Management of disused radium sources in Latin America and the Caribbean

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ABSTRACT

This paper describes the radium sources conditioning operation carried out in Latin American and the Caribbean by a team of the Brazilian federal research institute CDTN, as part of an International Atomic Energy Agency's hands-on assistance project to safely condition disused sources in developing countries. This initiative was spawned by the perceived hazard associated with the use of radium sources, caused mainly by the high likelihood that these sources leak during their use due to the accumulation of the radon gas in their interior. The conditions under which these sources are often stored in the target countries, without proper documentation, mixed with different radiation sources and under precarious conditions, urged the Agency to start this program at the end of 1996. The conditioning process starts with a pre-mission to the candidate country, when a place is selected for the forthcoming operation, suggest improvements in the local available infrastructure is suggested and gather the most complete information available about the country's source inventory is collected. The operation consists of transferring the sources from their original shields to sturdy multi-barrier packages, which are put under the control of the local nuclear authority. As part of the quality assurance program applied to this project, the relevant information about the conditioned inventory is recorded and made available to the host country, to the IAEA and to the conditioning team.

INTRODUCTION

It is estimated that several hundreds of thousands of radium-containing sources, mainly for medical uses, were produced and distributed all around the world for more than 50 years. When other radioisotopes became available after the 1950s and it was realized that radium sources were prone to leaking, the production and trading (or cost-free distribution) of radium sources was halted. The huge amount of disused sources, often improperly kept at hospitals and clinics, became a looming threat as regards site contamination or unnecessary people irradiation. The inadequate storage conditions often found include: disused radium sources not segregated from sources still in use; sources not positively identified as radium sources (and most commonly mistaken for cesium sources); shields overloaded, presenting high surface dose rates; sources stuck inside old rusted shielding devices; and shield contamination due to long periods of immersion in water or sludge. Even when radium sources are stored at a centralized facility under the supervision of the local nuclear authority, scarce dependable information is available on their activity, origin or physical condition.

The increasing awareness of the potential danger of this situation materialized in a project sponsored by the International Atomic Energy Agency – IAEA – aiming at conditioning all radium sources existing at countries lacking the proper means for dealing with this problem on their own. Recognizing that the long term disposal of radium will demand a more careful study – and, most probably, a costly engineered geological facility, the project was devised as a management practice to solve an immediate waste problem for the few decades to come.

Within the scope of this initiative, the Brazilian nuclear research institute CDTN – Centro de Desenvolvimento da Tecnologia Nuclear – has been chosen by the IAEA to provide the conditioning team for Latin America and the Caribbean. This team is made up of three people, a technical and administrative coordinator, a radiation protection supervisor and an experienced TIG welder. Since the beginning of operations in this region, in December 1996, ten countries have benefited from this hands-on assistance and the total activity already conditioned reaches 406 GBq (approximately 10,970 mg of radium), or almost 2,200 sources. This inventory is currently conditioned in 23 packages, produced during the operations according to an established quality assurance program.

A detailed description of the technical aspects of the conditioning operation was presented before (1). This paper, although briefly describing the technical aspects of the conditioning procedures and results achieved, focuses more on the managerial characteristics of the operations.

REASONS FOR THE PROGRAM LAUNCHING: NON-COMPLYING SITUATIONS FREQUENTLY FOUND

The very nature of this conditioning project implies that the recipient countries lack the necessary infra-structure, resources and manpower to properly manage their disused radium stock. It is therefore to be expected that several situations were to be found during the operations which did not meet the desired standard for radioactive waste storage. Some of the most frequent are discussed below.

The most common mismanagement practice observed was the storage of different types of sources in the same place, without proper identification. Cobalt teletherapy units, radium or cesium brachytherapy needles and tubes, cobalt, iridium or strontium industrial irradiators, calibration sources and americium lightning rods could be found within the same room without adequate sorting criteria. Figure 1 illustrates a situation commonly found.

Figure 1. A typical storage room for sealed sources.

Also very common is the lack of proper documentation or the complete absence of information concerning the national radium inventory. The absolute majority of the radium brachytherapy sources were donated to Latin American and Caribbean countries by international organizations in the 1950s and 1960s and the accompanying records were not preserved. In some instances the local authority compiled the available data on the national radium sources inventory – in which case, they were made available to the conditioning team – but even this information was rarely completely dependable.

As regards the shielding devices used for the source's storage, their most remarkable characteristic is the lack of standardization in terms of size and features. Small pots, cubic shields with drawers, devices provided with only one cavity or dotted with an array of narrow vertical ducts, and large safes have been used to condition the sources. This represents a challenge for the conditioning team, pushing it into devising adequate approaches for extracting the sources from their original shield without taking unnecessary doses or inflicting damage to the sources.

Similarly the physical condition of some shielding devices – especially the old ones – frequently poses additional difficulties for the team. Depending on the storage environment they were submitted to, corrosion can have taken place and made lids or sources get stuck to the shield's main body or inside the shield. If leaking sources existed, the rusted surfaces that eventually got contaminated can not be easily decontaminated and the whole shield has to be conditioned (separately from the sources) as secondary radioactive waste. Figure 2 shows a safe which contained radium sources and had been stored in a flooded concrete pit for a long period, along with other shields; the presence of leaking sources entailed the contamination of all items (the safe's opening mechanism was inoperative due to the severe rusting developed; its door's hinges had therefore to be cut open).

Figure 2. Contaminated safe.

DESCRIPTION OF THE CONDITIONING PROCESS

The main aspects of the conditioning process are presented in this section. It starts with a pre-mission to the candidate country, carried out by the radiation protection supervisor of CDTN´s conditioning team, normally one year before the operation itself. The objectives of this exploratory mission are to select a place for the forthcoming operation, suggest improvements in the local available infrastructure and gather as much information as possible about the country's source inventory. A report is issued relating the findings, making recommendations to the national counterpart institution and to the IAEA – and, if applicable, to the government of the host country – and fixing a tentative time schedule for the conditioning operation. The standard recommendations to the host country at that moment are:

- to gather all sources in the conditioning site (a common situation frequently found at the time of the pre-mission is that at least part of the national radium inventory is temporarily stored at the user's premises);
- to prepare the site for the operation, which includes the removal of all equipment, consumables or trash possibly stored at the place, improving the electrical wiring and water supply system and setting up the items sent by the IAEA (items described below);
- to provide the necessary local personnel for radiation protection services and supporting tasks during the operation, as sources transfer from the storage room to the conditioning room and packaging concrete shielding preparation;
- to supply the locally available equipment and consumables (calibrated radiation monitors, cement vibrator, metallic drums, argon cylinder for TIG welding, chemicals for decontamination, raw material for concrete preparation – cement, sand and gravel).

The standard recommendations to the IAEA are:

- to assist the candidate country in the conditioning of the national stock or radium sources using cost-free experts;
- to supply the following equipment/consumables:
  - HEPA filtration system;
  - lead shields;
  - stainless steel capsules;
  - lead bricks for protection barriers (only if the country can not afford manufacturing them locally).

Some of the items above refer to the preparation of the package used in these operations, whose main components are: stainless steel capsules, lead shielding device; 200L metallic drum with internal concrete shield; locking bars and hooks.

Once the necessary conditions are met, a mission date is set and the team travels to the country. The operation starts with the source transfer from the original shielding devices to stainless steel capsules. The activity in each capsule is tentatively limited to 2 GBq for standard capsules and 7 GBq for the large capsules; the latter are inserted into the shield's central cavity, being therefore more shielded than the former. The capsule individual limits are used with a certain amount of flexibility: as they are applied either to ensure an overall activity cap per package of 25 GBq and to prevent any "hot" spot on the package surface due to an overloaded capsule.
Once loaded, the capsules have their lids welded and, after a cooling period, a leak test is carried out. If approved, the capsules are transferred to a designated position in the lead shield. If it fails this test, the capsule can be returned once for a welding repair or, alternatively, can be re-encapsulated into a large capsule. Of the 173 capsules welded so far by the team, only a handful failed in the leak test.

The shielding devices, once loaded, are inserted into the cavity of the previously prepared steel drum. The package can hold up to two shields, but, as a means of limiting the final package weight to 500 kg and in order to have the lowest feasible external dose rate, the package content is almost always limited to one shield. Two measures are taken to enhance the package safety: the shield body and lid are spot welded together and two steel bars are welded across the package cavity after loading. Figure 3 shows a lead shield (without lid) with loaded stainless steel capsules sticking out of its cavities, whereas Figure 4 depicts the package's external component.

Figure 3. Lead shield and stainless steel capsules.

Figure 4. Package's external component: steel drum with internal concrete shielding.

As mentioned before, one of the most frequent inadequate practices observed in the visited countries is the lack of a proper sorting during the interim storage of the disused sources. As regards the small brachytherapy sources, this leads to cesium sources – and, to a lesser extend, cobalt sources – being mistaken as radium sources. In order to assure that only radium sources are conditioned during the operations, a source identification using a multi-channel analyzer is always conducted when there was even a shadow of doubt about the nature of a given source. Several cesium sources – and, in one particular instance, a cobalt source – were thus positively identified during the missions carried out in Latin America and the Caribbean.

QUALITY ASSURANCE PROGRAM

In order to accomplish the work with due reliability, a comprehensive QA Program was established and has been followed. This program includes the following items:

Quality of the capsule material and the capsule welding process

The capsules body and lids are manufactured according to design and material specifications. Plates and welded tubes are used as raw materials in the lid and body manufacture respectively, since the inherent flaws often presented in seamless tubes and in rods can lead to capsule leakage. The qualification of the capsule welding process also includes the welding of a few blank capsules at site to allow the welder to tune the welding current to local conditions.

Quality of the operational procedures

The operational procedures refer to all major steps of the conditioning operation, as well as radiation protection aspects. The tasks covered are: preparation of the packaging, spent radium sources conditioning – including activity and contamination measurements – and capsule leakage testing. The description of the equipment and material (consumable and non-consumable) necessary to fulfill the tasks are also addressed in the procedures.

Quality of the calibration of all monitors and radioactivity measurement

All dose rate and surface contamination monitors taken by CDTN are calibrated or gauged before use, a calibration certificate being issued in the first case. A radium source is used for the dose rate monitor calibration, while the surface contamination monitor is gauged using an Am-241 source. The reference spectra stored in the multi-channel analyzer used for source identification are acquired using standard Ra-226, Co-60 and Cs-137 sources.

Quality of the documentation of information and its retrieval

Information concerning the conditioned source inventory has to be available during the whole storage period. For this, the capsules, shielding devices and drums are engraved and/or painted according to a sequential pattern and a metallic plate, with all relevant data, is fixed to the interior of the prepared packages (see Figure 4). A protocol containing the conditioned activity (per capsule, per package and total), capsule position in the shielding device, packaging dose rate (superficial and at 1m distance and also on the surface of the inner lead shield), and conditioning date are prepared and signed by the local nuclear authority and the team leader. Each part receives a copy of this record. Tables 1 and 2 –included in the protocol – summarize the above data. The figures shown as an example refer to the conditioning operation carried out in Venezuela in July-August, 2000.

Table 1. Capsule information form

Measuring date: 2000-08-03

Packaging No	*Shield No*	*Capsule No*	*Capsule Position*	*Activity*		*Number of sources*	*Last owner*
				GBq	*mg*		
VEN01	01	1	1	1.8	50	04	SC
		2	4	1.9	51	04	SC
		3	7	2.2	60	04	SC, PM
		4	3	2.6	69	06	PM
		5	6	1.8	49	03	PM
		6	9	2.3	61	10	SC
		7	2	1.8	50	05	HUC
		8	5	2.3	63	06	HUC
		9	8	1.8	49	17	HUC
		1L	10	3.1	82	23	HZ
		TOTAL IN SHIELD		21.6	584	82	
VEN02	02	10	1	2.2	59	15	HUC, HdV
		11	2	1.9	52	04	HdV
		12	3	2.0	55	06	HdV
		13	4	2.3	61	05	HdV
		14	5	1.8	50	04	HdV, HM
		15	6	2.3	61	03	HM
		16	7	2.4	64	04	HM, HB
		17	8	1.8	48	04	SC
		18	9	2.4	65	14	HB
		L2	10	4.0	105	28	IVIC
		TOTAL IN SHIELD		23.1	620	86	

HdV	de Valera Hospital
SC	San Cristobal Hospital
PM	Padre Machado Hospital
HUC	Caracas University Hospital
HM	Militar Hospital
HZ	Zulia Hospital
HB	Barcelona Hospital
IVIC	Instituto Venezolano de Investigaciones Científicas

Table 2. Package information form

Measuring date: 2000-08-03

Package No	*Lead shield dose rate (μSv/h)*	*Package dose rate (μSv/h)*	
		Surface	*1m distance*
VEN01	3,430	770	154
VEN02	2,740	600	120
VEN03	4,180	784	157
VEN04	3,000	550	110
VEN05	1,023	223	44

CONCLUSIONS

The IAEA project herein described – aiming at conditioning disused radium sources in developing countries – began in the region of Latin America and the Caribbean in December 1996. As of the end of 2002, operations have been carried out in ten countries, whose radium stock is now safely stored and under the control of the national nuclear authority. Table 3 summarizes the more relevant data about the conditioned inventory.

Table 3. Conditioned inventory

Country	**Activity (GBq)**	**Radium mass (mg)**	**Number of packages**
Uruguay	58.7	1,586	4
Nicaragua	9.7	262	1
Guatemala	20.3	548	1
Ecuador	8.6	233	1
Paraguay	9.9	268	1
Costa Rica	25.1	679	1
Jamaica	70.8	1,899	4
Venezuela	96.8	2,614	5
Dominican Republic	13.9	376	1
Colombia	92.5	2,503	4
TOTAL	**406.3**	**10,968**	**23**

As regards radiation protection aspects, the guidelines contained in the written operational procedure "Radiation Protection Planning for the Conditioning of Radium Spent Sealed Sources" (3) were followed to their full extent. As a result, the doses recorded for the personnel involved in the operation showed no remarkable facts. With regard to the members of the Brazilian conditioning team, no radionuclide incorporation occurred as a result of these missions, as shown in the whole body counting performed after their return from each operation to Brazil. Concerning the dose exposure of all people involved in the mission, the results of external dosimetry showed that the chest, forehead and finger doses remained well below the limits for radiation workers.

The success of this project shows the feasibility of using inter-regional cooperation in the solution of the problem posed by spent sealed sources in developing countries. As mentioned before, these sources are often conditioned under unsafe conditions and represent a potential harm to the population and the environment.

However beneficial this initiative might be to the attended countries, not all aspects concerning the management of radium sources in the region have been solved. The final destination of the radium sources, for instance, remains an unsolved subject. As Ra-226 is an alpha emitter with a long half-life, its disposal in a engineered geological repository is the recommended solution (2). As the construction and operation of such repository is not scheduled in this region for the foreseeable future, it is mandatory that the local nuclear authorities devise means to safely store the produced packages in the decades to come.

Another open subject is that radium sources are still in use in private clinics or public hospitals in some of the countries already visited. These sources were not made available for conditioning at the time of the operations. In some cases the nuclear authority lacks the legal means to demand the sources to be surrendered; in others, they are the only ones available for treatment and the country can not replace them by the recommended cesium sources.

References

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(3) INTERNATIONAL ATOMIC ENERGY AGENCY. "Conditioning and interim storage of spent radium sources". Vienna: IAEA, June 1996. IAEA-TECDOC-886.