Density variation of ^{137}Cs activity in surface soil from the King George Island

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Resumen

El comportamiento del radiocesio procedente de los ensayos nucleares realizados en el hemisferio sur fue evaluado y se estimó su comportamiento en el suelo de la Isla Rey Jorge. En base a los resultados obtenidos por varios autores, se estimó en 4,5 años el tiempo de semiagotamiento para el Cs-137 acumulado en la región desde 1993.

Abstract

The behavior of radiocaesium from the nuclear tests conducted in the southern hemisphere was evaluated and their behavior was estimated on the floor of King George Island. Based on the findings made by several authors, was estimated at 4.5 years the time of semi-exhaustion for Cs-137 accumulated in the region since 1993.

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 [1] 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 [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. The annual deposition rates of ^{137}Cs were reconstructed from ^{90}Sr and ^{137}Cs deposition data reported for South Shetland Islands by several authors [8,9,10,11], assuming a $^{137}Cs/^{90}Sr$ activity ratio in the deposition of 1.6. Initially, the reported deposition was measured at Chilean Pedro Aguirre Cerda Base, Deception Island (geographical position 62°56'S, 60°36'W, annual precipitation rate 430 mm $year^{-1}$). In 1967, this meteorological station was destroyed by a volcanic eruption and the measurements were continued at the Chilean station located at Frei Base, King George Island. For the deposition during the years

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previous to those provided by HASL [8], the estimation was made on the basis of the reported annual deposition of ^{90}Sr in the Southern Hemisphere and the corresponding fraction of the total deposition at the 60°S – 70°S latitudinal band by UNSCEAR [1]. With the aim of improving knowledge on radioactive contamination of such soils, the study presented here describes the behaviour of the surface soil deposition of ^{137}Cs by determining its depletion factor in the ecosystem of King George Island.

2. Material and Methods

Surface soil samples were collected from Mackellar Inlet, near the Machu Picchu Antarctic Scientific Station, at Admiralty Bay, during the 2012/2013 Austral summer (Table 1). The sample collection was carried out 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 surface soil.

Sample	Code	Geographical Location Latitude	Geographical Location Longitude	Altitude (m)	Date
	S1	62,09411000° S	58,4674300° W	6.37	2013-02-20
Soil	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

Source: Angel Ramirez (Biologist from UNMSM)

Samples for ^{137}Cs analysis were dried at room temperature, then oven-dried for 48 hours at 105 °C, crushed and pass through a 2 mm sieve [12]. The ^{137}Cs activity concentration in soils samples 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 Becquerels per m^2 of dry weight ($Bq.m^{-2}$) by 2013-01-01 and the results were incorporated with other research data and adjusted to an exponential curve to determine the exhaustion coefficient.

The variation of the surface activity is described as:

$$A = A_o . e^{-(\alpha . t)}$$

Were:

A : Surface activity per year ($Bq.m^{-2}$)
A_o : Initial activity ($Bq.m^{-2}$)
α : Exhaustion coefficient expressed as: $(Ln(2))*(T1/2)^{-1}$
T1/2 : Semi-exhaustion time (year)
t : Elapsed time (year)

3. Results and Discussion

Derived activity values of ^{137}Cs in surface soil are presented in Table 2. 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 are very close to each other with respect to the area of higher altitude.

Table 2. Activity of ^{137}Cs in surface soil.

Sampling Areas	*Altitude (m)*	*Activity of ^{137}Cs (Bq.m-2 dry weight)*
S1	6.37	51,92 ± 14,67
S2	21	32,43 ± 10,01
S3	8	46,53 ± 11,10
S4	5	52,55 ± 15,09

Referred date 2013-01-01.

Table 3 presents the values of surface density of ^{137}Cs in soil from 1993 to 2013, all values have been referred to 2013-01-01 for better statistical evaluation, we can see that the values have been declining over time since the first studies by Schuller, *et al* [12].

Table 3. Activity density in soil (1995-2013).

Year	*Activity ($Bq.m^{-2}$)**	*Reference*
1993	195.36	Schuller *et al.*, 2002
1994	173.65	Schuller *et al.*, 2002
1995	238.47	Schuller *et al.*, 2002
1996	124.11	Gonzales *et al.*, 1996
1997	91.90	Godoy *et al.*, 1998
1997	27.56	Gonzales *et al.*, 2002
1998	35.20	Gonzales *et al.*, 2002
1999	75.99	Gonzales *et al.*, 2002
2000	32.57	Gonzales *et al.*, 2002
2013	45.86	

(*) Referred date 2013-01-01

It is important to note that the results have a wide degree of dispersion because the collection points of topsoil were carried out in different areas of King George Island.

The exponential model developed for the ^{137}Cs activity depending on the time, shows a negative correlation for soils, with a semi-exhaustion time equal to 4,5 years and a exhaustion coefficient equal to 0,15737371 (Figure 1).

$$A = A_o * e^{(-0{,}15737371*t)}$$

This proposed model does not include the process of re-suspension of ^{137}Cs from soil or new additions of this radionuclide due to fallout.

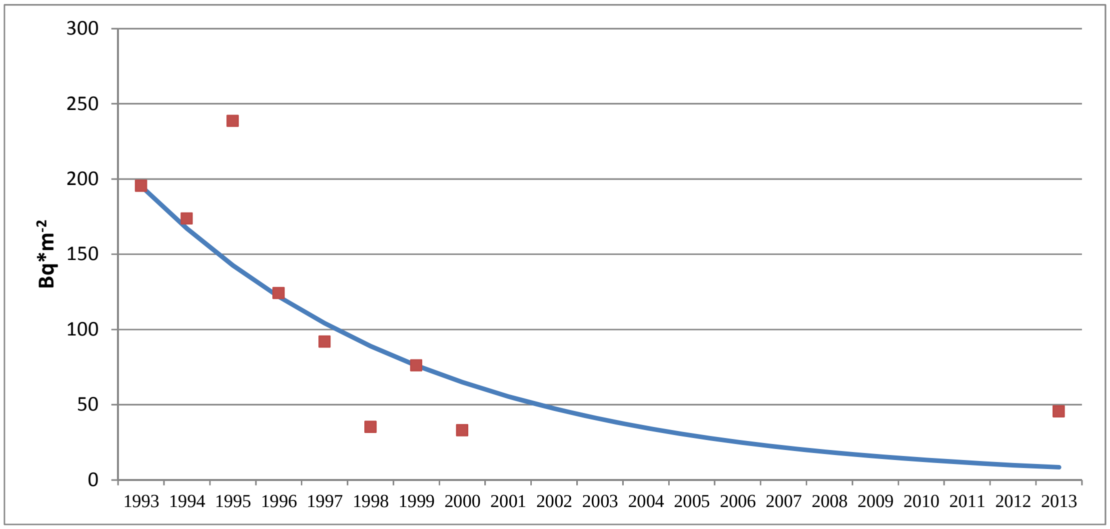

Figure 1. Variation of the surface activity from ^{137}Cs (1993-2013).

4. Conclusion

The semi-exhaustion time of ^{137}Cs in surface soil was 4.5 years from 1993 to 2013.

Currently the surface density of ^{137}Cs in the area of Machu Picchu Antarctic Scientific Station is in the range of 32.43 to 52.55 $Bq.m^{-2}$.

Although atmospheric ^{137}Cs inventory has decreased with the suspension of nuclear tests, it is still possible to register small concentrations in the surface soil.

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