Spatial Variability and Cesium-137 Inventories in Native Forest

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With the nuclear fission discovery and development of nuclear weapons in 1940s, artificial radioisotopes were introduced in the environment. This contamination is due to worldwide fallout by superficial nuclear tests realized from early 1950s to late 1970s by USA, former URSS, UK, France and China. One of theses radioisotopes that have been very studied is cesium-137. Cesium-137 has a half-life of 30.2 years and its biological behavior is similar to the potassium. The behavior in soil matrix, depth distribution, spatial variability and inventories values of cesium-137 has been determinate for several regions of the world. In Brazil, some research groups have worked on this subject, but there are few works published about theses properties of cesium-137. The aim of this paper was study the depth distribution, spatial variability, and inventory of cesium-137 in native forest. Two native forests (Mata 1 and Mata UEL) were sampling in region of Londrina, PR. The results shows that there is a spatial variability of 40% for Mata 1 and 42% for Mata UEL. The depth distribution of cesium-137 for two forests presented a exponential form, characteristic to undisturbed soil. Cesium-137 inventory determinate for Mata 1 was 358 Bq m^{-2} and for Mata UEL was 320 Bq m^{-2}.

1 Introduction

Because of nuclear fission discovery and atomic weapons development, many nuclear tests were realized, mainly by USA and former URSS until early of 1970s. Before of Limited Nuclear Test Ban Treat, in 1963, the majority of nuclear tests were realized in earth surface, which injected great quantity of debris into troposphere and stratosphere. Radioisotopes formed in nuclear explosion contaminated the debris, and when these contaminated particles reach troposphere and stratosphere, it is dispersed by atmospheric winds and are droplets gradually fall back to earth. This effect is referred to as fallout. Although the nuclear plant accidents have contributed with radioisotopes contamination, it is only as local fallout in the nearest regions.

Several radioisotopes were introduced in the environment by nuclear explosion, and one that has been widely study is cesium-137. Cesium-137 has a half-life of 30.2 years and its biological behavior is similar to the potassium. When cesium-137 reaches the earth's surface, it is rapid and tightly adsorbed by fine particles of soil. After adsorbed by soil, cesium-137 has a limited movement by chemical processes, and its redistribution in landscape is due to soil movement by physical processes. Because of this, cesium-137 has been used in superficial soil erosion assessment. Many works has been developed utilizing cesium-137 methodology in soil erosion determination in different countries [1-5]. In Brazil, scarce works has been realized using cesium-137 methodology for soil erosion quantification [6-9].

To use cesium-137 methodology, the knowledge of cesium-137 behavior and depth distribution in soil, spatial variability and inventory value is necessary. Many authors has devoted works to determine depth distribution, inventories values and spatial variability of cesium-137 [10-12]. Ritchie et al [13] presented cesium-137 inventory of 1590 Bq m^{-2} in Mississipi, USA. Martz and de Jong [14] presented cesium-137 inventory of 2537 Bq m^{-2} in Saskatchewan, Canada. Owens et al [15] presented cesium-137 inventory of 2172 Bq m^{-2} in Yendacott, UK and 252.3 Bq m^{-2} in Masna, Zimbabwe.

In Brazil, Guimarães [6] presented cesium-137 inventory of 306 Bq m^{-2} in a basin of Piracicaba, SP and Bacchi et al [8] presented cesium-137 inventory of 419 Bq m^{-2} in another basin of the same region. Andrello et al [9] presented cesium-137 inventory of 292 Bq m^{-2} in Londrina, PR. Cambray et al [16] shown that cesium-137 inventory of North Hemisphere is one order greater than cesium-137 inventory of South Hemisphere, as presented above.

Walling and Quine [17] presented several depth distribution of cesium-137 in different soil classes. In undisturbed soil, cesium-137 concentration shows an exponential decrease with depth, and in cultivated soil it is uniformly distributed in plough layer due to soil tillage.

In Brazil, little works present depth distribution of cesium-137. Guimarães [6] presented cesium-137 profile for three samples sites in cultivated soil, which shows an uniform depth distribution of cesium-137 activity. Bacchi et al [8] presented cesium-137 profile in undisturbed soil as result of average value of eight samples sites, in increments of 5 cm, which show an exponential decrease in depth.

The aim of this paper was study the depth distribution, spatial variability and inventory value of cesium-137 in undisturbed soil for two native forests.

2 Methodology

To determine the depth distribution of cesium-137 in undisturbed soil, two native forests were sampling at region of Londrina, PR, named Mata 1 and Mata UEL. These forests are Lowland rainforests and soil is classified as Oxisol. The slope of Mata 1 is 10 - 20% and for Mata UEL is 3 - 5%. Mata 1 had a 3 cm thickness of dried leaf and mulch on soil surface and presented a great quantity of little roots through to the soil profile that was sampled. Mata UEL had a 2 cm thickness of dried leaf and mulch on soil surface and presented little roots to 5 cm depth. In each forest, one site was sampling in depth increments of 1, 2, 4 and 5 cm, where was taking care to choose these sites far of great trees and holes for not sampling sites with cesium-137 accumulation due to rain water runoff through of stem and root of trees at time of fallout. In these sites, an area of 1 m^2 was defined and three replicate of 80 cm^2 was sampling for each depth increment. These three replicates were bulked, so that the punctual variability of cesium-137 was diminished, resulting soil samples of 2 kg for each depth increments. The samples of these two sites were used to determine the depth distribution of cesium-137 for two forests. In addition, was sampling a grid with nine sites in each forest, which were used to determine the spatial variability and the average value of cesium-137 inventory. In each site of grid, an area of 1 m^2 was defined and three replicates of 80 cm^2 were sampled. Each replicate were formed of three depth increments, 0 - 5 cm, 5 - 15 cm, 15 - 30 cm. These three replicates for each depth increment were bulked, so that each site in grid had three depth increment samples.

All samples were dried in open air for 48 hours. After each sample reach your dried weight, it was sieved in 2 mm mesh and packed in Marinelli beaker of 2 liters for gamma ray spectrometry with HPGe detector and shield for environmental samples. The time acquisition for each samples was 24 hours and the limit detection was 0.29 Bq kg^{-1}. Cesium-137 concentration of samples was determined at the 95% confidence level.

3 Results

Figure 1 shows depth distribution of cesium-137 for two forests. These figure shows that 66% of cesium-137 is concentrate in firsts 6 cm of soil. Analyzing the cesium-137 profile for Mata 1 (Figure 1a) can be seen that cesium-137 activity increase in first centimeters and then decrease exponentially, having no detected cesium-137 below to 20 cm. Analyzing the cesium-137 profile for Mata UEL (Figure 1b) can be seen that cesium-137 increase to 6 cm and then decrease exponentially having no detected cesium-137 below to 25 cm. This difference in cesium-137 profile of two forests can be due to there are animal perturbation in the firsts centimeters of Mata UEL. Depletion of cesium-137 in the first centimeter of two forests can be due to soil loss or cesium-137 migrations in the soil matrix.

Cesium-137 inventory determinate in these two sites was 241 ± 9 Bq m^{-2} for Mata 1 and 325 ± 7 Bq m^{-2} for Mata UEL. Table 1 present cesium-137 concentration of the depth increments in the sampling sites of grid.

Can be seen of Table 1 that for all sampling sites in two forests, 86% of cesium-137 concentration is concentrate in firsts 15 cm. For nine sites of each grid, five sites in Mata 1 and four sites in Mata UEL presented cesium-137 concentration below of limit detection. According to depth distributions of cesium-137 for Mata 1, cesium-137 was detected only to 20 cm, so that the profile 15-30 cm for this forest is a mixture of soil with cesium-137 and soil with no cesium-137 that generated cesium-137 dilution in this profile. For Mata UEL, that presented cesium-137 until 25 cm, little soil with no cesium-137 was incorporated in soil with cesium-137.

Cesium-137 inventory determinate for all sites in grids change from 171 ± 35 Bq m^{-2} to 595 ± 85 Bq m^{-2} for Mata 1 and from 119 ± 34 Bq m^{-2} to 506 ± 56 Bq m^{-2} for Mata UEL. Average value of cesium-137 inventory for Mata 1 was $359 \pm$ Bq m^{-2} and 321 ± 137 Bq m^{-2} for Mata UEL. Spatial variability of cesium-137 was 40% for Mata 1 and 42% for Mata UEL. This mean that there was a non-homogeneous deposition in the sampling forests, which can been due to the great canopy in this forests as well as by water runoff in stem and roots in time of fallout. Comparing the average value of cesium-137 inventory can be perceived that there is a spatial variability of 10% between two sampling forests, which can be due to different rainwater precipitation since Mata 1 is located 15 km beside of Mata UEL.

4 Conclusion

Regarding Fig. 1, can be observed that the depth distributions for two forests show a exponential decrease below of the firsts centimeters. Besides that, spatial variability show that there is need have refined sampling to determine cesium-137 inventory with a low spatial variability in forests. Although the soil analyzed in this work is clayed soil, the results obtained for depth distribution of cesium-137 are similar to that presented by Guimarães [6] and Bacchi et al [8] for sandy soil in undisturbed site. This show that cesium-137 present exponential decrease with depth and similar behavior of cesium-137 for these two soil kind.

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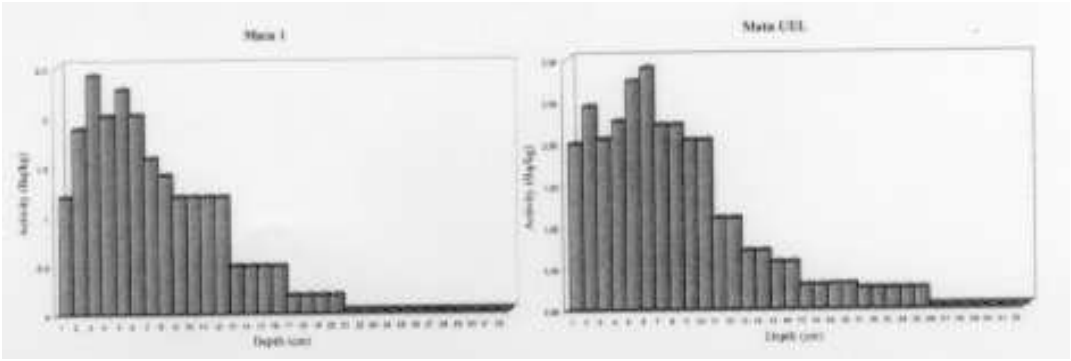

Figure 1. Depth distribution of cesium-137 for Mata 1 and Mata UEL.

TABLE 1. Cesium-137 concentration determinate for the sampling sites of grids.

Sampling Sites	Depth increments (cm)	Mata 1 Activity per unit mass (Bq kg^{-1})	Mata UEL Activity per unit mass (Bq kg^{-1})
	0 - 5	2.19	0.90
Site 1	5 - 15	2.13	0.43
	15 - 30	0.72	0.12
	0 - 5	2.79	2.21
Site 2	5 - 15	2.50	1.50
	15 - 30	0.88	0.45
	0 - 5	1.89	1.82
Site 3	5 - 15	1.34	0.77
	15 - 30	0.17	0.35
	0 - 5	2.88	1.61
Site 4	5 - 15	1.57	1.09
	15 - 30	0.25	0.92
	0 - 5	3.62	1.17
Site 5	5 - 15	1.55	0.40
	15 - 30	0.35	0.00
	0 - 5	2.12	2.22
Site 6	5 - 15	1.17	1.96
	15 - 30	0.51	0.49
	0 - 5	1.52	1.52
Site 7	5 - 15	0.70	0.99
	15 - 30	0.17	0.29
	0 - 5	1.30	2.08
Site 8	5 - 15	0.57	1.32
	15 - 30	0.09	0.26
	0 - 5	2.02	2.16
Site 9	5 - 15	0.73	1.72
	15 - 30	0.17	0.38

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