regulatory scheme above mentioned. Such documents do not necessarily exist in every region of Russia, but specific ones have been written as, for example, "The Rules on the Soil Protection in St. Petersburg. Regional Normative" [VII-20]. These documents, apart from everything else, allow for the formalization of intermediate and long term priorities in the on-site restoration activities. In principle, regional manuals or codes of practice should reflect specific features of climatic, hydrological, biological, socio-economic, cultural, irradiation conditions, etc. in different parts of the vast territory of the Russian Federation (it stretches across nine time zones from the West to the East, and from the Polar zone in the North to Subtropical zone in the South).

In turn, sectoral normatives and methodical documents are called upon to adapt Federal regulations to the needs and peculiarities of the particular parts of the national economy. The working out and practical employment of such documents are especially a function for Minatom. Since 1992, Minatom has developed sectional environmental restoration guides, legal, normative and methodological documents in terms of an integrated programme "Rehabilitation of Territories Contaminated with Radioactive and Toxic Substances in Consequence of Nuclear Weapon Production" (Programme "Rehabilitation"). The programme includes the following key aspects:

- methodology, conceptions and evaluation of environmental impact during planning, preparation and implementation of activities;
- normative on recultivation and restoration of radioactively contaminated territories;
- sanitary norms and rules on restoration of radioactively and chemically contaminated territories;

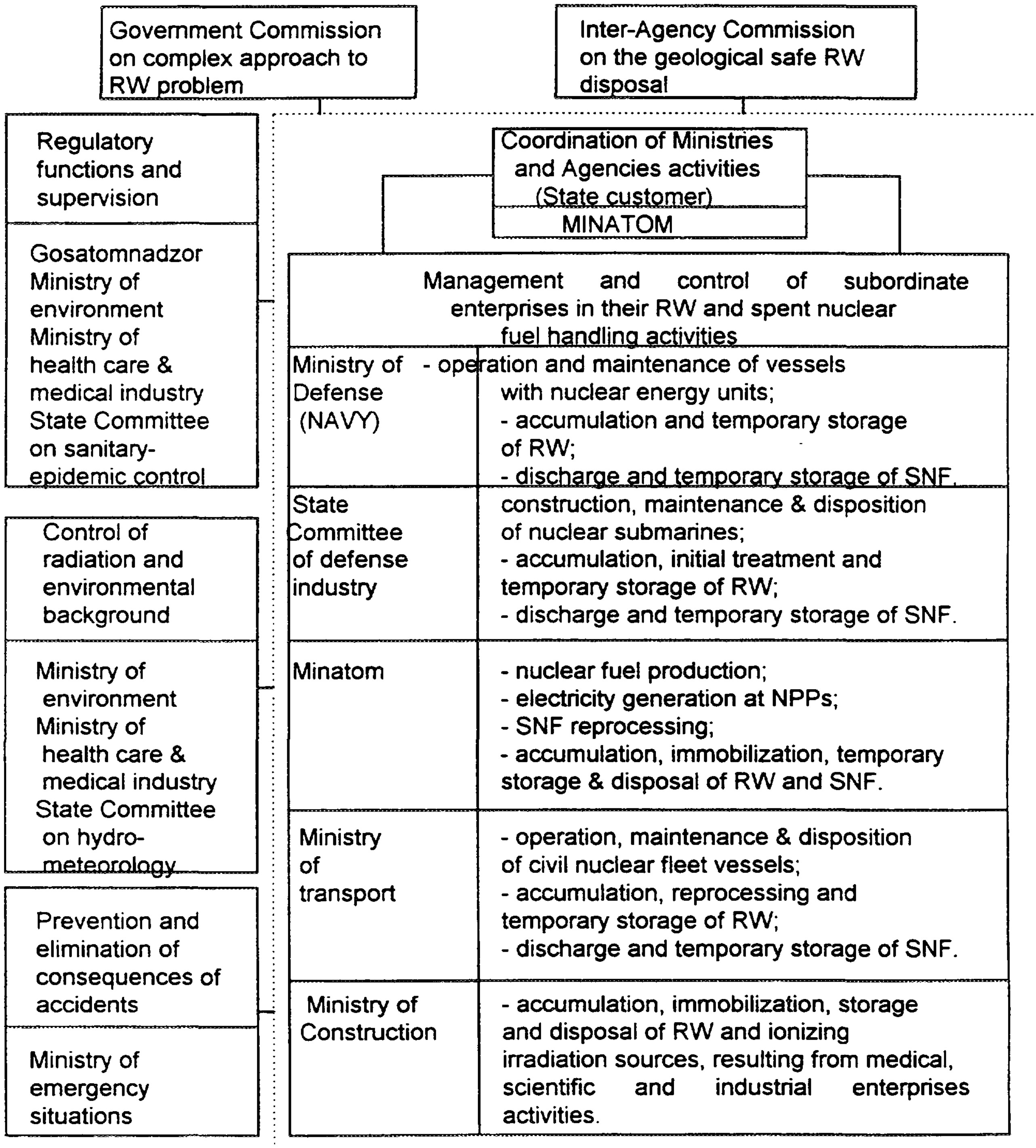

Fig. VII-1.Scheme of State Management of Radioactive Wastes (Russian Federation).

- methods and guides on restoration of territories and reservoirs; and

- information and organizing support.

It is important that environmental restoration decision makers are aware of the radiological impacts of contaminated sites and can establish realistic goals consistent with the improvement of the environment. Clean up criteria which have been developed for remedial actions are based on the levels specified in Federal Documents [VII-19]. Regional norms (for example, Ref. [5]) are in agreement with Federal ones.

The use of environmental impact assessments (EIA) is an obligatory ecological demand of RF legislation for implementation of environmental restoration programmes. EIAs include analyses and forecasts of the ecological, economical and social consequences of the planned new activity, along with an assessment of its acceptability for the affected parties and society. For example, the EIA methodology has been used for the evaluation and adoption of new technologies for addressing problems of Naval radwaste disposal in the Far East and in the northwestern regions, and for the development of nuclear programmes in the northwestern region of Russia [VII-21].

Public involvement in the decision making process is realized through the interaction of various public initiation groups and ecological movements with local official bodies.

VII-7. FACTORS AFFECTING THE IMPLEMENTATION OF ENVIRONMENTAL RESTORATION

As is true elsewhere in the world, there are a number of factors which may affect the implementation of environmental restoration, both positively and negatively. Because of the severe economic conditions that have existed in the Russian Federation, inadequate financial resources represent the most difficult problem in the implementation of environmental restoration programmes. Even ongoing state programmes (such as in Ref. [VII-5]) experience irregular and incomplete funding.

The needed base of technical resources which must address the environmental contamination problems comprises the great last experience of research and development in the field of nuclear technology.

In addition, human resources should be recognized as a critical factor which can drastically influence the success of current plans [VII-22]. In the past few years, the ready availability of trained personnel from research, design, and other scientific and engineering fields, as well as from a number of production organizations, has been considerably reduced. This has been due to the restricted opportunity for the professional development and advancement of technical workers and the fairly widespread staff reductions which have occurred for young specialists. Thus, a shortage of professionals to address the concerns of environmental contamination has developed. In addition, it is recognized that there is a continuing need to involve the public in the decision making processes to build public confidence and support [VII-22].

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Consultants Meetings

Vienna, Austria: 13–17 November 1995,

9–13 December 1996

Advisory Group Meeting

Vienna, Austria: 17–21 June 1996