Environmental Radioactivity at Machu Picchu Scientific Station

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ABSTRACT. Studies on environmental radioactivity at the Peruvian Scientific Station were carried out in the last two austral summer periods. The main objective of this study is to establish an environmental radiological monitoring program for evaluating environmental components and achieving a baseline study related to artificial and natural radioactivity levels. For this purpose, samples such as seaweeds, mosses, lichens, soil, sea water, ice, marine sediment and underground water were collected from the area surrounding the station starting from Punta Crepin to Playa Inca and Playa Naylamp; then they were pre-conditioned in Machu Picchu Station and were sent to the Environmental Radioactivity Laboratory of "RACSO" Peruvian Nuclear Center to conduct beta and gamma spectrometry. The obtained results showed the presence of Cs-137 in geological components (soil and sediment) and in biological components (lichens and mosses). Nevertheless, those levels seem to be in a range of normal fluctuations after atmospheric nuclear testing and they are not considered to be dangerous to the ecosystem of the Antarctic Region. On the other hand, high concentration of Be-7 has been detected in seaweed and lichens. Other natural radionuclides detected were Ra-226, Bi-214 and K-40.

Key Words: environmental radioactivity, King George Island, Mackellar Inlet, radiological monitoring

Introduction

Machu Picchu Station is located in Mackellar Inlet, King George Island (62°05′ 39″S, 58°28′ 16″W). Cs-137 is artificial in origin, therefore the presence of Cs-137 in the environment is due to nuclear testing or releases from nuclear accidents (Carter *et al.* 1997), in such cases, Cs-137 and other radionuclides are injected into the stratosphere circulating globally.

A baseline study about artificial and natural radioactivity at Machu Picchu Station surrounding has been initiated. The aim of collecting data on natural and artificial radiation is to evaluate the current status of the environment in this region and make future comparisons.

This article provides an overview on the radioactivity levels and summarizes preliminary results of radiological measurements in various environmental samples of the Antarctica Region.

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Materials and Methods

Sampling and treatment of samples

After recognition tasks, biological samples (Rodriguez *et al.* 1995) such as seaweeds (*Iridae cordata* and *Desmarestia* sp.), vascular plants (*Deschampsia antarctica* and *Colobanthus quitenses*), mosses (*Drepanocladus uncinatus*) and lichens (*Usnea antarctica*) were identified and collected to be analyzed. Geological samples (soil and sediment) and water samples (underground water and sea water) were also collected. Table 1 shows an outline of the environmental monitoring program around the Machu Picchu Station and the Fig. 1 shows the sampling areas.

Table 1. Outline of the Environmental Radiological Program

SAMPLE	SAMPLING AREA	NUCLIDES
Glaciar ice	Glaciar Lange Glaciar Domeyko	H^3, gross beta, gamma spectrometry
Sea water	Punta Crepin	H^3, gross beta, gamma spectrometry
Underground water	Estación Machu Picchu	H^3, gross beta, gamma spectrometry
Marine Sediment	Ensenada Mackellar	Gross beta, gamma spectrometry
Soil	Estación Machu Picchu	Gross beta, gamma spectrometry
Seaweed	Playa del Inca Playa Naylamp	Gross beta, gamma spectrometry
Lichen	Playa del Inca Playa Naylamp	Gross beta, gamm a spectrometry
Mosses	Estación Machu Picchu	Gross beta, gamma spectrometry
Whale bone remains	Playa del Inca	Gross beta, gamma spectrometry
Aerosols	Estación Machu Picchu	Gross beta, gamma spectrometry

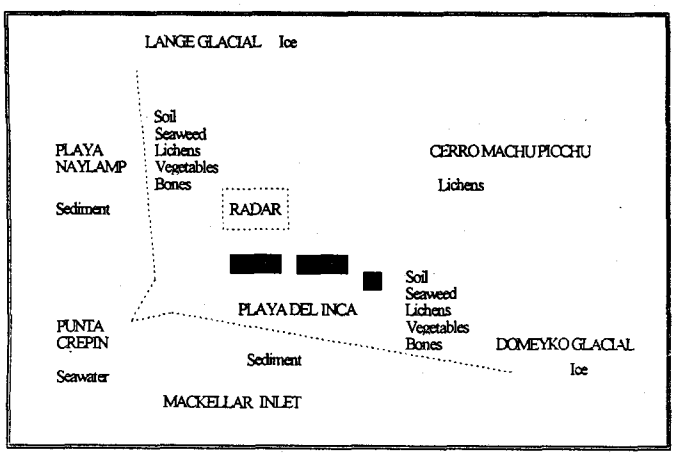

Fig. 1. Sampling areas around the Machu Picchu Station.

Air particulate matter was collected using a continuous high volume sampler. Marine sediment (0-10 cm depth) was collected using dredges in the Mackellar Inlet. Two upper layer soil samples (0-5 cm depth) at each site were sampled. The total of 95 geological and biological samples were collected at 19 different sites.

Biological samples washed and dried in Machu Picchu Station, were sealed in a container to be sent to the Environmental Control Laboratory of the "RACSO" Nuclear Center. Weighed and ashed biological samples, salts obtained from water samples and dried, ground and sifted marine sediments were placed in pre-established geometries in order to be analyzed (TRS 295 - IAEA 1989).

Instrumental analysis

The samples were measured mainly for gross beta activity, gamma ray spectrometry and analyzing a particular radionuclide such as H-3.

Total alpha activity. ZnS scintillation detector and Silena Analyzer were used to measure total alpha activity. Calibrations were done using the Am-241 sealed source in order to establish the efficiency of the detector and detection limits.

Total beta activity. LAS-3A Telecom Low Background Detector was used to measure total beta activity. Calibrations were done using K-40 in order to establish the efficiency of the detector and detection limits.

Gamma spectrometry. High resolution HPGe Semiconductor detector, nuclear electronics associated, lead shielding (0.6 cm of thickness), S-100 multichannel card installed in IBM-PC were used. System was calibrated for different geometries using standard solutions of Eu-152 and I-131. Efficiency curves for each geometry used were configured by establishing a logarithmic regression according to their energies. Minimum concentration detectable were determined on the basis from IAEA Technical Report Series 295 (Ballestra 1990). Counting of activity from environmental samples was performed for 60000 seconds.

Liquid scintillation. Pre-treated water samples were placed in vials containing Instagel scintillation solution for tritium analysis (Momoshima *et al.* 1991). Measurements in a Packard System were carried out.

Results and Discussion

Our findings about total alpha measurements show that the activity is caused by natural radionuclides (Thorium and Uranium daughters). Total beta measurements in biological and geological samples

Table 2. Radioactivity concentration in environmental samples in Machu Picchu Station

SAMPLE	Unit.	Be^7	K^{40}	Cs^{137}
Glaciar ice	bq l^{-1}	< 1.30	< 68.80	< 1.80
Sea water	bq l^{-1}	< 1.30	< 76.60	< 1.20
Underground water	bq l^{-1}	< 4.10	< 69.60	< 1.10
Marine Sediment	bq kg^{-1} dry	< 18.70	2713.5 ± 639.7	21.25 ± 7.35
Soil	bq kg^{-1} dry	14.10 ± 9.8	1798.80 ± 34.7	5.40 ± 5.1
Seaweed	bq kg^{-1} dry	67.18 ± 57.5	567.33 ± 362.0	< 3.00
Lichen	bq kg^{-1} dry	1458.55 ± 714.0	301.20 ± 54.0	55.85 ± 36.9
Mosses	bq kg^{-1} dry	14.2 ± 2.0	784.9 ± 28.0	20.00 ± 4.5
Whale bone remains	bq kg^{-1} dry	< 8.90	44.40 ± 6.7	< 1.80
Aerosols	bq m^{-3}	< 6.00	< 120.00	< 2.00

show high levels of radioactivity but those values can be explained by the presence of K-40 (TRS 169 - IAEA 1975). Values within the detection limit for tritium in water samples were detected. However, it is necessary to accumulate sufficient baseline data to evaluate this radionuclide (Momoshima *et al.* 1991).

Photopeak evaluations corresponding to natural and artificial radionuclides were done in order to assess the radioactivity by gamma spectrometry. Radioactivity concentrations in environmental samples of the Antarctica Region are summarized in Table 2. Cs-137 radioactivity concentrations in geological and biological samples are showed in Fig. 2. Be-7 was detected in biological samples in which concentrations of 67.18 ± 57.5 bq kg^{-1} dry have been detected in seaweeds and concentrations of 1458,55 ± 714,0 bq kg^{-1} dry in lichens (Fig. 3). Ra-226 and Bi-214 are natural radionuclides and they always are distributed in environmental matrices (TRS 169-IAEA 1975). The radioactivity of artificial nuclides in most of the environmental samples drop to the lowest detectable levels (Schuller *et al.* 1993).

Making a comparison with other biological samples, concentrations of Cs-137 have been detected in lichens at higher levels (55.85 ± 36.9 bq kg^{-1} dry). It would indicate that those organisms have the ability to concentrate radioisotopes, which could be used like biomonitors. In geological samples, there were clearly identified photopeaks corresponding to Cs-137. The concentration of Cs-137 and K-40 in sediment samples were of 21.25 ± 7.35 and 2713.5 ± 639.7 bq kg^{-1} dry, respectively. In comparison, sediment samples from the Chilean coast have Caesium-137 concentration values below 0.11 bq kg^{-1} on average; in the same way, concentrations among 14 and 32 bq kg^{-1} dry were found in antarctic lichens

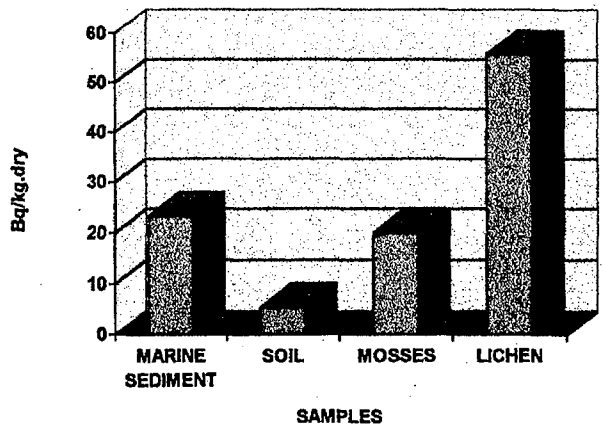

Fig. 2. Cs^{137} activity concentration in environmental samples (bq kg^{-1} dry).

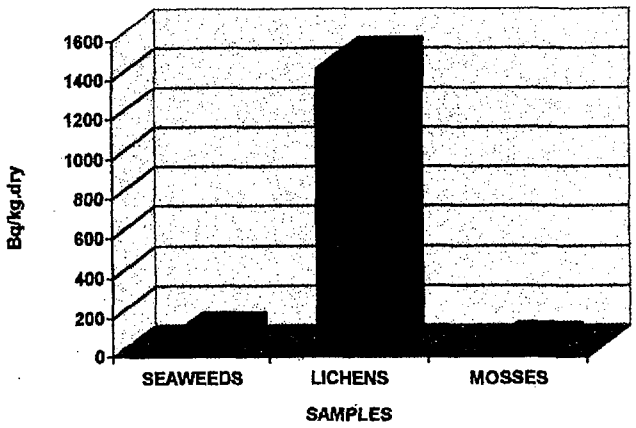

Fig. 3. Be^7 activity concentration in environmental samples (bq kg^{-1} dry).

(CPPS-PNUMA 1996). Cs-137 has a half time of 30.2 years and lichens have a long life span, therefore those radioactivity concentrations can be explained by atmospheric nuclear testing carried out in past decades. Cs-137 is strongly adsorbed on clay and organic particles and is essentially nonexchangeable (Kim 1994).

K-40 is a natural radionuclide and it is present in both biological and geological samples (TRS 169 - IAEA 1975), thus concentration of 1798.80 ± 34.7 bq kg^{-1} have been found in soil and concentration of 567.33 ± 362.0 bq kg^{-1} in seaweeds. Making comparison K-40 levels in Chilean coast sediment varied from 99 to 1015 bq kg^{-1}.

The results of this survey show the presence of Cs-137 in both geological and biological compartments. However, those levels do not constitute potential risk for the Antarctica Region (TRS 172 - IAEA 1976) and they could be considered to have radioactivity levels in a normal range of fluctuation after atmospheric testing and nuclear accidents (USARC, HASL-258 1972).

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