^{137}Cs Distribution in Guava Trees

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This paper presents results of ^{137}Cs concentration measured from a guava tree cultivated after the first decontamination work of one of the sites where the worst Brazilian radiological accident occurred. The present work aims to verify how the ^{137}Cs is transported and distributed along the tropical trees. Bi-dimensional analyses of the radial distribution of ^{137}Cs in the main trunk are also presented. Neither symmetrical nor homogeneous behaviors of the specific activity distribution in the tree rings were observed.

1 Introduction

One of the worst radiological accidents ever reported occurred in the city of Goiânia, Brazil, in 1987. A ^{137}Cs capsule from a recklessly abandoned old radiotherapy unit was intentionally violated by people unaware of the hazardous effects of radiation [1, 2]. Recently, a study of the environmental consequences of this radiological accident was performed by our research group. Detailed measurements of ^{137}Cs contamination were performed in junkyard II, one of the places involved in the accident [3, 4]. High values of ^{137}Cs activity per unit mass were found in soil layers at depths between 10 and 40 cm from the surface, reaching values as high as 175 kBq.kg^{-1}. High values of ^{137}Cs concentration in fruits and plants were also observed. As a continuation of this study, measurements of the ^{137}Cs concentration in some tropical tree samples cultivated in junkyard II, such as guava, mango and avocado trees, were performed between 2001 and 2003. Using gamma-ray spectrometry technique, analysis of the behavior of the absorption, transport and distribution of ^{137}Cs in xylem wood, twigs, leaves and fruits of a guava tree will be shown in this paper.

2 Material and Methods

As a result of the study on the environmental consequences of the radiological accident, in August 2001, the Brazilian National Nuclear Energy Commission (CNEN) performed a new intervention in junkyard II, covering all its extension with a thick concrete layer and removing some plants and trees [5]. Samples of soil, root, trunk, twig, leaf and fruit of two guava trees were collected before this intervention. In order to study the radial distribution of ^{137}Cs in tree rings, some disks of the main trunks of the two guava trees were also collected.

The sample preparation and analysis were carried out at the Laboratory of Radioecology (LARA) of the Federal Fluminense University. The collected samples were submitted to a drying process, at 110^{o} C. Afterwards, vegetal samples were ground to powder and packed into cylindrical plastic containers, dry-weighed and sealed. The soil samples were first submitted to a homogenization process being sieved in order to separate the small particles from the big ones, such as stones, grass, roots and other organic material. Then they were also packed into cylindrical plastic containers, dry-weighed and sealed.

The samples were analyzed by conventional gamma-ray spectrometry technique, using a NaI detector. In every spectrum, the peak associated to the 662 keV gamma-ray line from ^{137m}Ba was detected. The absolute activity of ^{137}Cs was determined by comparing the peak intensity, defined by the area under the peak of a sample spectrum, subtracting the corresponding background contribution, with that of a calibrated sample with the same geometry. The ^{137}Cs calibrated samples consisted of vegetal and soil samples collected in one of the places involved in the Goiânia accident, which specific activities were determined at the Laboratório de Monitoração Ambiental da Eletronuclear S.A. - Angra dos Reis [6]. Hence, using the dry weight of the samples, their respective ^{137}Cs concentrations could be expressed in activity per unit mass (Bq.kg^{-1}).

3 Results

Figure 1 shows an illustration of one of the guava trees analyzed, around five meters high. This picture shows the positions where root, trunk, twig, leaf and fruit samples were collected, including the positions of the disks of the main trunk used to evaluate the radial distribution of ^{137}Cs in the tree rings. This figure also presents the ^{137}Cs activity per unit mass as a function of the soil depth, at the location where this guava tree was cultivated and the distribution of ^{137}Cs concentration along one branch of the guava tree.

The soil-to-plant transfer factor (TF) is a parameter that allows estimating the transfer of radionuclides from soil to plants. TF is expressed as the ratio between the radionuclide concentration in the dried edible part of the plant and that in the oven dried soil and calculated as follows: TF = (Bq.kg^{-1} dry fruit weight)/(Bq.kg^{-1} dry soil weight) [7, 8]. Usually TF is calculated for homogeneously contaminated soil and depends on the chemical-physical properties of the soil: the concentration of chemical elements in the soil solution depends on soil moisture, pH, cation exchange capacity, quantity of organic matter, microbial activity and fertilizer application. Mass flow and diffusion of chemical elements depend on soil structure and porosity [7]. However, the soil profile where this guava tree was cultivated, as shown in Figure 1, proves that the ^{137}Cs concentration in the ground of junkyard II is not homogeneous. Even so, it is possible to evaluate TF for guava. Using a mean value for the ^{137}Cs concentration in the ground and the results of the ^{137}Cs concentration in fruits of guava tree (also presented in figure 1), the value of TF for soil to fruit transfer of cesium is $(1.9 \pm 0.4) \times 10^{-2}$. Usually, the TF for cesium is higher in tropical fruits than in temperate fruits, and the values obtained must be interpreted by taking into account different soil characteristics. This soil factor was found to be of stronger influence on determining TF than the variability among species [7]. In addition, the soil where the guava tree was cultivated presents a peculiar characteristic. The ground of junkyard II is composed by an alkaline sandy soil containing construction remains. Within this context, the information concerning the TF obtained in this work is important, since there are not many values of TF for guava available in the literature. Carini [7] has reported the TF value for guava as 1.8×10^{-3}, in other words, one order of magnitude lower than our result.

Analysis of the ^{137}Cs concentrations along the main trunk and one branch of the guava tree allows verifying how the transport and distribution of salts between different parts of a tree occur. The above results for this radioisotope confirm the current knowledge on the macroscopic pathway of salts in trees.

From the derived ^{137}Cs concentrations along the guava tree (see Fig. 1), some conclusions can be drawn. The specific ^{137}Cs activity is higher in the growing parts of the guava tree: fruits, leaves, needles, twigs and the outer growth layers. This value is even higher for the youngest parts of the guava tree (see the points 24, 25, 26, 27, 28 and their respective leaves and fruits). We can also observe that not only the specific activity is higher in the bark than in the core wood of the tree, but that the ratio between the specific ^{137}Cs activity in the bark and the core increases for the youngest parts of the guava tree. These results are in agreement with information available in the literature, where the specific activity of ^{137}Cs has been observed to be much higher in the fresh parts of trees than in the core wood [9].

^{137}Cs Concentration (kBq.kg^{-1})

ID	Inside	Bark
1	1,1 ± 0,1	
2	0,9 ± 0,1	
3	1,7 ± 0,1	
4	1,7 ± 0,1	
5	1,7 ± 0,1	
6	1,9 ± 0,1	3,1 ± 0,2
7	1,6 ± 0,1	3,2 ± 0,2
8	1,7 ± 0,1	3,4 ± 0,2
9	1,9 ± 0,1	2,5 ± 0,1
10	1,8 ± 0,1	3,6 ± 0,2
11	1,3 ± 0,1	2,7 ± 0,2
12	1,2 ± 0,1	2,5 ± 0,1
13	1,4 ± 0,1	3,9 ± 0,3
14	0,8 ± 0,1	2,4 ± 0,2
15	0,8 ± 0,1	2,3 ± 0,1
16	0,9 ± 0,1	2,3 ± 0,1
17	0,8 ± 0,1	
18	0,7 ± 0,1	2,2 ± 0,1
19	0,7 ± 0,1	2,2 ± 0,1
20	1,4 ± 0,1	3,7 ± 0,3
21	1,6 ± 0,1	3,2 ± 0,2
22	1,2 ± 0,1	3,5 ± 0,2
23	0,9 ± 0,1	3,5 ± 0,2
24	0,9 ± 0,1	3,1 ± 0,2
25	0,8 ± 0,1	3,3 ± 0,3
26	1,1 ± 0,1	4,3 ± 0,4
27	1,3 ± 0,1	4,3 ± 0,4
28	1,1 ± 0,1	4,5 ± 0,4
29	1,6 ± 0,1	4,5 ± 0,3
30	1,5 ± 0,1	4,6 ± 0,5

ID	Leaves	Fruits
A	2,4 ± 0,1	
B	4,6 ± 0,3	4,9 ± 0,4
C	6,5 ± 0,4	6,3 ± 0,4
D	4,2 ± 0,4	
E	2,5 ± 0,2	2,2 ± 0,1
F	2,2 ± 0,2	2,2 ± 0,2

Root 1 1,5 ± 0,1
Root 2 2,2 ± 0,2

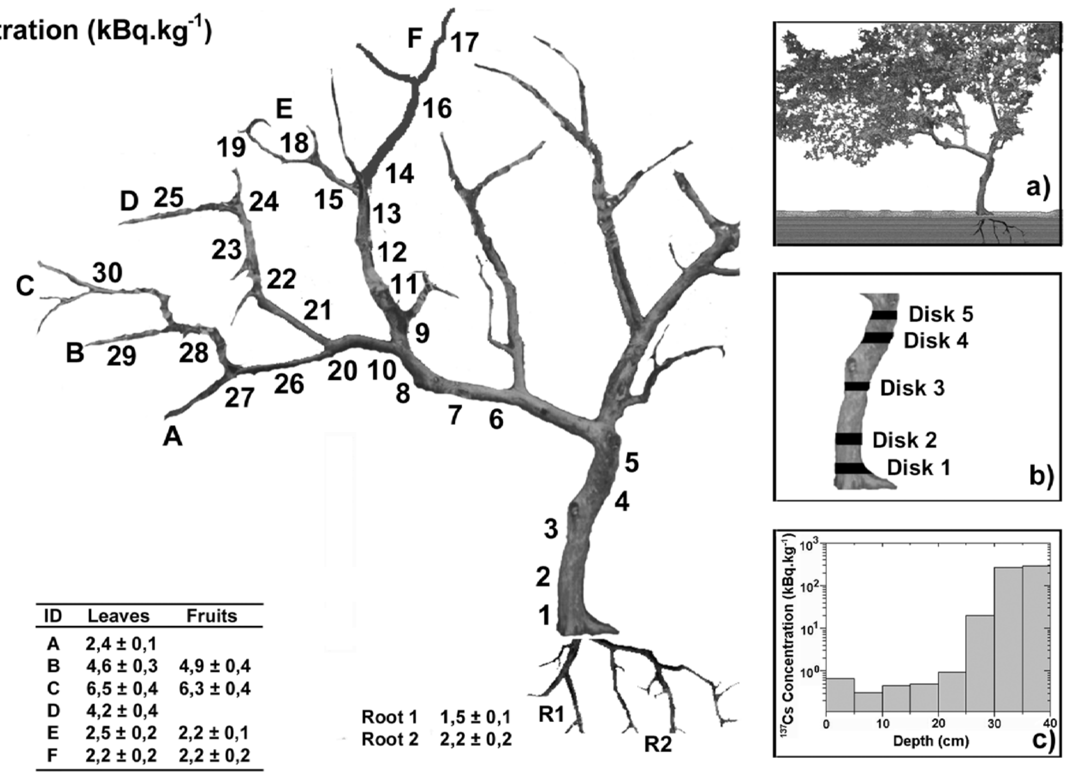

Figure 1. Distributions of the ^{137}Cs concentration (kBq.kg^{-1}) along 30 points of guava tree. A) Illustration of the guava tree, around five meters high; B) Positions of the main trunk disks used to evaluate the ^{137}Cs radial distribution in tree rings; C) ^{137}Cs activity per unit mass as a function of the soil depth at the location where this guava tree was cultivated.

Figure 2 shows one of the disks of the guava tree trunk analyzed in this work. Guava (Psidium Guajava) is a small tree of the Myrtaceae family. This family presents single characteristics. The tissues form each one year ring are mixed by tissues of other year rings and so, the tree rings do not present concentration areas of only one type of tissue. In addition, the tropical tree rings are usually not as easily identified as those in a temperate tree, due to the fact that the seasons in tropical areas are not well defined. Thus, although the identification of the guava tree rings is a difficult task, it is possible to observe seven annual rings in Figure 2. This number of rings is in agreement with the observation of junkyard II residents, that this guava tree was around seven years old.

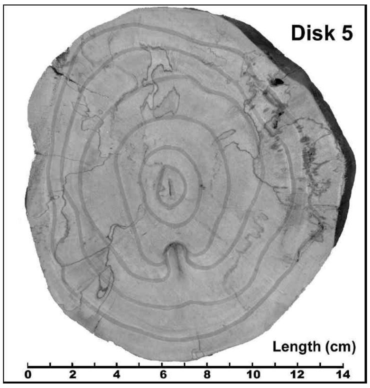

Figure 2. Picture of one of the guava tree trunk disks analyzed in this work. The tree rings were reinforced to allow a better identification of the guava tree rings.

Figure 3 presents a bi-dimensional illustration of the radial distribution of the ^{137}Cs in three disks of the guava tree trunk (see Figure 1 for identification of these disks). Neither symmetrical nor homogeneous behaviors of the specific activity distribution in any of the tree disks are observed. There are preferential sites in each tree disk where the ^{137}Cs concentration increases. The results also show that the ^{137}Cs contamination has a trend, increasing with the height of the disks. The highest values are observed for the sample corresponding to 1 m above the ground. Besides, there is a lateral migration of this radioelement in wood, where the highest concentration is located in rings near the bark. Again, we can observe that this increase is occurring in a preferential side of the trunk. A possible explanation to this fact is that cesium can move within the tree [9]. In addition, this guava tree was cultivated near (approximately 30 cm far) a wall, one of which sides much more sunlit than the other. It is interesting to mention that this side of the trunk has the corresponding highest values of ^{137}Cs concentration.

Also, potassium is a common vegetable nutrient and cesium has the ability to substitute potassium during the absorption process of nutrients by the vegetal. Besides, some works have shown that the ^{137}Cs radial distribution in tree rings has a similar trend in comparison with ^{40}K [10]. Thus, both the cesium mobility and the effect of sunlight can justify the experimental observation of the cesium preferential lateral migration. Thus, the ^{137}Cs mobility observed in this guava tree shows that cesium can be used to obtain a detailed modeling of salts transport through the interior of trees.

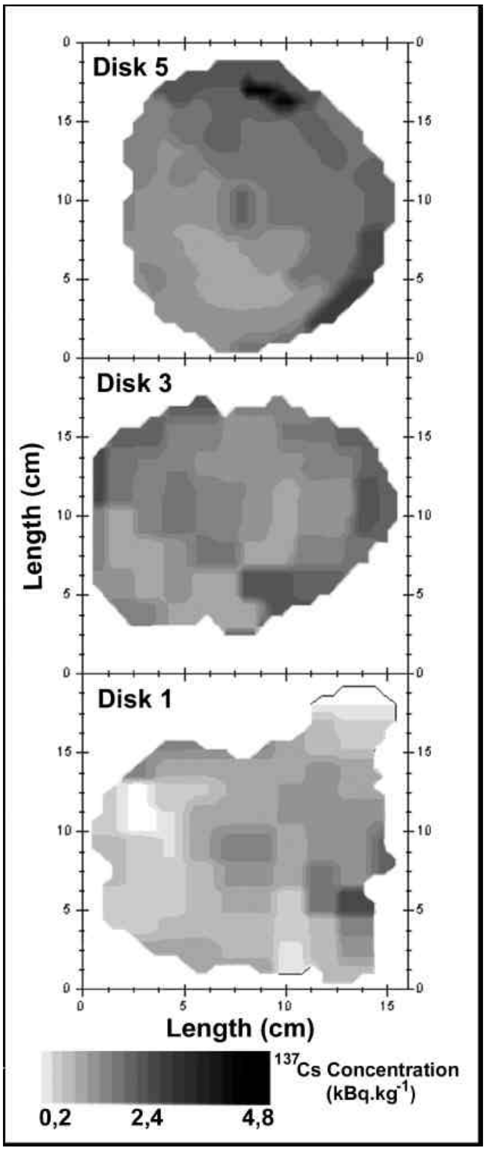

Figure 3. Illustration of the ^{137}Cs radial distribution in three of the guava tree trunk disks (see Figure 1 for identification of these disks).

4 Conclusions

The results presented in this paper indicate that the ^{137}Cs taken up by trees will migrate into the trunks and accumulate there, confirming the present knowledge on the transport and distribution of salts in guava trees. The specific ^{137}Cs activity is higher in the growing parts of the guava tree: fruits, leaves, needles, twigs and the outer growth layers. On the other hand, the bi-dimensional diagrams of the ^{137}Cs radial distribution show more accurate results than the conventional one-dimensional diagrams, disclosing no symmetrical or homogeneous behaviors of the specific activity distribution in any of the tree disks. Contamination of the edible parts of a guava tree can reach about 2% of the ^{137}Cs concentration present in soils such as this one in Goiânia.

Acknowledgments

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