# DECONTAMINATION OF THE HIGHLY CONTAMINATED SITES IN THE GOIÂNIA RADIOLOGICAL ACCIDENT

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**Abstract**

DECONTAMINATION OF THE HIGHLY CONTAMINATED SITES IN THE GOIÂNIA RADIOLOGICAL ACCIDENT.

In September 1987 a very serious radiological accident occurred in Goiânia, Brazil, when a 50.9 TBq $^{137}Cs$ source was inadvertently removed from a therapy unit and dismantled by junk dealers, contaminating several persons and sites in the city. Following radiation surveys, seven main foci of contamination were identified, which had resulted from the direct handling of the source or parts of it, either during its dismantling or subsequently. The paper describes the work carried out to decontaminate these highly contaminated sites. Details of the decontamination programme, including the radiation protection plant, the teams' organization, the sequence of operations and the procedures are presented. This decontamination programme was established in order to avoid the spread of the radioactive material and to optimize the rate of decontamination, keeping the workers' exposures as low as possible. During the operations seven houses, which presented high levels of contamination, had to be demolished and large amounts of soil had to be removed, as determined by soil profile measurements. The total volume of waste removed was 3100 $m^3$, which was packaged in more than 3500 containers. Although the remedial actions were carried out under adverse conditions due to the site characteristics, the very high exposure rates with levels up to 1.1 Sv/h at one metre, and the social and political pressures involved, the objectives were entirely achieved. Indeed, the decontamination of the main foci was performed in only forty days; the workers involved in the cleanup operations were not exposed in excess of the authorized dose limits (1.5 mSv/day, 5 mSv/week and 15 mSv/month) and their internal contamination was insignificant.

## 1. INTRODUCTION

In September 1987 a very serious radiological accident occurred in Goiânia, Brazil, when a 50.9 TBq $^{137}Cs$ source was inadvertently removed from a therapy unit and dismantled by junk dealers, contaminating several persons and sites in the city. As the result of the direct handling of the source or parts of it, either during its dismantling or subsequently, seven sites became strongly contaminated, these

being identified by radiation surveys. The total area of these seven main foci was about 5000 $m^2$. These sites were distributed within an area of about two $km^2$ in the central districts of the urban area of Goiânia.

The main objective of this paper is to describe the work carried out to decontaminate these main foci. Other aspects of the Goiânia radiological accident are described in detail elsewhere [1, 2].

The remedial actions took place under unusual conditions due to the sites' characteristics and their location in an urban area of a large town. It should be emphasized that because of political and social pressures, the decontamination had to be concluded in the minimum time, attaining extremely low levels.

## 2. DESCRIPTION OF THE MAIN FOCI

The seven main foci were: "Roberto's house" (57th Street), Junkyards I, II and III, COPEL, "Wagner's house" (63rd Street), and "the Cesspool house". The main characteristics of the first five sites, which were highly contaminated, are described in order to illustrate the unique conditions in which the decontamination work was done.

In the site named Roberto's house (57th Street) there were two houses, occupying about 50% of the 550 $m^2$ area. The source was broken in this site, transferring large amounts of radioactive material to the ground. By the action of a heavy rainfall, a planar source of 2 × 2 m was formed, resulting in the most highly contaminated hot spot with a dose rate around 1100 mSv/h at one metre. Three other hot spots were found in the yard with dose rates around 50 mSv/h. Furthermore, generalized contamination was also found in the yard and houses with dose rates between 0.2 and 5 mSv/h.

The Junkyard I site had an area of 900 $m^2$. In this area three houses and a metallic shed were located. It was characterized by piles of waste paper and metallic junk, and several bundles of papers distributed in disorderly fashion over the area. Seven hot spots were identified in this site, with dose rates between 50 and 1500 mSv/h, besides a generalized contamination with levels below 2 mSv/h.

The Junkyard II site had an area of 1250 $m^2$ (25 × 50 m). It comprised a house, a wooden shack and a square metallic structure (shed). These occupied around 30% of the yard. Several bundles and piles of paper, plastic wastes, debris and metal junk were spread all over the yard. The initial survey indicates a generalized contamination with dose rates below 3 mSv/h and twelve hot spots with dose rate levels up to 2000 mSv/h.

Junkyard III consisted of a shed of 400 $m^2$, where 60 t of metal junk were stored. These materials and the floor presented a generalized contamination with levels up to 2 mSv/h, and only one hot spot on the floor with 50 mSv/h was identified.

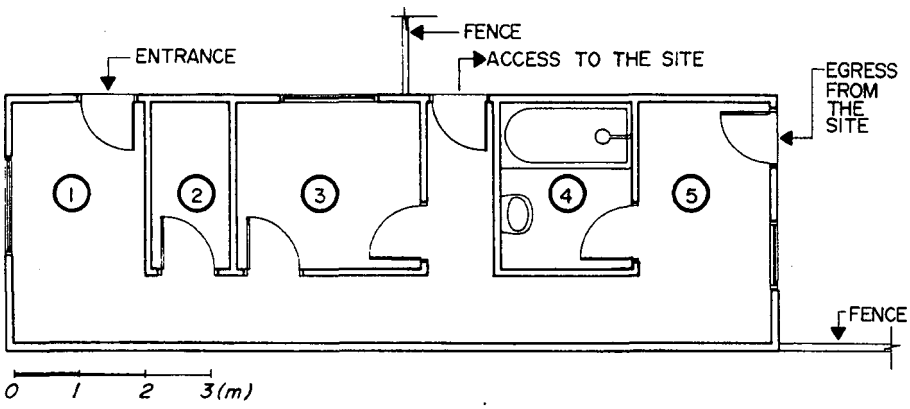


*FIG. 1. Layout of the radiological control station.*

COPEL was a used paper trading company. When the accident took place, this company had in its warehouse about 300 contaminated bundles of papers, each one weighing 270 kg, with a maximum dose rate of 50 mSv/h.

## 3. ISOLATION OF CONTAMINATED SITES AND CONTROL OF ACCESS AND EGRESS

The contaminated sites had been cordoned off using ropes immediately after their identification by radiation surveys. Even before the starting of the actual decontamination, the standard procedures for the control of access to the contaminated sites were adopted [3, 4]. Each controlled area was isolated by means of timber fences or existing barriers such as walls and gates. In the most highly contaminated sites, 57th Street, Junkyards I and II, it was necessary to isolate also part of the street at the entrance to the site in order to minimize the number of people who might be exposed, to avoid contamination of vehicles and to prevent interference in the decontamination operations.

At each site a checkpoint was established. At this checkpoint, a timber shed was constructed to serve as a radiological control station for individuals involved in the operation. It comprised an access control room, a dressing room, personal monitoring and decontamination rooms for the workers leaving the site and a small stockroom for materials and equipment used in the decontamination service. These rooms were distributed over an area of about 40 $m^2$, as can be seen in Fig. 1.

In cases where the controlled area was in the open, the checkpoint was located in the upwind direction.

## 4. THE DECONTAMINATION PROGRAMME AND ITS IMPLEMENTATION

The programme for the decontamination of the main foci was established with the following objectives in mind:

— to avoid the spread of contamination;
— to conclude the decontamination in the shortest period of time, attaining extremely low levels;
— to minimize the workers' exposure and to avoid their internal contamination.

In the planning of the decontamination process the following aspects were taken into account:

— the characteristics of the contaminated sites
— the contamination level
— the high levels of exposure rates
— the dimensions of the contaminated areas
— the kind and volume of contaminated material to be removed.

It is interesting to note that a great part of the decontamination work was carried out in the open, under typical tropical weather conditions: intense sunshine with temperatures up to 38°C and sometimes heavy rains.

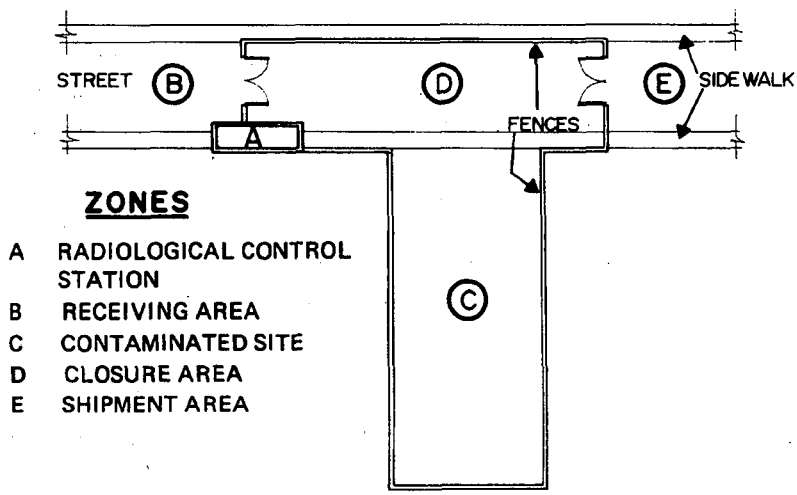


*FIG. 2. Schematic drawing of the working zones.*

In order to implement the decontamination programme in the most efficient way, and to optimize the rate of decontamination by speeding the cleanup, each highly contaminated site and its surroundings were divided into five working zones, shown in Fig. 2.

The main operations in each zone are described in the following sections.

### 4.1. Zone A

Zone A comprised the radiological control station and the checkpoint. Therefore, control of access to the contaminated area and the monitoring of persons leaving the controlled area were performed here. It was also used as a dressing room where the workers changed their clothes and shoes for protective clothing and working shoes. All persons entering the controlled area were provided with a personal dosimeter (film badge) and a direct reading dosimeter (quartz fibre electrometer (QFE) pen dosimeter). Each person leaving the controlled area was checked, the survey including the facial areas and the inside of the face mask. Surface contamination monitors with large end window Geiger–Müller detectors ('pancake' type) were used for this purpose.

### 4.2. Zone B

In Zone B, the empty packages were received and wrapped with plastic sheets. This procedure was adopted in order to reduce the probability of external contamination of the packages when they were transported to the contaminated area and during their filling with contaminated materials. Two types of containers were used to package the radioactive wastes: industrial drums of 0.2 $m^3$ made of 18 gauge carbon steel and ribbed metal boxes with capacity of 1.7 $m^3$ and a maximum load of 5 t [1]. A fork lift (auto lifter) was used to move ribbed metal boxes and filled drums.

### 4.3. Zone C

Zone C comprised the highly contaminated site itself.

In the highly contaminated sites presenting very high dose rate hot spots and generalized contamination with relatively high levels, it was necessary to remove everything, including houses and soil layers. Roberto's house and Junkyards I and II were in this situation.

Experience showed that the best order in which to carry out the cleanup operations of these sites was:

— removal, whenever possible, of the hot spots;
— removal of the loose paper, plastic waste and so forth;

— removal of the bundles of papers;
— cutting and removal of the trees;
— removal of the furniture from the houses;
— demolition of houses and wooden shacks and removal of debris;
— demolition of metal structures, cutting the girders and removing the pieces;
— removal of contaminated layers of soil according to soil activity profile measurements;
— covering the areas with padding soil or concrete.

Before the start of the decontamination actions, and periodically during the operations, area monitoring was performed using teletectors (Geiger–Müller detectors). The hot spots were identified and marked. Warning signs were posted near these points. In the final phase of the cleanup operations, surface contamination monitors (pancake type) were used to find the remaining bits to be removed.

At the beginning of the operations, a lot of materials spread over the yard, e.g. loose papers, metal junk and plastic waste, had to be removed by hand, in order to allow the use, in Zone C, of heavy machinery such as excavators (back and front loaders/motor scraper), mechanical shovels and fork lifts.

During the decontamination operations in these three main foci, seven houses which presented high levels of generalized contamination had to be demolished and large amounts of soil had to be removed. The excavators proved suitable for these operations.

Junkyard III and COPEL were closed areas. In these sites the cleanup operations comprised the removal of the materials and decontamination of the buildings. Parts of the floor with fixed contamination were removed and the new floor was made with a layer of concrete.

In Junkyard III, the metal junk was cut up using an acetylene torch and motor saw in order to reduce its volume and to allow it to be packed in ribbed metal boxes.

At COPEL, there was a large volume of low level waste in the form of contaminated bundles of paper. The bundles were wrapped with plastic sheets and packaged in roll-on-roll-off shipping containers with 32 $m^3$ capacity.

The total volume of waste removed from the contaminated sites was 3100 $m^3$, which was placed in more than 3500 packages, including drums, metal boxes and shipping containers [1].

### 4.4. Zone D

Zone D, part of the street at the entrance to the site, was included in the controlled area. In this zone, the full packages were closed and externally decontaminated.

The check for external contamination was performed by the usual wipe test technique. A pancake type detector was used for monitoring the wiping samples.

The external decontamination was done using water and a weak solution of acetic acid (vinegar).

### 4.5. Zone E

The packages, closed and free of external contamination, were carried out to Zone E, to be prepared for shipment according to the Regulations for the Safe Transport of Radioactive Material [5].

For each package the maximum radiation levels at the package surface and at one metre from the surface were determined. Thus, the category of the package and its Transport Index were established.

The packages were labelled and loaded on lorries which were monitored. Warning placards were put on the vehicles.

During the decontamination operations 275 lorry loads of waste were transported to the temporary storage site.

## 5. DECONTAMINATION TEAMS' ORGANIZATION

The decontamination teams working in different highly contaminated sites were similarly organized. They comprised about 24 persons, half of them professionals dealing with radiation protection. Each member of the team with radiation protection experience was responsible for one of the following functions:

(a) co-ordination of the actions at the site (team leader)
(b) radiation protection control (radiation protection officer)
(c) dosimetric control and access control
(d) dressing the workers with personal protective equipment
(e) supervision of the work in Zone C
(f) monitoring of Zone C
(g) monitoring of Zone D
(h) packages decontamination
(i) shipment of the packages
(j) monitoring and decontamination of persons leaving the controlled area.

The members of the decontamination teams belonged to the following organizations: CNEN and its Institutes, NUCLEBRAS (INB), FURNAS, the Brazilian Army and a large private construction company.

## 6. PERSONAL PROTECTIVE MEASURES

The very high exposure rates found in the highly contaminated sites gave rise to a potentially abnormal exposure of the workers involved in the cleanup operations.

In order to avoid the primary dose limits being exceeded, the following derived limits, authorized by the competent authority, were adopted for the occupational exposure of the working staff [1]:

— daily limit: 1.5 mSv
— weekly limit: 5.0 mSv
— monthly limit: 15.0 mSv
— quarterly limit: 25.0 mSv

Each worker entering the controlled area used a pen dosimeter, beside his film badge, in order to ensure that these limits were observed.

Every day at the end of the work period, or after each risk operation, the pen dosimeter was read and the dose was registered in an individual file and reported to a control centre.

Every day the workers with the lowest accumulated doses were chosen to work in Zones C and D in order to obtain better dose distribution over the team.

The decontamination actions were carefully planned in order to enable doses from external irradiation to be controlled by the usual combination of shielding, distance and exposure time. In this context, the use, whenever possible, of heavy machinery in the decontamination operations contributed significantly to reduce the individual doses.

In order to prevent contamination of skin, internal contamination by inhalation and ingestion of radioactive materials, the workers wore protective clothing and equipment. These items were selected considering the operations to be carried out and the hazard present in the working zone, bearing in mind their influence on the user's performance.

By taking into account these factors, the most appropriate protective devices for each working zone could be determined.

In working Zone A, B and E the persons wore a cloth coverall, boots or working shoes and gloves; in Zone D, the same protective clothing was used plus overshoes and a disposable plastic coverall; in Zone C, the highly contaminated site, the workers wore a cloth coverall, boots or working shoes, gloves, overshoes and, in addition, disposable plastic coveralls, a second pair of overshoes gloves and a full face mask.

A worker leaving Zone C would remove the external overshoes at a border between Zones C and D, go to the radiological control station, where he would remove the plastic coverall, the other overshoes and the face mask and would be monitored.

This procedure helped prevent the spread of contamination to the other working zones.

## 7. CONCLUDING REMARKS

Although the remedial actions were carried out under unusual and adverse conditions due to the site characteristics, the very high exposure rates, the large volume of waste to be removed, the unfavourable weather conditions, and the social and political pressures, the objectives of the decontamination programme were entirely achieved.

The decontamination of the main foci was performed in only forty days, restoring exposure levels similar to the natural background. In this period, a volume of waste of 3100 $m^3$ was removed from these sites.

The measures adopted for personal protection proved effective. The workers involved in the decontamination operations were not exposed in excess of the authorized dose limits and their internal contamination was insignificant.

Finally, it should be emphasized that the skill, courage and determination of the decontamination teams' members and their mutual co-operation were essential for the successful implementation of the decontamination programme.

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