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Determination and spatial distribution of ^{137}Cs in soils, mosses and lichens near Kavanayen, Venezuela

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The activity of ^{137}Cs was determined in soils, mosses, lichens and other vegetation along the Caruay River and near the town of Kavanayen. The range of values for the soils was from <1.2 Bq·kg^{-1} of ^{137}Cs (our detection limit) to 14.1 Bq·kg^{-1}. The range of ^{137}Cs activities in the mosses ranged from 9.9 to 17.9 Bq·kg^{-1} with a mean value of 13.4±4 Bq·kg^{-1}; all the moss samples were found along the river. While the ^{137}Cs activities in the lichens ranged from 9.1 to 29.8 Bq·kg^{-1}; the two values along the river were about three factors higher than the one near Kavanayen. It was concluded that the ^{137}Cs activities in the soils, mosses and lichens are much higher along the river in respect to the nearby town of Kavanayen.

Introduction

As a result of the Chernobyl nuclear power plant accident on April 26, 1986, many countries which were not affected directly by fallout began or revived environmental radioactivity studies. In Venezuela, measurements to monitor the importation of milk powders and meats began.[1,2] Afterwards, measurements were undertaken to generally define the environmental radiation natural background levels from soils country-wide, as well as the spatial distribution of ^{137}Cs.[3,4] Other reports involved the determination of ^{137}Cs activities in many different types of vegetation, such as mosses, grasses and cactus plants.[5,6] Many studies were able to relate significantly high ^{137}Cs concentrations in soils and vegetation as the result of the effects of cloud forest.[7–9]

In one of our recent studies,[10] four significantly higher values between 3.7 and 6.7 Bq·kg^{-1} of ^{137}Cs were determined from eleven soil samples on the western side of Kavanayen. All these values were from soils located in patches of very small dense forest with very rich organic soils rather than from areas with the commonly poor soils covered with coarse grasses. The climate near Kavanayen was classified as very humid pre-mountainous with high annual rainfall in the westerly direction. Thus, it was decided to study the soils west of Kavanayen and along the northern part of the Caruay River, since dense forest in the Gran Sabana are primarily found along the rivers and usually less than 50 meters wide. It should also be mentioned that fog is normally formed daily near them.

There have been many publications on the use and applications of lichens as bio-monitors of atmospheric contaminations, most of which can be found in a recent review.[11] Some studies mention correlation between the radionuclide concentration in lichen and the environment, but no well known relationship between the concentrations in lichens and their respective atmosphere.[12] Lichens obtain nutrients for growth and metabolism from both wet and dry precipitation.[13] Accumulation of dust or soil particles which settle in the intercellular space can also occur. Pollutants can be deposited onto lichens directly or indirectly from fog, dew or gas absorption.[14]

Mosses do not have root systems that interact with the top soil similar to lichens and depend on surface absorption for nutrient uptake from again both wet and dry precipitation. But, many sources of input to mosses other than the atmospheric are known, such as the marine effect, the vegetable effect and the soil factor.[15] Thus, both lichens and mosses can be used as bio-monitors of the environment, remembering that they not only reflect the wet and dry precipitations from the atmosphere but also other inputs.

Experimental

Soils, mosses and lichens were collected along the Caruay River and both east and west of Kavanayen (Venezuela), according to our routine laboratory procedures[6] during February 2004. A map showing the sampling areas is presented in Fig. 1 and the geographical coordinates of the exact locations are listed in Table 1. The soils were sampled from the top layer of soil (0–10 cm) after the surface was cleared from vegetation and mat material. In the laboratory, the soils were dried in a large oven in metal trays for two or three days at 105 °C. After cooling, they were ground with a ceramic mortar and pestle in order to pass a 20 mesh sieve (2.36 mm). Finally, the powdered sample was transferred to 1-liter plastic bottles to the fixed height of 10 cm and weighed. The mosses were broken into small pieces and were air dried for a week or two, before further drying in a large oven in 4-liter glass beaker at 60 °C for two days and at 80 °C for another two days.

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The dried material was ground between one's hands and then passed a 8 mesh sieve, before passing through a 20 mesh (<0.85 mm). These powders were transferred separately to 1-liter plastic bottles to the height of 10 cm, similarly as the soil samples and then finally weighed.

The ^{137}Cs measurements were performed by a high-resolution hyper pure germanium detector with an energy resolution of better than 1.8 keV for the FWHM of the 1.33 MeV photopeak of ^{60}Co and an efficiency of greater than 25%. The data was collected with an IBM-compatible computer with a Nucleus ADC/interface card and its software. The mosses were counted for 50,000 seconds and the soils for 20,000 seconds. The corrected net peak intensities of the ^{137m}Ba line at 661 keV were calculated for the samples and compared to the appropiate standard reference material. Soil-6[16] was the comparator for the soils and IAEA-156 (Clover)[16] was the standard reference material for the mosses. The limit of detection of ^{137}Cs for a typical moss was about 0.8 Bq·kg^{-1} and for a typical soil about 1.2 Bq·kg^{-1}. Further information can be found elsewhere.[5]

Results and discussion

The mean activities of ^{137}Cs (Bq·kg^{-1}) dried weight determined from three portions of the samples, the geographical coordinates and altitude (m.a.s.l.) are presented in Table 1 for the sixteen areas studied.

The range of values for the soils was from <1.2 Bq·kg^{-1} of ^{137}Cs (our detection limit) to 14.1 Bq·kg^{-1}. The detection limit was determined by calculating 3 times the square root of the background counts under the 661 keV gamma-ray. But, the values near Kavanayen (sites I to P) were only up to 4.3 Bq·kg^{-1} of ^{137}Cs, in respect to values as high as 14.1 Bq·kg^{-1} of ^{137}Cs along the river. The mean ^{137}Cs values for the soils along the river are more than double those near Kavanayen; 5.4±4 Bq·kg^{-1} versus only 2.3±1. Thus, the differences of the vegetation of the areas, dense forest along the river in respect to the areas with some bushes and grasses near Kavanayen could be a factor in the difference of the ^{137}Cs activities determined.

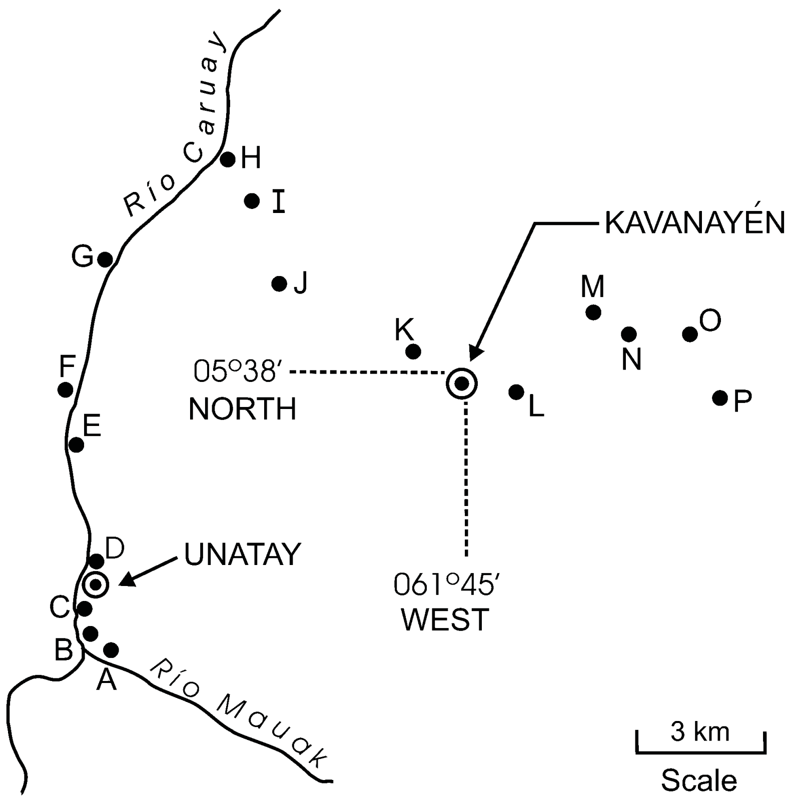

Fig. 1. Map of the sampling sites showing the northern part of the Caruay River and the town of Kavanayen in the state of Bolivar, Venezuela

Table 1. Locations, altitude and activity of ^{137}Cs in the samples collected near Kavanayen and along the Rio Caruay in the state of Bolivar, Venezuela

Site	Type of material	Geographical coordinates	Altitude, m.a.s.l.	^{137}Cs activity, $Bq\cdot kg^{-1}$
A	Soil	05°30.016’N 061°55.365’W	906	7.4
	Fern leaves	05°29.977’N 061°55.441’W	898	10.2
	Fruit	05°30.026’N 061°55.443’W	827	13.2
B	Soil	05°30.664’N 061°55.025’W	1000	2.1
	Soil	05°30.430’N 061°55.241’W	976	<1.2
	Soil	05°30.150N 061°55.335’W	957	1.6
C	Soil	05°31.192’N 061°54.723’W	935	7.2
	Moss	05°31.198’N 061°54.728’W	935	17.9
D	Soil	05°32.441’N 061°54.428’W	970	<1.2
E	Soil	05°34.923’N 061°55.014’W	888	4.7
	Moss	05°34.925’N 061°55.019’W	888	12.8
	Soil	05°35.241’N 061°54.953’W	923	9.2
	Lichen	05°35.243’N 061°54.956’W	926	29.1
F	Soil	05°36.188’N 061°54.585’W	985	2.8
	Moss	05°36.190’N 061°54.957’W	986	9.9
	Soil	05°37.098’N 061°54.899’W	985	1.7
	Soil	05°37.345’N 061°54.846’W	980	1.3
G	Soil	05°39.390’N 061°53.679’W	985	12.1
	Soil	05°39.163’N 061°53.799’W	966	7.5
H	Soil	05°41.545’N 061°51.652’W	1040	7.3
	Lichen	05°41.545’N 061°51.652’W	1040	29.8
I	Soil	05°40.574’N 061°50.740’W	1073	1.4
J	Soil	05°38.654’N 061°50.133’W	1226	1.7
K	Soil	05°37.175’N 061°46.743’W	1191	1.7
	Lichen	05°37.177’N 061°46.745’W	1189	9.1
	Soil	05°37.081’N 061°47.373’W	1223	2.9
L	Soil	05°36.253’N 061°44.721’W	1207	3.2
M	Soil	05°37.937’N 061°42.806’W	1187	1.3
N	Soil	05°37.501’N 061°42.112’W	1290	4.3
O	Soil	05°37.431’N 061°40.713’W	1400	1.9
P	Soil	05°36.093’N 061°40.003’W	1423	2.1

The other factor that could explain the higher values along the river is the differences in the temperatures of the water and air, which creates fog and moisture daily.

The ^{137}Cs activities in the mosses ranged from 9.9 to 17.9 $Bq\cdot kg^{-1}$ with a mean value of 13.4±4 $Bq\cdot kg^{-1}$; all the moss samples were found along the river. The ratio of ^{137}Cs activity in the mosses versus their corresponding soils were between 2.4 and 3.5 $Bq\cdot kg^{-1}$; these values are similar to those previous determined on the Venezuelan mainland.[6]

While the ^{137}Cs activities in the lichens ranged from 9.1 to 29.8 $Bq\cdot kg^{-1}$; the two values along the river were about three factors higher than the one near Kavanayen. The ^{137}Cs activity ratios between the lichen and their corresponding soil were between 2.4 and 5.4, the higher value being near Kavanayen. This suggests that the more organic rich soil along the river is a better accumulator of ^{137}Cs than the sandy soils near Kavanayen, which is general knowledge.

Conclusions

It was shown that the ^{137}Cs activities in the soils, mosses and lichens are much higher along the Caruay River than at the nearby town of Kavanayen. These differences can be explained by the following factors: types of soil (organic rich or sandy), vegetation (dense rainforest or small bushes and grasses) and the effect of condensation from the fog produced along the river.

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