INTRODUCTION

The Principles of Radioactive Waste Management

Note: The following is based on “The Principles of Radioactive Waste Management”[1].

Since the beginning of the twentieth century, research and development in the field of nuclear science and technology have led to wide scale applications in research, medicine, industry and in the generation of electricity by nuclear fission. In common with certain other human activities, these practices generate waste that requires management to ensure the protection of human health and the environment now and in the future, without imposing undue burdens on future generations. Radioactive waste may also result from the processing of raw materials that contain naturally occurring radionuclides. To achieve the objective of safe radioactive waste management requires an effective and systematic approach within a legal framework within each country in which the roles and responsibilities of all relevant parties are defined.

Radioactive waste occurs in a variety of forms with very different physical and chemical characteristics, such as the concentrations and half-lives of the radionuclides. This waste may occur:

- in gaseous form, such as ventilation exhausts from facilities handling radioactive materials;
- in liquid form, ranging from scintillation liquids from research facilities to high level liquid waste from the reprocessing of spent fuel; or
- in solid form, ranging from contaminated trash and glassware from hospitals, medical research facilities and radiopharmaceutical laboratories to vitrified reprocessing waste or spent fuel from nuclear power plants when it is considered a waste.

Such wastes may range from the slightly radioactive, such as in those generated in medical diagnostic procedures, to the highly radioactive, such as those in vitrified reprocessing waste or in spent radiation sources used in radiography, radiotherapy or other applications. Radioactive waste may be very small in volume, such as a spent sealed radiation source, or very large and diffuse, such as tailings from the mining and milling of uranium ores and waste from environmental restoration. Basic principles for radioactive waste management have been developed even though there are large differences in the origin and characteristics of radioactive waste, for example, concentration, volume, half-life and radiotoxicity. Although the principles are generally applicable, their implementation will vary depending on the types of radioactive waste and their associated facilities.

Radioactive waste, as a source of ionizing radiation, has long been recognized as a potential hazard to human health. National regulations and internationally recommended standards and guidelines dealing with radiation protection and radioactive waste management have been developed, based on a substantial body of scientific knowledge. It has been a feature of radioactive waste management that special attention has been

---

[1] International Atomic Energy Agency, Safety Series No. 111-F, Vienna (1995)

given to the protection of future generations. Considerations related to future generations may include potential radiation exposure, economic consequences and the possible need for surveillance or maintenance.

Radioactive waste may also contain chemically or biologically hazardous substances and it is important that hazards associated with these substances are adequately considered in radioactive waste management.

Fundamental safety approaches for the management of radioactive waste are based on international experience. In its Radioactive Waste Safety Standards (RADWASS) series of publications, the IAEA integrates this experience into a coherent set of fundamental principles, standards, guides and practices for achieving safe radioactive waste management.

[The following] presents radioactive waste management principles that apply to radioactive material, as defined to be radioactive waste by the appropriate national authorities, and to the facilities used for the management of this waste from generation through disposal. These principles apply to all aspects of radioactive waste management except where an activity is the specific subject of an IAEA document outside the RADWASS series or an international instrument, for example, the transportation of radioactive material and exports and imports of nuclear material. The principles also apply in the management of radioactive waste containing, for example, chemically or biologically hazardous substances, even though other specific requirements may also be applicable.

OBJECTIVE OF RADIOACTIVE WASTE MANAGEMENT

The objective of radioactive waste management is to deal with radioactive waste in a manner that protects human health and the environment now and in the future without imposing undue burdens on future generations.

.. The Annex describes the basic steps in radioactive waste management in order to provide a common understanding..

FUNDAMENTAL PRINCIPLES OF RADIOACTIVE WASTE MANAGEMENT

Responsible radioactive waste management requires the implementation of measures that will afford protection of human health and the environment since improperly managed radioactive waste could result in adverse effects to human health or the environment now and in the future.

The timely creation of an effective national legal framework and an associated organizational infrastructure provides the basis for appropriate management of radioactive waste. The individual steps in radioactive waste management as outlined in the Annex may be dependent on each other, and thus require co-ordination. Taking this interdependence into account will help to ensure safety in all radioactive waste management steps.

Observance of the principles of radioactive waste management will ensure that the above considerations are addressed, and thus contribute to achieving the objective of radioactive waste management. The principles [of radioactive waste management].. ..are presented in the following text.

Principle 1: Protection of human health

Radioactive waste shall be managed in such a way as to secure an acceptable level of protection for human health.

Principle 2: Protection of the environment

Radioactive waste shall be managed in such a way as to provide an acceptable level of protection of the environment.

Principle 3: Protection beyond national borders

Radioactive waste shall be managed in such a way as to assure that possible effects on human health and the environment beyond national borders will be taken into account.

Principle 4: Protection of future generations

Radioactive waste shall be managed in such a way that predicted impacts on the health of future generations will not be greater than relevant levels of impact that are acceptable today.

Principle 5: Burdens on future generations

Radioactive waste shall be managed in such a way that will not impose undue burdens on future generations.

Principle 6: National legal framework

Radioactive waste shall be managed within an appropriate national legal framework including clear allocation of responsibilities and provision for independent regulatory functions.

Principle 7: Control of radioactive waste generation

Generation of radioactive waste shall be kept to the minimum practicable.

Principle 8: Radioactive waste generation and management interdependencies

Interdependencies among all steps in radioactive waste generation and management shall be appropriately taken into account.

Principle 9: Safety of facilities

The safety of facilities for radioactive waste management shall be appropriately assured during their lifetime.

Annex

BASIC STEPS IN RADIOACTIVE WASTE MANAGEMENT

Effective management of radioactive waste considers the basic steps (shown schematically in Fig. A.1) in the radioactive waste management process as parts of a total system, from generation through disposal. Because decisions made in one step may foreclose certain alternatives in another step, the RADWASS programme emphasizes the importance of taking into account interdependencies among all steps during planning, design, construction, operation and decommissioning of radioactive waste management facilities.

This Annex describes the various steps in radioactive waste management in order to provide a common terminology and understanding.. ..The considerations are intended to be general and to apply to the management of radioactive waste including that from mining and milling and environmental restoration programmes, that from nuclear power generation and that from medical and industrial application of radioactive materials. They apply to radioactive waste generated during the operational period as well as during the decommissioning of a facility. The applicability of these steps will vary depending on the types of radioactive waste.

The waste should be characterized in order to determine its physical, chemical and radiological properties, and to facilitate record keeping and acceptance of radioactive waste from one step to another. Characterization may be applied, for example, in order to segregate radioactive materials for exemption or for reuse or according to disposal methods or to assure compliance of waste packages with requirements for storage and disposal.

It should also be noted that transportation may be necessary between the radioactive waste management steps. Effective radioactive waste management should take the implications of transportation into account.

Storage of radioactive waste involves maintaining the radioactive waste such that: (1) isolation, environmental protection and monitoring are provided; and (2) actions involving, for example, treatment, conditioning and disposal are facilitated. In some cases, storage may be practised for primarily technical considerations, such as storage of radioactive waste containing mainly short lived radionuclides for decay and subsequent release within authorized limits, or storage of high level radioactive waste for thermal considerations prior to geological disposal. In other cases, storage may be practised for reasons of economics or policy.

Pretreatment of waste is the initial step in waste management that occurs after waste generation. It consists of, for example, collection, segregation, chemical adjustment and decontamination and may include a period of interim storage. This initial step is extremely important because it provides in many cases the best opportunity to segregate waste streams, for example, for recycling within the process or for disposal as ordinary non-radioactive waste when the quantities of radioactive materials they contain are exempt from regulatory controls. It also provides the opportunity to segregate radioactive waste, for example, for near surface or geological disposal.

Treatment of radioactive waste includes those operations intended to improve safety or economy by changing the characteristics of the radioactive waste. The basic treatment concepts are volume reduction, radionuclide removal and change of composition. Examples of such operations are: incineration of combustible waste or compaction of dry solid waste (volume reduction); evaporation, filtration or ion exchange of liquid waste streams (radionuclide removal); and precipitation or flocculation of chemical species (change of composition). Often several of these processes are used in combination to provide effective decontamination of a liquid waste stream. This may lead to several types of secondary radioactive waste to be managed (contaminated filters, spent resins, sludges).

Conditioning of radioactive waste involves those operations that transform radioactive waste into a form suitable for handling, transportation, storage and disposal. The operations may include immobilization of radioactive waste, placing the waste into containers and providing additional packaging. Common immobilization methods include solidification of low and intermediate level liquid radioactive waste, for example in cement or bitumen, and vitrification of high level liquid radioactive waste in a glass matrix. Immobilized waste, in turn, may be packaged in containers ranging from common 200 litre steel drums to highly engineered thick-walled containers, depending on the nature of the radionuclides and their concentrations. In many instances, treatment and conditioning take place in close conjunction with one another.

Disposal is the final step in the radioactive waste management system. It consists mainly of the emplacement of radioactive waste in a disposal facility with reasonable assurance for safety, without the intention of retrieval and without reliance on long term surveillance and maintenance. This safety is mainly achieved by concentration and containment which involves the isolation of suitably conditioned radioactive waste in a disposal facility. Isolation is attained by placing barriers around the radioactive waste in order to restrict the release of radionuclides into the environment. The barriers can be either natural or engineered and an isolation system can consist of one or more barriers. A system of multiple barriers gives greater assurance of isolation and helps ensure that any release of radionuclides to the environment will occur at an acceptably low rate. Barriers can either provide absolute containment for a period of time, such as the metal wall of a container, or may retard the release of radioactive materials to the environment, such as a backfill or host rock with high sorption capability. During the period when the radioactive waste is contained by the system of barriers, the radionuclides in the waste will decay. The barrier system is designed according to the disposal option chosen and the radioactive waste forms involved.

Although it is planned to dispose of most types of radioactive waste by concentration and containment, disposal may also comprise the discharge of effluents (for example, liquid and gaseous waste) into the environment within authorized limits, with subsequent dispersion. For all practical purposes this is an irreversible action and is considered suitable only for limited amounts of specific radioactive waste.

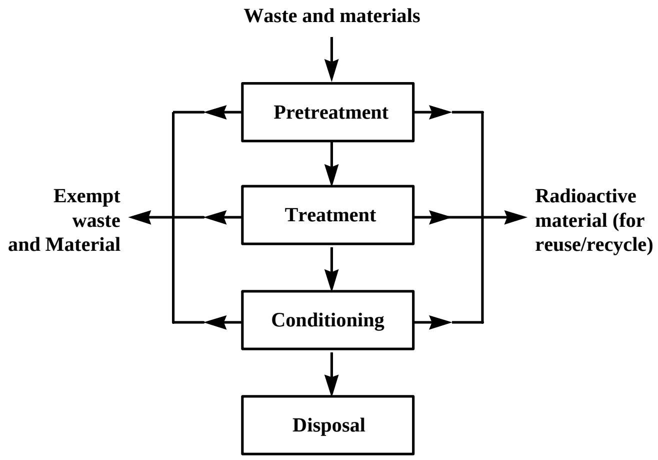

FIG. A.1. Basic steps in radioactive waste management. Characterization, storage and transportation of waste and materials may take place between and within the basic radioactive waste management steps. The applicability of these steps will vary depending on the types of radioactive waste.

The Classification of Radioactive Waste

The 1997/98 Questionnaire that was used to compile information for the WMDB (described in the next subsection of the Introduction), asked Member States to provide information about their national waste management programmes, activities, plans, policies, relevant regulations and waste inventories according to the following:

Low and Intermediate Level Waste - Short Lived (LILW-SL),
Low and Intermediate Level Waste - Long Lived (LILW-LL),
High Level Waste (HLW),
Alpha Bearing Waste (TRU),
Spent, Sealed Radiation Sources (SRS),
Spent Fuel (SF),
Decommissioning Waste (DW), and
Uranium Mine and Mill Tailings (UMMT).

The above waste classification is based on both qualitative criteria (wastes are grouped according to their origin, activity content, radiotoxicity and thermal power) and quantitative criteria (waste are grouped according to the safety aspects of their management). The quantitative classification of waste according to the LILW-SL, LILW-LL and HLW classes is based on "Classification of Radioactive Waste"**[2]**, Section 3, entitled "Proposal for a Radioactive Waste Classification System", which states the following:

TABLE II. TYPICAL CHARACTERISTICS OF WASTE CLASSES

Waste classes	Typical characteristics	Disposal options
1. Exempt waste (EW)	Activity levels at or below clearance levels given in Ref. [4], which are based on an annual dose to members of the public of less than 0.01 mSv	No radiological restrictions
2. Low and intermediate level waste (LILW)	Activity levels above clearance levels given in Ref. [4] and thermal power below about 2kW/m^3	
2.1. Short lived waste (LILW-SL)	Restricted long lived radionuclide concentrations (limitation of long lived alpha emitting radionuclides to 4000 Bq/g in individual waste packages and to an overall average of 400 Bq/g per waste package); **see paragraphs 324 and 325**	Near surface or geological disposal facility
2.2. Long lived waste (LILW-LL)	Long lived radionuclide concentrations exceeding limitations for short lived waste	Geological disposal facility
3. High level waste (HLW)	Thermal power above about 2kW/m^3 and long lived radionuclide concentrations exceeding limitations for short lived waste	Geological disposal facility

2 International Atomic Energy Agency, Safety Series No. 111-G-1.1, Vienna (1994)

324. The boundary between short lived and long lived waste cannot be specified in a universal manner with respect to concentration levels for radioactive waste disposal, because allowable levels will depend on the actual radioactive waste management option and the properties of individual radionuclides. However, in current practice with near surface disposal in various countries, activity concentration is limited to 4000 Bq/g of long lived alpha emitters in individual radioactive waste packages, thus characterizing long lived waste which is planned to be disposed of in geological formations. This level has been determined based on analyses for which members of the public are assumed to access inadvertently a near surface repository after an active institutional control period, and perform typical construction activities (e.g. constructing a house or a road).

325. Applying this classification boundary, consideration should also be given to accumulation and distribution of long lived radionuclides within a near surface repository and to possible long term exposure pathways. Therefore, restrictions on activity concentrations for long lived radionuclides in individual waste packages may be complemented by restrictions on average activity levels or by simple operational techniques such as selective emplacement of higher activity waste packages within a disposal facility. An average limit of about 400 Bq/g for long lived alpha emitters in waste packages has been adopted by some countries for near surface disposal facilities.

Most Member States that responded to the 1997/98 WMDB Questionnaire indicated that they did not have **national waste classification systems** that conformed to the IAEA's quantitative classification scheme described above (please click on the blue highlighted text to view information about national classification systems in the Overviews Section of this report).

A number of Member States reported that they had difficulty responding to the 1997/98 WMDB Questionnaire because their national waste classification system(s) did not match the system used by the Questionnaire. This issue is being addressed by the proposed **WMDB upgrade** (please click on the red highlighted text to view information about the upgrade in the Foreword Section of this report).

The Waste Management Database - Purpose and Objectives

In recognition that international co-operation is playing an increasingly important role in the development and implementation of national radioactive waste management programmes, the IAEA developed the WMDB. The purpose of the WMDB is to provide a mechanism for the collection, archival and dissemination of information about radioactive waste management in Member States. The WMDB contains information on national waste management programmes, activities, plans, policies, relevant regulations and waste inventories. The information is provided by Member States and is compiled and stored by the Agency.

The major objectives of the WMDB are to:

- routinely collect information about national, radioactive waste management programmes in Member States and to make this information accessible to all Member States,
- assist the routine review of current and planned IAEA activities through the International Radioactive Waste Technology Advisory Committee (WATAC)
- support the Agency's International Management Assessment and Technical Review Programme (WATRP), which provides international peer review services, and
- archive information about radioactive waste management activities at the international level.

With respect to the first bullet in the list above, during the collection of information for this report, a number of Member State representatives expressed concern that WMDB information was not readily accessible. This issue is being addressed by the proposed WMDB upgrade.

The Waste Management Database - Structure and Source of Data

The 1997/98 WMDB Questionnaire was structured as follows:

Subsection Number	Waste Class
1	Low and Intermediate Level Waste - Short Lived (LILW-SL)
2	Low and Intermediate Level Waste - Long Lived (LILW-LL)
3	Spent, Sealed Radiation Sources (SRS)
4	Alpha Bearing Waste (TRU)
5	High Level Waste (HLW)
6	Spent Fuel (SF)
7	Decommissioning Waste (DW)
8	Uranium Mine and Mill Tailings (UMMT)

This modular structure allowed information to be reported according to the management and disposal requirements for each waste class, except for DW and UMMT, where the information collected was primarily related to activities and plans.

This modular structure also allowed Member States to respond only to questions relevant to their national programmes. For example, many Member States do not have SF or UMMT. However, each module asked the same or similar questions, such as requests for information about regulatory authorities, regulations, and disposal options. A number of Member States, which completed multiple sections of the Questionnaire, expressed concern about the repetitive nature of the questions. This issue is being addressed by the proposed WMDB upgrade.

For LILW-SL, LILW-LL, alpha (TRU) and HLW, the following information was requested from each Member State:

- Responsible organizations and applicable laws, policies and statutes that mandate the organizational responsibilities and activities,
- Regulatory organizations and applicable laws, standards, regulations or codes that have been established or planned to regulate disposal activities,
- National definitions of waste (if applicable) that correspond to the Agency's LILW-SL, LILW-LL, alpha (TRU) or HLW classes,
- Volume of accumulated waste in 1996 and its status (as-generated or treated and/or conditioned)
- Volume of accumulated waste projected for the year 2014 (as-generated or treated and/or conditioned),
- Treatment and conditioning processes currently used, planned, or under R&D,
- Storage period and the type of storage facility,
- Current or planned disposal method(s),
- Type of host rock selected or under study (only for geological repositories),

- Disposal facility capacity, name, location and current status (for each facility),
- Planned or actual disposal programme schedule (for each facility), and
- Comments on significant milestones and/or events in their national programmes.

For HLW, the following information was also requested:

- Heat generation rate (kW/l or kW/canister), and
- Canister type

With respect to the request for the status of waste, the Questionnaire only allowed Member States to select either (1) as-generated or (2) treated and/or conditioned. However, many Member States reported that their waste was distributed between these two states. Therefore, Member States were asked to select the option that most closely reflected the status of their wastes or they provided information that was entered into free-format text areas of the database. This issue is being addressed by the proposed WMDB upgrade.

For SF, the following information was requested:

- Responsible organizations and applicable laws, policies and statutes that mandate the organizational responsibilities and activities,
- Regulatory organizations and applicable laws, standards, regulations or codes that have been established or planned to regulate disposal activities,
- Mass of accumulated SF in 1996 in metric tonnes
- Mass of accumulated SF projected for the year 2014 in metric tonnes,
  Note: The electronic version of the Questionnaire requested the <u>*volume*</u> *of accumulated SF and allowed Member States to report either a volume (m^3) or mass (metric tonnes). This issue is being addressed by the proposed WMDB upgrade.*
- The type(s) of reactor(s) that generated the SF,
- Storage period and the type of storage facility,
- Heat generation rate (kW/l or kW/canister),
- Canister type
- Current or planned disposal method(s),
- Type of host rock selected or under study (only for geological repositories),
- Disposal facility capacity, name, location and current status (for each facility),
- Planned or actual disposal programme schedule (for each facility), and
- Comments on significant milestones and/or events in their national programmes.

For SRS, the following information was requested:

- Regulatory organizations and applicable laws, standards. regulations or codes that have been established or planned to regulate management and disposal activities,
- registries and/or inventory lists,
- replacement plans for radium needles and tubes,
- return of SRS to the original supplier, including any agreements,
- type(s), location(s), activity(ies), and measurement date(s) for sources greater than 1.85E10 Bq (500 mCi),

- type(s), location(s) and mass (mg) of radium sources,
- storage type(s) and facility marking(s),
- Conditioning processes currently used, planned, or under R&D,
- Current or planned disposal method(s),
- Type of host rock selected or under study (only for geological repositories),
- Disposal facility capacity, name, location and current status (for each facility),
- Planned or actual disposal programme schedule (for each facility), and
- Comments on significant milestones and/or events in their national programmes.

For DW, the following information was requested:

- Responsible organizations and applicable laws, policies and statutes that mandate the organizational responsibilities and activities,
- Regulatory organizations and applicable laws, standards, regulations or codes that have been established or planned to regulate decommissioning activities,
- Mandated time period(s) (if any) for carrying out decommissioning activities,
- Mandated financing (if any) for carrying out decommissioning activities,
- Status (name, location, shut down date, decommissioning start year / end year) of facility decommissioning for nuclear power reactors, research reactors and other nuclear facilities,
- Decontamination processes currently used, planned, or under R&D,
- Treatment and conditioning processes currently used, planned, or under R&D,
- Volumes and categories of different waste projected to be produced by decommissioning activities. Member States were also asked “Are these volumes already included in Subsections 1 (LILW-SL) and 2 (LILW-LL)? If yes, please specify amounts.”
  Note: Free-format responses were allowed for this question. Member States were allowed to report DW as part of other waste if they wanted to. In addition, no reference year for projections was specified. As such, the WMDB cannot report DW accumulations in the same manner as it can for other waste, such as LILW-SL. This issue is being addressed by the proposed WMDB upgrade.
- Comments on significant milestones and/or events in their national programmes.

For UMMT, the following information was requested:

- Responsible organizations and applicable laws, policies and statutes that mandate the organizational responsibilities and activities,
- Regulatory organizations and applicable laws, standards, regulations or codes that have been established or planned to regulate UMMT disposal activities,
- UMMT site(s), location(s), size of each impoundment in hectares,
- Treatment methods for liquid mill effluent that are current or planned,
- Impoundment methods that are current or planned,
- Cover materials in use or planned,
- Seepage control in use or planned,
- Long-term plans for closed out sites,
- Comments on significant milestones and/or events in their national programmes

All data in this report, except for the information provided for the Russian Federation, derive from responses to the 1997/98 WMDB Questionnaire, which was sent out to Member States in IAEA information circular T2.06.01 Circ., dated 1998.01.28. The source of information for the Russian Federation is provided in the WMDB record for this Member State.

In a database such as WMDB, the source of the information is very important to its credibility. Efforts were made to retain the original wording and intent of each Member State's response to the Questionnaire. However, some of the data returned did not fit the design format of the database, therefore, some editing was required to process the information.

When evaluating the WMDB data, it is important to keep in mind that the information was provided by the Member States in a form and at a level of completeness desired by the individual country. There is no assurance that the data provided are complete or comprehensive. Also, national programmes are often fairly complex and extensive and they cannot be completely documented within a generic database format. The information presented in this report merely provides an abbreviated overview of national programmes.