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Beryllium-7 in lichens (*Usnea antarctica* Du Rietz) colllected in the Machu Picchu Antarctic Scientific Station during the austral summer 2012-2013

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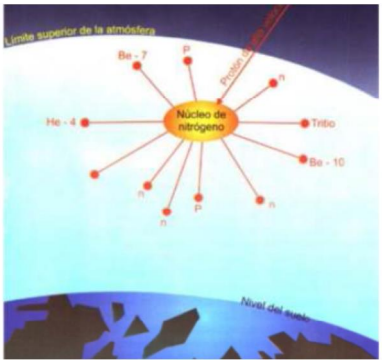
1. INTRODUCCIÓN

Beryllium-7 (^{7}Be) is a natural radionuclide (Eγ = 477,6 keV, t1/2 = 53,3 d), which is produced in the upper atmosphere by the interaction of cosmic rays with nuclei of nitrogen and oxygen (Kaste *et al*., 2002). Enter the environment mainly by wet deposition (rain, snow), while its income from dry tank (gravity) is less than 10% (Benitez-Nelson & Buesseler, 1999).



The atmospheric concentration of ^{7}Be is not uniform, depending on the geographical location, solar activity, the exchange of air masses in the atmosphere and the efficiency of removal from the troposphere (Kaste *et al.*, 2002). Several authors reported variations of ^{7}Be content in rain with the magnitude and intensity of precipitation, the duration of the event, and the elapsed time between events (Wallbrink & Murray, 1994; Caillet *et al*., 2001, Kaste *et al.*, 2002; Ioannidou & Papastefanou, 2006, Lohaiza *et al*., 2011).

Once the ^{7}Be reaches the surface of the planet, not dispersed evenly but tends to be set mainly in superficial or aquatic plants and to a lesser degree in the topsoil. Currently this radionuclide is being used frequently for studies of climate change in different countries (Liu *et al*., 2013).

Lichens are symbiotic organisms formed by a mycobiont and photobiont, living in an intimate morphological and physiological perhaps one of the most perfect symbiosis known. The literature of lichens as bio-indicators of air pollution and bio-accumulators has increased greatly in recent years. The first observations on the sensitivity of lichens to air pollution dating from the last century, although most of the researches in this field are recent.

Lichens possess several characteristics of an optimal biological indicator:

- They have no protective or selective structures with respect to substances in the environment.
- They do not have a mechanism of active absorption from the substrate, most of the nutrients used for deriving lichens atmospheric deposition.
- They are quite sensitive to certain gases, such as sulfur dioxide and hydrogen fluoride contaminants, and at the same time they tend to accumulate without apparent damage, high concentrations of other pollutants (eg various mineral elements).
- They do not have a mechanism for excretion of substances.
- They contain significant amounts of cellulose or lignin, most lichen thalli fungal hyphae are composed of a thin wall of chitin
- They are quite sensitive even to small changes in the pH of the substrate.
- They are common to a variety of substrates in all areas where pollution does not reach extreme levels.

The aim of this report is to present the ^{7}Be concentration levels in Antarctic lichens collected during the Antarctic Summer 2013 in the Machu Picchu Antarctic Scientific Station, located in Admiralty Bay, King George Island.

2. MATERIAL AND METHODS

Antarctic lichen samples collected during February 2013 in the Machu Picchu Antarctic Scientific Station were provided by scientific staff from the Museum of Natural History from the Universidad Nacional Mayor de San Marcos.

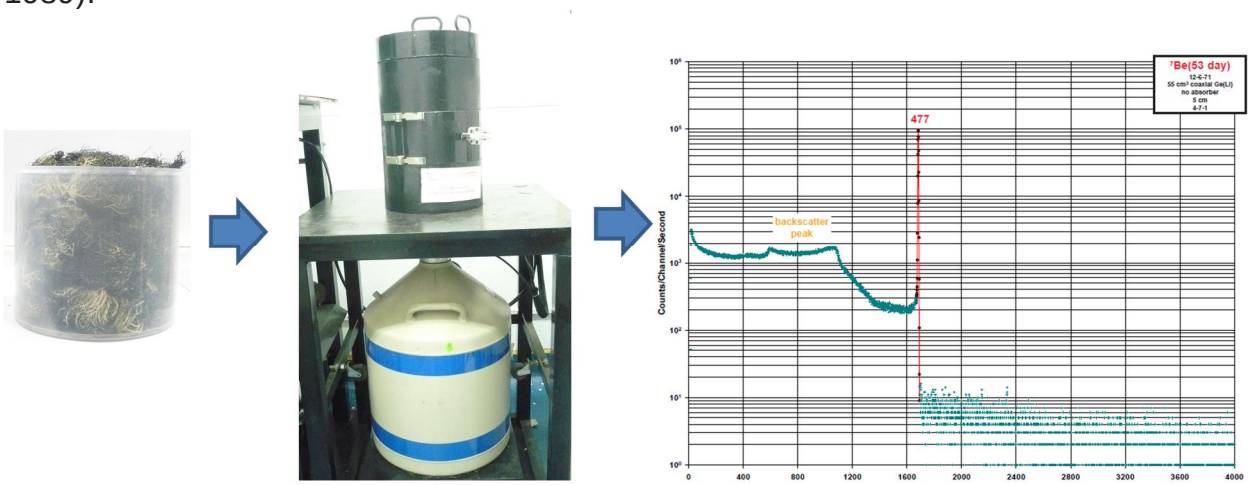
The material was received in paper bags properly identified. Sampling points are presented in Table No.1

Table No.1. Sampling areas of lichens in the Peruvian Antarctic Station 2013

Area	Geographic coordinates		Date of sampling	Altitude (m)
1	-62,09344444	-58,4692500	19 de febrero	21
2	-62,09427778	-58,4738056	19 de febrero	30
3	-62,09185700	-58,4756810	22 de febrero	3

Source: Ángel Ramírez (UNMSM)

In order to identify the presence of ^{7}Be in the energy level of 477 keV, the samples were properly aconditionated and analyzed with a gamma spectrometry system with high resolution and low background, with a hyper pure germanium 35% relative efficiency detector. The data collection times were 80000-300000 seconds per sample (IAEA, 1989).



Instrumental efficiency curve was determined with the Genie 2000 software (Canberra Industries, 2004) for each of the samples as a function of its density and geometry test.

^{7}Be activity in lichens samples was determined by the following equation (Osores, 2013):

$$A = \frac{S}{E * y * T_1 * K_c * K_w * M}$$

Were:

E : Instrumental efficiency
S : Net area calculated by the following equation: $S = (N_m - \frac{T_1}{T_f} N_f)$
N_m : Net area of sample
N_f : Net area of background
T_1 : Counting time of sample (s)

T_f : Counting time of background (s)
A : Activity of the sample (Bq/kg)
y : Branching ratio of the peak energy
K_c : Correction factor for the nuclide decay during counting (K_c = 1)
K_w : Correction factor for the nuclide decay from the time the sample was obtained
M : Sample mass (kg)
Tw : Elapsed clock time from the time the sample was taken to the beginning of the measurement

$$K_w = e^{-\frac{\ln(2)t_w}{T_{1/2}}}$$

^{7}Be values of each sampling area were statistically evaluated with analysis of variance using the Excel software, in order to identify possible differences in the concentrations of this radionuclide.

The final results were compared with those values recorded in previous campaigns conducted by IPEN in the area of influence of the Machu Picchu Antarctic Scientific Station (Gonzales, *et al.*, 1996, 2002).

3. RESULTS

Figure No.1 shows a gamma spectrum obtained from analysis of antarctic lichens which is observed in the presence of the energy level (fotopeak) for the ^{7}Be (477,6 keV)

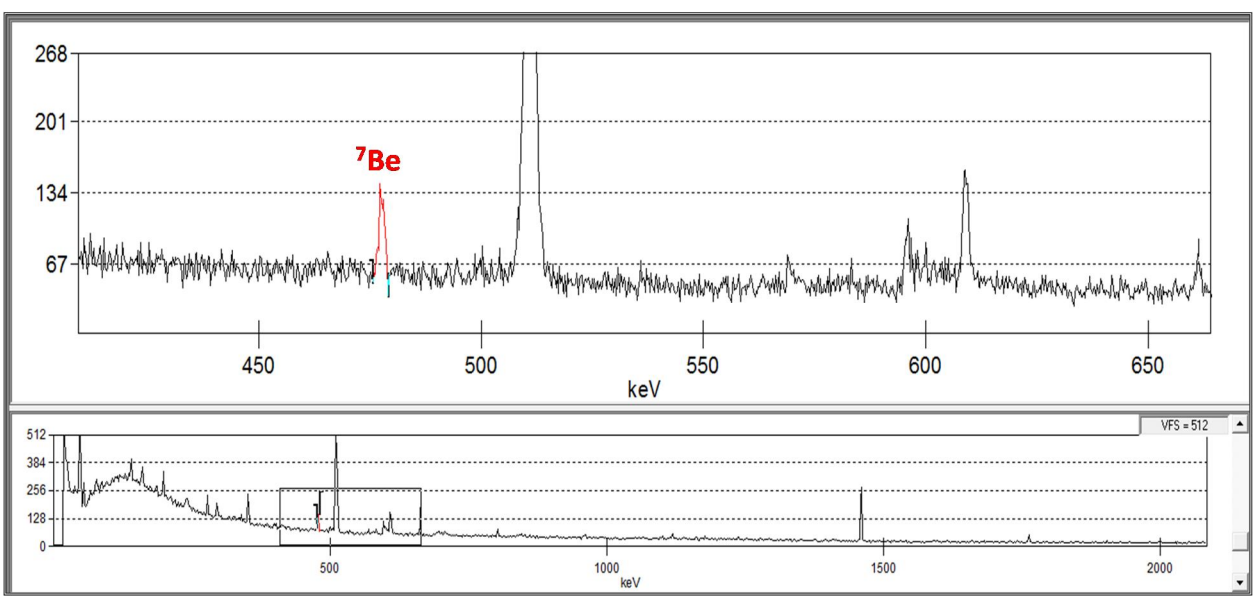


Figure No.1: Gamma Spectrum of ^{7}Be

Table No. 2 shows that the activity values derived from ^{7}Be present ranges between 366,5 to 515,1 Becquerels per kilogram (Bq/kg) of fresh weight, with an overall weighted average of 423,13 ± 80,39 Bq/kg for 2013.

Table No.2. Derived Activity of ^{7}Be in *Usnea antarctica* Du Rietz by sampling area

Sampling Area	Derived Activity ^{7}Be (Bq/kg)	Variability (%)
1	387,80 ± 49,36	12,73%
2	366,45 ± 7,71	2,10%
3	515,13 ± 112,48	21,83%

The analysis of variance showed no statistically significant differences among the three sample areas, although in area 3 a slight increase in the average derived activity is observed (Table No. 3).

Table No.3: Analysis of Variance between Sampling Areas

Sources	Degree of Freedom	Sums of Squares	Mean Squares	F value	F critical
Sampling areas	2	38543,8225	19271,91125	2,3823	5,7861
Error	5	40447,8125	8089,5625		

According to the records of ^{7}Be in lichen monitoring within the area of influence of the Machu Picchu Antarctic Scientific Station conducted by IPEN from 1996 to 2000, shows that the derived activity of this radionuclide tends to increase without reaching values yet reported in 1996 (Figure No.2).

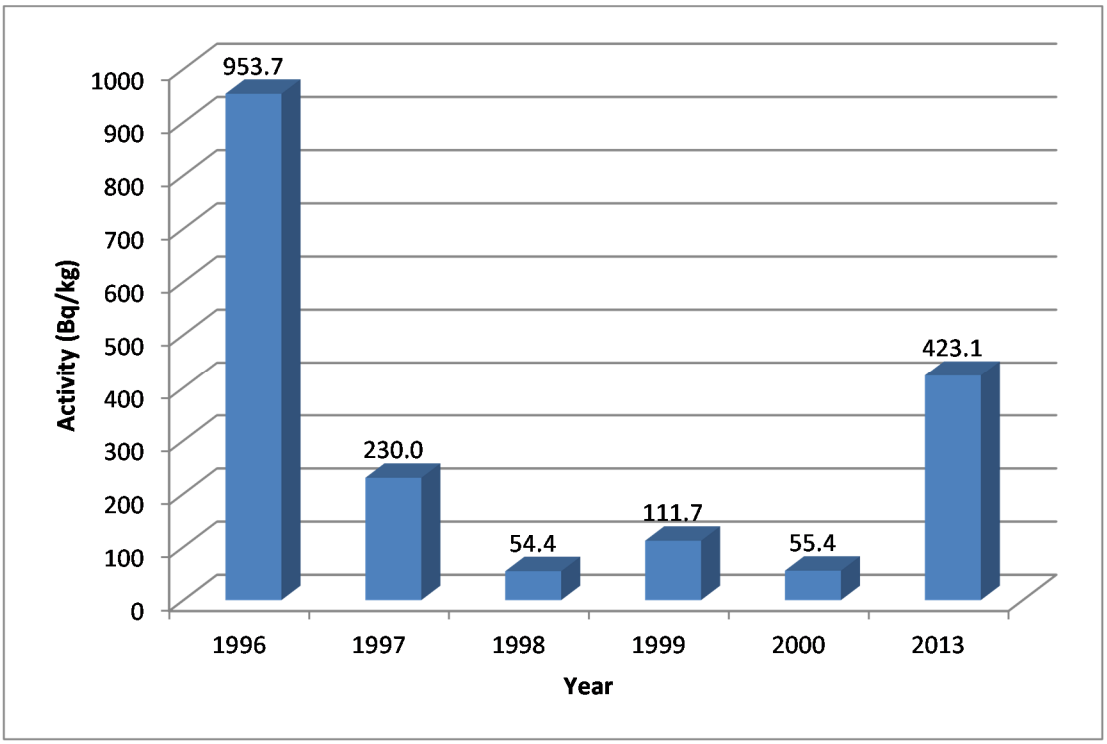


Figura No. 2. Derived Activity of ^{7}Be in *Usnea antarctica* Du Rietz (1996-2013)

4. DISCUSSION OF RESULTS

The activity concentration values derived from ^{7}Be in different lichen samples show no variation depending on sampling areas within the zone of influence of the Machu Picchu Antarctic Scientific Station, so it is considered as a uniform distribution of this radionuclide in the atmosphere of the region.

However, it has been seen that these values are increasing over last decade without reaching its maximum value observed in 1996, the probable causes of this increase require the contribution of other environmental variables such as weather conditions of the place, levels cosmic radiation, levels of wet and dry deposition, environmental enrichment factors and others, such that using mathematical models to interpret and predict the environmental behavior in this area of study and to extrapolate to the region comprised of Admiralty Bay.

5. CONCLUSIONS

The presence of ^{7}Be in Antarctic lichens is verified with an increase in their levels of concentration, showing an average derived activity 423,13 ± 80,39 Bq/kg for 2013.

Because of the good capability of incorporation of ^{7}Be in Antarctic lichens, they can use these organisms as biomonitors to assess the cosmogenic activity and also use them as tools in the evaluation of geomorphological and sedimentary processes in the region.

6. ACKNOWLEDGMENTS

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