Transport of Radioactive Wastes Arising From the Decontamination Work Performed in Goiania-Brazil

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ABSTRACT

The present article describes the major aspects related to the packaging and transport operations performed in Goiania, Brazil, following the violation of a Cs-137 teletherapy source, in September 1987, which led to the generation of about 3,500 m^3 of radioactive wastes.

1—INTRODUCTION

The violation of a teletherapy source in the city of Goiania, State of Goias, Brazil, in the month of September 1987, and the subsequent spread of most of its radioactive contents over a large urban area, brought about the need for the establishment of specific provisions to ensure an adequate packaging and transportation of the radioactive wastes to an interim storage.

The purpose of this article is to describe the main aspects related to the above mentioned operations, which were performed, as far as possible, according to the IAEA requirements, as well as to discuss the difficulties that were faced by the technical staff of CNEN.

2—SPECIFICATION FOR PACKAGING

The physical and chemical form of the Cs-137 source favoured its dispersion into the environment, giving rise to a large amount of organic and inorganic wastes spread over five main areas.

Following an evaluation of the contaminated areas, it became evident that a large number of packagings were to be used for the conditioning of the wastes. The acquisition of drums from the national industry was the first step to deal with the situation.

The type of drum chosen was the same as the supplied to the Brazilian Nuclear Power Plant Angra I. However, the mode of waste collection performed with large equipments required the design and manufacture of larger packagings. This was achieved with the help of the local industry, which set up an on-line production of metal boxes with dimensions of 1.2m x 1.2m x 1.2m.

Additional shielding were provided to some drums by means of specially designed 200 L reinforced concrete packagings.

Roll-on-roll-off shipping containers were also necessary to condition large bundles of contaminated paper.

The main difficulites associated with this initial step were:

— the small rate of production of packagings by the local industry;
— the impossibility, due to time constraints, of qualifying the metal boxes;
— the transfer of drums from other States to Goiania, as fast as required;
— the non availability of type B packagings in Brazil.

3—PREPARATION FOR SHIPMENT AND TRANSPORT OPERATION

After conditioning, each package was numbered, labelled, decontaminated when necessary and an individual form was filled with data concerning origin, contents (soil, debris, paper, etc), dose rates at the surface and Transport Index. The following aspects are worth to mention:

— the lack of knowledge of the Cs-137 activity in each package, at the time of conditioning, has led to the completion of labels with maximum values of dose rates at the surface, instead of values of activities;
— the impossibility of on-site determination of the gross mass of each package;
— the overestimation of the radiation level measurements at the surface of and at 1 metre from each package caused by the influence of radiation fields in the working areas.

In spite of the difficulties in fulfilling the applicable requirements of the transport regulations, mainly due to dose rates in excess of those prescribed and absence of information on activity contents, precautions were undertaken in such a way as to ensure an overall safety equivalent to that which would be provided if all specific requirements had been met. Thus, the exclusive use conditions as well as the special arrangement mode were employed as compensatory safety measures, when necessary, and involved:

— no loading and unloading operations between the working areas and the storage facility;
— limiting the convoy speed to 20 km/h and 45 km/h within the city limits and on the outskirts, respectively;
— maintaining an on-route radio communication to be kept informed of the conditions of transport;
— police escort;
— presence of a radiation officer in each convoy;
— availability of emergency equipments on route;
— administrative controls, including transport documents; and
— radiation protection provisions.

Special attention was also devoted to:

— providing an adequate load distribution in the vehicle to conform with the limits for radiation levels, whenever possible;
— instructing the drivers to follow the provisions established for normal and accident conditions of transport;
— proper securing of packagings in the vehicle, with the aid of ropes;
— filling in individual forms with data concerning dose rates measured on the outer side of each external lateral and rear walls of the vehicle, as well as on the driver's seat;
— establishing a daily schedule for the transport in convoys (twice a day on average).

After each shipment, trucks were unloaded, inspected for contamination, decontaminated when necessary, and sent back to the working areas.

Table I gives the amount of packages transported to the storage site in Goiania, and presents the total volume of wastes collected, which required 322 shipments over a period of 5 months, as shown in Figures 1 and 2.

4—DETERMINATION OF PACKAGE ACTIVITY CONTENTS

In order to estimate the contents of each package, a mathematical model based on the "Point Kernel" theory was developed, taking into account the source geometry, the self absorption of the medium, the exposure rate at the surface of the package, and the following assumptions:

— uniform distribution of the conditioned wastes;
— flux equation for cylindrical geometry:

$$\phi = S_v * G (\mu_s h / 2 , 2\mu_s R) / 2 \mu_s \qquad \text{(Eq. 1)}$$

— adjusting of the Green function in the flux equation, by means of the least square method;
— negligible build-up factor and attenuation, except for packages with additional shielding;
— gamma energy of the Cs-137 equal to 0.66 MeV;
— mass attenuation coefficient taken as 0.0783 cm^2/g (dry soil) and the linear attenuation coefficient corrected for the multiform densities of the wastes.

A computer programme was thus developed in such a way that knowing the dimensions of the package, the density of the conditioned waste and the exposure rate at the surface, the activity could be estimated, employing the following equation:

$$\dot{X} = \phi e^{-\Sigma \mu x} \; B E \mu/\rho f_c \qquad \text{(Eq. 2)}$$

ϕ = flux (fotons/cm^2s)

f_c = Convertion factor =1.8 x 10^{-8} x 3.6 x 10^6 (g m R s/MeV h)

E = Energy of gama (MeV)

μ/ρ = The mass absortion coefficient (cm^2/g)

B = Build-up factor

$\dot{X}$ = Surface Exposure Rate (mR/h)

With known values of the source dimensions and density, Equation 2 can be further simplified, as exemplified below.

Package	0.5 g/cm³	1.0 g/cm³	1.6 g/cm³	1.8 g/cm³
200 L	500 X/1476	500 X/766	500 X/478	500 X/425
Metal Box	500 X/288	500 X/114	500 X/71	500 X/63
VBA	500 X/83	500 X/43	500 X/27	500 X/24

5—CLASSIFICATION OF PACKAGES

To fulfill the requirements set forth in the regulations, the classification of packages should be based on the allowable activity limits established for the package contents, as well as on other specifications related to the conditioned material. Thus, with the help of the above linear equations, individual activities were estimated and the packages could be theoretically classified as excepted, industrial, type A or type B. The hypothesis of radioactive material distributed throughout a solid

led to the classification of most of the waste as LSA II, requiring, as a consequence, industrial packagings. However, if a conservative approach is adopted, the different types of packages used to carry the wastes collected in Goiania, should be classified as excepted, type A or type B packages (see Table II). Furthermore, some packages that might have been classified as excepted, due to activity contents, should be taken as Type A, whenever the surface dose rates exceeded 0,005 mSv/h.

Special attention was given to an emergency operation performed to condition the metal disc with the remaining Cs-137 source that was not dispersed. As a result of this operation a package that should be classified as "type B" was obtained.

The metal piece was initially shielded with concrete, since exposure rates superior to 10 Sv/h (1000 R/h) were found near its surface and about 0.4 Sv/h (40 R/h) at a distance of 1 metre (Figure 2). Additional shielding was required to further reduce radiation levels to comply with transport regulations. The final package weighted approximately 4000 kg, showing a maximum value of 8 mSv/h (800 mR/h) at the surface and a Transport Index of 40 (Figure 3).

6—DISCUSSION

During the transport operations, only one minor incident occurred, which led to the drop of 3 metal boxes from one lorry, with fortunately no dispersion of radioactive contents.

This incident served (i) to demonstrate the integrity of containment of those packages under normal conditions of transport, since they were not submitted to prescribed tests nor to a formal quality assurance programme, and (ii) to apply the previously established emergency plan and preparedness procedures.

In spite of all difficulties faced during the initial and control phases of the radioactive accident in Goiania, the waste management and transport group of CNEN implemented a methodology of work that permitted not only a safe transport of the collected wastes to an interim storage facility but also the posterior identification of location, contents, etc., of each package stored in Abadia de Goias. This latter control will be of great value when planning the transfer of the radioactive wastes to a final disposal site.

7—CONCLUSIONS

The present article has shown that the provisions established by CNEN to deal with the packaging and transportation of radioactive wastes arisen from the decontamination work performed in Goiania were adequate and with a degree of safety comparable with that required by the Regulations.

REFERENCES

Regulations for the Safe Transport of Radioactive Material, 1985 Edition, IAEA, Vienna, 1985.
Transporte de Materiais Radioativos, CNEN-NE-5.01, Brasil, 1988.
Regulamento para o Transporte Rodoviario de Produtos Perigosos, Ministerio dos Transportes, Brasil, 1988.

C.N.E.N. — Table I – Number of Packages Stored in Goiania Brazil.

Type of Packaging	Quantity	Volume (m^3)	Activity (Bq)
200 l Drums	4,018	803.6	1,01 E12
1700 l Metal Boxes	1,301	2,211.7	4,03 E13
Shielded 200 l Drums	8	1.6	7,32 E11
32 m^3 Containers	10	320	-------
Concreted Metal Cylinder	1	1.5	4,48 E12
TOTAL	5,338	3,339.4	4,65 E13

C.N.E.N. — Table II – Classification of Radioactive Waste Packages.

Remarks	Activity (Bq)	No.of Drums	No.of Boxes	Type
Non Radioactive Waste [<2nCi/g]	< = 7.4 E06	1324	----------	E
	<= 6,29 E07	----------	204	E
A_2 Based on Safety Series No.6 (1985) Edition	>7.4 E06 <= 3,7 E08	2372	----------	E/A
	>6,29 E07 <= 3,7 E08	----------	216	E/A
	>3,7 E08 <= 3,7 E11	322	857	A
	>3,7 E11	1*	24	B

Obs: 1* ——> Concreted Metal Cylinder Containing The Remaining Cs-137 Source.
E ——> Excepted
A ——> Type A
B ——> Type B

FIG 1 - TRANSPORT OF WASTE PACKAGES IN GOIANIA
(October, November and December/1987)

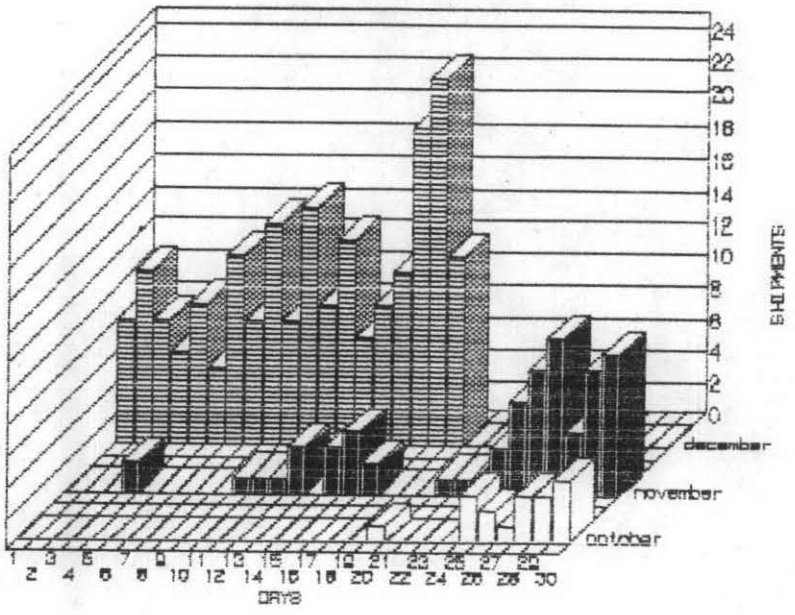
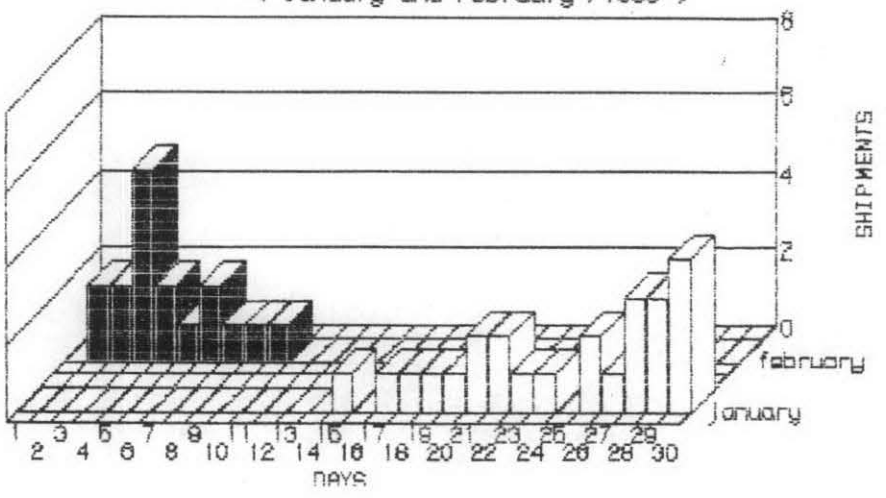


FIG 2 - TRANSPORT OF WASTE PACKAGES IN GOIANIA
(January and February /1988)



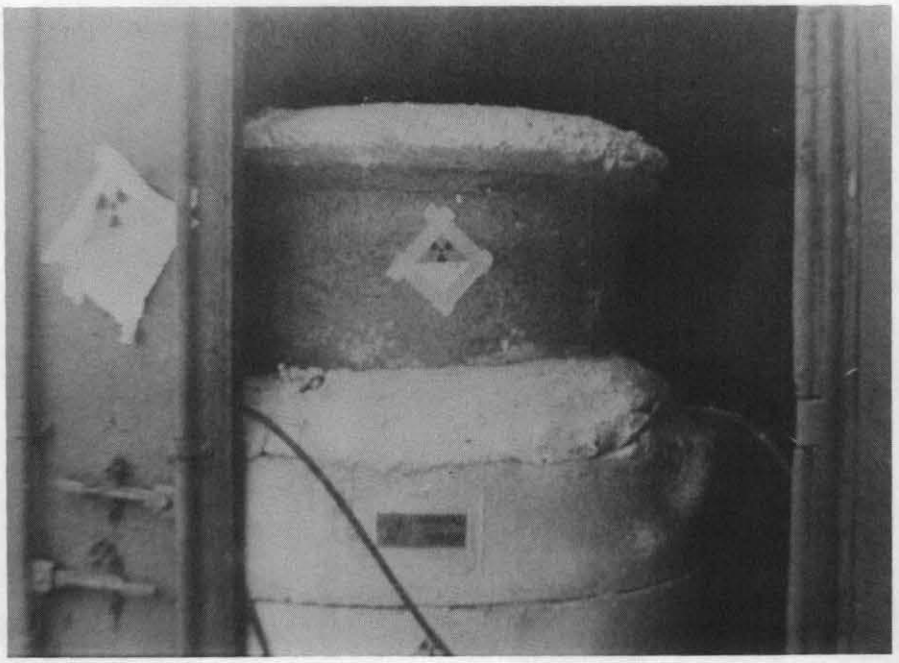


Fig. 3 - CONCRETED METAL CYLINDER WITH THE REMAINING Cs-137 SOURCE

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