Fallout radiocaesium in Mackellar Inlet during the austral summer 2013

José Osores*, Susana Gonzáles

Laboratorio de Radioecología, Dirección de Servicios, Instituto Peruano de Energía Nuclear.
Av. Canadá 1470, Lima 41, Perú

Resumen

Las actividades de radiocesio en muestras de suelo y líquenes colectados durante el verano austral fueron determinadas por espectrometría gamma de alta resolución. Los resultados muestran que la cantidad de radiocesio retenido por las muestras de líquenes está dada en función de la altitud de las áreas de muestreo y los valores en suelo superficial muestran que la cantidad de radiocesio retenido por el suelo es una función inversa a la altitud de las áreas de muestreo. Aunque en el año 2013, el inventario de radiocesio atmosférico ha disminuido con la suspensión de los ensayos nucleares, aún es posible registrar pequeñas concentraciones en el aire gracias al estudio de líquenes como biomonitores.

Abstract

Radiocaesium activity in soil samples and lichens collected during the austral summer were determined by high resolution gamma spectrometry. The results show that the amount of radiocaesium, retained by the lichen samples, is a function of the altitude of the sampling areas, and values in surface soil show that the amount of radiocaesium, retained by the soil, is an inverse function of the altitude of the sampling areas. Although in 2013, atmospheric radiocaesium inventory has decreased with the suspension of nuclear tests, it is still possible to register small concentrations in the air thanks to the study of lichens as bio-monitors.

1. Introduction

The global anthropogenic radioactive fallout mainly originated from atmospheric atomic explosions carried out since 1945 and from other atmospheric emissions from atomic facilities. According to UNSCEAR (1982) only about 25 % of the global ^{137}Cs and ^{90}Sr fallout caused by above ground nuclear tests has been deposited within the Southern Hemisphere. The deposition density of this global fallout is estimated to be in general higher at mid-latitudes and to decrease towards the equator and the poles [1, 2].

The information about the anthropogenic radioactive levels and the migration of the radionuclides in the soil is of fundamental importance to evaluate the radioecological sensitivity of an ecosystem, in terms of risk related to existing and potential future radioactive contamination.

The Antarctic territory is relatively distant from the above-mentioned radioactive sources. Therefore, and due to its extreme latitudinal position, it can be regarded as an area having the lowest anthropogenic radioactive levels on earth. In general data on radioactive contamination at the Antarctica are sparse compared to information about Arctic environments [3]. The proportion of the Antarctic territory not covered by snow and ice is very low; nevertheless there are a few studies about fission product concentrations in surface soils at the Antarctica [4, 5, 6, 7].

The global repository of ^{137}Cs associated with nuclear weapons testing in the decades of the 50s and 60s has provided an artificial tracer for studies of soil erosion and sediment delivery. In many environments (tropical, subtropical, temperate, etc.), the ^{137}Cs penetrates the soil surface and is strongly and rapidly adsorbed by clay minerals and subsequent lateral redistribution occurs in association with sediment particles response to the processes of erosion, transport and deposition. The more complex calibration relationships for converting ^{137}Cs loss in soil loss rates require the annual deposit information ^{137}Cs (Bq.m-^{2}.year^{-1}). In the absence of such information, the annual deposit rate and the temporal distribution of ^{137}Cs can be estimated from the values recorded by other environmental radiation monitoring stations.

With the aim of improving knowledge on radioactive contamination of such soils, the study presented here describes the activity of

* Correspondence author: josores@ipen.gob.pe

^{137}Cs at Mackellar Inlet and the fraction of the activity retained in the lichen cover (Bio-accumulation factor).

2. Material and Methods

Mackellar Inlet **(**Coordinates: 62°5′S 58°28′W) is an inlet forming the northwestern head of Admiralty Bay [8], at King George Island in the South Shetland Islands (Figure 1). It was probably named by the Fourth French Antarctic Expedition under Jean-Baptiste Charcot, who charted Admiralty Bay in December 1909. Admiralty Bay is an irregular bay, 8 km wide at its entrance between Demay Point and Martins Head, indenting the southern coast of King George Island for 16 km, in the South Shetland Islands of Antarctica. The name appears on a map of 1822 by Captain George Powell, a British sailor, and is now established in international usage. It has been designated an Antarctic Specially Managed Area (ASMA 1).

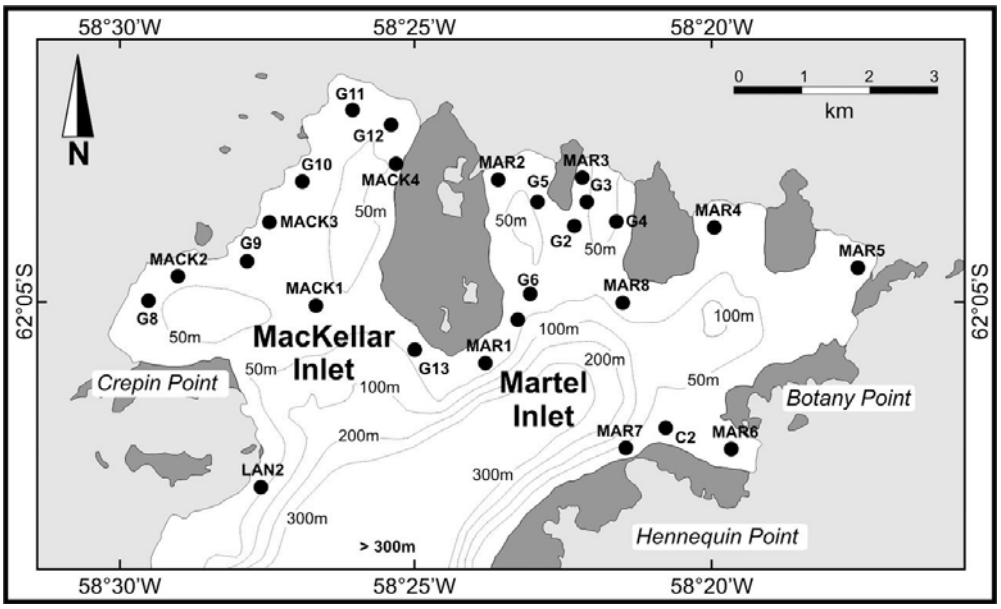

Figure 1. Location of Mackellar Inlet.

Lichen and soil samples were collected from Mackellar Inlet, near the Machu Picchu Antarctic Scientific Station, at Admiralty Bay, during the Austral summer 2013 (Table 1), and identified as *Usnea antarctica* Du Rietz.

The sample collection and identification was performed by a biologist-lichenologist of the Natural History Museum of the Universidad Nacional Mayor de San Marcos (UNMSM) from Lima, Peru.

Table 1. Sampling of lichen and soil form Mackellar Inlet.

Sample	*Code*	*Geographical Location*		*Altitude*	*Date*
		Latitude	*Longitude*	*(m)*	
Lichen	L1	62,09344444° S	58,4692500° W	21.00	2013-02-19
	L2	62,09427778° S	58,4738056° W	30.00	2013-02-19
	L3	62,09185700° S	58,4756810° W	3.00	2013-02-22
Soil	S1	62,09411000° S	58,4674300° W	6.37	2013-02-20
	S2	62,09359000° S	58,4697100° W	21.00	2013-02-20
	S3	62,09191000° S	58,4763300° W	8.00	2013-02-21
	S4	62,09282200° S	58,4687650° W	5.00	2013-02-22

Figure 2. Sampling of surface soil.

The samples for ^{137}Cs analysis were dried at room temperature, then oven-dried for 48 hours at 105 °C, crushed and passed through a 2 mm sieve [9].

The ^{137}Cs activity concentration in vegetation and soils was determined in 500 mL plastic taper geometry with a gamma spectrometry system (high purity Ge detector of 35% relative efficiency and measuring time 18–20 h).

The concentrations are expressed in Becquerel per kilogram of dry weight ($Bq.kg^{-1}$) and the results were statistically evaluated by analysis of variance with 90% confidence, in order to determine the existence of differences between sampling areas.

Figure 3. Gamma spectrometry system.

3. Results and Discussion

Figure 4 shows a gamma spectrum obtained from analysis of Antarctic lichens which is observed in the presence of the energy level (fotopeak) for the ^{137}Cs (661,66 keV).

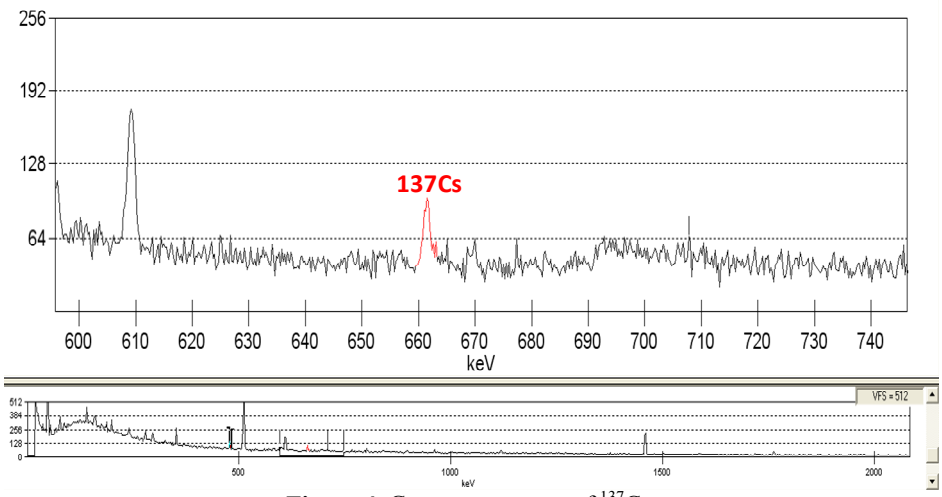

Figure 4. Gamma spectrum of ^{137}Cs.

Derived activity values of ^{137}Cs in lichen samples are presented in Table No.2 and Figure No.5. The results show that the amount of radiocaesium, retained by the lichen samples, is a function of the altitude of the sampling areas.

Table 2. Activity of ^{137}Cs in *Usnea antarctica* Du Rietz.

Sampling Areas	Altitude (m)	Activity of ^{137}Cs (Bq.kg^{-1} dry weight)
L1	21	0,31 – 1,61
L2	30	3,17 – 7,66
L3	3	0,13 – 0,69

The analysis of variance in lichen for different sampling areas showed statistical differences at 90% confidence (Table 3); based on these results it can be stated that the distribution of these radionuclide depends on the altitude of the sampling area.

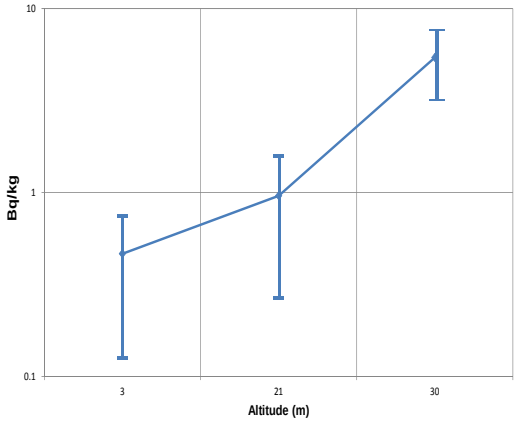

Figure 5. Activity of ^{137}Cs in *Usnea antarctica* Du Rietz.

Table 3. Analysis of variance from lichen results.

Sources	Degree of Freedom	Sums of Squares	Mean Squares	F value	F critical
Sampling areas	2	32,55595	16,277975	5,87859233	4,32455532
Error	4	11,076104	2,769026		

Derived activity values of ^{137}Cs in surface soil are presented in Table 3. The results show that the amount of radiocaesium, retained by the soil, is an inverse function of the altitude of the sampling areas. No analysis of variance was performed because three of the four sampling areas were very close to each other with respect to the area of higher altitude.

Table 4. Activity of ^{137}Cs in surface soil.

Sampling Areas	Altitude (m)	Activity of ^{137}Cs (Bq.kg^{-1} dry weight)
S1	6.37	1,31 – 1,74
S2	21	0,80 – 1,10
S3	8	5,40 – 6,02
S4	5	1,32 – 1,76

The exponential model developed for the derived ^{137}Cs activity depending on the altitude, shows a positive correlation for lichens and a negative correlation for soils (Figure 6).

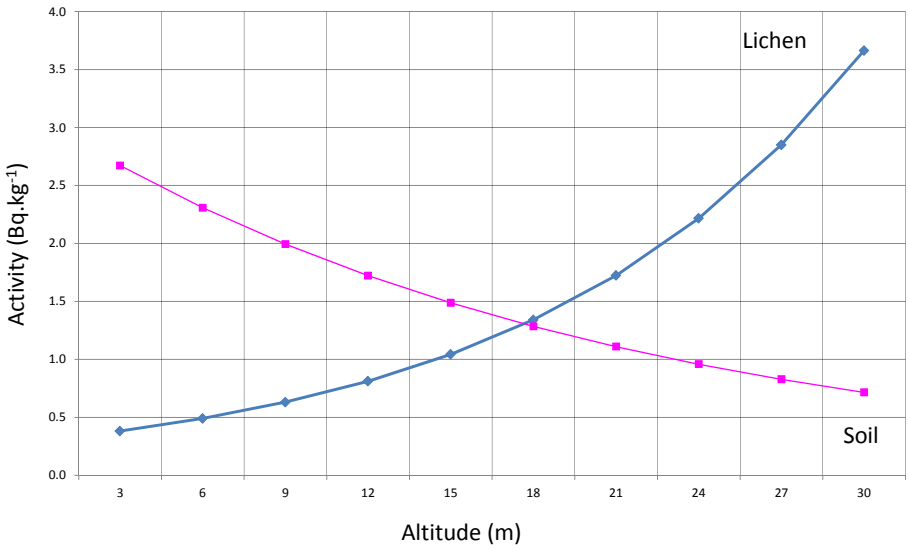

Figure 6. Distribution of ^{137}Cs vs altitude.

$$Activity_{(Lichen)} = 0{,}2970274 * e^{(0{,}0837452 * Altitude)}$$

$$Activity_{(Soil)} = 3{,}0924693 * e^{(-0{,}.487962 * Altitude)}$$

As ^{137}Cs is precipitated from the atmosphere, it is expected that organisms located at a higher altitude will have more of this radionuclide bio-accumulated.

Otherwise occurs with soil samples, where most activity is found in lower levels, which is due to the ^{137}Cs deposited at higher altitudes is transported to the coast by different processes such as rain or erosion.

The bio-accumulation factor of lichens from the soil is less than 1 until the 15 meters, because the lower soil receives ^{137}Cs from elevated areas due to erosion or rain (Figure 7).

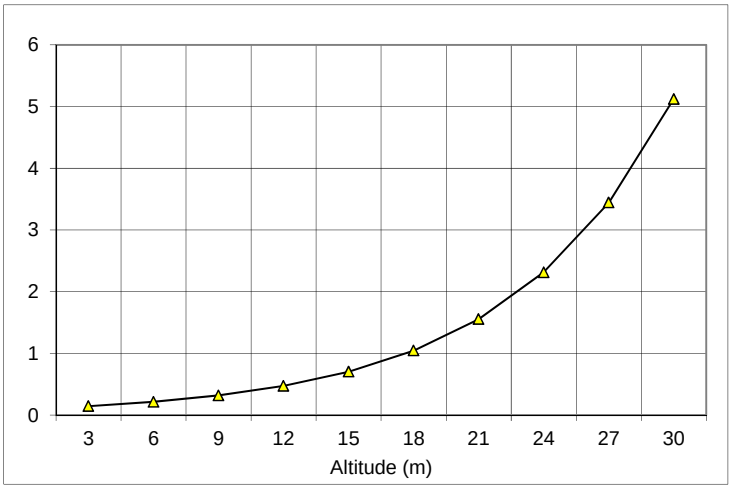

Figure 7. Bio-accumulation factor of lichens from the soil.

4. Conclusion

Although atmospheric ^{137}Cs inventory has decreased with the suspension of nuclear tests, small concentrations in the air are still possible to be registered thanks to the study of lichens as bio-monitors.

Furthermore, this study has verified that the ^{137}Cs can be used as an indicator of sedimentary phenomena in the Mackellar inlet.

5. Acknowledgments

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