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Planning and Implementation of Radioactive Waste Management System

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1. Introduction

The application of radioactive and nuclear materials in power generation, industries, and research can lead to radioactive pollution. The sources of this pollution might include the discharge of radionuclides to the environment by nuclear power facilities, military establishments, research organizations, hospitals and general industry. Also, historical tests of nuclear weapons, nuclear and radioactive accidents and the deliberate discharge of radioactive wastes are representing major sources for this pollution (R.O. Abdel Rahman et. al 2012). Several international agreements and declarations were developed to control the radioactive pollution especially those related to the discharge of radionuclides to the environment. These agreements and declarations impose obligations on national policies to prevent the occurrence of radioactive pollution (IAEA 200a, 2010). On national scale, governments are responsible for protecting the public and environments; the manner at which this responsibility is implemented varies from country to country by using different legislative measures.

The protection of the environment and human health from the detrimental effects of radioactive wastes could be achieved through the effective development and implementation of radioactive waste management system. Recently, some trends that influence the practice of radioactive waste management have emerged worldwide. These trends include planning and application of radioactive waste policy and strategy, issue of new legislation and regulations, new waste minimization strategies, strengthen the quality assurance procedures, increased use of safety and risk assessment, strengthened application of physical protection and safeguards measures in designing and operation of waste management facilities, and new technological options (R.O. Abdel Rahman et. al 2011 a). In this chapter, the recent development in radioactive waste management planning and implementation will be overviewed, the prerequisites and elements for developing and implementing radioactive waste policy and strategy will be highlighted. The advances in the development and application of legal framework and different technical options for radioactive waste management activities will be briefly introduced.

2. Waste management policy and strategy development

Policy is defined as a plan or course of action, as of a government, political party, or business, intended to influence and determine decisions and actions (the three dictionary http://www.thefreedictionary.com/policy). In the beginning of the nuclear era, the countries that first started to utilize nuclear and radioactive materials did not have any radioactive waste policy or strategy. To address the radioactive waste issue, some countries had developed and implemented permanent disposal repositories for radioactive wastes and other countries placed radioactive wastes into on-site or off-site storage facilities without the development of national policy for dealing with these wastes.

Preventing risks, to human and the environment, associated with exposure to radioactive wastes was the primary reason to motivate the International Atomic Energy Agency (IAEA) to formulate and publish the policy principals statement in 1995 that deals with the environmental and ethical issue related to managing and disposing these wastes. This statement indicated that "*Radioactive waste should be managed in such a way as to secure an acceptable level of protection for human health, provide an acceptable level of protection for the environment, assure that possible effects on human health and the environment beyond national borders will be taken into account, ensure that the predicted impacts on the health of future generations will not be greater than relevant levels of impact that are acceptable today, and that the management practice will not impose undue burdens on future generations. Also, radioactive waste should be managed within an appropriate national legal framework including clear allocation of responsibilities and provision for independent regulatory functions, the generation of radioactive waste shall be kept to the minimum practicable, interdependencies among all steps in radioactive waste generation and management should be taken into account and the safety of facilities for radioactive waste management shall be appropriately assured during their lifetime*" (IAEA 1995).

These policy principles can be applied to all types of radioactive wastes, regardless their physical and chemical characteristics or origin. In addition to these principles, each country have its own policy principles that define the aims and requirements for the regulatory and legislative framework and might includes administrative and operational measure (R.O. Abdel Rahman et. al). These principals are reflecting the national priorities, circumstances, structures, and human and financial resources. In 2009, IAEA has identified the prerequisites and elements for the development of national radioactive waste management policy. These prerequisites and elements are summarized in Table 1 (IAEA 2009).

As indicated above, some countries started to build and operate radioactive waste disposal without the existence of national waste management policy. Nowadays, these countries started to develop national radioactive waste management policy principals. On the other hand, some existing national radioactive waste management policy principals may need to be updated to improve parts of the policy based on experience of its application and to reflect the changing circumstances in the country and in the world (IAEA 2009). Within this context, the South African policy and strategy document recently developed and was issued in 2005. It included beside the international principals proposed by the IAEA some national principals, that identify the financial and human resources, management transparency and public perception, nature of waste decision making process, international cooperation and national involvement (Department of minerals and energy 2005). In 2007, policy for the long-term management of the United Kingdom's solid low-level radioactive waste was developed following public consultation. That policy statement covers all management aspects for these wastes; it defines this waste category and the key requirements for the management plans. It identifies the importance of using risk informed decision making process, minimization of waste generation, transparency and public involvement, and the consideration of potential effect of climatic changes. Finally it outlines waste import and export and the national organization involvement (Defra 2007).

Prerequisites	Elements
Existence of institutional structure (regulatory body, operational organization)	Allocation of responsibilities between the government, regulatory body and operational organizations
Existence of national legal structure and regulatory framework	Identification of safety measure in addition to physical protection and security of facilities
Availability of resources to implement the policy	Mechanisms for providing and maintaining the financial, technical and human resources
Applicable international conventions	Address the need to minimize the generation of radioactive waste at the design. Identify the export/import of option for radioactive wastes.
Indicative national inventories (amounts and types) of existing and anticipated wastes should be identified	Decide whether the spent fuel is considered as resource or as waste, or returned to supplier Identify the main sources of radioactive waste and the intended technical management arrangements. Identify whether the nuclear regulations are applied to naturally occurring radioactive material (NORM) or not based on its radioactive properties.
The main parties concerned and involved with spent fuel and radioactive waste management in the country	Indicate the extent of public and stakeholder involvement
The existing relevant national policies and its applicable strategies, if any, should be available in response to any policy development	

Table 1. Prerequisites and element for the development of national radioactive waste policy

After developing the waste management policy principals there is a need to have practical mechanisms to implement these principals, those practical mechanisms are forming the strategy. The first step in developing the waste management strategy is to assign the strategy development responsibility, then assess the availability of information that will be used to develop the strategy. The IAEA has developed a list of important information that should be taken into account during the development of waste management strategy. Those include the estimation of existing and anticipated waste inventory and waste management facilities, the existence of acceptable waste classification system and regulation, the evaluation of waste characteristics and available resources, the knowledge of waste management strategies in other countries and the identification of concerned parties (IAEA 2009). The second step in the development of waste management strategy is the identification of possible end point and technical options. Finally the optimal strategy is determined and the implementation responsibility is assigned. It is worthy to mention that in strategy development, there are two alternatives. The first is a one level method called national plan, which is formulated from a national perspective and often specify one waste operator who is responsible for coordinating the development of such plans. While in the second method, there are two levels for formulating the strategy. At the first level the principal strategy elements are prescribed in general terms as a national strategy by government. At the second level, the detailed implementation of the principal strategy elements is delegated to particular waste owners (company strategies).

To assist the member countries in the nuclear energy agency (NEA), in developing safe sustainable and broadly acceptable strategies for the long-term management of all types of radioactive wastes. NEA has published recently the strategic plan that identity the role of the radioactive waste management committee (RWMC) with respect to the challenges that face the member countries and describe the area of interest for the future work. The identified strategic areas of interest included the following (NEA 2011):

1. Organization of a comprehensive waste management system, including its financing
2. Development of robust and optimized roadmaps for spent fuel and radioactive waste management towards disposal, including transportation
3. Licensing the first geological repositories for high level wastes and /or spent fuel and for other long-lived wastes
4. Industrial implementation of deep geological disposal
5. Effective decommissioning
6. Management of low level wastes and special types of radioactive waste
7. Knowledge management and long-term preservation of records, knowledge and memory

3. Developments and implementation of legal framework

To ensure a safe practice for radioactive waste management, there is a need to develop and implement legal framework successfully (IAEA 2000 b). This framework is a part of the national legal system and usually has a hierarchy structure. IAEA has identified a four-level legal framework. The first level in this hierarchy is at the constitutional level, where the basic institutional and legal structure governing all relationships in the country is established. Below this level, there is the statutory level, at which specific laws are enacted by a parliament in order to establish necessary bodies and to adopt measures relating to the broad range of activities affecting national interests. At this level the independency of the regulatory body should be established and maintained. The third level comprises regulations for authorization, regulatory review and assessment, inspection and enforcement. And the final level consists of non-mandatory guidance instruments, which contain recommendations designed to assist persons and organizations in meeting the legal requirements (Stoiber et. al. 2003). In 2005, NEA identified the responsibility of each level development as follow: the first and second level is the responsibility of the main national legislative body. The third level is the responsibility of the government departments or ministries whose portfolios cover one or more aspects affected or influenced by the management of radioactive waste. Exceptionally, the third level in the form of binding rules or codes as distinct from standards may be the responsibility of other bodies such as EPA and NRC in the United States or SSI and SKI in Sweden. There are two philosophies that could be adopted to develop the third and fourth levels, at the first there is a need to develop specifications standards and guides to direct the implementer on how to implement the first and second legislations. At this philosophy, the regulator has some responsibilities and the operator elaborate the detailed specifications then the reviewer and decision is made by the regulator. In the second philosophy, the regulation system is based only on the primary and secondary legislations (NEA 2005, Norrby & Wingefors 1995).

After the establishment of the policy principles set, legal framework is created. To ensure the compliance with the legal framework, there is a need to acquire a formal legal instrument often described as license, permit or authorization. Depending on national legal framework, the licensing process may begin with some kind of decision on the site selection or site authorization or with the construction permit. Successful experiences in facility sitting have shown that active regulatory involvement is needed and is also possible without endangering the independence and integrity of the regulatory authorities (NEA 2003).

4. Technical option for radioactive waste management

Radioactive waste management schemes differ from country to country, but the philosophical approach adopted generally is to dispose these wastes in environmentally acceptable ways (R.O. Abdel Rahman et. al 2005 a). During the planning for such scheme, the collection and segregation of wastes, their volume reduction and appropriate conditioning into a form suitable for future handling, transportation, storage and disposal are considered. Pertinent activities in managing radioactive waste are schematically given in Fig. 1. This section is focused on introducing different waste management activities with special emphasizes on new waste minimization strategies, importance of quality assurance, risk and performance assessment.

4.1 Minimization of waste generation

The objectives of waste minimization strategy are to limit the generation and spread of radioactive contamination and to reduce the volume of the managed wastes in the subsequent storage and disposal activities. The achievement of these objectives will limit the environmental impacts and total costs associated with contaminated material management. The main elements of this strategy can be grouped into four principals: source reduction, prevention of contamination spread, recycle and reuse, and waste management optimization (IAEA 2001 a, 2007). The reduction of the waste generation at the source begins during the planning for any facility that produces radioactive or nuclear wastes. This principal could be achieved by selecting appropriate processes and technologies, the selection of construction and operational material, and the implementation of appropriate procedures during the operational phase. Also, raising the awareness of the importance of waste minimization through training the employees, and the development and application of contamination and quality control procedures represent important tools to implement the waste minimization strategy.

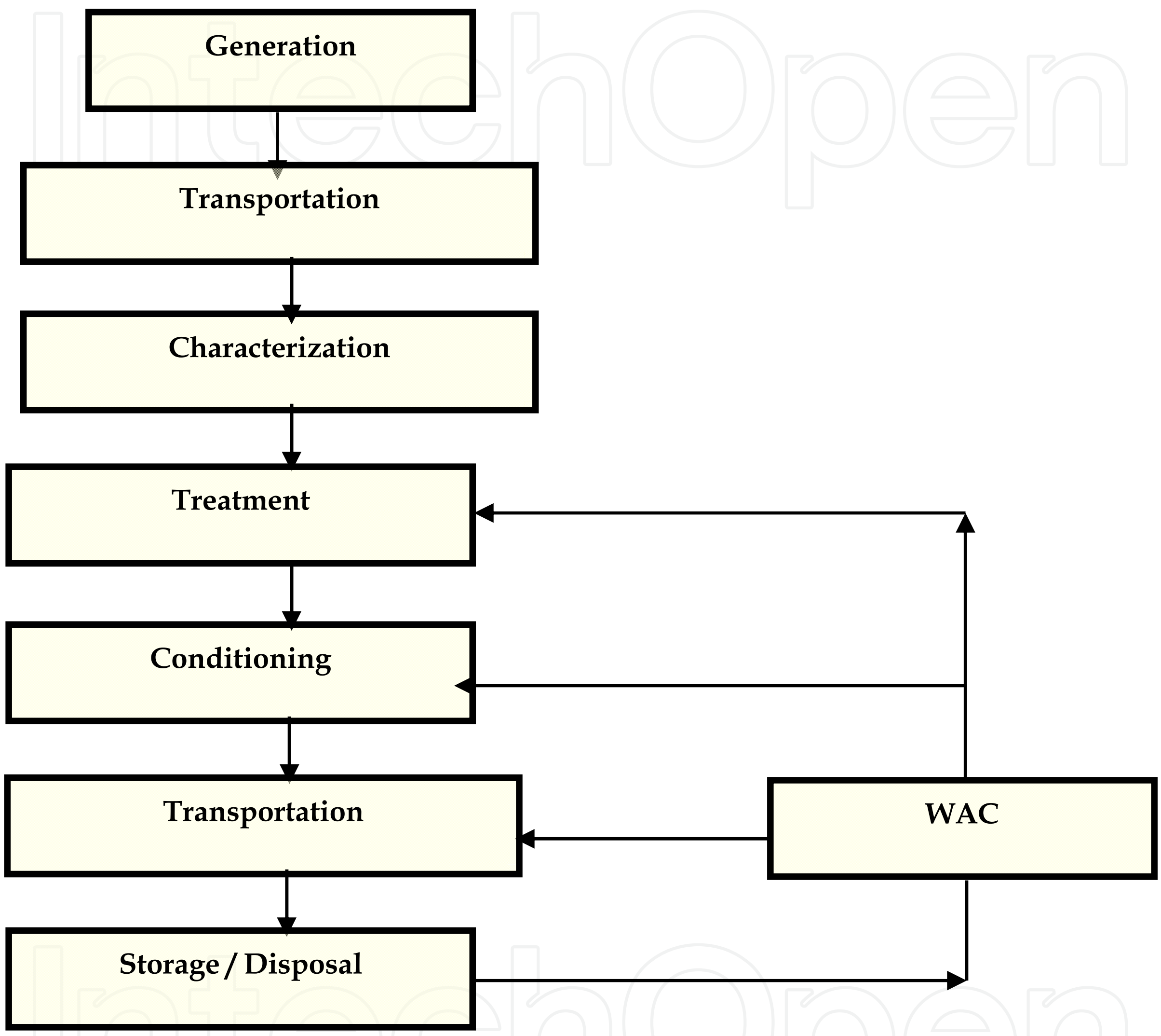

Fig. 1. Radioactive Waste System

Spread of radioactive contamination can lead to creation of secondary wastes, so preventing contamination is consider one of the waste minimization principals. Proper zoning of the facility at the design phase, administrative controls, management initiatives, and selection of decontamination processes are mean keys in reducing the probability of contamination. Finally, the selection of the treatment processes and the utilized chemicals may help in avoiding the production of chemically toxic radioactive wastes.

The recycle and reuse is an attractive method to minimize the generated wastes during the refurbishment and decommissioning of radioactive and nuclear facilities. The decision of selecting this method is dependent on the availability of regulations and criteria, suitable measurement methodology and instrumentation and public acceptance.

The last element in the waste minimization strategies is the optimization of radioactive waste management program that can reduce the volume of the secondary waste. Proper characterization of the generated wastes helps in sorting and segregation of the wastes according to its physical, chemical and radiological characteristics and facilitates the optimization of the treatment option.

4.2 Treatment technical options

Treatment is defined as operations intended to benefit safety and/or economy by changing the characteristics of the waste. The basic treatment objectives are volume reduction, removal of radionuclides from the waste and changing the composition of the waste (IAEA 2003 a). There are various commercial volume reduction technologies; the selection of any of these technologies is largely depending on the waste type. To facilitate the selection of the treatment options, the wastes are classified according to their activity limit (e.g. exempt waste, very low level waste, low level waste, intermediate level waste, and high level waste), chemical properties (e.g. aqueous/organic waste, acidity/alkalinity, chemical stability, redox potential, toxicity), physical characteristics (liquid/solid/gas, density, morphology, compactability and level of segregation) and biological properties. Table 2 lists the commercial technical treatment options for managing different waste classes (IAEA 1999, 1994 a ,2009, Ojovan, 2011).

Liquid aqueous waste	Liquid organic waste	Solid wastes	Gaseous
Chemical precipitation (Coagulation/flocculation /separation)	Incineration	Storage for decay (for very low level wastes)	Filtration
Ion exchange	Emulsification	Compaction	Sorption,
Evaporation	Absorption	Melting,	Scrubbing
Reverse osmosis	Phase separation (e.g. distillation)	Fragmentation	
Membrane processes	Wet oxidation	Incineration	
Evaporation	Alkaline hydrolysis	Encapsulation,	
Electrochemical			
Solvent extraction			

Table 2. Available technical treatment options for different waste categories

4.3 Conditioning technical options

The conditioning activity includes the 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 (immobilization), enclosure of the waste in containers, and, if necessary, providing an over-pack (IAEA 2003 a). The produced waste form must be structurally stable to ensure that the waste does not degrade and/or promote slumping, collapse or other failure. Chemical and physical immobilizations provide the required structural stability and minimize the contaminant migration. Immobilization techniques consist of entrapping the contaminant within a solid matrix i.e. cement, cement-based material, bitumen, glass, or ceramic (R.O. Abdel Rahman et al. 2007 a).

Cementation of radioactive waste has been practiced for many years basically for immobilization of low and intermediate level radioactive waste. The majority of cementation techniques rely on using Portland Cement as the primary binder. Other binders might be used to improve either the mechanical performance of the final waste matrix or to improve the retention of radionuclides in that matrix, these include fly ash, blast furnace slag, bentonite, zeolite and other materials (R.O. Abdel Rahman & A.A. Zaki 2009 a). The implementation of this technique worldwide is supported by its compatibility with aqueous waste streams, capability of activated several chemical and physical immobilization mechanisms for a wide range of inorganic waste species. Also, cement immobilization possesses good mechanical characteristics, radiation and thermal stability, simple operational conditions, availability, and low cost (R.O. Abdel Rahman et al. 2007 a).

Bituminisation is applied to immobilize the secondary wastes resulting from the treatment of low and intermediate level liquid effluents of very low heat generation (< 40 TBq/m^3). The bituminized product has a very low permeability and solubility in water and is compatible with most environmental conditions (IAEA 1998). This kind of immobilization media is restricted for wastes that contain strongly oxidizing components, e.g. nitrates, biodegradable materials and soluble salts. A special care should be given to this waste form during its storage owing to its flammability.

Vitrification is one of the important immobilization techniques which relays on the utilization of glass as immobilizing media, because of the small volume of the resulting waste-form, its high durability and stability in corrosive environments. To ensure the high durability of the produced matrix, the vitrification process should be conducted under very high processing temperatures (>1500 °C), which impose limitations on the immobilized radionuclides and increase the amount of generated secondary wastes. As a result, the most common glasses used in vitrification of nuclear waste are borosilicates and phosphates which use lower processing temperatures (≈1000 °C) while still forming a durable product (M.I. Ojovan & W.E.Lee 2005).

The above-mentioned immobilization technologies are available commercially and have been demonstrated to be viable. The highest degree of volume reduction and safety is achieved through vitrification although this is the most complex and expensive method requiring a relatively high initial capital investment. The potential of using new immobilization matrices were emerged to deal with difficult legacy waste streams. These matrices include crystalline (mineral-like) and composite radionuclide immobilization matrices as well as using thermochemical and in situ immobilization techniques (M.I. Ojovan & W.E.Lee 2005).

4.4 Transport of radioactive wastes

The transport of radioactive wastes includes three stage namely; preparation, transfer and emplacement (IAEA 1994 b). The safety of the transport processes could be provided through meeting the provisions of transport regulations, which aim to protect persons, property and the environment from the effects of radiation during the transport of these materials. Transport regulations include requirements on the waste package that ensure its survival under accident conditions. Depending on importance of the shipped wastes from security, safeguards, and safety point of views, the risk assessment of the transport process might include the following (IAEA 2003 b):

1. Shipment information,
2. Radiological, physical, an chemical characteristics of the waste,
3. Physical characteristics of the package and conveyance,
4. Exposure parameters for the transport workers,
5. Routing data and population characteristics,
6. Frequency and severity of accident for a given transport mode, and
7. Estimation of doses to public

4.5 Storage technical options

Long-term management of spent fuel is becoming of increasing concern, since few decisions are now available with regard to the implementation of their final disposal. This might be attributed to the public perception towards the final disposal of spent fuel and/or the need to gain better insights into the long-term performance of spent fuel and materials. This class of radioactive wastes is currently stored in different storage types. These include, nuclear power plant pools, wet and dry storage facilities. Figure 2 illustrates the capacity and inventories of different types of spent fuel storage (IAEA 2002).

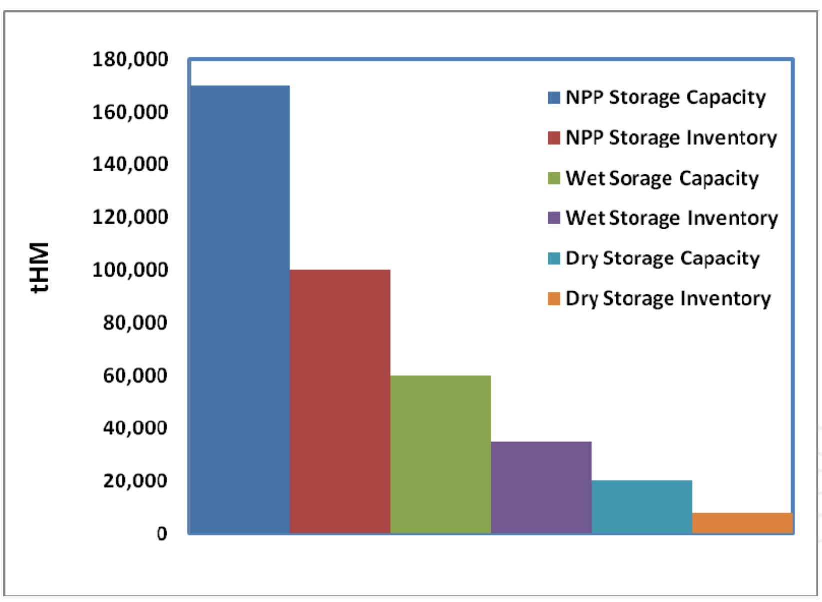

Fig. 2. Comparison of capacities and inventories of different types of spent fuel storage (IAEA 2002)

Interim storage of radioactive waste packages is not only required if the disposal facility is not available but also for wastes those include very short lived radionuclides. The design and operation of storage facilities must comply with the basic safety principles set up on both the national and international scale. To assess the compliance of the storage facility, a licensing process including safety and environmental impact assessments must be part of the waste management system. The main functions of a storage facility for conditioned radioactive waste are to provide safe custody of the waste packages and to protect both operators and the general public from any radiological hazards associated with radioactive wastes. The design of storage facilities should be capable of (IAEA 1998)

1. Maintain the "as-received" integrity of the waste package,
2. Protect the waste from environmental conditions that could degrade it,
3. Keep the external dose rate and contamination limits for waste packages to be accepted by the facility,
4. Minimize the radiation exposure to on-site personnel,
5. Allow control of any contamination from gaseous or liquid releases.

The storage facility may be associated with an area for inspection (including sorting and/or non-destructive examination), certification and labeling of waste packages. The storage facility is usually divided into areas where low contact dose rate packages are stored, areas where packages not meeting waste acceptance criteria (WAC) are stored, and a shielded area where high contact dose rate packages are kept secure (IAEA 1998). The design of the facility usually permits package stacking, sorting and visual inspection. Provision for maintaining a database keeping chain-of-custody for each waste package in storage must be included in the design. Key information about the waste package should include the total radionuclide content, the waste matrix used for immobilization, the treatment and/or conditioning method (as applicable), and the unique package designator. A hard copy file should follow the waste package from conditioning to its final disposal (IAEA 2001 b).

4.6 Disposal technical options

Disposal is the last step in the integrated radioactive waste management, it relay on the passive safety concept. The disposal facility includes waste emplacement area, buildings and services for waste receipt. Its design aims to provide isolation of the disposed waste for appropriate period of time taking into account the waste and site characteristics and the safety requirements (Bozkurt 2001, R.O. Abdel Rahman et. al 2005 a, b). To achieve this aim, the multi-barrier concept that relays on using engineered barriers to augment natural barriers has been developed. The use of engineered barriers helps in ensuring that increasingly stringent design aims are satisfied to an appropriate level (IAEA 1997). This concept helps in avoiding over-reliance on the natural barriers to provide the necessary safety (IAEA 1992 a, 1993 a).

Engineered barriers may consist of a number of separate components, including structural walls, buffer or backfill materials, chemical additives, liners, covers, leachate collection and drainage systems, cut-off walls, gas vents and monitoring wells (IAEA 1992 b). The design criteria for each barrier will differ according to the waste class and disposal type, IAEA have define the main function for the engineering barriers in a near surface disposal type. Those functions are listed in Table 3 (IAEA 2001 c).

Disposal facilities could be place in geological formation or near surface. Near-surface disposal includes two main types of disposal systems: shallow facilities located either above or below the ground surface; and underground facilities, usually in rock cavities. Geological disposal refers to disposal at greater depths, typically several hundreds of meters below ground (R.O. Abdel Rahman et. al 2012). Table 4 lists a summary for underground disposal practices.

Barrier	Function
Container	Mechanical strength, Limit water ingress, Retain radionuclides
Waste form	Mechanical strength, Limit water ingress, Retain radionuclides
Backfill	Void filling, Limit water infiltration, Radionuclide sorption Gas control
Structural materials	Physical stability containment barrier
Cover	Limit water infiltration, Control of gas release, Erosion barrier Intrusion barrier

Table 3. Function of each engineered barrier.

Place	Depth (m)	Type of reservoir
Czechoslovakia		
Hostim	30	Limestone mine
Richard	70-80	Limestone mine waste
Bratrstvi	--	Uranium mine
Germany,		
Asse	725-750	Salt mine
Morsleben	400-600	Potash and salt mine
Swedish Final Repository	50 below Baltic Sea	Metamorphic bedrock
Finland		
Olkiluoto	60-100	Crystalline bedrock
Loviisa	70-100	--------
USA WIPP	655	Rock salt formation

Table 4. Summary of some underground disposal

The optimization of the disposal is done by conducting safety assessment studies. These studies are complex due to the dynamic nature of the hydrological and biological subsystems in the host environment that affects the degradation scenarios of the disposal facility. So treating the disposal as one system is not possible, instead these subsystems are decoupled and divided into modules for which the evolution of the disposal is distinguished into step changes rather than continuous time change [NCRP 2005]. Generally, safety assessment relays on specifying assessment context, describing the disposal system, developing and justifying evolution scenarios, formulating and implementing of models; and finally analyzing the assessment results for each module. During the development of safety assessment, all confidence building tools should be utilized and illustrated (R.O. Abdel Rahman et. al 2011 c).

4.7 Safety of radioactive waste management.

IAEA recommended that assessment studies have to be developed and well adapted to situations of concern to ensure the protection of human health and the environment (IAEA 1993 b). To apply this recommendation, an initial assessment of the planned waste management practice needs to be performed that identifies the radiological sources, foresees potential exposures, estimates relevant doses and probabilities, and identifies the required radiological protection measures. Various methodologies with varying complexity have been and are being developed to assist in the evaluation of radiological impact of nuclear and radioactive facilities. Despite there are differences in the details of these methodologies to correspond to each facility, the general objective of any radiological assessment is to determine the impact of radioactive material on individuals and their environment (R.O. Abdel Rahman 2010). In 2002, IAEA published procedure for conducting probabilistic safety assessment for non-reactor nuclear facilities (IAEA 2002 b). This procedure is consist six interlinked steps, which include

1. Management and organization,
2. Identification of source of radioactive releases, exposure and accident initiator,
3. Scenario modeling,
4. Sequence quantification,
5. Documentation of the analysis and interpretation of the results, and
6. Quality assurance.

The identification of the source and exposure is done through the consideration of source-pathway- receptor analysis at which different aspects are identified i.e. how radio-contaminants released from the studied facility, the pathways along which they can migrate, and their impacts on human. In developing such analysis, it is important to understand that radio-contaminants are transported by air, soil or water through advective or diffusive processes and that the principal means of human exposure is by direct radiation exposure, inhalation of gases or particulates, and ingestion of contaminated food or water (R.O. Abdel Rahman 2010).

To quantify the sequence of the release there is a need to model the release scenario, this could be performed through the development of conceptual model, mathematical model selection, and development or selection of numerical tools. Generally, a conceptual model describes with words and diagrams the key processes that occur within the studied system (or have a reasonable likelihood of occurring). These models can be formulated at varying levels of complexity and realism to abstract the reality (Environment Agency 1999). The developed conceptual model forms the basis for the selection of mathematical models, which in turn govern the selection and creation of numerical models and computer codes (R.O. Abdel Rahman et. al 2009b).

The planning, development and application of quality assurance program for the safety assessment of the radioactive waste management facilities begin with the identification of quality policy then it associates each step in the assessment. Different quality assurance activities should be performed that include sample control, quality assurance for the documentation. In the scenario modeling step, the range, accuracy and precision of equipment used for input data collection must be verified. The personnel should be suitably trained and qualified to perform the data collection step in accordance with standards. Also the utilized computer software must be verified, validated and documented. Computer software must be placed under configuration control as each baseline element is approved and released. Changes to computer software must be systematically evaluated, co-ordinated and approved to assure that the impact of a change is carefully assessed before updating the baseline (USDOE 2003).

4.8 Waste acceptance criteria and quality assurance programs

The waste acceptance is defined as "Quantitative or qualitative criteria specified by the regulatory body or by waste operator and approved by the regulatory body, for radioactive waste to be accepted in a waste management facility "(IAEA 2003). The development of the waste acceptance criteria is carried out in parallel with the development of the waste management facility and is derived from both safety and operational requirements. The compliance with these criteria includes two stages; the first is the definition of the waste characteristics and identification of quality related parameters. This stage is developed by using the results of the safety assessment studies and the operational experience. The second stage is the confirmation of the conformance of the individual waste packages to the WAC, this stage could be checked directly or indirectly by using data sheets that includes information about the preceding waste producer, the waste type, activity, source, description, and radiological characteristics and package identifier number and type if any. The dose and heat rate, surface contamination and the weight are also important parameters that are widely used to confirm conformance with WAC (IAEA 1996). Assurance that a waste package can meet WAC could be provided if the development and design of the management process is carried out under a Quality Assurance Program (QAP).

Inadequate procedure specification and verification of required actions in the selection, design, construction, and operation of individual facilities and processes through the waste management system may lead to a failure in the achievement of waste management goals. The application of a Quality Assurance Program (QAP) to all waste management activities including treatment, conditioning, storage, transport, and disposal is intended to ensure the achievement of the waste management objectives. Within the QAP, there is a need to establish a quality control program that intended to ensure the compliance of the products from the waste management facility with the WAC at the preceding waste management facility and/or meet the regulatory requirements for discharge, transport, condition, store, and or dispose this waste product (R.O. Abdel Rahman 2009 c, 2007 b). The elements of this program are similar to any other program in non-radioactive industry. It includes: organization and responsibilities planning and implementation, personnel training and qualification, existence of procedures and instructions, document control, research and development, procurement, process control, inspection and testing, non-conformance and corrective actions, records, management review and audit.

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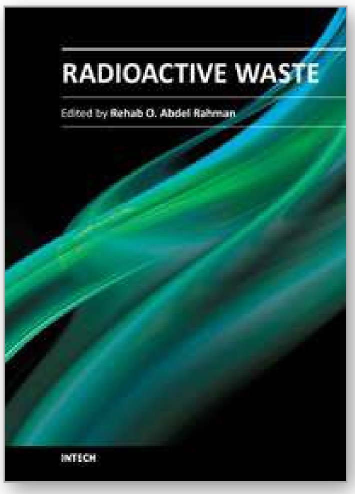

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The safe management of nuclear and radioactive wastes is a subject that has recently received considerable recognition due to the huge volume of accumulative wastes and the increased public awareness of the hazards of these wastes. This book aims to cover the practice and research efforts that are currently conducted to deal with the technical difficulties in different radioactive waste management activities and to introduce to the non-technical factors that can affect the management practice. The collective contribution of esteem international experts has covered the science and technology of different management activities. The authors have introduced to the management system, illustrate how old management practices and radioactive accident can affect the environment and summarize the knowledge gained from current management practice and results of research efforts for using some innovative technologies in both pre-disposal and disposal activities.