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Management of Spent High Activity Radioactive Sources in the Philippines Using Mobile Hot Cell

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Spent high activity radioactive source (SHARS) is one type of sealed radioactive sources that are typically found inside teletherapy and irradiator devices. As described by the International Atomic Energy Agency (IAEA), these sources are classified as Categories 1 and 2, which pose high risks to human health if they are not managed properly. The radioactive waste management facility (RWMF) does not have the capability of handling SHARS; thus, the RWMF of the Philippine Nuclear Research Institute (PNRI) initiated the safe and secure management of these sources with the assistance of the IAEA through the Nuclear Energy Corporation of South Africa (NECSA). The RWMF performed site preparation for the construction of the mobile hot cell (MHC). The management process involves dismantling the equipment, recovering and encapsulating the source, and placing it inside the long-term storage shields (LTSSs), which are performed inside the MHC. In total, 16 sources were successfully retrieved with a total activity of 204 TBq. The dose rate of both LTSS-1 and LTSS-2 at the surface of the shield was 103 µSv/h and 102 µSv/h, respectively – both of which are below the regulatory limit of 2 mSv/h for the safe transportation of radioactive package. The utilization of the MHC in managing SHARS has made it possible the safe and secure retrieval of SHARSs, given the lack of capability of the Philippines in handling this type of wastes.

Keywords: conditioning, mobile hot cell, sealed radioactive sources, security, SHARS

INTRODUCTION

Radioactive wastes are generated from diverse applications – including the hospital, academic and commercial research activities, industrial use of radioisotopes, recycling of spent nuclear fuels, and other fields (Donald *et al.* 1997). There is no operational nuclear power plant in the Philippines. However, the majority of radioactive sources that are known as waste are generated from the medical field, industrial radiography, and irradiation facilities. The type of radioactive waste varies based on its form. It can be solid, liquid, gas, or sealed source. Sealed radioactive sources (SRS) are radioactive materials that are enclosed in small, metallic vessels with activity ranging from kBq to TBq. The equipment in which the SRSs are embedded in typically last for 10–15 y. However, the half-lives of the radionuclides vary from hundreds to thousands of years. Hence, the SRSs still pose health hazard even though the devices containing them are not functional anymore (Vicente *et al.* 2004). They are categorized based on their application, impact on people and the environment, and radioactivity. Categories 1 and 2 pose high risks to human health; on the other hand, Categories 3 to 5 present a lower risk (IAEA 2003). One of the processes in radioactive waste management

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is conditioning wherein the main objective is to create a waste package which is acceptable for safe handling, storage, transportation and disposal (IAEA 2000). This process varies depending on the categories of the radionuclides being processed. The PNRI operates and maintains the centralized radioactive waste processing and storage facility, which is responsible for conditioning radioactive waste to facilitate interim storage until a final disposal facility is available in the country. The operators of the facility have been processing Categories 3 to 5 sources since commencement; however, the presence of Categories 1 and 2 or SHARSs have become a security issue because of the lack of appropriate tools, equipment, and expertise to process and condition these type of wastes. This leaves the SHARS untouched and open due to degradation or corrosion in the storage facility. In total, there are 22 units of Co-60 sources, in which 18 units came from different tele-therapy devices of various hospitals in the Philippines and four units from gamma irradiators of PNRI. Only a specialized technique can be used in management of SHARS without increasing the risk posed to human health. One of the technologies being used is the utilization of an MHC. The MHC is a mobile facility that can be assembled to reach remote areas that need assistance for SHARS conditioning. It also incorporates a LTSS wherein the recovered SHARS are put for interim storage in the host facility (Bahrin *et al.* 2016, IAEA 2007).

In order to strengthen the security of the stored SHARS, the RWMF team spearheaded the project to dismantle, retrieve, encapsulate, and store the SHARS using the MHC.

MATERIALS AND METHODS

Authorization from the Regulatory Body

Any activity involving radioactive material should be authorized by the regulatory body (RB). The RWMF, in behalf of NECSA, applied for authorization to conduct the SHARS conditioning by submitting the following documents: a) signed trilateral contract (IAEA, NECSA, and PNRI) containing the terms of reference, responsibility, and liability of PNRI-RWMF, NECSA, and IAEA; b) names of individuals from NECSA and their relevant qualifications; c) equipment to be used including specifications; d) procedures relevant to SHARS conditioning; e) radiological protection and operational safety program for the conditioning of high activity radioactive sources; and f) radiological and operational safety assessment for the conditioning of high activity radioactive sources.

The PNRI-RWMF was then granted the authorization for NECSA to perform the SHARS conditioning after submitting all the required documents to the RB.

Site Preparation

The site for SHARS conditioning must not be close to any multi-story building to avoid the sky-shine, external radiation scattered off-air, during actual operation. The area must have at least 30 m x 30 m flat level surface with a compact hard surface area of 8 m x 8 m in the central reinforced concrete. The flat surface is a requirement for the assembly of the MHC. The site borders should not be closer than 10 m to the occupied building or facilities. The site should allow for a free height of about 6 m. Heavy vehicle access to the site is required for the delivery of the shipping containers, equipment, sand, and other materials.

In order to comply, a land area with a 30 m by 30 m flat level surface within the RWMF compound was selected for the assembly of the MHC. The proximity was 10 m away from the other buildings and the center of the area was reinforced concrete to establish an 8 m x 8 m hard surface center for the MHC's actual site of establishment.

MHC Construction

The biological shield of the MHC (Figure 1) was built using a 1.5 m thick double-wall cavity filled with river sand with a density of 1.6 kg/m^3 to enforce maximum shielding. The roof is made up of concrete slabs with a thickness of 0.23 m. Moreover, the window is made up of a steel container with polycarbonate ends and filled with 50% $ZnBr_2$ for watching actual activities inside the MHC. The telescopic manipulator (20 kg capacity) was installed, together with an internal crane to perform handling of objects inside the MHC. In addition, a 360° camera, table with necessary tools plus welding and leakage testing equipment, lighting and an exhaust ventilation unit was installed as miscellaneous devices. Two LTSSs (RWE Nuken, United Kingdom) were coupled at one side of the biological shield to accomplish safe transfer of the encapsulated SHARS from the hot cell to the storage container.

SHARSs Inventory

There are a total of 22 units of Co-60 sources pre-disposed in PNRI in which 18 units came from teletherapy devices (Figure 2) and four units from irradiator devices. These sources vary from different manufacturers, models, brands, and types of devices (Table 1).

Management Strategies

The SHARS conditioning team was divided into two teams that are responsible for the MHC assembly and the

Figure 1. Complete assembly of the MHC.

Figure 2. Teletherapy heads.

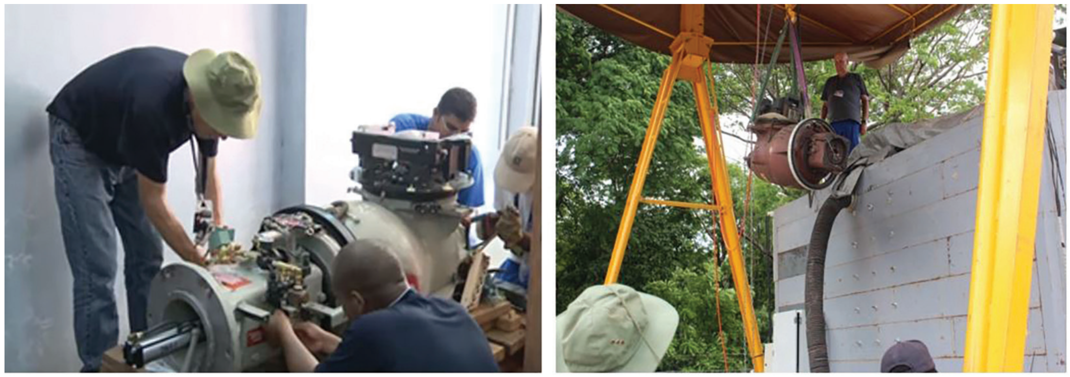
Table 1. Inventory of SHARSs for conditioning.

Manufacturer	Teletherapy device (units)	Irradiator device (units)
Siemens	2	–
Atomic Energy Canada Ltd.	6	2
Picker	1	–
Toshiba	2	–
Nordion	1	–
Cis-Bio	2	–
Shimadzu	4	–
Unknown	–	2

retrieval of SHARS. The devices were first dismantled (Figure 3a) to allow the MHC operators to locate the SHARS inside the devices without the risk of exposure. Then, the dismantled teletherapy devices were lowered by the crane and placed inside the MHC (Figure 3b).

Inside the devices, there are source drawers (Figure 4a) that contain the actual SHARS. The drawers were retrieved using the remote manipulator and tested for leaks to check for contamination. SHARS were retrieved using the same technique with the manipulator (Figure 4b) and were loaded inside a specialized stainless-steel capsule (Figure 5).

The lid of the capsule was sealed using a tungsten inert gas welding machine. The welded capsule was tested for



(a) (b)

Figure 3. a) Dismantling before subjecting the device to the MHC; b) pre-dismantled teletherapy device being lowered on the cavity of the MHC.

(a) (b)

Figure 4. a) Source drawer being retrieved inside the teletherapy device; b) removal of the source from the drawer as viewed from one of the cameras inside the MHC.

Figure 5. Specialized capsule for the retrieved SHARSs.

leakages and transferred to one of the four drawers of LTSS via a transportation port between the LTSS and the MHC (Figure 5).

Radiation Protection Program

The radiation exposure of the personnel involved in the SHARS conditioning was monitored by the Radiation Protection Services Section of PNRI. To ensure that both teams were monitored for radiation exposure effectively, dosimetry analysis of their TLD was performed. It was found that the exposure of the pre-dismantling team members and the MHC operators were all below the action level category as per regulatory limits and were within the occupational dose limit of 20 mSv/y for the deep dose (Hp 10 mm) and 500 mSv/y for the shallow dose (Hp 0.07

mm). The exposure of the MHC operations team was significantly higher than the pre-dismantling team due to the actual presence of the sources in the MHC without its housing or the device where it was retrieved from.

RESULTS AND DISCUSSION

Results

The SHARS conditioning project has led to the retrieval and storage of 16 units of high activity sources with a total activity of 204 TBq. The conditioned SHARS were placed into two LTSSs and were bolted inside security cages at the storage facility.

Discussion

There were 16 units of SHARS successfully retrieved using the MHC. These sources were recovered and conditioned into two LTSSs. This is to avoid the concentration of the radiation emitted by the sources. LTSS-1 consists of sources from a unit of irradiator device and nine units of teletherapy devices. The dose rate at the surface of LTSS-1 is 103 μSv/h, while the dose rate at 1 m distance is equivalent to 25.4 μSv/h. On the other hand, LTSS-2 contains sources from two units of irradiator devices and four units of teletherapy devices. The contact dose rate is 102 μSv/h while the dose rate at 1 m distance is 34 μSv/h. The dose rates of both LTSS are below the 2 mSv/h dose limit for safe transport of radioactive material indicating that the LTSS is effective in shielding the radiation emitted by the sources.

CONCLUSION

In summary, the utilization of the MHC in conditioning SHARS has brought a safe and secure way of retrieval of Co-60 and Cs-137 high activity radioactive sources from teletherapy and irradiator devices. However, six units out of the 22 devices were not processed due to the constraints in the device's structure leading to unsuccessful retrieval of the sources.

On the other hand, the overall structure of the MHC has also reduced the risks of conditioning team on being overexposed to radiation, thus making them safe to radiological hazards as per international guidelines on radiation dose limits. Through adequate coordination with the RBs, NECSA and IAEA, this project has proven the efficiency of an essential method in conditioning SHARS given the lack of capability of the Philippines in conditioning this type of wastes.

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