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SURVEY OF ARTIFICIAL RADIONUCLIDES IN THE ANTARCTIC

Takeo HASHIMOTO[1], Takao MORIMOTO[1], Yoshihiro IKEUCHI[1], Katsumi YOSHIMIZU[1], Tetsuya TORII[1] and Kazuhisa KOMURA[2]

[1]*Japan Chemical Analysis Center, 295-3 Sanno-cho, Chiba 281*
[2]*Low Level Radioactivity Laboratory, Kanazawa University, Wake, Tatsunokuchi, Nomi-gun, Ishikawa 923-12*

Abstract: In order to estimate the concentration and distribution of the environmental radioactivity in the Antarctic, artificial radionuclides such as ^{90}Sr, ^{137}Cs, ^{238}Pu and $^{239+240}Pu$ in soil, algae, lichen and water samples were determined. The average concentrations of artificial radionuclides in the environmental samples collected from the McMurdo Sound area and around Syowa Staiton during 1984 to 1987, were compared with those in the Northern Hemisphere. Concentrations of artificial radionuclides in the Antarctic for soil, sea water, lichen, oceanic life (krill, *Euphausia superba*), viscera of fish (*Dissostichus mawsonii*), etc. were several times lower than those in the Northern Hemisphere.

1. Introduction

The Antarctic is believed to be the least contaminated area in the world because of the lowest human activity. Measurement of artificial radionuclides in environmental samples in the Antarctic is of interest in order to estimate the global environmental pollution caused by nuclear explosion tests since 1945.

We report here the results of measurement of artificial radionuclides in environmental samples such as soil, algae, lichen, water, etc. These samples were collected from the Dry Valleys area (77–78°S, 160–162°E) (Fig. 1) and Ross Island (77°51′S, 166°45′E) (Fig. 2) in the austral summer of 1984–85, 1985–86 and 1986–87, and also around Syowa Station (69°00′22″S, 39°35′24″E) (Fig. 3) by the 26th Japanese Antarctic Research Expedition in 1985–86 (Table 1).

2. Method

A large volume, 1000 *l*, of water samples were treated by the following two different methods in the field. The one was co-precipitation with iron(III) hydroxide to concentration of Pu isotopes, and the other was adsorption with polyacryronitrile fiber fixed with manganese dioxide and cobalt-potassium ferrocyanide to concentration of γ-ray emitting nuclides such as ^{137}Cs, ^{60}Co, etc.

Soil samples were dried in an electric oven at 105°C and the fraction having diameter less than 2 mm was collected by sieving. Algae, lichen, krill (*Euphausia superba*), excreta of penguin and viscera of fish (*Dissostichus mawsonii*) were ashed in the electric

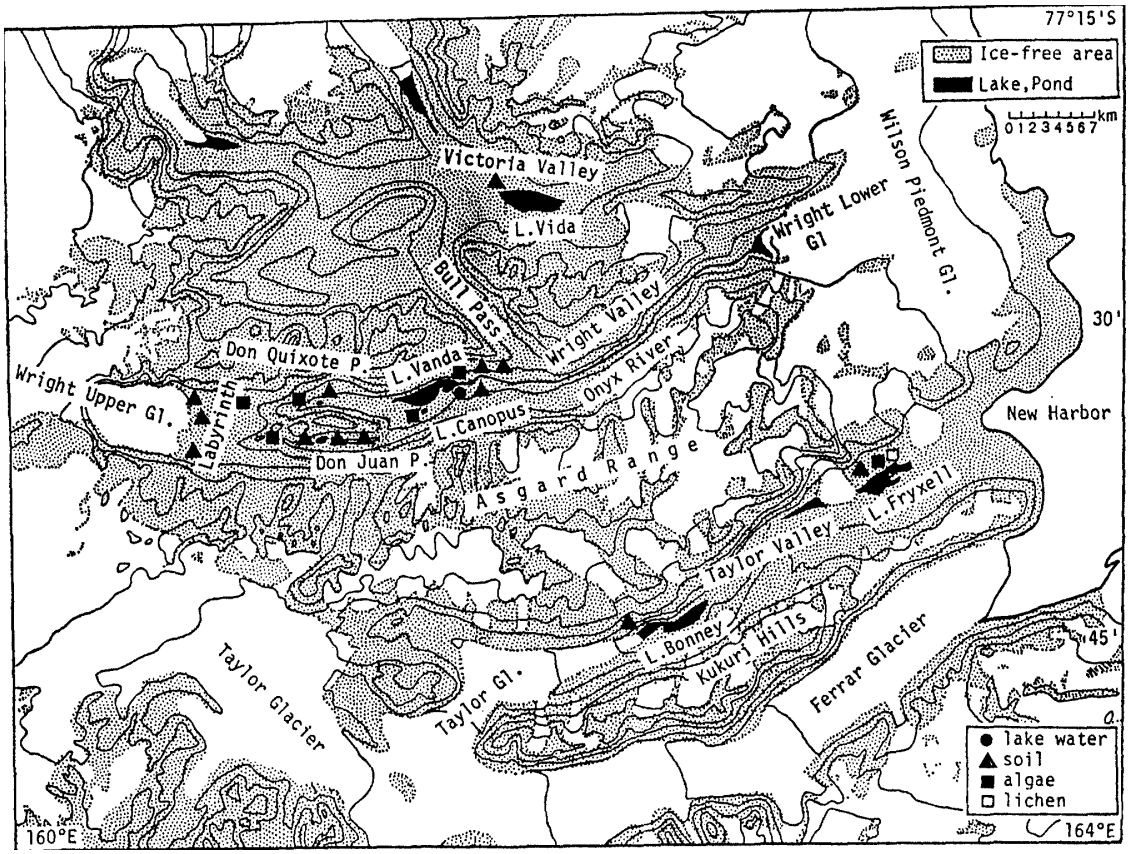

Fig. 1. Sampling location in the Dry Valleys, Antarctica.

furnace at 450°C in 24 h.

Pu isotopes co-precipitated with iron(III) hydroxide were purified by the ion exchange method and determined by α-ray spectrometry with the Si (Au) detector, γ-ray emitting nuclides were determined by γ-ray spectrometry with the Ge detector, and ^{90}Sr was purified by fuming nitric acid method and measured with the low background GM counter.

3. Results and Discussion

Analytical results are shown in Table 2. Errors cited in the table consist of only 1 σ error due to the counting statistics and no errors from other sources were taken into account.

3.1. Land water

Concentrations of ^{90}Sr and ^{137}Cs in land water were a little lower than those in lake and river waters in Japan (^{90}Sr: 1.5–6.3 [Av.=3.7] Bq/1000*l*, ^{137}Cs: 0.1–1.1 [Av.=0.37] Bq/1000*l*) (N.I.R.S., 1985a, b). On the other hand, concentrations of $^{239+240}Pu$ was higher than those in Japan ($^{239+240}Pu$: 0.0005–0.001 Bq/1000*l*) (AOYOMA *et al.*, 1986). Little ^{238}Pu has been detected in those samples in Japan, but this radionuclide was determined in the Antarctic.

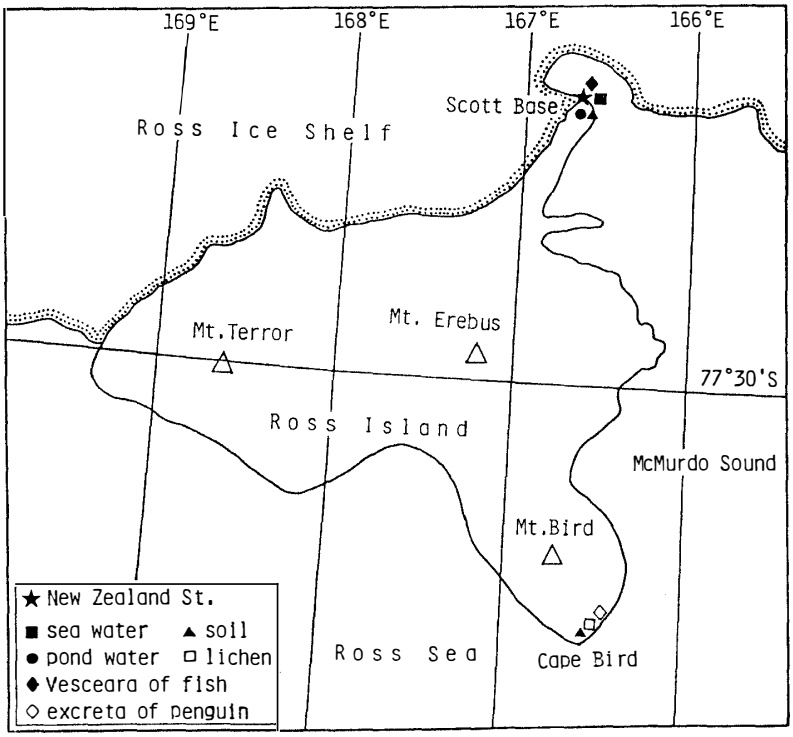

Fig. 2. Sampling location in Ross Island, Antarctica.

3.2. Soil

In spite of the long distance of more than 3000 km between the McMurdo Sound and Syowa Station, the concentrations of ^{90}Sr, ^{137}Cs and $^{239+240}Pu$ in soil in the two areas were of the same order of magnitude. The concentrations of ^{90}Sr, ^{137}Cs and $^{239+240}Pu$ in soil were one order of magnitude lower than those in Japan (^{90}Sr: 0.22–48 [Av.=5.9, n=31] Bq/kg-dry, ^{137}Cs: 0.37–160 [Av.=22, n=31] Bq/kg-dry) (N.I.R.S., 1985a, b), ($^{239+240}Pu$: 0.22–2.5 [Av.=1.3, n=17] Bq/kg-dry) and Northwest Italy ($^{239+240}Pu$: 0.059–1.51 Bq/kg) (CIGNA and CIGNA, 1987). ^{22}Na (24 Bq/kg-dry) was detected in soil at Cape Bird. Perhaps ^{22}Na produced by cyclotron was brought here for the purpose of some kind of tracer experiment.

3.3. Algae and lichen

Concentrations of ^{90}Sr, ^{137}Cs, $^{239+240}Pu$ and ^{238}Pu in algae and lichen were 2–10 times higher than in soil of Antarctica. Concentrations of ^{137}Cs in algae and lichen in the Antarctic were one order of magnitude lower than those in lichen (138–185 Bq/kg-dry) in Canada (64°18′N, 96°3′W) (LOONEY *et al.*, 1986).

Concentrations of ^{90}Sr, ^{137}Cs and $^{239+240}Pu$ in algae collected at Lake Canopus during 3 years (^{90}Sr: 0.96–1.3 Bq/kg-dry, ^{137}Cs: 21–24 Bq/kg-dry, $^{239+240}Pu$: 0.48–0.52 Bq/kg-dry) were almost constant.

3.4. Sea water

Concentrations of ^{90}Sr and $^{239+240}Pu$ in sea water in the Antarctic were one order of magnitude lower than those in sea water around Japan and Northern Pacific Ocean

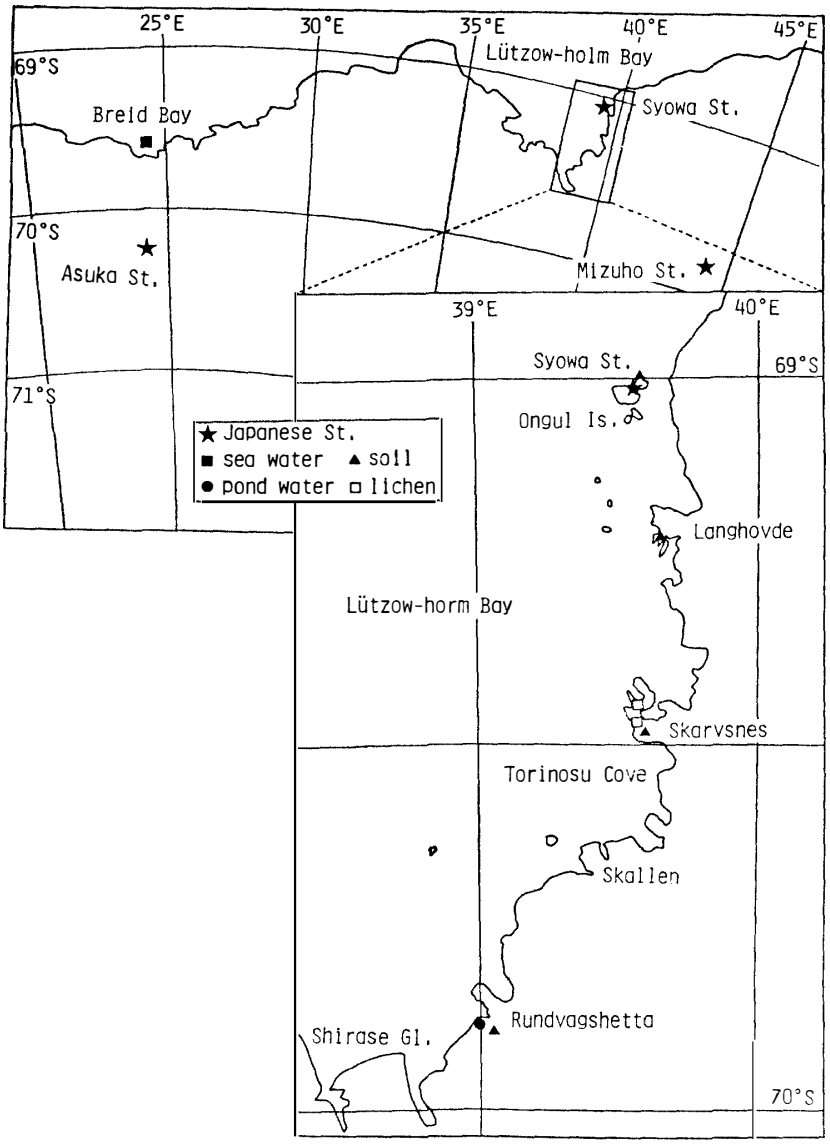

Fig. 3. Sampling location around Syowa Station, Antarctica.

(^{90}Sr: 1.5–5.2 Bq/1000 *l* (SHIBAYAMA *et al.*, 1986), $^{239+240}$Pu: 0.004–0.03 Bq/1000 *l* (NAGAYA and NAKAMURA, 1984). The concentration of ^{137}Cs in the Antarctic was one to two orders of magnitudes lower than those in sea water (^{137}Cs: 2.6–7.0 Bq/1000 *l* (SHIBAYAMA *et al.*, 1986)) around Japan.

3.5. Krill and viscera of fish

Concentrations of ^{137}Cs in krill and viscera of fish were 2–5 times lower than oceanic life around Japan (fish (viscera): 0.22–0.44 Bq/kg-fresh, plankton: 0.074–0.15 Bq/kg-fresh, shrimp: 0.15–0.26 Bq/kg-fresh) (OKUBO *et al.*, 1986).

The $^{239+240}$Pu in the land water seems to be supplied from meltwater of a glacier in which $^{239+240}$Pu has been accumulated by nuclear explosion tests since 1950. ^{238}Pu,

Table 1. Sampling in McMurdo Sound area and around Syowa Station in the Antarctic.

Sample	Area	Sample No.	Sampling date	Sampling location	Latitude (S)	Longitude (E)
Sea water	Ross Is.	W 1	Dec. 17, '86	Ross Sea (near Scott Base)	77°51′04″	166°45′23″
	Syowa St.	W 2	Feb. 13, '86	Breid Bay	77°10′	24°00′
Land water	Ross Is.	W 3	Dec. 19, '86	Crater Pond (near McMurdo St.)	77°50′20″	166°40′15″
	Dry Valley	W 4	Jan. 6, '87	Lake Vanda (near Vanda St.)	77°32′	161°40′
	Syowa St.	W 5	Jan. 25, '86	Rundvågshetta (running water from Shirase Gl.)	69°54′	39°01′
Soil	Dry Valley	S 1	Dec. 9, '84	South Fork (SF-1 Pond)	77°34′	161°04′
		S 2	Dec. 9, '84	South Fork (VXE-6 Pond)	77°34′	161°21′
		S 3	Dec. 14, '84	Labyrinth (L-4 Pond)	77°32′	160°45′
		S 4	Dec. 9, '84	Don Juan Pond (0～2 cm)	77°34′	161°11′
		S 5	Dec. 9, '84	Don Juan Pond (2～5 cm)	77°34′	161°11′
		S 6	Dec. 18, '84	Don Quixote Pond (0～2 cm)	77°32′	161°09′
		S 7	Dec. 18, '84	Don Quixote Pond (2～5 cm)	77°32′	161°09′
		S 8	Dec. 11, '85	Lake Fryxell	77°36′	163°06′
		S 9	Dec. 24, '85	Labyrinth (E-3 Pond)	77°31′47″	160°44′14″
		S 10	Dec. 28, '85	Labyrinth (near Mt. Electra)	77°31′21″	160°52′13″
		S 11	Dec. 19, '86	Crater Pond (near McMurdo St.)	77°50′20″	166°47′15″
		S 12	Dec. 29, '86	Don Juan Pond (east side)	77°34′	161°12′
		S 13	Dec. 29, '86	Don Juan Pond (basin)	77°34′	161°11′
		S 14	Jan. 1, '87	Taylor Valley (near terminal of Taylor Gl.)	77°43′	162°18′
		S 15	Jan. 9, '87	Wright Valley (near Bull Pass)	77°31′	161°49′
		S 16	Jan. 9, '87	Wright Valley (near Bull Lake)	77°31′	161°42′
		S 17	Jan. 10, '87	Lake Vanda (east side)	77°32′	161°40′
		S 18	Jan. 10, '87	Lake Vida (west side)	77°23′	166°49′
	Ross Is.	S 19	Dec. 18, '84	Cape Bird	77°16′36″	166°23′8″
		S 20	Jan. 12, '87	Cape Bird	77°16′36″	166°23′8″
		S 21	Jan. 12, '87	Cape Bird (near rookery)	77°16′36″	166°23′8″
	Syowa St.	S 22	Jan. 18, '86	Langhovde (near Lake Nurume)	69°14′	39°40′12″
		S 23	Jan. 19, '86	Skarvsnes (near Torinosu Cove)	69°28′	39°35′
		S 24	Jan. 22, '86	Ongul Is. (Miharasi Peak)	69°00′25″	39°36′50″
		S 25	Jan. 25, '86	Rundvågshetta	69°54′	39°01′
Algae	Dry Valley	A 1	Dec. 8, '84	South Fork (SF-1 Pond)	77°34′	161°04′
		A 2	Dec. 19, '84	North Fork (1-2 Pond)	77°32′	161°06′
		A 3	Dec. 17, '84	Labyrinth (E-5 Pond)	77°32′	160°50′
		A 4	Dec. 20, '84	Lake Vanda (west side)	77°32′	161°28′
		A 5	Dec. 26, '84	Lake Canopus	77°34′	161°04′
		A 6	Dec. 11, '85	Lake Fryxell	77°36′	163°06′
		A 7	Jan. 5, '86	Lake Canopus	77°33′	161°31′
		A 8	Dec. 28, '86	South Fork (near SF-1 Pond)	77°34′	161°04′
		A 9	Dec. 28, '86	South Fork (east side of SF-1 Pond)	77°34′	161°04′
		A 10	Jan. 7, '87	Lake Canopus (in the water)	77°33′	161°31′
		A 11	Jan. 7, '87	Lake Canopus (near shore line)	77°33′	161°31′
Lichen	Dry Valley	L 1	Nov. 26, '84	Lake Fryxell	77°36′	163°06′
	Ross Is.	L 2	Jan. 12, '87	Cape Bird (near hut)	77°16′36″	166°23′8″
	Syowa St.	L 3	Jan. 19, '86	Skarvsnes (near Lake Hunazoko)	69°25′	39°35′
		L 4	Jan. 19, '86	Skarvsnes (near Torinosu Cove)	69°28′	39°35′
Excreta of Penguin	Ross Is.	P 1	Jan. 12, '87	Cape Bird (at penguin rookery)	77°16′36″	166°23′8″
Viscera of Mawsonii	Ross Is.	M 1	Jan. 5, '86	Ross Sea (near McMurdo St.)	77°51′	166°40′
		M 2	Jan. 14, '87	Ross Sea (near McMurdo St.)	77°51′	166°40′
Krill		K 1	Feb. 16, '87	Southern Ocean	61°	56°

Table 2. Environmental radioactivity in McMurdo Sound area and around Syowa Station in the Antarctic.

Sample No.	^{90}Sr	^{137}Cs	$^{239+240}Pu$	^{238}Pu
W 1	0.3 ±0.1	0.07±0.01	0.0020±0.0004	0.0003±0.0002
W 2	—	0.4 ±0.4	—	—
W 3	—	0.08±0.02	0.0015±0.0004	0.0007±0.0003
W 4	—	0.08±0.02	0.0059±0.0008	0.0016±0.0004
W 5	3.6 ±0.2	0.2 ±0.1	0.022 ±0.004	ND
S 1	0.34 ±0.08	0.22±0.06	0.006 ±0.005	ND
S 2	0.10 ±0.06	1.4 ±0.1	0.018 ±0.006	ND
S 3	0.18 ±0.06	1.2 ±0.1	0.013 ±0.006	ND
S 4	ND	ND	ND	ND
S 5	ND	ND	ND	ND
S 6	0.20 ±0.07	1.4 ±0.6	0.028 ±0.007	ND
S 7	0.06 ±0.05	0.07±0.04	ND	ND
S 8	0.18 ±0.05	ND	0.003 ±0.003	ND
S 9	3.7 ±0.1	6.3 ±0.5	0.18 ±0.02	0.016 ±0.007
S 10	0.56 ±0.07	1.4 ±0.4	0.03 ±0.01	0.006 ±0.004
S 11	0.14 ±0.06	ND	ND	ND
S 12	0.17 ±0.05	ND	ND	ND
S 13	ND	ND	0.007 ±0.004	ND
S 14	0.52 ±0.06	ND	ND	ND
S 15	0.14 ±0.05	ND	0.003 ±0.003	ND
S 16	1.9 ±0.1	4.4 ±0.8	0.16 ±0.02	0.033 ±0.009
S 17	0.32 ±0.06	1.2 ±0.3	0.013 ±0.006	ND
S 18	0.48 ±0.08	1.3 ±0.4	0.015 ±0.006	ND
S 19	0.7 ±0.1	0.26±0.06	ND	ND
S 20	0.35 ±0.07	1.6 ±0.6	0.016 ±0.006	ND
S 21	2.1 ±0.2	2.2 ±0.7	0.07 ±0.01	0.013 ±0.005
S 22	0.36 ±0.07	9.3 ±0.4	0.17 ±0.02	0.030 ±0.008
S 23	0.44 ±0.07	1.1 ±0.5	0.030 ±0.007	0.010 ±0.004
S 24	0.41 ±0.07	19.6 ±0.7	0.41 ±0.03	0.09 ±0.01
S 25	0.09 ±0.05	ND	ND	ND
A 1	1.4 ±0.2	—	0.09 ±0.02	0.01 ±0.01
A 2	1.1 ±0.1	—	0.23 ±0.03	0.03 ±0.01
A 3	0.4 ±0.2	6.7 ±0.7	0.14 ±0.02	0.03 ±0.01
A 4	0.4 ±0.3	—	0.009 ±0.006	ND
A 5	1.3 ±0.2	24 ±1	0.52 ±0.05	0.11 ±0.02
A 6	4.4 ±0.2	14.4 ±0.6	0.31 ±0.03	0.07 ±0.01
A 7	1.0 ±0.1	21.5 ±0.7	0.48 ±0.03	0.13 ±0.02
A 8	1.8 ±0.2	5.9 ±0.6	0.15 ±0.02	0.041 ±0.009
A 9	1.5 ±0.2	4.8 ±0.6	0.13 ±0.01	0.023 ±0.006
A 10	0.5 ±0.2	23.3 ±0.6	0.48 ±0.03	0.08 ±0.01
A 11	1.0 ±0.2	24.1 ±0.7	0.48 ±0.04	0.11 ±0.01
L 1	5.6 ±0.3	12.6 ±0.6	0.21 ±0.03	0.03 ±0.01
L 2	2.1 ±0.3	5.9 ±0.4	0.10 ±0.02	ND
L 3	3.4 ±0.2	27.4 ±0.8	0.63 ±0.04	ND
L 4	7.4 ±0.3	35.2 ±0.7	0.93 ±0.06	0.14 ±0.02
P 1	5.9 ±0.3	4.4 ±0.5	0.21 ±0.02	0.036 ±0.009
M 1	—	0.07±0.02	—	—
M 2	0.007±0.004	0.05±0.01	ND	ND
K 1	—	1.7 ±0.8	—	—

Unit: soil (Bq/kg-dry), algae, lichen (Bq/kg-dry), water (Bq/1000 *l*), excreta, viscera (Bq/kg-fresh).
ND: not detected. —: not determined.

which was nearly undetectable in Japan, was detected in water, soil, algae and lichen in Antarctica and it might have been originated by accidental burn-up of SNAP-9A satellite over the Indean Ocean in 1964.

Concentrations of artificial radionuclides were similar in excreta of a penguin to those in soil, and several times higher in algae and lichen than those in soil. Propensity of lichen and algae for collecting nutrients from air and precipitation suggests that they will be available as the indicator sample for monitoring artificial radionuclide in the Antarctic.

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