Health Physics Vol. 60, No. 1 (January), pp. 87–90, 1991
Printed in the U.S.A.

0017-9078/91 $3.00 + .00
© 1990 Health Physics Society
Pergamon Press plc

704617

● *Instrumentation and Monitoring*

CONSIDERATIONS RELATED TO THE DECONTAMINATION OF HOUSES IN GOIÂNIA: LIMITATIONS AND IMPLICATIONS

C. J. da Silva, J. U. Delgado, M. T. B. Luiz and P. G. Cunha
Instituto de Radioproteção e Dosimetria/CNEN, Av. das Américas Km 11,5,
Rio de Janeiro, CEP 22602, Brazil

and

P. D. de Barros
Comissão Nacional de Energia Nuclear, DEX III/CNEN, Av. das Américas Km 11,5, Rio de Janeiro, CEP 22602, Brazil

***Abstract*—We are considering some aspects related to the decontamination activities of about 50 houses affected by ^{137}Cs in Goiânia. We describe the way these contaminations occurred, the instruments used, and the procedures. We also discuss the dose limits established for decontamination and the consequences resulting from this action. We call attention to the importance of not only the technical aspects in such activities but also the psychosocial implications resulting from them.**

INTRODUCTION

IN THE radiological accident that occurred in Goiânia, significant amounts of the original source of ^{137}Cs were transported to various parts of the city. The source, consisting basically of an agglutinant and ^{137}Cs chloride, was easily reduced to powder and was soluble in water.

Dispersion of the material in the environment was caused by improper handling by uninformed individuals and the consequent direct deposition of the material on the ground. Atmospheric dispersion was the main factor in the contamination of housing. The ^{137}Cs was transported by the wind in the form of an aerosol and deposited on the roofs of houses and farms, and, to a lesser degree, inside them. This took place mainly within a radius of 50 m from the premises where the source was recovered, which defines the area most affected (Street 57, No. 68, Airport Sector). In addition, houses situated at 40 km from the main area suffered contamination caused by the residents themselves, their relatives and friends, who transported the ^{137}Cs on their shoes, clothing or directly on their bodies, and/or by domestic animals that had passed through areas already contaminated.

Approximately 50 houses were treated. The majority were modest constructions, with an average of three to four rooms, generally with red cement floors (an iron-oxide-based dye) and without any roof insulation. Some houses, particularly those situated outside the urban boundary of Goiânia, are not served by the public sewer and water systems and water is obtained from wells constructed on the farms. No ^{137}Cs contamination was observed in water from these wells (IAEA 1988).

Most of the houses had suffered general structural contamination, with varying degrees of contamination of the furniture, clothes, and personal items.

The psychosocial conditions of the residents made it necessary to carry out the decontamination work as rapidly and efficiently as possible. The chemical and physical decontamination methods were therefore adjusted in order to meet the requirements of efficiency, minimum refuse generation, and the necessity to evacuate the houses for as short a time as possible. The work was carried out over a period of 60 d by a work force of about 10 men per day.

An inventory was made of objects removed or damaged by the decontamination process, with a view to subsequent compensation. Restoration work was carried out on homes from which structural parts had been removed. The expenses incurred by this process were met by the state and federal governments.

The decontamination work was administered in such a way as to observe the following limits:

- Surface contamination: 3.7 Bq cm^{-2} (CNEN 1973);
- Exposure inside the houses: 1.29×10^{-8} C kg^{-1} h^{-1} (50 μR h^{-1});
- Exposure from outside the houses: 2.58×10^{-8} C kg^{-1} h^{-1} (100 μR h^{-1}).

1005181
REPOSITORY DOE-FORRESTAL
COLLECTION MARKEY FILES
BOX No. 3 of 6
FOLDER BRAZIL 87 GOIANIA CESIUM-137

INSTRUMENTATION

The radiometric survey was carried out using measuring instruments sensitive to β and γ radiation. Measurements of exposure rates at 1 m from the surface were considered as well as the contamination levels at specific points. The main instruments used for radiometric monitoring of the houses are shown in Table 1.

The scintillation counters [NaI(Tl)] and the dose rate meters (Geiger-Müller) were calibrated by the Institute of Radioprotection and Dosimetry/CNEN. The surface contamination meters were calibrated with an extended source of ^{137}Cs with a surface activity of 3.7 Bq cm^{-2}. The calibration factors were verified periodically using test sources.

In the course of the work in Goiânia, there were periods of rainfall and high temperatures (35–40°C). During the rainy periods, the equipment was covered with plastic sheeting. This procedure hindered operation of the equipment and the reading of indicator dials. Damage to the plastic packaging while the equipment was in use resulted in some instruments being damaged by moisture. Exposure to the sun and high temperatures decreased the accuracy of some detectors, and their effect on the results could not be determined.

In addition to the climate factor, mechanical problems resulted in frequent malfunctions of certain instruments. Particular mention should be made of the surface contamination meters that were equipped with probe shielding. Their weight rendered them difficult to operate, and on some occasions the electric cables suffered inappropriate strain and tension. As a result, there were faults in the electrical contacts.

A small electronics workshop was set up in order to carry out preventive maintenance and small repairs to the equipment, in addition to verification of the calibration factors.

MONITORING

Following the arrival of two CNEN technicians in Goiânia, a radiometric survey was begun in the premises affected by the accident. When levels were found to be higher than 2.58×10^{-7} C kg^{-1} h^{-1} (1 mR h^{-1}), the houses were evacuated and the residents transferred to other accommodations. In buildings where levels were found to be higher than the natural background radiation in Goiânia, but lower than 2.58×10^{-7} C kg^{-1} h^{-1} (1 mR h^{-1}), objects that had suffered greatest contamination were collected and recorded for subsequent analysis so that decontamination could be considered.

The decontamination services began in the residences situated in areas adjacent to the two main locations of contamination. Decontamination was initiated with a thorough radiometric survey of the area outside the houses in order to identify a site from which the objects inside could be easily monitored. The site chosen was covered with plastic sheeting.

Contamination levels of the areas outside the houses varied significantly according to the means by which contamination occurred. The highest values, in tens of Bq cm^{-2}, were observed in the areas closest to No. 68, Street 57.

Surface contamination meters were used in the screening of objects. A scintillation counter was frequently used to monitor clothing. When the background radiation level in the premises required it, a fixed device was installed to hold a scintillation counter shielded with lead sheets.

Objects considered to be free of contamination were wrapped in plastic bags. The remaining objects were decontaminated or packaged as refuse.

At a later stage, when the house had been evacuated, the dust was removed by vacuuming and a detailed radiometric survey was conducted. The boundaries were identified for areas with contamination higher than the established limit. The walls, windows, floors, basins, and water tanks were monitored. The roofs of houses contaminated by atmospheric dispersion showed various levels of contamination. Figure 1 shows characteristic values for the roof of a house where the interior showed an increase in radiation levels of approximately 6.5×10^{-9} C kg^{-1} h^{-1} (25 μR h^{-1}) over the background radiation at a height of 1 m above the floor. The contamination was mainly responsible for this. The local background radiation value fluctuated in the region of 4×10^{-9} C kg^{-1} h^{-1} (15 μR h^{-1}).

With regard to the contamination levels found inside the buildings, the mean values also showed slight differences according to the way in which the ^{137}Cs had been dispersed. In the proximity of the main foci, values of the order of 70 Bq cm^{-2} were often recorded, whereas in buildings located at some distance from the foci, the values recorded were significantly lower, with a mean value of 7 Bq cm^{-2}, as shown in Fig. 2.

Table 1. Main instruments used for monitoring houses.

Manufacturer/ country	Detector	Model
Microlab/Brazil	NaI (Tl)	346
Nortron/Brazil	Geiger-Müller	NDG 1000 A
Victoreen/U.S.	Geiger-Müller	492
Eberline/U.S.	Geiger-Müller	E 520/HP 270
Eberline/U.S.	Geiger-Müller	E 120/HP 210

DECONTAMINATION

Psychological considerations affected the choice of decontamination procedures. Evacuated from their homes and housed in less comfortable accommodations without their personal effects, the residents insisted that the work be completed within a short time. As there had been victims of the accident, they rejected the concept of acceptable levels of contamination. They insisted that their

1005182

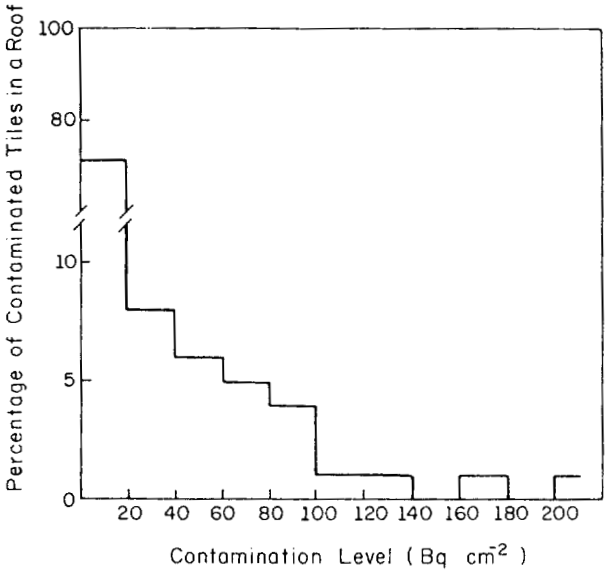

Fig. 1. Contamination level for the roof of a house.

homes should be entirely free of ^{137}Cs as they had been before. They also refused to accept that objects such as clothes and cooking utensils had been decontaminated. Such items were discarded if they showed the lowest detectable level of radiation ($\sim$0.4 Bq cm^{-2}).

The work was made more difficult by the lack of a specific facility for decontamination services in Goiânia. The large quantity of items, and the limited time and space available, made it essential to find rapid and efficient methods. When decontamination was not easily effected by use of paint solvents or acid substances, the surface was treated using abrasive processes (sandpaper) or the affected part was simply removed, which sometimes made the object unsuitable for use. Particular attention was always given to electrical appliances and jewelry.

With regard to the structural parts of the buildings, the walls could usually be decontaminated by the simple application of paint remover. The red cement floors were treated with chemical products, acid, and resins containing Prussian Blue, or the contaminated parts were simply removed and later restored. It was noted that the floor contamination was generally restricted to a surface layer approximately 1-mm thick. The bathrooms, and particularly the areas around the baths, showed the greatest amounts of ^{137}Cs, approaching in some cases the level of the soil and consequently requiring the removal of large amounts of material.

In the buildings contaminated by atmospheric dispersion and where the exposure rate inside approached or exceeded the established limit of 1.3×10^{-8} C kg^{-1} h^{-1} (50 μR h^{-1}), the roofs were vacuum cleaned on the inside and washed outside with pressurized water jets. This method was not very efficient, as the dose rates decreased by only 20%. In the case of two houses, the roofs had to be removed.

The procedures that followed for treating furniture, utensils, and walls resulted in a residual contamination level much lower than the limits established. Although these values were difficult to determine, the maximum level could be estimated as 0.70 Bq cm^{-2}.

Residual contamination in the floors varied according to the method of decontamination adopted. The highest values occurred in the case of chemical treatment, as this was discontinued when the limiting value was reached (3.7 Bq cm^{-2}).

It was confirmed that subsequent to the treatment of houses contaminated by the residents or their acquaintances, the radiation levels inside were practically indis-

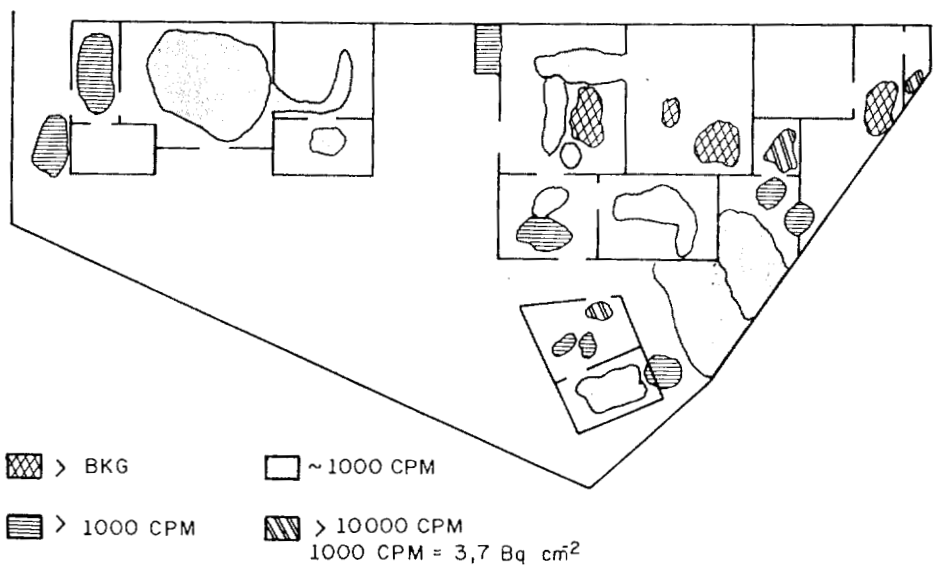

Fig. 2. Contamination level in a residential area.

1005183

tinguishable from those of natural background radiation. This can be demonstrated by the observation that the exposure rate expected at a distance of 1 m from a surface uniformly contaminated by 3.7 Bq cm^{-2} of ^{137}Cs is approximately 1.8×10^{-9} C kg^{-1} h^{-1} (7 μR h^{-1}) (Kocher 1983). The houses contaminated by atmospheric dispersion at present show the highest levels of radiation, mainly owing to the ^{137}Cs retained in the tiles. For example, the exposure rates inside houses located at a distance of 50 m from No. 68, Street 57 were approximately 1.3×10^{-8} C kg^{-1} (50 μR h^{-1}); at 100 m, this value was 7.7×10^{-9} C kg^{-1} (30 μR h^{-1}).

DOSAGE AFFECTING THE INHABITANTS IN THE SHORT AND LONG TERM

Our dosage projections considered the contributions of external irradiation. The critical group was defined as persons spending 19 h d^{-1} inside their place of residence (occupancy factor 0.8), and for the average individual this figure was 12 h d^{-1} (occupancy factor 0.5). As mentioned above, the critical group lived in the houses contaminated by atmospheric dispersion, where the increase in exposure rate inside was 9×10^{-9} C kg^{-1} (35 μR h^{-1}).

The effective dose equivalent, H_E, is estimated to be 2 mSv for the critical group at the end of the first year. The complete dose over 50 y, considering the radioactive decay of ^{137}Cs alone, is 60 mSv. The roof decontamination factor is unknown. Table 2 shows the dose values in the short and long term for the critical group.

Table 2. Dose received by critical group and average individual.

Population group	Dose over first year H_E (mSv)	Future dose H_{50} (mSv y^{-1})
Critical group	2.0	1.2
Average individual	1.3	0.8

COMMENTS AND CONCLUSIONS

The adoption of 3.7 Bq cm^{-2} as the derived limit for surface contamination complies with the CNEN *Basic Radiological Protection Standards* (CNEN 1973). However, this value was inconsistent with the derived limits obtained as a function of the primary limits (total dosage of the critical group over the first year: 5 mSv; mean dose over the lifetime of an individual in the critical group: 1 mSv), as the limit of 3.7 Bq cm^{-2} would give dose values significantly lower than the primary limits. It had been hoped that the adoption of such a strict limit in Goiânia would reduce the consequences of the accident and allay public concern.

Furthermore, the Standards define the limit of 3.7 Bq cm^{-2} as the mean value obtained in a maximum area of variable magnitude according to the type of surface (1000 cm^2 in the case of floors). In Goiânia, this limit was applied to an area appropriate to the detector employed, which in the majority of cases was 20 cm^2 and the effective limit was therefore lower than 3.7 Bq cm^{-2}. For this reason, the value of the surface contamination limit and the method of its application may have increased the number of treatments. It is possible that some of the houses contaminated by the residents or their acquaintances could be included in this category.

The behavior of the residents whose houses were being treated appeared rather paradoxically: While refusing to reuse decontaminated items and insisting that their homes be returned to the "cesium-free" state in which they had been prior to the accident, their anxiety nevertheless increased in proportion to the amount of work carried out. This was understandable as they automatically correlated the intensity of the work with the "danger" to which they had been exposed.

It was therefore demonstrated that one of the reasons for adopting such a limit in Goiânia, the desire to alleviate public concern, was incorrect. The limit adopted also influenced the volume of refuse generated, which was a significant amount in relation to that generated during decontamination of the main foci.

It should be pointed out that after the roofs had been washed, collection of rainwater showed that rainfall can remove part of the retained ^{137}Cs. This would indicate that the long-term dosage for the critical group should be less than calculated.

Finally, mention should be made of the scarcity of information, at least in the official bibliography of international organizations such as the International Atomic Energy Agency and the International Commission on Radiological Protection, relating to conversion factors for the infant population (for example, measurable H_E quantities). These factors are of great importance in the decision-making process during an accident such as the one that occurred in Goiânia.

REFERENCES

International Atomic Energy Agency. The radiological accident in Gioânia. Vienna: IAEA; 1988.

Kocher, D. C. External dosimetry. In: Radiological assessment, chapter 8. Washington, D.C.: U.S. Nuclear Regulatory Commission; NUREG/CR 3332, ORNL-5968; 1983: 8-1 to 8-52.

National Nuclear Energy Commission. Basic radiological protection standards. Rio de Janeiro, Brazil: CNEN; Document 6/73; 1973.

1005184