5. RADIOACTIVE WASTE MINIMIZATION AND PROCESSING

Note: this section focuses mainly on Low and Intermediate Level Waste (LILW) minimization and processing. High Level Waste (HLW) and spent fuel processing are covered in Section 3.3. See Section 3 for information about waste classification.

5.1 Waste Minimization

The IAEA defines waste minimization as [5.1]:

> *The process of reducing the amount and activity of radioactive waste to a level as low as reasonably achievable, at all stages from the design of a facility or activity to decommissioning, by reducing waste generation and by means such as recycling and reuse, and treatment, with due consideration for secondary as well as primary waste.*

According to Article 11 of the Joint Convention (see Section 1), each Contracting Party shall take the appropriate steps to ensure that at all stages of radioactive waste management individuals, society and the environment are adequately protected against radiological and other hazards. In so doing, each Contracting Party shall take the appropriate steps to ensure that the generation of radioactive waste is kept to the minimum practicable.

In addition, decisions to minimize radioactive wastes typically focus on minimizing costs. However, focusing on cost considerations alone can oversimplify the issue and could entail other drawbacks, since many factors are involved and the timing of decisions is important. Waste minimization is an integral part of a wider and comprehensive waste management and safety culture that aims at efficiently reducing radiological and environmental impacts of generated wastes.

Waste minimization may offer financial savings but it may also introduce new hazards or modify those already associated with a facility. In each approach to waste minimization, cost reductions must always be compared with other factors, especially those related to the safety of operators and the general public.

The following presents an overview of major aspects of waste minimization and it points out considerations that could be taken into account in the decision-making process. The main focus is on the operation and decommissioning of nuclear power plants, since these activities are major sources of radioactive waste and are expected to have the greatest potential to achieve success in waste minimization policy and techniques. The relevant waste minimization approaches could also be applied by other waste producers.

Waste minimization encompasses organizational, technological, and economical aspects. Each project should therefore be carefully assessed in consideration of the individual conditions and circumstances. The type of assessment that needs to be made, the level of detail to which the assessment is taken, and the thoroughness of reviews by internal bodies and/or regulatory authorities should be related to the significance of the changes involved. Of course, some types of waste are clearly more problematical than others and, if possible, their generation should be avoided. One typical example is radioactive wastes that are simultaneously chemically hazardous and/or toxic and are often identified as mixed waste.

The real benefit from waste minimization projects has to be measured against their complexity and scope. The highest effectiveness can be expected from national or company projects covering one or more nuclear facilities and/or from the systematic implementation of improvements in radionuclide applications.

The following components are usually considered in the planning and implementation of complex, significant waste minimization projects: waste minimization strategy; minimization of radioactive waste arisings; and minimization of the volume of radioactive waste that has been generated.

Waste minimization strategy: The need for waste minimization arises from the generally accepted, principal objective of radioactive waste management, namely, "The generation of radioactive waste shall be kept to the minimum practicable, in terms of both its activity and volume, by appropriate design measures and operating and decommissioning practices. This includes the selection and control of materials, the recycle and reuse of materials, and the implementation of appropriate operating procedures. Emphasis should be placed on the segregation of different types of waste and materials to reduce the volume of radioactive waste and facilitate its management" [2.1]. This objective is properly reflected in relevant Agency documents and also in basic regulatory and legislative documents in many IAEA Member States (see reference [5.2] for an example).

A waste minimization strategy should be established to serve as a conceptual basis for co-ordinated planning and implementation of desired measures. The following topics, among others, may be covered:

> Administrative considerations: These include the legislative basis for waste management and waste minimization, including proper and sound waste clearance (see page 30 and *minimization of radioactive waste arisings*, below) and discharge policies (see page 16); identification of responsibilities and commercial arrangements between utilities and waste managers; economic assumptions (economic support, tax rates, discount rates); the quality assurance system; and qualification and training of staff.

> Technical and safety considerations: These include the power plant capacity and performance, reactor type, location; design principles of the nuclear facility and individual components; the expected operational lifetime of facilities; the waste conditioning strategy (national and also facility-specific); and the waste disposal strategy, scale, type and location of storage and disposal facilities.

Minimization of radioactive waste arisings: The minimization of the amount of radioactive waste that is generated, in both terms of volume and activity, is an effective way to minimize waste management costs. The most proactive way is to consider minimization during the design and construction phases for new facilities. Reviewing and changing existing practices at operating facilities also can significantly reduce waste generation rates. Significant reductions of waste arisings can be realized by considering potential decommissioning procedures as early as during a facility's design phase.

Consideration of waste minimization in the design and construction phases of nuclear facilities may have a direct impact on future waste generation during both the operational and decommissioning phases. The main design-related, technical options are:

- the proper choice of materials (resistance to corrosion, high-quality surface treatments, low tendency to activate and/or produce radionuclides that may cause problems),

- application of the most effective, reliable and up-to-date technology to assure that equipment will remain operable as long as possible without replacement and/or maintenance,
- high performance of components and prevention of unintended accumulation of waste, and minimization of leakage/drainage to avoid repairing active components and producing additional waste, and
- strong separation of radioactive and non-radioactive media and segregation of radioactive media according to their nature and activity.

The decommissioning of nuclear facilities is a source of very large volumes of radioactive waste (see Section 4.2), most of which may be LILW.

The generation of decommissioning wastes can be significantly reduced through the application of proper decontamination techniques, the rigorous segregation and separation of the waste streams, the recycle and reuse of selected metals and construction materials, and the establishment and implementation of proper clearance and discharge policies.

At nuclear power plants, the co-ordinated efforts of operators over the last 10 years have enabled large reductions of LILW by a factor of four to five, when measured by volume, and by a factor of ten, when measured by total activity, in the production of operational wastes. The largest potential benefit from waste reduction efforts can be expected in the decommissioning phase. The main reason is that about 75% of waste from dismantling could be categorized as VLLW (see page 30 in Section 3.1), much of which could have a high potential for clearance from regulatory control.

Typical, practical steps that can contribute to the minimization of operational radioactive waste generation include:

- limiting the number and size of the controlled areas and identifying all points in the working areas and all stages in the process where it is possible to prevent material from becoming radioactive waste,
- establishing waste accounting and tracking systems to quantify sources, types, amounts, activities and characteristics of waste,
- applying recent technological processes (good operational practice) and modifying maintenance and refurbishment procedures leading to waste reduction,
- reusing recovered materials (e.g. boric acid, special metals, fission material) to minimize waste generation and decrease operational costs,
- recycling and reuse liquids within the process (such as decontamination solutions and laundry water) to minimize the volume and potential environmental impact of discharged liquids,
- establishing a system of sorting waste and separating waste streams to prevent improper mixing and to assure more efficient characterization and subsequent processing,
- improved instrumentation which assists in the clearance of suspect materials,
- establishing a rigorous system for segregation of non-active and active waste in the controlled area, and

- increasing the flow of information among staff regarding waste reduction philosophies, techniques and improved methods, and emphasizing the training of staff in waste minimization practices.

These procedures are oriented mostly to the minimization of radioactive waste arisings at large nuclear facilities. Nevertheless they are applicable to the minimization of arisings of nuclear applications waste.

<u>Clearance</u> (also refer to page 30)

As stated previously, proper and sound clearance practices can contribute significantly to the minimization of radioactive waste arisings. At a recent Joint NEA/IAEA/EC workshop on decommissioning [3.7], the issue of clearance was discussed at length relative to decommissioning waste. Among other topics, the use of consistent terminology [5.3], the harmonization of clearance levels in the European Union [5.4], [5.5] and the need for international consensus [5.6] were discussed. At the time of writing of this Status and Trends report, references [5.7] and [5.8], which had been in preparation by the IAEA, were suspended as the Agency reviews its position on the issue of clearance. Reference [5.9] is a recent IAEA publication in the subject area.

<u>Recycle / Reuse</u>

As stated previously, the segregation of materials for recycle or reuse can be an effective way to minimize the amount of radioactive waste that needs to be managed.

In the past, recycle and reuse of materials arising from activities related to the nuclear fuel cycle was not a priority, with the exception of some processes like fuel reprocessing and some aspects of nuclear power plant operation. A shift in emphasis in the last decade towards waste minimization in all parts of the nuclear fuel cycle has resulted in the development of technologies and procedures for recycle and reuse. Factors supporting this shift include corporate responsibility and the ever-increasing cost of radioactive waste disposal. However, for a number of Member States, ongoing issues concerning clearance of materials for restricted and unrestricted release have presented challenges that have impeded full implementation [5.10].

A number of reuse and recycle approaches have been successfully considered in facility design, construction, operation, maintenance and modification. Substantial quantities of materials (mainly metal and concrete) are likely to be generated in the near future from decommissioning of nuclear fuel cycle facilities, which will create considerable opportunity for the implementation of recycle and reuse options. A recent IAEA technical document [5.11] indicates and discusses major factors influencing decision making process and methodologies to optimize waste minimization through recycle and reuse at the facility and national level. The methodologies are broad enough to allow customization of the decision making process for various technical and regulatory environments. New generation nuclear fuel cycle facilities, that are in various stages of design and construction, employ appropriate technologies to facilitate reuse and recycle activities in all facets of the facility life-cycle.

Figure 5-1 to Figure 5-3 illustrate reductions achieved in the amount of radioactive waste generated from nuclear power reactors in two Member States with large nuclear programmes [5.12].

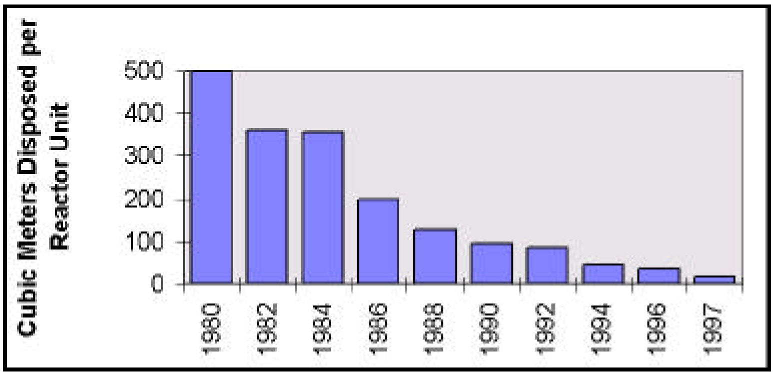

Figure 5-1: Waste Minimization for PWR Reactors in the United States of America

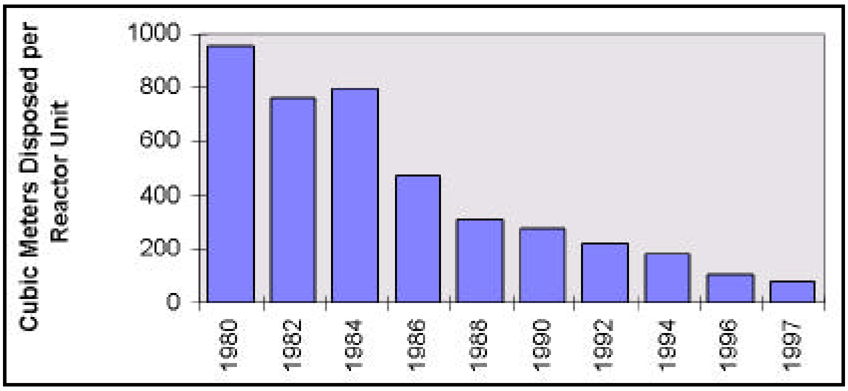

Figure 5-2: Waste Minimization for BWR Reactors in the United States of America

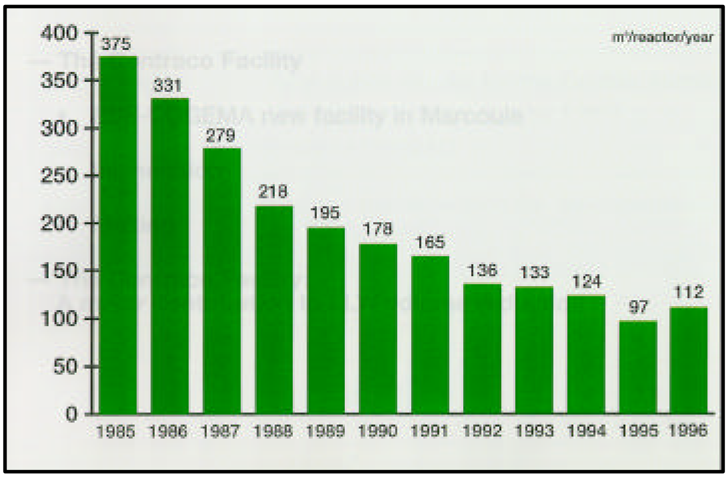

Figure 5-3: General Waste Minimization Data from France (m^3/reactor/year)

In May 1996, the United States of America Secretary of Energy established a 50 percent Department of Energy (DOE) Complex-Wide Waste Reduction Goal (relative to the 1993 baseline) for routine operations radioactive, mixed, and hazardous waste generation, to be achieved by December 31, 1999. The DOE has reported [5.13] that it has achieved its waste reduction goals for routine operations ahead of target based upon a comparison of 1998 waste generation to the 1993 baseline. Excluding sanitary waste, routine operations waste generation decreased 67 percent overall from 1993 to 1998.

Minimization of the volume of radioactive waste that has been generated: Storage and disposal costs are often the main, though not the single reason, for operators to reduce the volume of generated wastes. In the face of public and political opposition to the construction of facilities, for environmental or other reasons, the effort to maximize the use of space in existing storage and disposal facilities has taken on added importance for waste management organizations.

One technique is to store radioactive waste for sufficient time periods over which their radioactivity levels decay. It is commonly used for waste from short-lived radioisotope applications, and, to a certain extent, for waste from nuclear facilities in operation or being decommissioned. This approach could simplify and increase the effectiveness of subsequent waste treatment and/or conditioning processes, or lead to the clearance of the waste from regulatory control. Reduction of radioactive waste volumes by natural decay is one important factor leading to the selection of a deferred dismantling strategy for decommissioned nuclear facilities.

Another technique is to recycle and reuse metals as well as some types of civil construction materials (concrete), arising from the refurbishment and decommissioning of nuclear facilities. The main economic benefit arises from savings achieved in avoided disposal costs, rather than through material reuse or recycling directly.

Additionally, the volume of waste that has been generated can be minimized by various treatment methods (see Section 5.2). For example, for large volumes of aqueous waste containing low concentrations of radiochemical and chemical contaminants, advanced membrane and micro-filtering processes are being developed. At the Los Alamos National Laboratory in the United States, a new integrated membrane filtration system was developed to treat about six to ten million litres of liquid radioactive waste [5.14]. The titanium-dioxide microfiltration system yields a higher concentration factor over a previous treatment method, reduces chemical usage, and provides high-quality effluent water for discharge.

Other methods build upon the use of incineration and supercompaction, which are most widely applied to reduce the volume of solid radioactive wastes, offering reduction factors of more than ten. Through the combined incineration of solid waste and many types of low-level organic wastes, some specific problems can be resolved. For example, used oil and ion exchange resins can be transformed into stable, homogenous mineral forms suitable for final conditioning and disposal.

The impact of minimization Waste minimization is expected to have an impact on future disposal operations. In the United States of America, waste volumes from operating nuclear power plants have decreased dramatically during the past ten years [5.15]. As waste volumes decline, questions are being raised as to whether it is necessary to continue with developing additional disposal facilities [5.16]. However, decisions on future waste disposal capacity have to take decommissioning wastes into consideration. Of note, the issue of relatively large volumes of VLLW, as discussed previously, has to be considered since "VLLW is of such a low activity that it is not desirable, for financial reasons, to dispose of them in LLW repositories." (see page 31).

References [5.17] and [5.18] are recent IAEA publications in the area of waste minimization.

5.2 Waste Processing

Processing involves the treatment and/or conditioning of waste, where treatment and conditioning are defined as follows [5.1].

treatment: operations intended to benefit safety and/or economy by changing the characteristics of the waste. Three basic treatment objectives are (a) volume reduction, (b) removal of radionuclides from the waste, and (c) change of composition of the waste.

conditioning: operations that produce a waste package suitable for handling, transport, storage and/or disposal. Conditioning may include the conversion of the waste to a solid waste form, enclosure of the waste in containers and, if necessary, providing an overpack.

As discussed previously (see page 12 and Figure 2-1), waste processing should be integrated with other waste management activities since decisions made in one step may foreclose certain alternatives in another step. In addition, careful consideration should be given to the selection of processing technologies and the configuration of waste processing facilities to optimize the application of treatment and conditioning methods. Over the last decade, the Agency has issued a variety of technical guidance documents related to waste processing for both nuclear fuel cycle and nuclear applications waste [4.9], [5.19] to [5.26].

In general, liquid and solid radioactive wastes are treated and conditioned to facilitate their handling, transport, storage and disposal. The waste processing technologies employed in the nuclear industry are often based on established technologies that are used in non-nuclear industries, such as water and non-radioactive liquid waste treatment. Solid wastes are often treated to reduce their physical size or to minimize the dispersion of particulates.

The current, commonly used methods for treating LILW include:
- compaction, super compaction, and incineration (solids)
- chemical precipitation, evaporation, ion-exchange, and membrane separation (liquids)

The current, commonly used methods for conditioning LILW include:
- encapsulation / immobilization, e.g., grouting / bituminization, cementation, polymerization (solids)
- immobilization, e.g., bituminization, cementation, and polymerization (liquids and “wet solids”, such as ion exchange resins, sludges and slurries)

The treatment/conditioning of HLW and spent nuclear fuel is discussed in Section 3.3.

A recent international symposium [5.12] illustrated that proven technologies exist for managing radioactive wastes in ways that are safe, economical and environmentally sound and that considerable experience exists with these technologies in many Member States. Some Member States, however, lack the infrastructures or the resources to implement these technologies. Assistance from the Agency to assist in training, to advise on programmes and to provide equipment or support would be useful.

In addition to the commonly used treatment and conditioning methods described above, some specialized and innovative technologies have been developed to deal with specific waste arisings. Several examples are provided in references [5.27] to [5.30].

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