

OVERVIEW OF MANAGEMENT OF LOW AND INTERMEDIATE LEVEL RADIOACTIVE WASTES IN CUBA

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ABSTRACT

Cuba has been firmly committed to the peaceful applications of ionizing radiations in medicine, industry, agriculture and research in order to achieve socioeconomic development in diverse sectors.

Consequently, the use of radioactive materials and radiation sources as well as the production of radioisotopes and labeled compounds may always produce radioactive wastes, warranting safe and proper management. The Center for Radiation Protection and Hygiene (CPHR) is responsible for developing and implementing a national centralized strategy for the collection, transportation, handling, treatment, conditioning, long term storage and disposal of radioactive waste, as well as for developing new waste conditioning and containment methods.

The current national strategy involves the use and development of storage and conditioning facilities and a continuous programme of research and assessment to ensure that each type of waste is managed in the most appropriate way. The Cuban waste management system comprises the operational capability for dealing with radioactive wastes and the regulatory capability for controlling the way in which it is deal with.

At present there are some projects in progress related with radioactive waste management, including the establishment of requirements and methods for waste package acceptability, conditioning of organic liquid wastes, etc. The development of methods for Quality Assurance and in particular for Quality control has also become an important issue. Effort is now focusing on the conditioning of all stored non-conditioned radioactive wastes and the safety assessment of the long-term storage facility for conditioned wastes.

The Cuban specialists on radioactive waste management have gained experience in radioactive decontamination and decommissioning of small nuclear facilities. This experience was also applied in external mission within Latin-America region.

ORIGIN OF RADIOACTIVE WASTES

The wastes arisen from the applications of radioisotopes in medicine are mainly liquids and solid materials contaminated with short lived radionuclides and sealed sources used in radiotherapy and for sterilization of medical materials. Radioactive wastes from industrial applications are generally spent sealed sources, which were used in level detection, quality control, smoke detection and non-destructive testing. The principal forms of wastes generated by research institutes are miscellaneous liquids, trash, biological wastes, and scintillation vials, sealed sources and targets. Solid radioactive wastes are mainly produced during research works, cleaning and decontamination activities and they consist of rags, paper, cellulose, plastics,

gloves, clothing, overshoes, etc. Laboratory materials such as cans, polyethylene bags and glass bottles also contribute to the solid waste inventory. Small quantities of non-compactable wastes are also collected and received for treatment. They include wood pieces, metal scrap, defective components and tools.

The collection of wastes consists in their transference from the place of origin to the place where they will be treated and/or stored. Collection is made periodically by the Center for Radiation Protection and Hygiene (CPHR) and transportation is carried out in accordance with the actual Regulation. Radioactive wastes are qualitatively classified and segregated according to their composition and established methods for treatment and conditioning.

CLASSIFICATION OF RADIOACTIVE WASTES

According to Decree No.142, Article 133 (1), liquid wastes are considered radioactive if the concentration of radioactive materials in them is higher than maximal permissible concentration for ordinary water, defined in Cuban Basic Safety Rules (2). According to Article 134, solid wastes are considered radioactive when: a) the specific activity is higher than 74 KBq/Kg for β -emitters, b) the specific activity is higher than 3.7 KBq/Kg for γ -emitters, and c) the specific activity is higher than 7.4 KBq/Kg for α -emitters (for transuranic wastes (TRU) higher than 0.37 KBq/Kg).

A widely used qualitative classification system separates radioactive wastes into three classes: Low Level Waste (LLW), Intermediate Level Waste (ILW) and High Level Waste (HLW). In Cuba there is not any HLW at all. LLW was defined in the past to mean radioactive waste that does not required shielding during normal handling and transportation. Radioactive waste that requires shielding but needs little or no provision for heat dissipation was classified as ILW. As quantitative values, liquid wastes with specific concentration between 37 KBq/m³ and 3.7 GBq/m³ are considered LLW and from 3.7 GBq/m³ up to 370 TBq/m³ are considered ILW. For solid wastes, a contact dose rate of 2 mSv/h is used to distinguish between the two classes.

An updated inventory of stored wastes is kept at CPHR. The current inventory of stored radioactive wastes and inventory of spent sealed sources are presented in Table 1 and Table 2, respectively.

Table 1. Volume of radioactive waste in the Storage Facility

Type of waste	Volume
Liquid	2,8 m ³
Solid	11,5 m ³
Conditioning by cementation	6,5 m ³
Spent Sealed Sources	9 603 u

Table 2. Spent Sealed Source Inventory

Nuclide	Activity	Quantity	Nuclide	Activity	Quantity
²⁴¹ Am	38 GBq	7 114	²³⁹ Pu	1 GBq	18
Am-Be	80 GBq	5	Pu-Be	960 GBq	4
¹³⁷ Cs	75 TBq	494	¹⁵² Eu	3 GBq	3
⁶⁰ Co	200 TBq	123	⁹⁰ Sr	16 GBq	12
²²⁶ Ra	22 GBq	1 500 ^b	⁹⁰ Sr - Y	5 GBq	193
¹⁰⁹ Cd	67 MBq	3	³ H	40 GBq	4
²⁵² Cf	^a	1	¹⁹² Ir	^a	109
²³⁸ Pu	9 GBq	14	⁸⁵ Kr	4 GBq	6

- a. Sources of unknown activity
- b. This is an estimated number of sources

RADIOACTIVE WASTE MANAGEMENT POLICY AND INFRASTRUCTURE

The first steps for the control of the radioactive waste in the country were given up with the creation, in 1979 of the Cuban Atomic Energy Commission (CEAC) and subsequently the Executive Secretariat for Nuclear Affairs (SEAN). In 1982 the inventories of all radiation sources and users of radioactive materials in the country were carried out. By the year 1984 the inventories were revised and updated. A Circular, addressed to all users of radioactive materials, prohibiting the direct discharges of radioactive wastes into the environment, was issued during 1985. The construction and implementation of adequate storage facilities at the institutions was demanded.

Since 1994 the Cuban integral policy of nuclear development is entrusted to the Nuclear Energy Agency of the Ministry of Science, Technology and Environment (CITMA). This Ministry assumes the functions of the former CEAC. The National Center for Nuclear Safety (CNSN) is responsible for the licensing and supervision of radioactive and nuclear installations. The Center for Radiation Protection and Hygiene is in charge of waste management policy. The management and disposal of radioactive wastes in Cuba are controlled by a Decree that regulates the work with radioactive materials (1) and a Practice Guide that establishes the methods for segregation, registration and control of radioactive waste (3). CPHR is responsible for centralized collection, transportation, treatment, conditioning, long term storage, and disposal of radioactive waste, as well as for developing new waste conditioning and containment methods.

All operations and conditions associated with the transportation of radioactive wastes from nuclear applications and waste packages are well identified, controlled and documented, as it is demanded in Cuban Decree No. 137 (4). The conditioned waste packages must satisfy the requirements for the safe transport of radioactive materials specified in reference (5). The regulations for import, transit and export of radioactive materials, as well as the requirements for issuing special permits for performing these activities are established in the refereed Decree.

Resources are needed for the implementation of a national waste management legislative regime. These resources are the same or shared with the ones needed for a general radiation protection in the country. Financial resources for the national plan for radioactive waste management are

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provided from the national budget, and by users of the services offered by the CNSN and CPHR. The government will cover the expenses related to the long-term activities (essentially the near-surface long-term storage).

RADIOACTIVE WASTE MANAGEMENT FACILITIES

The facilities for Radioactive Waste management include buildings and laboratories as well as facilities for treatment and storage of radioactive wastes. They have been designed to comply with the current radiological regulation in Cuba.

Waste Treatment and Conditioning Plant

The present facility was described in a previous paper (6). It is a building that includes a technological area of 100 m² and a laboratory area with a surface of around 30 m². Other areas to be distinguished inside the treatment plant are: Office, Clothes Change Room, Storage Area for Decay, Reception and Segregation Area. The Technological Area includes 4 zones: Liquid Waste Treatment Zone, Zone for cementation of non-compactable solid wastes and spent sealed sources, Compaction Zone and Control zone for conditioned drums. The Laboratory Area is adequate for quality and process control. Researches to support the technological process in the plant are carried out in this laboratory.

The necessary equipment for waste characterization, radiation protection as well as for quality and process control is available at the Waste Treatment and Storage Facility. This equipment has been supplied under the IAEA Technical Co-operation Project CUB/9/010 (7). The acquired equipment was: Compression Tester: to perform compression tests on cement specimens used for immobilization of radioactive wastes and spent sealed sources. Mortar Mixer fitted with automatic controller and automatic sand dispenser: for preparation of cement mortars in the laboratory during the studies for selecting the adequate formulation of mortars. Vicat Apparatus: to determine both the initial and final setting times. Marsh Cone for consistency control (Sieve Funnel): used to determine the bulk density of cement. Liquid Scintillation Counter: for sample characterization, and the following equipment for radiation and contamination monitoring: Portable Contamination Monitor Contamat FHT 111M, Portable Ratemeter with Pet-Pet cable, RDS – Multipurpose Survey Meter and Aerosol Contamination Monitor.

There also are available some instruments and equipment for emergency situations. In the CPHR there is a Secondary Laboratory for Dosimetric Calibrations.

Radioactive wastes from nuclear applications are conditioned by cementation. Drums of 210 liters have been used for conditioning radioactive wastes and small spent sealed sources. The drums for immobilization of spent sealed sources are prepared with concrete. A mould of proper size is used for this purpose. Compactible wastes are compacted in 60 liters metallic drums, which are placed in 210-liters drums.

Liquid radioactive wastes are directly immobilized in 210 drums using cement mortar.

Storage Facility

The storage facility is located in a sparsely populated region - Managua. There are about 11 000 inhabitants living within a radius of 5 km. It is an area of low seismic activity and is not subject to surface flooding. The climate of the region is humid.

The facility is a construction above the original ground surface as an earth-covered mound. The storage design includes the use of engineered barriers, according to the site-specific conditions. The facility is a concrete building with two compartments (21m x 6m x 4.5m). One of them is occupied by approximately 11.5 m³ of solid and 2.8 m³ of liquid wastes, which are mainly contaminated with ³H, ¹⁴C, ¹³⁷Cs and ⁶⁰Co. In the same compartment there also are thirty 200-liter drums (6m³) containing conditioned liquid wastes. The other compartment is occupied by around 9 600 spent radiation sources. Up to date radioactive wastes and spent sealed sources are collected and stored in the facility without conditioning. Inventories of stored spent sealed sources and radioactive wastes are available, including radionuclides, type of waste, activity, identification and place of their present storage. The estimated capacity of the storage facility is about 200 m³. According to the storage capacity and an optimal distribution of conditioned wastes, Cuba can guarantee a low level waste interim storage for a period of 30 years (6). Waste packages should be stored in a safe and well organized manner to facilitate later retrieval for transport and final disposal, as it is recommended in the IAEA publication (8).

MAIN ACTIVITIES IN RADIOACTIVE WASTE MANAGEMENT

Taking into consideration our particular situation it is necessary to perform some research and development activities. The CPHR specialists are conducting R & D on problems of local nature as it is not always possible to transfer technology from other countries that are completely adaptable.

• *Radiological Characterization of Unknown Spent Sealed Sources*

More than 9 000 spent radiation sources were collected and stored up to 1999 into the Centralized Storage Facility for radioactive waste. The radiological characteristics of around 200 of these sources were unknown, although they were well registered in the national waste management inventory and in the control system of the storage facility. The study for characterization of these sources included the determination of radionuclide, activity, identification number and the type of source. The absence of external contamination was verified, the dose rate was measured, and the spectrum of each source was analyzed. Two Gamma Ray Spectrometric Systems, one of them portable were used for this purpose. The methodology applied for identification and characterization of the sources, as well as the obtained results are described in procedures and registered under the Quality Assurance Programme in Radioactive Waste Management.

• *Characterization of Low Level Liquid Radioactive Wastes*

A research project to define a methodology for conditioning of radioactive liquid wastes was carried out. The first task of this project was the characterization of liquid wastes. This study comprised the determination of radionuclides, phase (organic or aqueous), pH and sulfate contain. More than 150 samples were analyzed. A Gamma Ray Spectrometric System has been used to determine the present radionuclide for γ emitters. A Liquid Scintillation Counter has

being used for β emitters. According to the radionuclide present in wastes and the activity contain, it was estimated that around 1 m³ of stored wastes could be discharged. The others need to be conditioned. The methodology applied for characterization of liquid wastes, as well as the obtained results are well described in procedures and well registered under the quality assurance programme.

• *The Radioactive Waste Repository Project*

According to the perspective to conclude and operate the Juragua Nuclear Power Station and development of nuclear applications, the establishment of a suitable disposal facility in Cuba is justified. The specialists of the Nuclear Technology Center (CTN) are working in the conceptual design of the facility. Some studies, which include the waste characteristics, the design of the repository, the waste packages, the studies for sitting and performance assessment in a preliminary stage are going on. A technical-economical study for the repository was performed (9). The radioactive wastes foresee by project from operation and maintenance of two WWER-440 reactors and from nuclear applications in the country had been considered in the studies. The expected annual quantity of low level wastes (in 210 liters) are 645 of solidified, 80 of compacted solid, 540 of solid and 105 of ionic exchange resins. The expected annual quantities of Intermediate level wastes are 80 ionic exchange resins and 470 of solids. The principal radionuclides involved are Cs-137, Fe-55, Co-60, Mn-54, Cr-51, Co-58, Sr-90 and Zr-95. The repository designed in Cuba consists of a centralized facility to dispose of the conditioned low and intermediate level radioactive wastes from Juragua NPP and nuclear applications. The characteristics of Cuban nuclear programme, the national policy, the economical, climatic, geological and geographic considerations, as well as the constructive experience in the country influenced the repository design.

The facility designed is located in a stable geological formation, considered in rock cavities near subsurface. The sector is located in massive granite in the Central Region of the Country. The sector is little mountainous, with medium height between 40 and 70 m over sea. The repository has opening and access by 3 vertical pits of 270 m between each other and connected by one gallery for its ventilation and personal transit. The central pit, will be technological pit to transport the conditioned wastes and the extreme pits will be auxiliaries, to ventilate the underground construction. This construction will be up to – 30 m, with a structure of 8 burial horizontal vaults to dispose radioactive wastes. Three vaults for containers of intermediate-level radioactive wastes, 4 vaults for metallic drums of low level radioactive wastes and also 1 vault to dispose any radioactive wastes from accident situations. The design foresees the possibility to dispose radioactive wastes in the transport gallery. The repository structure encompass 552x300 m area of underground construction and the capacity will be 12 150 m³. The performance assessment of the defined disposal system was performed in a very preliminary stage. The methodology used included the characterization of the system, analysis of scenarios, analysis of consequences and analysis of uncertainties. In the characterization of the system, the near field, remote field and biosphere was also evaluated. The design system, foresee a facility in near surface located in granite rock cavity where natural and artificial barriers will be used.

• *Conditioning of Radioactive Wastes and Spent Sealed Sources*

The procedures for treatment and conditioning of solid and liquid radioactive wastes were developed under Nuclear Agency Project PRN/1/09 (10). Compaction was considered for the

treatment of solid compactable wastes. Aqueous liquid wastes will be directly immobilized by cementation. Conditioned radioactive wastes should comply the requirements for long term storage and the requirements for IAEA type A packages (11,12). The procedures for immobilization of spent sealed sources were established and proved. There is a prototype of conditioned drum for each kind of sealed source. One of the main activities was the conditioning of radium sources.

• *Establishment of the Quality Assurance Programme for the Radioactive Waste Management Service*

A Quality Assurance Program (QAP) is being developed in order to guarantee that activities and services provided by CPHR were satisfactory fulfilled. The Radioactive Waste Management Service comprises the centralized collection, transportation, segregation and temporary storage of radioactive waste. The procedures for these operations and the inventory system to registry radioactive waste and to control the performed activities have been developed and implemented. The Programme also considers other aspects necessary to guarantee and demonstrate that the required quality has been achieved. The QAP involve a Quality Policy, an Organizational Structure, Definition of Responsibilities and a Quality Control System.

• *Establishment of Requirements and Methods for Low Level Waste Package Acceptability*

At the end of 1998 the general procedures and instructions for conditioning of radioactive wastes were be established. As a disposal strategy has not been defined yet, radioactive wastes will be packaged for interim storage. Such conditioned wastes include those awaiting further disposition. A new Research Project related with the establishment of General Acceptance Criteria for long term storage of conditioned radioactive wastes began in 1999 (13). The CPHR in conjunction with the national regulatory authority is responsible for the establishment of these criteria. In order to avoid radiological and economic impacts of unnecessary reconditioning, waste conditioning strategies have considered the requirements for long-term storage and further transportation. Development of waste acceptance criteria should be carried out in parallel with the development of safety analysis of Cuban long term Storage Facility.

• *Safety Analysis for Cuban Long Term Storage Facility*

The Cuban Nuclear Programme will generate approximately 120 m³ of conditioned wastes (waste packages including matrix and container for disposal) at the end of 2 030. According to the storage capacity and an optimal distribution of these waste packages, the Storage Facility will be fulfilled at that year. Most conditioned wastes, in terms of activity content and volume will be spent sealed sources. As a final repository to receive waste packages has not been defined yet, the existing Storage Facility will operate as a "long term" storage facility of conditioned wastes. Because of that, the long-term safety of this facility has to be evaluated. For this reason, a new Research Project will begin next year (14). Some aspects relating with the Site Characteristics (geography, meteorology, climatology, geology, hydrology), Facility Design, Construction, Operational Aspects, Waste and Container characteristics, Radionuclide release under normal and unusual operation conditions, the Assessment of impacts and the long-term stability will be detailed studied and evaluated. Some important parameters of waste packages: mechanical strength, resistance to impact, radiation stability, chemical durability, fire resistance and containment should be assessed and demonstrated. Finally a Safety Analysis Report (SAR) will be prepared according with the IAEA recommendations.

• *Decommissioning of the brachytherapy facility at the INOR, Havana.*

The National Institute of Oncology and Radiobiology (INOR) used for many years Radio-226 sealed sources for brachytherapy service. Brachytherapy is radiotherapy in which the radiation sources are virtually in direct contact with the tumor, either externally or internally, so as to produce carefully defined irradiation at very short distances. For safety reasons and according to international recommendations, the use of Ra-226 in medicine has been excluded and these sources are substituting by other radionuclides (mainly Cs-137, Co-60 and Ir-192). Therefore, most Ra-226 sources were collected from the hospital in 1996 and they are now storing in the National Centralized Storage Facility for radioactive waste. For technical reasons, all Radium sources could not be evacuated this time from the place where they were stored in the hospital. Some of them were leaking and it caused the contamination of the area and other things stored in this place: containers, medical materials and instruments, etc. In May 1997 the Direction of the hospital asked the CPHR to evaluate the radiological situation in the contaminated area and to carry out the decontamination and decommissioning of these locals.

Once this is the end of the facility's useful life, the decommissioning took place to retire the facility from service.

The radiological evaluation of the area was carried out immediately. After the necessary conditions were created, in June 1999 took place the decommissioning and decontamination of this facility. The institution received the authorization to perform this work through a License for Definitive Closing from the Regulatory Body. The work was carried out in a manner that provided adequate protection for the health and safety of the decommissioning workers, the general public and the environment.

136 spent Radio-226 sources were found, some of them inside the PVC tubes and the others directly in the sand. These sources were conditioned, according to procedures described in previous paper (15).

The safe, effective and cost efficient strategy used for decontamination and decommissioning granted the minimization of secondary radioactive wastes. The following quantities of wastes were generated:

Non-radioactive wastes: around 5 m³ (sand, tubes, wood, etc.).

Radioactive Solid Wastes - Compactable – 0.4 m³ (PVC tubes, gloves, rags, paper)

Radioactive Solid wastes – non-compactable - 1 m³ (wood, lead containers, and sand)

The dose rate levels reached in the area after decontamination was less than 0.1 μSv/h.

The surface contamination was less than 0.4 Bq/cm².

According to the radiological levels reached after the decommissioning and decontamination of the brachytherapy facility, the area is acceptable for unrestricted use, therefore the locals will be used as offices.

Expert Missions in Latin-America Region

• *Radioactive Decontamination of brachytherapy areas at Oncology Institute “Dr. Heriberto Pieter” in Dominic Republic*

During the inspection at the Oncology Institute “Dr. Heriberto Pieter” in June 1996, the National Commission of Nuclear Affairs detected a radioactive contamination. The aid of IAEA was requested for the decontamination. The IAEA sent experts from CPHR to perform this task. The radionuclide in contaminated areas was ^{137}Cs . All the removable contamination was eliminated as well as the source of contamination. Because of non-removable contamination, 26 m² of the floor was demolished. The procedures applied guaranteed a dose rate level and a surface contamination at the natural background. Therefore the decontaminated areas can be use for any purpose without any Radiation Protection restriction.

• *Radiological Characterization and Relocation of Radioactive Wastes at the INEA – Colombia*

The Instituto de Ciencias Nucleares y Energías Alternativas (INEA) was responsible for radioactive waste management in Colombia. Under IAEA Cooperation Project COL/9/005 Cuban specialists carried out the radiological characterization of the working areas destined for radioactive waste management at INEA facilities. The unknown radioactive wastes stored were also radiologically characterized. After characterization and adequate segregation of stored radioactive waste the relocation of wastes was performed.

• *Conditioning of Spent Radium Sources for Safe Long Term Storage in Colombia*

The IAEA's Spent Radiation Source Programme was established in 1991 with the specific purpose of assisting developing Member States in their efforts to prevent unnecessary exposure and accidents with spent sealed sources. One activity specifically related with the conditioning of radium sources is included in the programme.

Radium conditioning activities were carried out at INEA, Colombia. The National Institute of Cancerology (INC) was the largest user of radium sources in Colombia. The radium source inventory at INC included 114 sources with a total activity of 12.3 GBq (308 mg), all of them from medical applications (needles, tubes, cervical applicators and plates). The sources stored at INC, were brought to INEA for conditioning. The transportation was carried out in accordance with national transport regulations. A concrete filled drum was prepared for the conditioning and 16 stainless steel capsules were used for encapsulation of radium sources. The dose rate at 1 meter was measured during conditioning; in order to control and verify the activity accumulated in each capsule. The loaded capsules were placed into two lead-shielded containers and then they were covered with the corresponding shielded lids. The design of the shielding container considered the total activity of the sources to be stored, retrievability, physical security, radiation protection and storage period. The containers with the capsules were placed in the center of the previously prepared concrete-filled 200L drum, placed one over the other onto the iron cylinder, which had been used as mould. Finally 147 spent radium sources were conditioned, with a total activity of 19.3 GBq (482 mg of Ra). The performed conditioning process permits further conditioning if it is required before, for example, disposal. The work carried out promoted international cooperative efforts aimed at solving spent radium sources issues related to their conditioning and safe long-term interim storage (16).

CONCLUSIONS

Cuba is giving attention to radioactive waste management, while the nuclear program is developing.

The Cuban Radioactive Waste Management program includes all elements of an integrated system, that means laws and regulations, operating and regulating organization, systems for processing, storage and disposal of radioactive wastes.

Owing to the final repository for LLW is not in operation yet, all radioactive wastes arising from nuclear facilities should be treated and stored at WTSF. Therefore, there is continued reliance on interim storage method for the management of LLRW in Cuba. The existing WTS Facilities guarantee a rational management of radioactive wastes generated in Cuba at present.

In parallel with the operation of these facilities, an R&D program is in progress, covering different aspects of radioactive waste management.

The gained practical experience in radioactive decontamination and decommissioning of small facilities is one of the most important achievements of the nuclear programme in Cuba.

Cuban specialists have carried out some IAEA expert missions in order to improve the radioactive waste management in other countries in Latin America.

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