XA0054910

THE SPREAD OF ^{137}CS BY RESUSPENSION OF CONTAMINATED SOIL IN THE URBAN AREA OF GOIÂNIA

M.A. PIRES DO RIO, E.C.S. AMARAL
CNEN—Instituto de Radioproteção e Dosimetria,
Rio de Janeiro, Brazil

H.G. PARETZKE
GSF—Institut für Strahlenschutz,
Neuherberg, Oberschleißheim,
Germany

Abstract

SPREADING OF ^{137}CS BY RESUSPENSION OF CONTAMINATED SOIL IN THE URBAN AREA OF GOIÂNIA.

Measurements regarding the population exposure were performed in Goiânia after the radiological accident as well as studies on resuspension and redeposition of ^{137}Cs in urban areas, on the contribution of soil splash to the ^{137}Cs uptake by leafy vegetables and on the transfer of ^{137}Cs from soil to chicken meat and eggs. Periodical street dust sampling was used to follow-up the spreading of the radionuclide in the city. The results do not indicate a measurable spreading of this radionuclide throughout the city from the contaminated areas, but resuspension can lead to significant local contamination of agricultural products, equipment, structures, etc.

1. INTRODUCTION

The accidental opening of a ^{137}Cs teletherapy unit at the city of Goiânia, Brazil, in September 1987, resulted in the irradiation and contamination of many inhabitants as well as of the surrounding environment; a restricted local secondary contamination by weather and human action occurred within an urban area of about 1 km^2 around the main foci of primary contamination (Figure 1) (IAEA, 1988; Health Physics, 1991). This situation allowed important studies on resuspension and redeposition processes of ^{137}Cs in an urban area under tropical climate conditions (Pires do Rio, 1993; Pires do Rio *et al.* 1994). Also performed were dose rate measurements and ^{137}Cs determination in vegetables cultivated in the garden as well as chicken meat and eggs from poultry that incidentally ingested contaminated soil (Amaral *et al.* 1992, 1994a). For these studies, a house at 57th street 80 m distant from focus 1, where the source was broken, was chosen for the experiments (Figure 2). Street dust samplings were used to follow-up the spreading of radionuclides from the contaminated area to other areas of the city.

2. MATERIAL AND METHODS

The following methodologies were adopted in the experiments:

a) Resuspension and redeposition studies: Air, total deposition, rain water and surface soil were sampled over two years at a front and backyard of the experimental house and analysed for ^{137}Cs. Standard EPA-type air samplers were used intermittently eight times per day for 20 minutes and the filters were measured after every 10 days. The total deposition was collected in stainless tubs (0.8 x 0.8 m^2, 0.3 m high walls) with a permanent water layer of 5 cm. After every 10 days the tubs were drained and the volume reduced by evaporation to 250

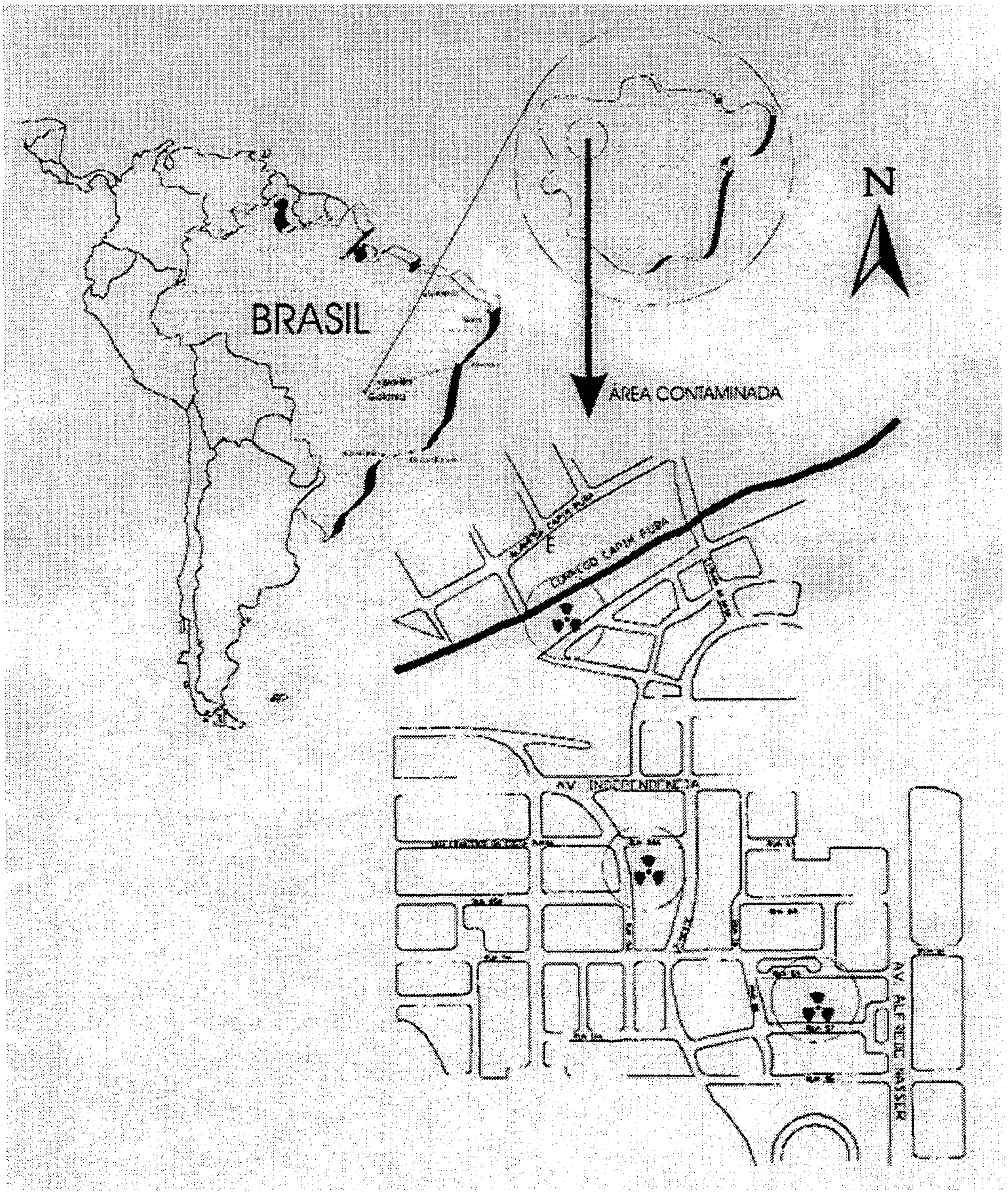

FIG.1. Location of Goiânia and of the main focus of contamination.

ml, prior to analysis. Periodically, surface soil was sampled at representative locations by pressing sticky paper (10 x 10 cm^2) directly on the soil and kept in individual plastic envelopes. Also was used a four stages high-volume cascade impactor with an inlet cut off of 15 µm to collect size differentiated aerosol samples. Taking the deposition pattern and the wind direction data into account, two grids of street dust sampling with a total area of 36 km^2 were established in the city. Periodical sampling were performed from May 1989 until August 1994. The samples were collected using a brush and kept in individual plastic bags (Pires do Rio, 1993; Pires do Rio *et al.*, 1994).

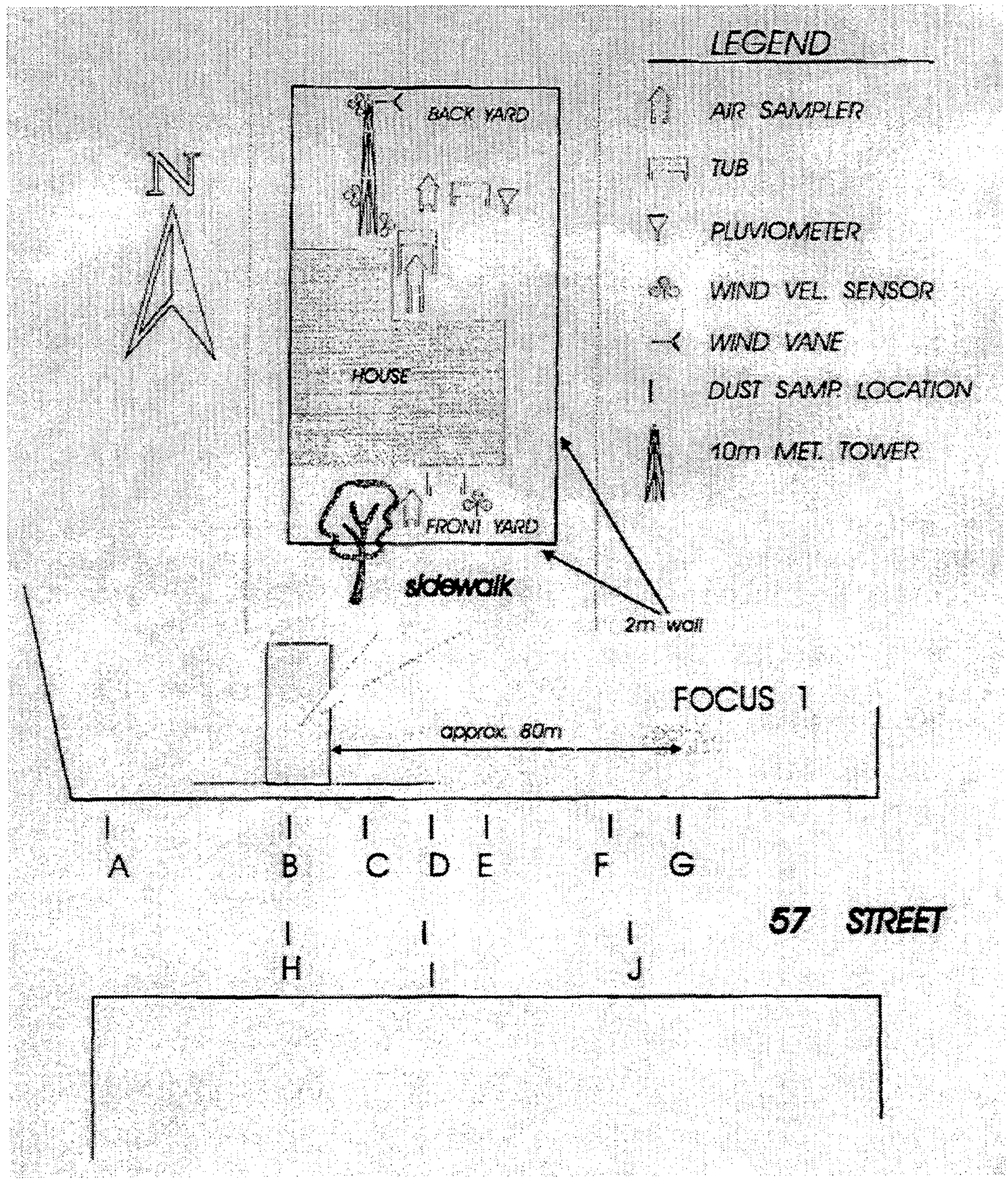

FIG. 2. House at 57th street used for the experiments.

b) Vegetables experiments: Three 90 cm x 80 cm areas in the vegetable garden were prepared for cultivation of lettuce and green cole and organic fertiliser was added to the soil. The plants were grown during a typical tropical dry season. In one area the soil was covered with stones in order to hinder soil splash, and this area was separated from the others by plastic walls (ca. 60 cm in height). In the other areas normal conditions were used (Amaral *et al.*, 1992, 1994).

c) Chicken experiments: Different experiments were performed with varying contamination and decontamination periods at places where the soil was contaminated or uncontaminated with ^{137}Cs. The experiment was started with a breed of chicken that at the time of the accident were being kept at a small residential garden used later for this experiment. The Isa Brown and Leghorn breed of hens were also used in the experiment. All animals were fed with uncontaminated fodder. Meat and eggs were analysed for ^{137}Cs determination. The meat was separate from organs and bones, dried at increasing temperatures up to 90^{0}C and ashed at 40^{0}C. Eggs were weighed and cooked for sample preparation. After, the shell was removed and the albumen separated from yolk; all were weighed separated (Amaral *et al.*, 1992, 1994a).

All ^{137}Cs measurements were performed by gamma spectrometry using germanium detectors from ORTEC, with resolution from 1.7 and 2.0 keV and relative efficiencies from 11.6 to 33 %. Different counting geometric were used depending on the type and size of the samples to be analysed. Energies and efficiencies were calibrated with standard solutions. The counting time was 1000 min or until the statistical counting error was less than 10%.

3. RESULTS AND DISCUSSION

Figure 3 shows the air activity concentration in air as a function of the period of the experiment and of the precipitation data for the 3 location sampling (front yard, back yard and back yard at roof height). It can be observed the very slow long term decrease with time and a strong seasonally effect, with the higher values obtained during the dry season and the lower during the wet season. The fact that the soil has became less erodible could explain the slow long term decrease with time, since the activity concentration of surface soil did not decrease during the experiment period (Table I).

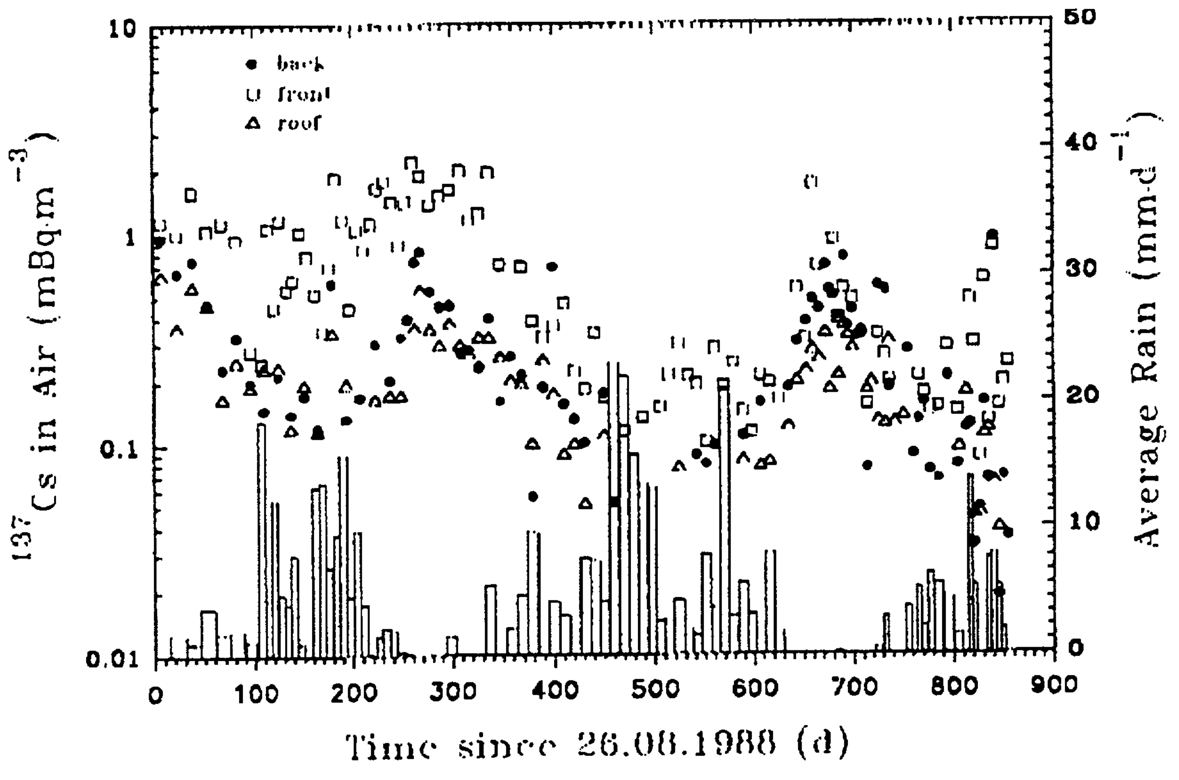

FIG. 3. Air activity concentration as a function of time and precipitation data for the 3 sampling locations.

TABLE I. ^{137}CS ACTIVITY CONCENTRATION IN SURFACE SOIL OF THE FRONT AND BACKYARD OF THE EXPERIMENTAL HOUSE DURING THE PERIOD OF THE EXPERIMENT.

Sampling Period	Sampling Location	Activity Concentration ($Bq\ kg^{-1}$)			
		Average	SD	number of samples	Minimum-Maximum
May 89	Frontyard	11791	4791	10	6112-20457
	Backyard	3544	922	8	1808-5006
Out 89	Frontyard	14730	5751	10	6734-21950
	Backyard	2954	1009	10	1636-4582
Mar 90	Frontyard	14650	3230	10	8148-18460
	Backyard	4882	1732	8	1313-7115
Jul 90	Frontyard	13110	2576	10	9986-17410
	Backyard	2656	1256	9	1319-4620
Jan 91	Frontyard	7345	3001	10	3452-14077
	Backyard	2393	923	8	1443-4415

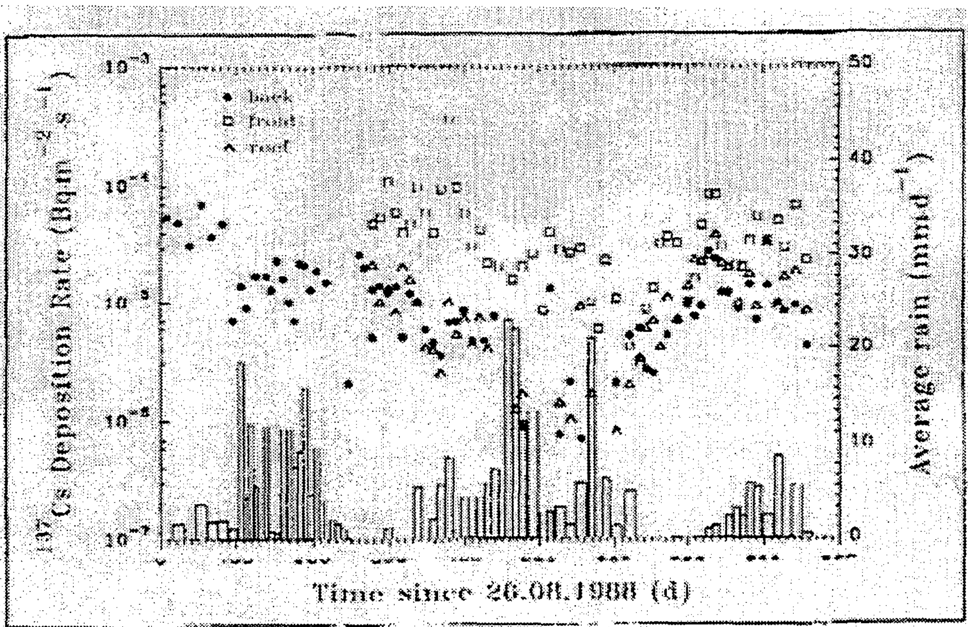

FIG. 4. Total deposition rate as a function of time and precipitation data for the 3 sampling locations.

The same can be observed for the deposition rate measurements. Figure 4 shows the total deposition rate as a function of the period of the experiment and of the precipitation data for the 3 location sampling. Again, the higher values were obtained during the dry season and the lower during the wet season.

From these results, very high values for the rate of deposition were derived suggesting that much of the ^{137}Cs activity in air must be attached to aerosols too large to be detected by the EPA air sampler used. This fact could be confirmed with cascade impactor measurements that were compared with those obtained with the EPA air sampler. Table II shows the deposited material measured in the tubs and those predicted based on four stages cascade impactor measurements and using size dependent deposition velocities from the literature. As one can see, 30 to 70% of mass in air was invisible to the EPA air sampler in both sampling location. Because of the low air activities we could not measure the ^{137}Cs activity on the impactor stages.

TABLE II. MEASURED AND PREDICTED DEPOSITION RATE AND MASS OF AIR INVISIBLE TO THE EPA AIR SAMPLER.

Location	Mass deposition rate ($\mu g\ m^{-2}\ s^{-1}$)		"Invisible" mass in air ($\mu g\ m^{-3}$)
	Observed	Predicted	EPA-type
Backyard	5.35	2.15	79 (49%)
	5.30	2.36	92 (51%)
	7.67	0.7	90 (60%)
	4.55	2.05	97 (59%)
Frontyard	10.7	2.45	115 (50%)
	11.6	3.12	170 (63%)
	7.34	1.84	117 (66%)
	7.33	3.10	79 (36%)

Figure 5 shows the ^{137}Cs activity concentration in street dust as a function of the distance from 57th street in sampling performed in July 1991. The highest values of the ^{137}Cs activity were restricted to the area of primary contamination. This could be explained by the fact that most activity is probably attached to large particles of soil that cannot travel long distances and are deposited locally and also due to the complex pattern of urban structures. Because of that, we do not expect, also for the future, a significant spreading of ^{137}Cs in the city.

Table III shows the estimate of the contribution of direct deposition, root uptake and soil splash to the ^{137}Cs uptake by lettuce and green cole. As one can see, for those vegetables which grow near the ground (that is up to 30 cm height) the contribution of the soil splash was up to 80%.

TABLE III. CONTRIBUTION OF DIRECT DEPOSITION, ROOT UPTAKE AND SOIL SPLASH TO THE ^{137}CS UPTAKE BY LETTUCE AND GREEN COLE

Cultivation area	Lettuce (Bq kg^{-1}_{dry})			Green Cole (Bq kg^{-1}_{dry})		
	Deposition	Root	Splash	Deposition	Root	Splash
with stones	17 (23%)	55 (77%)	-	125 (61%)	81(39%)	-
near wall	17 (7%)	56 (22%)	183 (71%)	125 (25%)	83 (17%)	284 (58%)
inner border	17 (3%)	59 (10%)	500 (87%)	125 (28%)	85 (20%)	231 (52%)

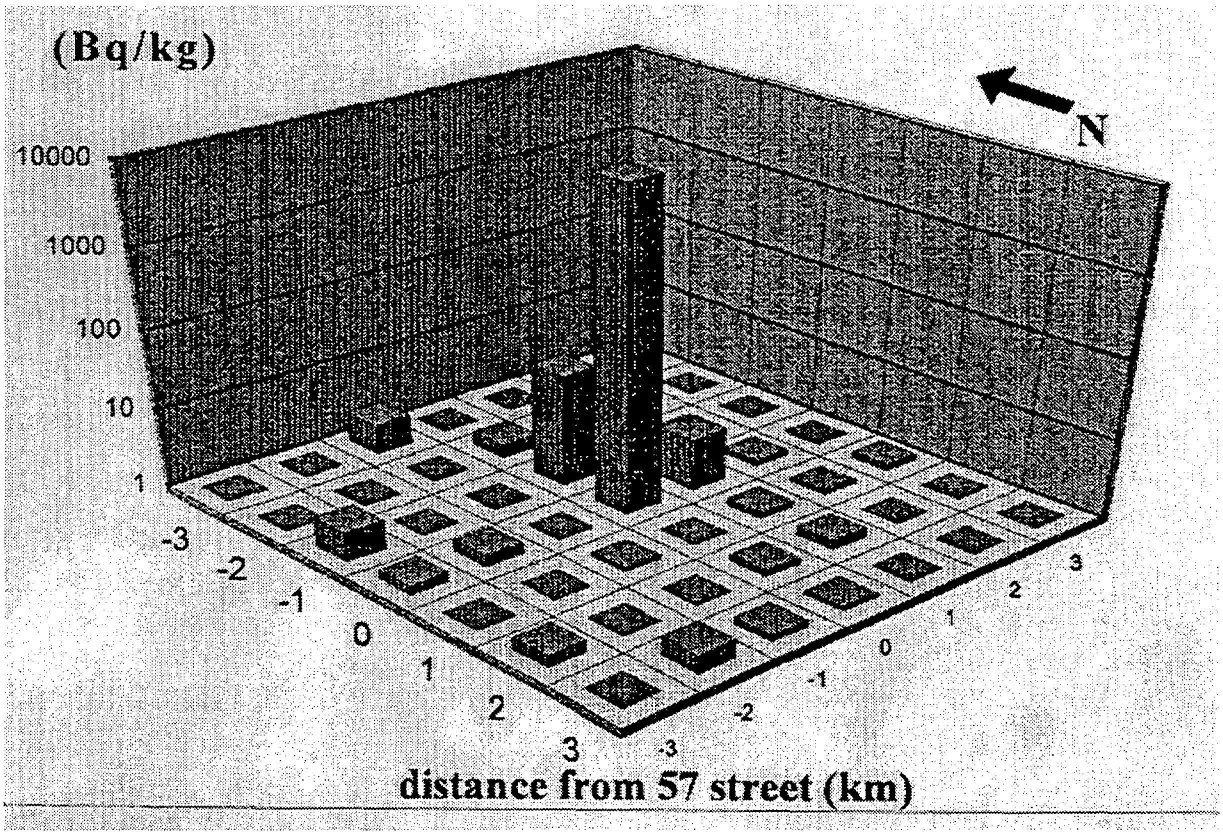

FIG. 5. ^{137}Cs activity concentration in dust samples as a function of the distance from 57th street. Sampling performed in July 1991.

Regarding the chicken experiment, the distribution and biological half-lives of ^{137}Cs in poultry after prolonged ingestion of contaminated soil were studied. The number of chickens available for the measurements was not large enough to be able to obtain statistically significant conclusions concerning the chicken meat. Tables IV and V show the results for ratio respectively egg constituent and meat to soil activity for the three different types of chicken studied.

TABLE IV. CONCENTRATION RATIOS FOR ^{137}CS UPTAKE INTO CHICKEN EGGS BY SOIL INGESTION.

Experiment/Species	Egg Constituent	Concentration Ratio ($kg_{soil}\,kg^{-1}_{egg}$)	Concentration Ratio (kg_{soil}/egg)
Black India	albumen	7.5×10^{-3}	4.7×10^{-3}
	yolk	1.6×10^{-3}	9.7×10^{-3}
	edible part	9.1×10^{-2}	5.7×10^{-3}
Leghorn	albumen	6.9×10^{-3}	3.9×10^{-4}
	yolk	1.5×10^{-3}	8.2×10^{-5}
	edible part	8.3×10^{-3}	4.7×10^{-4}
Isa Brown	albumen	1.3×10^{-2}	7.8×10^{-4}
	yolk	2.7×10^{-3}	1.6×10^{-4}
	edible part	1.6×10^{-2}	9.4×10^{-4}

TABLE V. CONCENTRATION RATIOS FOR THE ^{137}CS UPTAKE BY MEAT DUE TO SOIL INGESTION.

Experiment/Species	Concentration Ratio ($kg_{soil}\,kg^{-1}_{meat}$)
Black India	$8.2\ 10^{-2}$
Leghorn	$5.2\ 10^{-2}$
Isa Brown	$3.1\ 10^{-2}$

4. CONCLUSIONS

The strongly heterogeneous, locally restricted contamination in Goiânia and a virtual lack of any previous contamination from atmospheric atomic bomb test and from Chernobyl accident permit ideal studies of the fate of ^{137}Cs in the urban environment.

The air concentration and deposition rates of resuspended ^{137}Cs in Goiânia 5 years after the primary contamination show a very slow long term decrease with time but a significant seasonally effect.

The spreading of ^{137}Cs in this city is slow. After 5 years most of the activity is still confined to less than 200 m of its initial deposition.

Resuspension does not contribute much in Goiânia to the total radiation exposure, but can lead to significant local contamination of agricultural products, equipment, structures, etc.

REFERENCES

[1] AMARAL, E.C.S., PARETZKE, H.G., PIRES DO RIO, M.A., CAMPOS, M.J., Radiological measurements after the Goiânia accident, Proceedings of the 9th International Congress on Radiation Research, Toronto, 7–12 July 1992 460–465.

[2] AMARAL, E.C.S., PARETZKE, H.G., CAMPOS, M.J., PIRES DO RIO, M.A., FRANKLIN, M., The contribution of soil adhesion to radiocaesium uptake by leafy vegetables, Radiat Environ Biophys **32** (1994).

[3] AMARAL, E.C.S., PARETZKE, H.G., CAMPOS, M.J., PIRES DO RIO, M.A., FRANKLIN, M., Transfer of ^{137}Cs from soil to chicken meat and eggs, (submitted for publication) (1994a).

[4] HEALTH PHYSICS, The Goiânia Radiation Accident, New York: Pergamon Press, Vol. 60, No. 1, Special Issue (1991).

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, The Radiological accident in Goiânia, ISBN 92–0–129088–8, Vienna (1988).

[6] PIRES DO RIO, M.A., Ressuspensão e disseminação de ^{137}Cs em áreas urbanas: a experiência de Goiânia. Master thesis, Federal University of Rio de Janeiro, (in Portuguese) (1993).

[7] PIRES DO RIO, M.A., AMARAL, E.C.S., PARETZKE, H.G., The resuspension and redeposition of ^{137}Cs in an urban area: the experience after the Goiânia accident, *J. Aerosol Sci.* **25** (1994) 821–831.