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Natural and Artificial Radioactivity Levels in Livingston Island (Antarctic Regions)

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Radioactive contamination of the sea and land is due, on the one hand, to fallout from atmospheric atomic explosions since 1945, and, on the other, to emissions produced by nuclear and radioactive facilities. Given its geographic position far distant from the aforementioned main sources of radioactive contamination, Antarctica should have the lowest levels that can be measured on the Earth of artificial radionuclides in the various receptor media which are characteristic of the trophic chain. In the case of Antarctica, these are melt-water, sea-water, mosses, algae, and lichens.

With the aim of contributing basic information on the radiation levels present in the Antarctic ecosystem, we have identified and measured for the first time the radioactive levels of natural emitters (of cosmic and terrestrial origin) and man-made emitters in the aforementioned receptor media, in the vicinity of the Spanish Antarctic Base, Juan Carlos I, situated on Livingston Island in the South Shetland archipelago, Antarctic region.

MATERIALS AND METHODS

The study area, shown in Figure (1), is the zone which is not permanently covered by glaciars in the vicinity of the Spanish Antarctic Base, in the South Bay of Livingston Island, the second largest of the South Shetlands. It is situated approximately 150 km west-northwest of the northernmost tip of the Antarctic Peninsula.

Samples of river and of sea water were collected in this area. Diverse plant species were also studied, in particular: mosses belonging to the genus Bryum, samples of algae of the genus Desmarestia and of the species Gigartina papillosa, and, with respect to lichens, the species sampled was Usnea antartica, which is the most abundant in the zone (Olech 1989).

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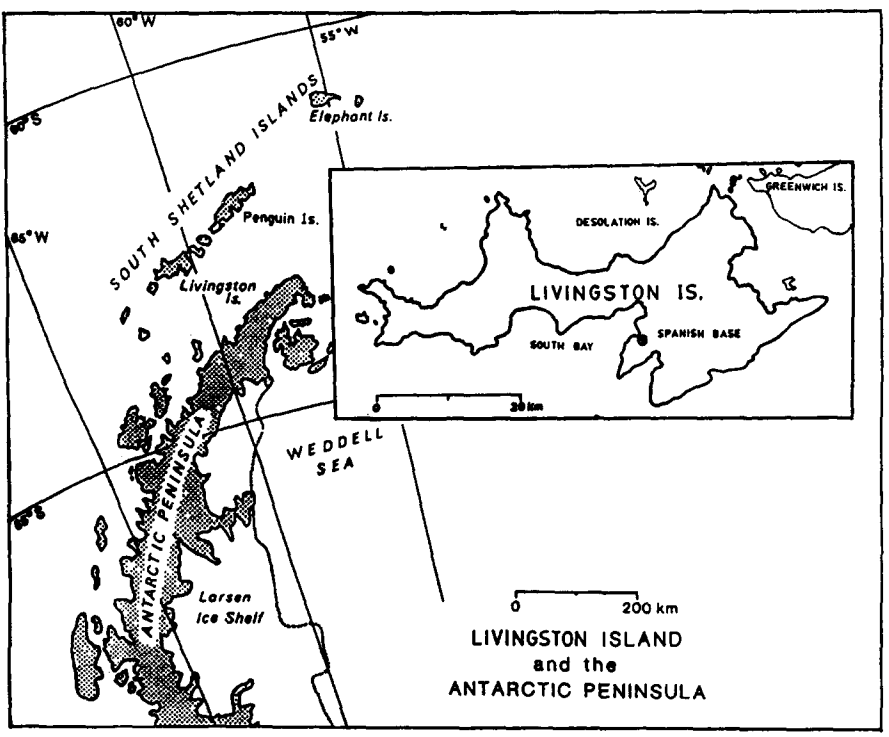
The processes followed to quantify the radioactive levels in the different receptor media under study depend on the type of sample, on the isotopes being looked for, and on their level of activity. In Table 1, we present in a summarized form the types of sample, the amounts of each of them used in the analyses, and the different steps carried out in the treatment previous to the analyses. It can be seen that the greatest diversity of pre-treatment was performed on water samples, since this receptor medium is that which would be expected to have the lowest levels of specific activity.

In the analyses, specific detectors are used for the radiations emitted by the isotopes that one wishes to detect. Each sample is then made to adopt the geometry for which the detector has been calibrated. In Table 2, we present the methods used to detect the radiations that are emitted by the samples. With regard to the water samples, their ^{3}H content was measured with a low-background liquid

Figure 1.- Location of the study area around the Spanish Antartic Base (BAE) on Livingston Island.



scintillation counter; the ^{228}Ra, ^{232}Th, ^{40}K, and ^{137}Cs activities were quantified using N-Type Ge(Hp) detectors, with a relative efficiency of 25.6% for 1.33 MeV; the ^{90}Sr was determined with a gas flow proportional counters, with a counting efficiency at zero thickness of 35% for ^{90}Sr and ^{90}Y in equilibrium; and the levels of the isotopes $^{234,235,238}U$ were measured using Si surface barrier

Table 1.- Procedures followed for the pre-analysis treatment of the different types of sample that were studied.

SAMPLE	VOLUME (l) OR FRESH WT.(kg)	RADIOISOTOPES	PRE-TREATMENT FIRST STEP	SECOND STEP	REFERENCE
FRESH	450	^{137}Cs	OBTAIN THE AMP-Cs PRECIPITATE		(Dutton 1988)
AND	25	GAMMA EMITTERS	pH=1 AND VOLUME REDUCTION	DESICCATION AND PACK	(Baeza et al. 1991)
SEA	20	$^{89,90}Sr$	pH=1 AND VOLUME REDUCTION	Sr SELECTIVE EXTRACTION	(HASL 1976) (Gascó and Alvarez 1988)
	2	^{3}H		ELECTROLYSIS ENRICHMENT	(Kakinchi et al. 1991)
WATER	50	$^{234,235,238}U$	pH=1 OBTAIN URANIUM CHLORIDE PRECIPITATE	URANIUM ISOTOPES ELECTRODESPOSITION	(Hallstadius 1984) (Garcia-Tenorio et al. 1986)
ALGAE	4	GAMMA EMITTERS AND	DESICCATION	TRITURATE AND PACK	
LICHENS	0'4				
MOSSES	0'6	$^{89,90}Sr$	DESICCATION	Sr SELECTIVE EXTRACTION	(HASL 1976) (Gascó and Alvarez 1988)

detectors of 400 mm^2 active area and 300 μm active thickness, with a 24 keV energy resolution at 5468 keV.

The samples of mosses, lichens, and algae, were analyzed by gamma spectrometry to quantify the activities of all the radioisotopes that appear in Table 3, except for the case of ^{90}Sr, whose concentration was determined with the use of a proportional counter. Both experimental setups have been described previously.

Table 2.- The measured specific activities or the detection limits obtained in fresh- and sea-water samples, for the isotopes specified.

DETECTION METHOD	ISOTOPES	FRESH WATER A (mBq/l)	SEA WATER A (mBq/l)
LIQUID SCINTILLATION	^{3}H	280±15	< 200
GAMMA SPECTROMETRY	^{226}Ra	<7.4	< 26
	^{232}Th	<5.8	< 11
	^{40}K	49±25	3980±100
	^{137}Cs	0.33±0.11	0.20±0.12
PROPORTIONAL COUNTER	^{90}Sr	1.2 ±0.5	NO DATA
ALPHA SPECTROMETRY	^{234}U	0.44±0.04	39±3
	^{235}U	0.054±0.007	1.4±0.1
	^{238}U	0.32±0.03	34±3

RESULTS AND DISCUSSION

One can see in Table 2 the results obtained from the analyses carried out on the fresh- and sea-water samples. The values given are either the net specific activities, or, when the activity in the sample for the different radioisotopes measured was below the detection limit, the detection limit itself. It was impossible to obtain the ^{90}Sr specific activity for the sea water, starting from an initial volume of 20 litres, see Tables 1 and 2, because his salinity was found to be incompatible with the method of extraction employed (HASL 1976, Gascó and Alvarez 1988). The method was effective for a maximum initial volume of sea water of 5 litres, yielding a detection limit of 5.3 mBq/l.

In light of the results obtained from the water samples, the following aspects are worthy of note:

a) The ^{3}H levels detected are comparable to those obtained by other workers at different points of the Antarctic region. In particular, one can cite the values between 400 and 800 mBq/l measured by Sakanoue (Sakanoue 1987) in fresh waters sampled at different points of the South Polar region, and the activities between 30 and 100 mBq/l detected by Michel (Michel et al. 1979) in sea-water. There is thus confirmation of the great variability of the values obtained as a function of the sampling point, as well as of the steady decline in specific activity of this isotope, wich began in the 1960's as Koide (Koide et al. 1979) showed in an analysis of tritium concentrations of different ice cores from the Ross ice shelf.

b) Only two gamma emitters were detected with activities above the corresponding detection limits: ^{40}K in the gamma spectrometry of the dry residue from 25 l of water, see Tables 1 and 2, and ^{137}Cs found on selectively concentrating this element from 450 l of water.

The activities detected for ^{40}K imply that the natural potassium content of the waters is 131 ± 3 and 1.6 ± 0.8 mg/l for sea and fresh water respectively. The latter value is similar to that often found in river waters of different regions of the world (Lambrechts et al. 1983, Conway et al. 1974).

The levels detected for ^{137}Cs are very similar for fresh and for sea water. The latter value is identical to that found by Holm recently (Holm 1990) as representative of the sea water in the Antarctic ecosystem. These levels are at least three times lower than those normally detected in the Northern hemisphere in the latitude band in which Spain is situated (Baeza et al. 1991. Carreiro et al. 1991, Mitchel et al. 1988)

c) The activity detected for ^{90}Sr in fresh water is a relatively high value with repect to the ^{137}Cs value in that same type of sample, and also with repect to the value expected from the measurements on continental waters in Spain and the world latitudinal distribution of ^{90}Sr deposition as given in the UNSCEAR report (UNSCEAR 1982). It is, however, inferior to the measurements on snow samples from different locations in Antarctica (Lambert et al. 1971). In any case, this value, as well as the results for the other man-made isotopes measured, is entirely negligible with respect to its contribution to the total absorbed dose.

d) Regarding the activities of different uranium isotopes in the water, the values are roughly two orders of magnitude higher for the sea water than for the fresh water. This relationship agrees with the total uranium activity levels given in the literature (Ivanovich and Harmon 1982), the values reported lying between 26 and 130 mBq/l for sea water, and between 0.5 and 160 mBq/l for river water.

As to whether or not there exists a disequilibrium between the isotopes ^{234}U and ^{238}U, this is practically non-existent in the waters analyzed: the $^{234}U/^{238}U$ activity

ratios are 1.15±0.13 for sea water and 1.38±0.18 for fresh water. These values agree well to those obtained in different parts of the world: the mentioned ratios ranges from 1.03 to 2.03 for river water, and from 1.10 to 1.18 for sea water (Ivanovich and Harmon 1982). In particular, the sea water radio obtained for us is identical to the calculated by H.H. Veeh (Veeh 1968) for two water samples collected in the east Pacific sector of the Antartic Ocean.

The results of the analyses of the radioactive content of the moss, lichen, and algae samples are presented in Table 3. As is seen in Table 1, in all cases the quantity of sample utilized was greater than 400 g fresh weigth, and for the algae, 4000 g. The amount of sample available for analysis allowed the detection limit to be reduced to levels where it was possible to determine, for the mosses, the net content of the radioisotopes of the natural radioactive series. One can nevertheless affirm that, for these isotopes, there do not exist any appreciable differences in the radioactive content for the different plant species analyzed.

With regard to ^{40}K, this is present to a greater proportion in algae than in mosses and lichens. This was to be expected, given the greater ^{40}K concentration in sea water than in fresh water. In any case, the levels detected for the latter two are within the ranges reported for mosses and lichens by different authors (Eckl et al. 1986, Papastefanou et al. 1989) in different parts of the world.

Table 3.- Results obtained for the specific activities of the different radionuclides present in Antartic plant samples.

	SAMPLE			
Ae (Bq/kg fresh)	MOSSES (genus: Bryum)	LICHENS (Specie:Usnea antartica)	ALGAE (Specie: Gigartina papillosa)	ALGAE (Genus: Desmarestia)
^{226}Ra	0.8 ± 0.3	< 1.22	< 1,36	1.5 ± 0.5
^{235}U	0.16 ± 0.07	< 1.6	< 0.17	< 0.14
^{238}U	3.6 ± 1.5	< 3.7	< 3.6	< 3.0
^{228}Ac	0.81 ± 0.18	0.9 ± 0.5	< 0.41	< 0.46
^{208}Tl	0.80 ± 0.17	1.0 ± 0.5	< 0.54	< 0.55
^{40}K	34.7 ± 1.2	64 ± 3	374 ± 6	131 ± 2
^{7}Be	< 0.61	0.27 ± 0.06	< 2.4	< 0.69
^{137}Cs	3.6 ± 0.1	17.2 ± 0.3	< 0.12	< 0.07
^{90}Sr	0.69 ± 0.15	4.05 ± 0.10	< 0.033	< 0.019

The detection of net activity levels for the cosmic origin ^{7}Be and the man-made ^{90}Sr and ^{137}Cs in mosses and lichens confirms the characteristic that these nonvascular plants have of being biological monitors of environmental radiation levels. Nevertheless, the levels recorded for ^{137}Cs are one or two orders of magnitude below those found at various points of the Northern hemisphere (Papastefanou et al. 1989). This is a direct consequence of the distance separating Livingston island in the Antarctic from the production sources of radioactive contamination.

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