Development of a Comprehensive Radioactive Waste Managment Program in the Kingdom of Morocco - 9266

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ABSTRACT

The Kingdom of Morocco has been a signatory of the International Atomic Energy Agency **(**IAEA**)** Joint Convention on the Management of Spent Fuel and Radioactive Waste since 1999. In fact Morocco was the first African country to ratify the joint convention. The Centre National de Energie des Sciences et des Techniques Nucleaires (CNESTEN) has been designated as the lead entity within the country for radioactive waste management. Morocco is in the process of receiving authorization to begin operating a new 2 MW MARK-II TRIGA research reactor at its Nuclear Energy Research Center (CENM) in Maâmora. With the commissioning of the research reactor imminent, the waste management program has been preparing to disposition waste streams from the reactor, associated research operations, production of radioisotopes and anticipated future needs. The center is also the designated collection and storage facility for radioactive waste generated in the country, primarily spent sealed sources.

This paper focuses on developing a radioactive waste management program that meets international standards in a class C country as described in *Selection of Efficient Options for Processing and Storage of Radioactive Waste in Countries with Small Amounts of Waste Generation* [1] (class C countries are countries with research reactors but without nuclear power plants). In building their radioactive waste management program Morocco has made good use of experts from the IAEA and under a Sister Laboratory Agreement has worked with waste management personnel from the United States. This cooperative approach has provided assistance to Morocco in developing a safe and compliant program. Developing waste stream disposition pathways for all possible waste types can be especially challenging given the lack of commercial waste management infrastructure within the country. This paper will detail how waste management decisions are made, the waste management technology that was selected and how waste conditioning methods were developed.

The paper will also discuss the various challenges that class C countries encounter when designing and implementing a waste management program including lack of waste management infrastructure, little or no regulatory framework to guide activities, no waste disposal facilities. The waste management program then needs to be flexible and creative when dealing with these challenges. Morocco has done an exceptional job in cooperating with the international community on the development of their program. In particular Lawrence Livermore National Laboratory (LLNL) in the United States had partnered with Morocco through a sister laboratory agreement on the development of a waste management program. The paper will discuss how this agreement has helped in the establishment of the current waste management program. The resulting outcome demonstrates that a class C country can implement the terms of the joint convention and develop a comprehensive waste management program that meets or exceeds international standards.

INTRODUCTION

In developing its radioactive waste management program the Kingdom of Morocco has adopted a proactive approach, including building provisions for waste management into the design of its premier nuclear research facility. Since there is no final disposal option for radioactive waste in Morocco all waste generated must be conditioned for long-term storage. With the opening of the CENM in 2003, Morocco took a major step forward in providing state-of-the-art radioactive waste treatment and storage capacity to the country. In establishing an effective regulatory framework Morocco has incorporated into regulations governing ionizing radiation basic standards for the management of radioactive waste. A program is currently underway to strengthen regulation of radioactive waste by issuing a set of radioactive waste specific regulations. With the commissioning of a brand new 2 MW TRIGA Mark – II research reactor this year, Morocco is poised to enter a new era in the management of radioactive waste.

Morocco has been a strong supporter of international collaboration on waste management issues. In May 1999 Morocco became the first African country to ratify the Joint Convention on the Management of Spent Fuel and Radioactive Waste. Since then Morocco has applied its growing expertise to become a leader in regional radioactive waste issues and has made use of international technical assistance to improve its own program.

MOROCCO'S REGULATORY FRAMEWORK

One of the challenges facing countries developing nuclear programs is the absence of comprehensive regulations covering the management of radioactive waste. In Morocco there currently are no regulations governing the management of radioactive waste where the responsibilities and the roles of all organizations involved in the process are specified and defined in detail. There is however, a proposed set of regulations signed by the Minister of Energy and Mines which is expected to bring greater clarity to radioactive waste management requirements.

PROPOSED REGULATIONS

Morocco is planning to strengthen it regulatory framework by adopting a set of new waste specific regulations. The proposed regulatory text is based on a model developed from a regional cooperation project of African countries, under the aegis of the IAEA. The proposed text was inspired by this model and was adapted to the national context. The present regulation is applicable to all waste types (solid, liquid, and gaseous) generated by any activity using nuclear materials or radioactive substances. The text covers all stages of the management of radioactive waste generated arising from a wide variety of sources including the medical industry, industrial installations, and research installations. The proposed regulations for the management of radioactive waste address the collection, separation, characterization, treatment, conditioning (packaging), storing, and preparation for transport.

These proposed regulations define the responsibilities of CNESTEN, and the producer of the waste. It also defines the following:

- A system of authorizations.
- Technical requirements applicable to the management of radioactive waste.
- Requirements for the producer and the national organization responsible for the management of the radioactive waste to maintain a register of the radioactive materials and make it available to the relevant inspectors of the corresponding authorities.
- Classification of the radioactive waste.

EXISTING REGULATIONS

Although not as comprehensive as the proposed regulatory set, there are articles (regulations) in various decrees and law, which provide for the management of radioactive waste. Following is brief description of the current regulatory structure:

The first article of Decree No. 005-71 (October 12, 1971) relative to protection against radiation exposure, requires that any manipulation, treatment, storage or the transport of radioactive waste be submitted to a regulatory body for approval.

In Decree No. 2-94-666 (December 7, 1994) addressing the authorization and control of nuclear installations, there are four articles that address the management of radioactive waste. They are:

Article 7: Authorization to Construct - Requires that application for approval to construct must be accompanied by a Preliminary Safety Analysis Report which contains the information on control, handling, and storage of radioactive waste resulting from the nuclear installation.

Article 9: Authorization for discharge of liquid or gaseous radioactive effluents must be sent to the Minister in charge of Energy, accompanied by a document supplying information about the treatment of liquid and gaseous radioactive effluents to maintain the quantity and the concentration of radioactive waste within the prescribed limits.

Article 12: Requests for authorization to operate must be sent to the Minister in charge of Energy, accompanied with a temporary Safety Analysis Report which completes and updates the preliminary Safety Analysis Report. This report must contain information on the conditions of handling and storage of spent fuel and the control, handling, and storage of radioactive waste on the site.

Article 17: Authorization for decommissioning must be sent to the Minister in charge of Energy, accompanied by a document which contains information on:

- Measures taken for decommissioning, including the dismantling, transport, and storage of radioactive components, taking into account the regulation relative to protection against ionizing radiation.

- The important radioactive constituents, which are proposed to be removed from the installation, the estimation of their radioactivity, and the measures proposed for their elimination.

In Article 43 of Decree No. 2-97-30 (October 28, 1997) taken from the application of Law No. 005-71 (October 12, 1971) relative to protection against ionizing radiation, any discharge of radioactive substances to the environment at levels greater than the limits of exemption, is subject to a prior authorization.

Regarding the discharge of radioactive substances to the environment, the operator of the concerned establishment must conduct studies to identify critical groups and the critical exposure pathways. Article 51 of the same Decree stipulates that for authorization to an installation other than a nuclear installation, along with the application the applicant must supply information on measures taken to assure compliance with regulations governing the elimination or minimization of radioactive waste.

In the appendix of Decree No. 2-97-132 (October 28, 1997) concerning the use of the ionizing radiation in medical or dental applications, Articles 13, 14, 15, and 16 of Chapter III address the processes of the discharge and storage of effluents and radioactive waste. The Decree also gives values that cannot be exceeded for the discharge of gaseous and aqueous effluents: four Becquerel (108 Pico curies) per cubic metre and seven Becquerel (189 Pico curies) per litre - these values must be recorded and kept in archives.

For storage, Article 16 requires that installation subject to authorization must have, for the storage of the radioactive waste waiting removal, an outside area of storage of at least 20 square meters, covered, enclosed, and in the regular manner marking out, containing;

- A zone allocated to the radioactive waste put in appropriate drums.

- A zone allocated for liquid radioactive waste kept in appropriate containers.

The *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management* [2], which Morocco ratified in May 1999, stipulates:

- In Chapter 2. Safety of spent fuel management, Article 4, General safety requirements that: “Each Contracting Party shall take the appropriate steps to ensure that at all stages of spent fuel management; individuals, society and the environment are adequately protected against radiological hazards.”

- In Chapter 3. Safety of radioactive waste management Article 11. General safety requirements that: “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.”

Decree No. 2-99-111 (February 26, 1999) authorizing the construction of CENM, Article 6, concerning the management of the radioactive waste states:

- That no storage of radioactive waste will be realized in the perimeter (buffer) area of CENM.

- That the facilities for the management of radioactive waste will reduce the volume and toxicity of the waste generated inside the CENM and those received from the outside. To facilitate treatment, conditioning and storage, the radioactive waste will be sorted by type and by radioactive or radiotoxic harm effect category.

- That shipping of radioactive waste outside of CENM will be controlled and authorized.

- That an inventory of all types of radioactive waste inside the perimeter of CENM, notably indicating their origin, physical and chemical characteristics, mode of conditioning, volume and activity, will be updated by CNESTEN.

CNESTEN

CNESTEN is a government entity created in 1986. CNESTEN operates under supervision of the Ministry of Energy, Mines, Water and Environment and is controlled by an Administrative Board and Technical Committee.

According to the law establishing CNESTEN (No. 3879 March 4, 1987) and signed by the prime minister, CNESTEN has the following missions:

1. To conduct research on energy, basic science, nuclear techniques, and to promote their development with the goal of the implementation of a national nuclear power program and the use of nuclear techniques in different socioeconomic sectors of the country.

2. To make available at the request of the State or for its account, any works or studies necessary for the administration to exercise control over the realization and the operation of the nuclear installations as well as on the management of the nuclear materials.

3. To import, store, and distribute nuclear fuel, CENM maintains a monopoly on the exercise of these activities.

4. To collect and store for the users of the radioactive materials, the radioactive waste resulting from the use of the radioactive materials, in association with providing competent radioactive waste management services.

5. To initiate activities concerning the production and marketing of any processes, equipment, or materials used in nuclear activities, directly or through subsidiary companies created for that purpose.

To meet items one through four above, CNESTEN is responsible for the management of radioactive waste at the national level in Morocco. CNESTEN collects, transports, treats, conditions, and stores radioactive waste generated from operations throughout the country. In order to carry out this mission, CNESTEN has built a radioactive treatment and storage facility at CENM. The facility treats aqueous waste streams by evaporation, and compacts solid waste. After conditioning, the waste is stored in a long-term storage building.

CENM

To carry out its mission, CNESTEN created CENM. It is a 25 hectare facility, located 22 km to the north of Rabat and 15 km east of Kénitra in the forest of Maâmora (see Figure 1 for a layout of the facility).

CENM is a technological complex which houses six scientific and technical modules:
- Reactor Module (2MW Mark – II TRIGA).
- Module on the applications of life sciences.
- Laboratories of instrumentation and the industrial application of the ionizing radiation.
- Laboratories of the application of earth and environmental sciences.
- Laboratories of radiological safety and environmental protection.
- Module of the management of radioactive waste.

The main activities conducted at CENM, are:
- Nuclear medicine and life sciences.
- Industrial applications: Non Destructive Testing (NDT), gauges, instrumentation.
- Water, climate, agriculture and soil sciences, impact studies (air pollution, water and soil).
- Energy.
- Safety and security.
- Radioactive waste management.
- Training and consulting.

Human resources at CENM are:

- 100 professional and engineering staff.
- 70 technicians.
- 60 administrative staff.

CENM has a partnership with:

- Universities and research institutes.
- National stakeholders.
- Non-governmental organizations.
- International organizations (IAEA, LLNL, CEA).

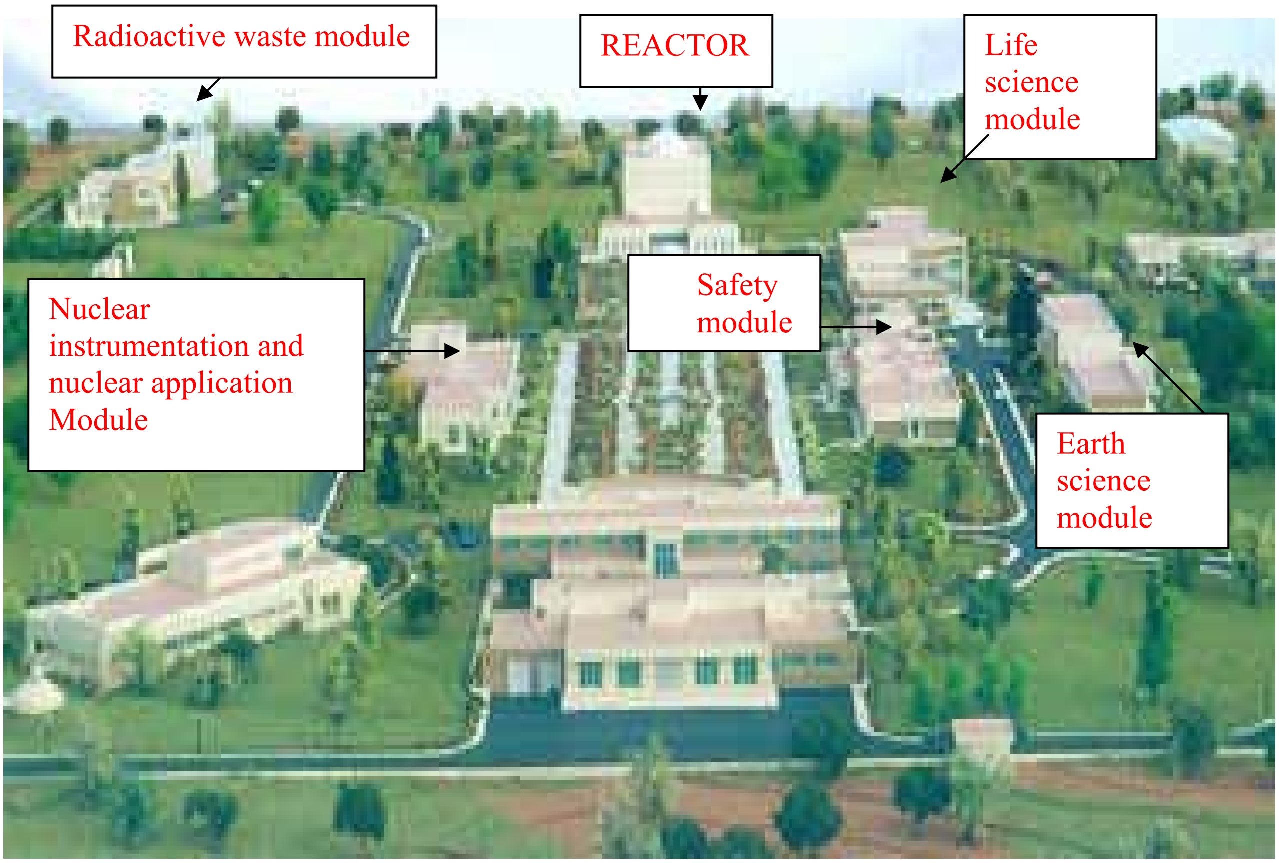

Fig. 1. CENM

GENERAL DESCRIPTION OF WASTE MANAGEMENT FACILITIES

In order to carry out its mission CNESTEN incorporated modern waste management facilities into the design of its nuclear research center. The facilities were designed in such a way as to give maximum flexibility in waste management operations for both current and future waste streams. The treatment facility provides for a controlled and contained environment with all treatment operations conducted in a system of containment. Building air from the treatment facility is filtered through a series of HEPA and carbon filters prior to discharge to the environment. A key component of the waste management strategy was providing for safe and secure long-term storage until a national decision can be made on the disposal of radioactive waste. This is accomplished through both the selection of conditioning and treatment technologies that both reduce volume and provide for a stable retrievable waste form. Another key component of the installation is two laboratories built into the waste treatment building. The analytical laboratory allows for in process testing ensuring the acceptability of incoming waste and the effectiveness of waste treatment operations. The cement laboratory provides for bench scale testing capability for testing cement mixture for long-term conditioning of radioactive waste.

The waste management facility consists of two buildings:

- A treatment building referred to as building DT (surface area at the ground 472.5 m^2) consisting of three levels –4.00, 0.00, +3.50. The underground level houses storage tanks. The ground level houses the evaporation system, compaction system, and the radiochemical laboratory. The first floor houses the offices of the technical staff and concrete laboratory.

- A long-term storage building called DE (280 m^2) consists of four concrete vaults with a capacity of 616 drums per vault.

The DT (Treatment) facility contains:

- An evaporator unit designed to treat five m^3 of aqueous liquid in each campaign the volume of the sludge generated after each campaign is 200 liters.

- A in drum compactor for compactable waste.

- A glove box to sort solid waste.

- A mortar injection system used to condition the sludge generated from evaporator operations in 100 liter drums.

- A drum tumbler to ensure the homogeneity of radioactive waste inside the conditioned drum of sludge.

- Two stainless steel storage tanks for radioactive aqueous waste. Each has a capacity of six m^3 and two additional tanks with a capacity of three m^3 each to store clean effluent waiting discharge to the river.

- A chemical laboratory to characterize radioactive liquid waste.

- A concrete laboratory.

The main characteristics of DE facility are:

- Designed to operate as a long-term storage facility.

- Capacity is 2,496 drums on four levels. The fourth will contain only unconditioned waste.

- Designed to allow for expansion when the current storage is full.

RADIOACTIVE WASTE MANAGEMENT

CNESTEN's approach to radioactive waste management is based on the principle of minimization of the production of radioactive waste (gases, liquid, or solid). In order to minimize the volume of radioactive liquid waste, the following principles are applied:

- Segregation of contaminated waste from liquid waste susceptible to contamination.

- Separation at the point of origin, waste contaminated by short lived isotopes from those contaminated by long lived isotopes.

Solid wastes are sorted at origin of production according to their nature (compactable or non-compactable), activity, and half life, and are collected in shielded bins or in 100 liter drums, lined with a polyethylene or plastic bag.

The nature, volume and activity of solid and liquid waste generated both inside and outside CENM is listed in Table I.

Table I. Description of Waste Types Managed

Waste Type	Description	Maximum Volume m^3/year	Maximum Activity	Radioactive Isotopes
Compactable solid waste	Paper, cotton, gloves, small metallic pieces etc	20	0,37 GBq/m^3 (0,1 µCi/l)	
Non compactable solid waste	Other solid waste	10	3,7 MBq/kg (0,1 mCi/kg)	50% 60Co 30% 137Cs
Aqueous liquid waste	Production of modules R, L, D, T	36	≤1 MBq/m^3 (0,27 µCi/l)	20% Divers short half -life
Organic liquid waste	Oil, scintillation liquid, solvents	0,1	37 MBq/m^3 (1 mCi/m^3)	
Ionic exchange resin		0,1	Normal: 37 MBq/m^3 (1 mCi/m^3) Abnormal: 11 GBq/m^3 (0,3 Ci/m^3)	

THE MANAGEMENT SYSTEM FOR RADIOACTIVE AQUEOUS WASTE

Low activity liquid waste is collected in tanks located in the lower level of each module. After characterization, and according to the technical specification of the radioactive waste management module, the waste is transported in an appropriate tank to the treatment building to be evaporated. After treatment, the clean water is collected in a separate tank for discharge once it complies with the requirements of release. The sludge is conditioned in 100 liter drums with mortar and transferred to the storage building for long-term storage. Table II provides the expected decontamination factor for liquid waste treatment operations.

Table II. Liquid Waste Evaporation

Initial volume (m^3)	**Sludge volume (m^3)**	**Distillate volume (m^3)**
36	1.44	34.56

THE MANAGEMENT SYSTEM FOR RADIOACTIVE SOLID WASTE

The management of solid waste consists of collection, conditioning, and storage. The solid waste is collected from different module in 100 liter drum segregated into two categories compactable and non compactable. The sludge generated from evaporation is injected in 100 liter drum (40 liter of liquid waste) and mixed with mortar prepared outside the module. The mixing operation is ensured by mixing stones placed in the drum. The rotation of the drum is ensured conducted on a drum tumbler.

Ion Exchange Resin

This resin is derived from the purification circuit of the reactor. After neutralization the resin is conditioned in the same way as the sludge resulting from evaporation operation. The resin is placed into a drum and mixed with cement to a predetermined optimized ratio. The drum is then thoroughly mixed on the drum tumbler, after curing the drum is placed into long-term storage.

Radioactive Liquid Organic Waste

It is anticipated that only small volumes of organic liquid waste will be generated. These small volumes will treated by cementation or another suitable stabilization method. Storage will be accomplished in standard 100 liter drums.

Disused Sealed Sources

Spent sealed sources are conditioned in 100- or 200-liter drums according to their overall size. Since sealed sources themselves are of small volume CENM is currently exploring options for the removal of shielding prior to encapsulation. They are immobilized within a concrete matrix.

Contaminated Protective Clothing

The clothes contaminated by short lived isotopes are stored for decay and washed. Those contaminated by long lived isotopes are considered waste and compacted prior to long-term storage.

Sampling System

Liquid waste: The radioactive effluent is sampled after the homogenization of the tank and analyzed to check for compliance with the requirements established by the radioactive waste management unit. The distillate from evaporation operations is sampled and analyzed before discharge to the environment. Limits for treated aqueous waste being discharged to surface waters are specified in a decree signed by the minister of Health, Environment and Energy and Mines.

Solid waste: Sampling is performed to verify that the waste meets waste management units waste acceptance criteria and to ensure the proper segregation of solid waste. Specifically waste being released after decay in storage must be sampled to verify that release criteria have been met. Conditioned waste is visually verified to determine compliance with requirements for stable long-term storage. Representative samples are also subject to a series of physical tests to ensure long-term stability.

WASTE MANAGEMENT PROJECTS CURRENTLY UNDER DEVELOPMENT

Sealed Source Conditioning – CNESTEN is currently engaged in a project sponsored by the IAEA to condition spent radioactive sources by removing the sources from their shielding. This process reduces the total number of drums to be stored.

Waste Tracking System – As part of an agreement with LLNL a comprehensive waste tracking system has been developed. The system was developed by LLNL using commercially available database software. After testing and establishing proof of principle in Livermore an expert mission was organized during which the system was installed at CENM. CENM personnel were then trained in its use and modifications were made to meet the operational needs of the CENM waste management system. The system is designed to be flexible and easily modified by either CENM personnel or LLNL personnel. The system can track waste from the moment it is created through treatment and then to placement in long-term storage.

Ion Exchange Conditioning – Under a similar agreement CENM and LLNL personnel jointly developed and tested a conditioning process for spent ion exchange resins. A recipe was developed and tested at LLNL and then transferred to CENM where it was implemented at both bench and full scale. The process enabled CENM personnel to commission the cement testing laboratory and gain experience on the development of cement stabilization techniques. Test data was actively shared between LLNL and CENM to provide a cross check on method development. Work is expected to continue in this area as CENM develops standards for conditioned waste to ensure compliance with a long-term storage environment.

INTERNATIONAL COOPERATION

Work with the United States under the Sister Lab Program

Morocco and LLNL have participated in an international cooperation agreement for more than ten years. The agreement signed in 1999 detailed a specific partnership between Morocco's nuclear research institution CNESTEN and LLNL. The agreement has been one of the most successful in the international cooperation programs. To date more than 20 expert missions have been fielded to Morocco by the United States. There also have been several IAEA fellowships of Moroccan scientist hosted by LLNL. The fellowships have been especially effective providing hands-on experience in various programs at LLNL. Specific to the waste management program LLNL has hosted two IAEA sponsored fellowships and there have been three expert missions to CNESTEN from LLNL personnel.

Work with the International Atomic Energy Agency

Morocco has been actively involved in work with the IAEA including the following initiatives:

- Training of technical staff.
- Expert missions in various technical areas.
- Providing of equipment for laboratories.

Work in Africa

CNESTEN coordinates eight African Regional Cooperative Agreement (AFRA) projects, including several projects related to radioactive waste management. Under the AFRA sponsored strengthening radioactive waste management infrastructures program CNESTEN has:

- Conditioned radium 226 sources.
- Prepared a model of generic regulations specific for African countries.
- Participated in events organized by AFRA.
- Received expert missions.
- Obtained equipment for waste management use.

FUTURE PLANS/CHALLENGES

The challenges facing the Moroccan waste management program are similar to those of other small countries

Lack of Final Disposal Options requires Robust Waste Conditioning

Not knowing what the final repository requirements will be leads to some uncertainty in the adoption of conditioning methods. CENM has adopted a flexible approach where waste will be conditioned in such a manner that it will remain stable for the next 50 years. This approach will allow adequate time for a final repository to be sited and built. CENM also pursues an aggressive program to reduce the amount of waste being generated including the decaying of short-lived isotopes in storage. Morocco's long-term storage facility is built to meet IAEA standards for radioactive storage facilities. A robust records collection and tracking program ensures that important waste related data is maintained in a retrievable manner. This will allow for any future decisions regarding waste disposition to be made in a fully informed manner. All waste placed into storage is done so in a retrievable manner to ensure that if future plans call for a transfer of waste to a disposal facility this can achieved in a safe and compliant manner.

Discharges to the Environment

As with many countries the discharge of effluents from nuclear installations is subject to not only substantial regulatory oversight but also intense public scrutiny. As CENM moves ahead, regular discharges of compliant waste waters will need to be made. CENM has developed an approach to sampling and analyzing all waste that will be released to the environment and documenting that it is below applicable authorized limits. In addition CENM has worked with both regulators and the public to ensure that a common understanding is reached and the true risks are adequately discussed. This has been and is expected to continue to be an area of significant activity for the CENM waste management program.

Lack of a Commercial Waste Management Infrastructure Requires a Robust National Radioactive Waste Management Program.

In countries with well developed nuclear programs a system of either private or governmental infrastructure is in place to manage radioactive waste. This includes services that are provided across multiple facilities. For example in the United States there are several major companies dedicated to the treatment and disposal of radioactive waste from nuclear power plant operations. This allows for large and expensive treatment operations to be developed and implemented. In a country like Morocco with virtually no commercial infrastructure the task of disposition of radioactive waste falls to the national organization that is deemed responsible, in this case CNESTEN. Without the large economies of scale present in countries with a larger nuclear program the solutions selected for Morocco have been purposely derived from well developed methods. For example the selection of the use of cement stabilization techniques for the management of radioactive sludges was based in part on the long history of the use of the treatment method in the nuclear waste management.

SUMMARY

With the commissioning of the 2 MW TRIGA Mark-II research reactor expected shortly Morocco will enter a new phase in the operation of it radioactive waste management program. Because of substantial planning and foresight Morocco has designed and built a modern waste management program that will allow for its scientific community to fully exploit the benefits of this new research tool. The key to developing a waste management program has been strong support from the leadership of CNESTEN to ensure that modern facilities were incorporated into the design of the CENM and that adequate resources were made available to the CENM waste management team. Another key component has been the extensive use of international cooperation that has allowed Morocco to build a program that takes the best from other programs around the world and customizes it into a program that is unique to Morocco. The Moroccan experience demonstrates that a country with limited resources can implement the terms of the

Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management [2] in a real and tangible way.

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