A SPECIAL TOPIC IN RADIOACTIVE WASTE: THE MANAGEMENT OF SPENT SEALED RADIATION SOURCES IN CHILE

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ABSTRACT

Waste from nuclear application in the country is composed mainly of spent sealed radiation sources, for which different options, presented here, are available to generators in Chile. Development in the manage of this kind of waste: methodology and process control for the direct immobilization inside its own container and the conditioning with volume optimization processes are described. As result of this management, the registered data on the incoming spent sealed radiation sources and on the inventory as conditioned waste is also shown.

INTRODUCTION

Nuclear Energy Chilean Comission is the organization encharged to advice the Supreme Govern in those matters related to the use, transference, transport and destiny of nuclear and radioactive materials acquired and produced for peaceful uses in the country. With the objective of controling all those materials arising from the use of nuclear energy that remain contaminated or that have in their composition some radioactive material and not any further use is forseen, which classify as radioactive waste, CCHEN has made itself responsible of supporting a minimum infrastructure that considers human capacities and material resources. So assumed, well-being and safety to people from nuclear energy applications in the country is provided. This infrastructure organized in CCHEN works under one dependency which is the Radioactive Waste Management Unit, UGDR, encharged for the research and development related to, operates facilities and satisfies necessities of radioactive waste management arising from the domestic nuclear plan.

A total volume of around 25 m^3 per year is managed in the Radioactive Waste Treatment Plant operated by UGDR . One half from these waste arises from the nuclear research centers under CCHEN's organization. Nuclear aplications in the industrial, health and research (universities) fields give rise to the other half from the total volume. One of the most relevant type of waste from nuclear aplications is the so called spent sealed radiation source, which are being collected and processed to give them a conditioned form to keep them in the interim storage ready to be disposed of. Options available in the country, way of processing, quantities managed and control, as an overview of the chilean contribution to keeping the environment, are described herein.

SPENT SEALED RADIATION SOURCES GENERATION IN CHILE

A spent sealed radiation source is a radioactive particle which has a volume of some cubic centimeter and it is contained into a special shielding that allows to irradiate through a controled beam outgoing emitting radioactive energy to be applied. When its activity is decreased to a level no longer useful, or when its life has come to a limit on which it cannot be applied for the use it was made, and no further use is forseen, it becomes a waste. The owner is the responsible for the waste.

Evaluations to the users of sealed radiation sources are made from time to time, with the purpose of counting with an estimation of spent sealed sources projected to be processed at the Radioactive Waste Treatment Plant (PTDR). Table I shows quantity of spent sealed sources asrising from industrial applications in a variety of processes that have been collected by UGDR in the las 4 years period (1997 up todate). It is projected to receive spent sealed sources containing Cs-137 and Am-241 at the end year 2000.

Table I. Spent Sealed Sources Arising From Industries In Chile

YEAR	GENERATOR (TYPE OF INDUSTRY)	QTY.	RADIOISOTOPE	ACTIVITY [Bq]	VOLUME [dm^3]
1997	Wood	1	Co 60	7.4 E08	5
1997	Cement	1	Cs 137	1.2 E10	12
1997	Tobacco	10	Sr 90	4.7 E09	10
1997	Forest	1	Kr 85	6.7 E09	5
1997	Mining	14	Cs 137	8.9 E10	3700
1997	Mining	1	Fe 55	3.7 E08	
1997	Mining	1	Cd 109	3.7 E09	
1997	Mining	1	Ra 226	1.7 E08	
1998	Mining	15	Co 60	1.8 E08	362
1998	Mining	4	Cs 137	3.7 E09	96
1998	Woody fibre	6	Co 60	3.3 E09	460
1998	Woody Fibre	2	Cs 137	5.6 E09	116
1998	Mining	19	Cs 137	3.1 E14	3700
1998	Gaseous Factory	5	Am 241	1.85 E10	13
1998	Construction Ent.	10	Cs 137	3.5 E09	850
1998	Construction Ent.	15	Am 241-Be	7.4 E13	850
1998	Woody Fibre	1	Cs 137	2.3 E12	100
1998	Cement	3	Cs 137	3.2 E13	30
1998	Metalurgie	1	Am 241	3.7 E10	50
1998	Mining	13	Cs 137	1.6 E10	8900
1998	Woody Fibre	1	Kr 85	9.2 E09	10
1998	Bear factory	1	Co 60	3.7 E09	80
1998	Ind. Cervecera	1	Am 241	3.7 E08	80
1999	Mining	15	Cs 137	4.4 E10	1200
1999	Mining	6	Cs 137	1.7 E10	211
1999	Mining	4	Cs 137	6.7 E13	600
1999	Woody Fibre	1	Co 60	8.9 E10	35
1999	Metalurgie	1	Cs 137	1.5 E10	50
2000	Mining	15	Cs 137	4.4 E 10	1460
2000	Woody Fibre	13	Cs 137	4.5 E10	647
2000	Ind. Celulosa	1	Am 241	3.6 E09	20
2000	Woody Fibre	1	Cs 137	3.3 E08	13
2000	Paper factory	1	Cs 137	1.4 E08	25
2000	Paper factory	1	Kr 85	1.8 E10	25
2000	Mining	8	Cs 137	4.6 E10	112
2000	Construction Ent.	1	Cs 137	3.0 E08	51
2000	Constructio Ent.	1	Am 241-Be	1.5 E09	51
2000	* Petrolist	4	Cs 137	2.5 E10	60
2000	* Petrolist	3	Cs 137	1.4 e10	20
2000	* Construction Ent.	1	Cs 137	2.9 E08	80
2000	* Construction Ent.	1	Am 241- Be	1.4 E09	80

* Programmed to receive in Novemeber and december '2000

As it can be seen, sealed radiation sources with different uses, sizes and characteristics are widely used in Chile. Industrial processes employ this kind of sources to measuring in-line

level of minerals, by means of Co-60, Cs-.137 sources; also, they are applied in the paper and cellulose manufacturing, and metal concentration to measure in-line density of sludges, liquors, etc. using those sealed sources containing Cs-137, Co-60, Kr-85 radioisotopes; another industrial use in the tobacco manufacturing is to determine in-line thicknes and weight by means of Cs-137, Co-60, Kr-85, Am-241, Sr-90 sealed sources located on a driving belt where the material to be measured is being processed.

A not industrial use, but very common is that of smoke detectors containing Am-241 with activities from 37 [KBq] (1 microCi) to 370 KBq (10 microCi). They are present in a very wide range of buildings where public affluence is high per day. These smoke detectors containing spent sealed radiation sources are managed as radioactive waste, according to our environmental legislation.

With regard to medicine applications, Co-60, Cs-137, Sr-90 sealed sources are commonly used in radiotherapy; brachitherapy emploies Cs-137, Ir-192; bons densitometry uses Am-241, mainly. Some years ago, Ra-226 was very used in radiotherapy; nowadays, it has been replaced by another radioisotopes of shorter life and safer to manage than Radium. As interesting issue, a total of 2,5 [Ci] Ra-226 (9.25 E10 Bq) has been conditioned by UGDR, according to IAEA's recommendations. Sealed radiation sources applied in research are mainly those for analytic purposes and calibration uses, bearing some KBq.

Table II presents quantity of spent radiation sources arising from hospitals and that have been collected in the last four years. For the end of this year, it is programmed to receive a Co-60 source from teletherapy, and a quantity of Ir-192 from hospitals.

Table II. Spent Sealed Sources Arising From Hospitals In Chile

YEAR	GENERATOR	QTY.	RADIOISOTOPE	ACTIVITY [Bq]	VOLUME [dm^3]
1997	Teletherapy	1	Co 60	4.7 E13	1000
1998	Brachtherapy	39	Ra 226	2.9 E09	257
1999	Brachitherapy	14	Cs 137	4.8 E09	600
1999	Brachitherapy	8	Ir 192	1.0 E09	300
1999	Brachitherapy	5	Ra 226	1.5 E09	100
2000	*Teletherapy	1	Co 60	5.9 E10	1000

* Programmed to receive in Novemeber and december '2000

WASTE MANAGEMENT OPTIONS FOR SPENT RADIATION SOURCES

According to in force law, users of nuclear techniques in the country, or, generators of this type of waste have the following alternatives:

- Storage for decay (Decay & release)
- Return back to the manufacturer (Devolution)
- Tranfer to another user (Reuse)
- Management as radioactive waste at UGDR (CCHEN)

Following is described every option to be adopted by the waste producer (user of nuclear techniques in the country)

Storage for decay

Storage for decay is practiced when spent sources contain low level and short-lived radioisotopes. The typical sources are those containing Ir-192 with 74 days half-life, coming from Hospitals, and from industrial radiography. After some time, in the Decay Storage Facility, which may be some months or some years, they are cleared by the regulatory body and are disposed of as non-radioactive material. If activity is over the boundary to be disposed of as non-radioactive waste, a detailed characterization is done, to decide the following step. According our rules, a time of minimum 10 half-life is enough.

Return back to the manufacturer

From the strategic standpoint, the most convenient alternative is this option: the return back to the manufacturer. No impact to the environment is made; spent sealed source is delivery back to the manufacturer country where it is supposed the source is recycled or managed as spent sealed source to be disposed of in a storage facility, complying safety conditions. The high cost per unit is an impediment that difficults enterprises to do this devolution. A US$ 1600 per unit, plus flreights, transport and internation costs; the requirements, which demand specialists assessorship is added; so the final cost is higher than that.

Transfer to another user

This option is not applied commonly, since sources are not longer used due to the decreasing half-life. There are some significative exemples, worthy to mention. For instance, a teletherapy source with activity of 1.14 E11 [Bq] Co-60 (3000 Ci) has been re-used and transferred to another Hospital. Another example is an irradiator Nordion with an activity of 3.7 E14 [Bq] of Co-60, was transferred from a particular to CCHEN to be used in research and development irradiation in different materials.

Management as radioactive waste at UGDR (CCHEN)

One of the most recurrent alternative selected by users in the country, is to manage the spent sealed sources at UGDR facilities. Due to the convenient cost, it is the most common option for the users. UGDR, belonging to CCHEN a govern entity, operates without lucrative ends, so the price is based only on the operation cost involved, which contributes to keep safety at this regard.

WASTE MANAGEMENT FOR SPENT SEALED SOURCES, AT UGDR

Operation at Radioactive Waste Treatment Plant obeys to the concentration and confinement principles of waste management. Sizes, when it is possible, are minimized, without causing any dammage in the source. It has to be kept in shutted position, clamps and mechanic parts that increase the real volume of the shielding itself, are cut. So done, the source is confined and immobilized, with other sources bearing the same radiological features, in a suitable container the standard 200 l drum which is the base of the Conditioned Waste Storage Facility design. In this way, volume optimization and economy in the total cost for waste management of spent sealed sources is obtained.

Spent sealed sources are freighted by air or terrestrial transport according to the in force Transport Regulation (1), from the user facility to the PTDR where characteristics are verified while Source Data Form is filled. This record will serve for the control and register (2) of the conditioned waste package. Once the data is verified, the source goes to be conditioned into the Plant.

Spent sealed sources conditioning at PTDR

Infrastructure available, safety conditions and quality to satisfy, allow to make difference into 2 lines of sources immobilization, since the process point of view:

- Spent radiation source immobilization within its own shielding (direct conditioning)
- Spent radiation source immobilization with transference to a special device (volume optimization)

It results a variable number of conditioned radiation sources in a cement morter matrix into a 200 [l] drum, from the immobilization within its own shielding. Fig. 1 shows type of sources that are going to be conditioned in this direct way in the PTDR. Activity to immobilize is determined by the limit indicated for non dispersable material in the Radioactive Material Transport Regulation. The limit in this case is not the activity, but the sources volume and its external dose radiation. Other than the 200 [l] drum as final package is also obtained: a cube about 1 m^3 is used when the conditioned waste is a cobaltotherapy source, and for which its own shielding is emploied.

Fig. 1. Direct conditioning of spent sealed sources

Spent radiation source immobilization with transference to a special device, consists of placing them into a container, which has been specially designed, acting as shielding which optimizes volume to occupy. A similar but not identical process is the retrievable conditioning of specific sources (3). Dose radiation to the operator is kept to be no more than 0.025 [mSv/h]. With the aim of optimizing the volume to be confined, sources are set into the shielding. In this case, the shielding is sealed and it is placed, among other devices containing sources, into the 200 [l] drum. The total activity to be introduced per drum is the restrictive characteristic, which makes the process to be very well planned and calculated. Fig. 2 shows a type of shielding used for sources containing 9.2 10E08 [Bq] (25 mCi) Sr-90 arising from weigher and that have been withdrawn from its original container (the weigher itself).

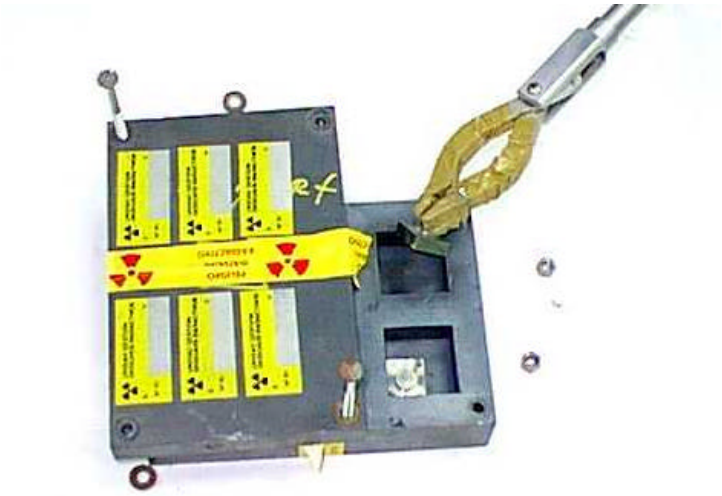

Fig. 2. Optimization of spent sealed radiation sources volume

They are being located into the device which goes in benefit of the volume to be imobilized. The dose radiation to the contact with the source is 2,5 [mSv/h]. There are 6 sources in the container finally. The dose radiation is 92 [microSv/h] to the contact of the container.

Immobilization matrix is a mortar done with puzzolanic cement available in the domestic industry, sand and water, strengthened with iron bars and metallic mesh placed in a diameter between the center and the walls of the drum. Composition follows the recommended formulation (4) and is composed of a water/cement rate of 0.4 and sand/cement rate of 2. Sand amount varies depending on its granulometry. Mortar preparation performance for every container is controled, according to quality control programme.

Characterization of waste package containing spent sealed sources

The Radioactive Waste Register System (SCDR) developed to have the control on every waste that is being entered to the waste facilities of UGDR, is designed to give an unique number, which identifies the waste whatever the step, and wherever it is along the waste management processes. According to SCDR, every step in the conditioning process is documented on paper forms and in the central informatic system, as well.

The preparation of the drum to set the sources, follows a procedure. Performance with the practice data to do the mixture, composition and way of preparing have to be fulfiled. While sources are being introduced in the drum, the corresponding form of Introducing Sources in the Drum is filled. The number which identifies the source, radioisotope contained, in contact dose radiation, activity, volume and weight of every source which is being set in the 200 [l] conditioining drum, are written on.

When the conditioning follows the immobilization of sources with transference to a special device process, every shielding (device) is registered as a whole, whose radiological features are those representing the inside or contained sources .

Every package is tested with regard to settling time (5) based on the chilean standards and compression resistence (6). Typical values obtained of settling time are 5 [h] and compression resitences 270 [Kg/cm^2], that are recorded on the Quality Control Form, for every waste conditioning drum. Later, this information consolidates the waste conditioned package data.

Once the package is immobilized, sources are completely covered with the cement mixture, the register of the package is done. It is signalized, according to own storage specifications: body and cover yellow coloured, on which the trisector indicating radioactivity is shown in red colour. A correlative number assigned per year (SCAT XX-Y), in black colour is painted on the drum. A 10 [cm] horizontal fringe is painted, which according to the colour, indicates the radioisotope contained. Data on radiological features: radioisotope, total activity, dose radiation on the wall and at 1 m, total volume and weight of waste confined, and final weight of the drum are recorded. These data are put on Conditioned Package Control Form, which, joined to the other forms, conform all data related to sources kept in the package and features of this.

CONDITIONED WASTE STORAGE

A total amount of 72 conditioned package contanining differents waste produced in Chile have been treated an conditioned at PTDR, since its start-up at the end of '92. From this quantity, a number of 68 packages are stored at the Conditioned Waste Storage Facility, and the 4 other that contain conditioned Ra-226 in a retrievable way (6) have not been kept in this facility, until the technic-economic feasibility of radioactive waste storage determine its store. The retrievable conditioning Ra does not go with the conditioned form package on which the design of this facility is based. This design considers the package disposed in an horizontal way.

Table III shows the number of conditioned packages by direct immobilization, by trasferring the source to a special device or volume optimization and in the retrievable way. Type of waste producer is also indicated, which allows to know what type of immobilization is the most frequent in our case.

From the Storage Facility inventory, a number of 36 packages containing spent sealed sources in conditioned form. It represents about 50 % of the total conditioned packages. From these, a quantity of 26 packages are immobilized by direct conditioning, 6 by volume optimization. The remainder packages are those containing other kind of waste than spent sealed sources.

EXTENSION AND FUTURE ACTIVITIES

As consequence of methodology and aplicability of waste processes implemented in Chile, UGDR participates in the extension programme of CCHEN, giving assessment in handling and management of radioactive waste in a simple, economic and safety way, to different entities in the country.

Radioactive waste generators in the country assessment

One of the most frequent jobs developed by UGDR, is to give assessment to waste producers in the country. Procedures to be follow, evaluation of spent radiation sources and the waste management service are some of the services offered.

According to the in force law, the user or the waste producer is responsible for his waste. So, waste producer has to support the cost originated by the management of the spent sealed source until it is disposed off. This cost depends on the quantity of sources to be managed per time, volume, activity and time to be storage. As an information, at the moment, cost for processing a Cs-137 is about US$ 500 including authorizations, treatment, conditioning and storage.

Table III. Spent Sealed Radiation Sources Conditioned In Chile

YEAR	TOTAL PACKAGE	TOTAL PACKAGE OF SSRS	RADIOISOTOPE	SSRS Unit/pack	PACKAGE ACTIVITY [Bq]	CONDITIONING TYPE	GENERATOR
1993	10	5	Co-60	14	9.1 E09	Optimization	Industry
			Co-60	1	1.39 E13	Direct	Hospital
			Co-60	13	1.44 E10	Optimization	Industry
			Co-60	7	1.20 E10	Direct	Industry
			Co-60	1	5.00 E13	Direct	Hospital
1994	11	5	Co-60	13	2.93 E09	Direct	Industry
			Co-60	1	3.75 E13	Direct	Hospital
			Co-60	1	8.73 E12	Direct	Hospital
			Cs-137	20	8.89 E10	Direct	Industry
			Co-60	15	1.01 E09	Optimization	Industry
1995	7	1	Co-60	1	3.30 E13	Direct	Hospital
1996	7	3	Cs-137	2	6.66 E08	Direct	Industry
			Co-60	1	6.29 E13	Direct	Hospital
			Cs-137	1	2.15 E09	Direct	Industry
1997	9	5	Ra-226	78	1.85 E10	Retrievable	Hospital
			Ra-226	69	1.85 E10	Retrievable	Hospital
			Co-60	1	4.65 E13	Direct	Hospital
			Co-60	1	4.14 E13	Direct	Industry
			Cs-137	12	3.00 E10	Direct	Industry
1998	10	6	Am-241	25	1.39 E11	Optimization	Industry
			Ra-226	91	1.85 E10	Rectrievable	Hospital
			Co-60	1	1.37 E09	Direct	Industry
			Cs-137	9	3.17 E09	Direct	Industry
			Cs-137	10	2.96 E09	Direct	Industry
			Ra-226	81	1.85 E10	Retrievable	Hospital
1999	10	7	Cs-137	8	1.00 E10	Direct	Industry
			Co-60	5	4.96 E07	Direct	Industry
			Co-60	4	1.80 E08	Direct	Industry
			Cs-137	7	2.4 E09	Direct	Industry
			Co-60	7	5.25 E09	Direct	Industry
			Cs-137	6	1.19 E10	Direct	Industry
			Cs-137	10	8.14 E10	Optimization	Industry
2000	8	4	Cs-137	13	2.9 E10	Direct	Industry
			Cs-137	9	3.7 E10	Direct	Industry
			Cs-137	14	2.5 E10	Optimization	Industry
			Cs-137	5	2.8 E10	Direct	Industry
			*Cs-137	7	3.7 E10	Direct	Industry
	2*	2*	*Cs-137	7	3.7 E10	Direct	Industry

*Programmed to receive in November and December '2000

Demonstration courses on spent radiation sources processing

Another extension activity to be mentioned here, is that chilean experience and infrastructure developed has been taken to satisfy capacitation needs of IAEA with regard to carry up practices courses addressed to Latin America and El Caribe countries belonging to A, B and C groups (according to waste generation countries classification). These practical courses, called "demonstration course on methods and procedures previous to evacuation in the radioactive waste management", are conducted by chilean professionals at the UGDR facilities, according to its own procedures in agreement with the Agency. In this way, UGDR acts as a Demonstration Center recognized by IAEA.

The conditioning of spent sealed radiation sources is one of the procedures that participants of the course must do in these courses. Every participant characterizes spent sealed radiation sources, verifies data, and developes all steps involved in the immobilization

process: drum preparation, introducing the sources into the drum and direct conditioning, until the final conditioned waste package is obtained.

A 32 people in 4 demosntration courses held for 14 countries in the region have been trained in this way with the purpose of developing the process in their countries for their domestic spent sealed sources.

Future activities

There are some large spent seales sources in Chile, that cannot be processed as radioactive waste with the actual procedures and infrastructure in the UGDR. Planning and authorization has to be done. By now, about 8 different shapes of spent sealed sources are registered as waste and stored in their own container. It will be the next task that UGDR will do in the coming years. Also, the technic-economic feasibility of storing of this kind of waste in the actual storage building has also to be determined.

CONCLUSIONS

Spent sealed radiation sources are conditioned routinerily at UGDR facilities, standing out the existence of 2 lines of processing: direct immobilization and that which uses a device for volume optimization.

Both methods employ cement mortar whose processes are controled to measure characteristics of product in every step: package preparation, immobilization mixture, conditioned waste package, etc.

With regard to spent sealed sources processing, control is done since they are joined as radioactive waste: data verification, introduction of sources to the container register, and conditioned waste package record, as it can be seen in the tables shown.

Most of waste arising from nuclear applications in the country are the spent sealed sources that can be immobilized in a direct way, as it is shown in the present data. Conditioning by transferring the source to a special shielding is also a practice, but in minor quantity. The conditioning of large spent sealed sources has to be developed, since there are some of them that must be conditioned.

Besides the own benefit obtained, conditioning of spent sealed sources in Chile has contributed with the know how, in an economic and safety way, to other countries in the region.

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