# SURVEY OF ARTIFICIAL RADIONUCLIDES IN THE ANTARCTIC

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*Abstract:* In order to estimate the concentration and distribution of the environmental radioactivity in the Antarctic, artificial radionuclides such as <sup>90</sup>Sr, <sup>137</sup>Cs, <sup>238</sup>Pu and <sup>239+240</sup>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  $(77-78^{\circ}S, 160-162^{\circ}E)$  (Fig. 1) and Ross Island  $(77^{\circ}51'S, 166^{\circ}45'E)$  (Fig. 2) in the austral summer of 1984–85, 1985–86 and 1986–87, and also around Syowa Station  $(69^{\circ}00'22''S, 39^{\circ}35'24''E)$  (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  $\gamma$ -ray emitting nuclides such as <sup>137</sup>Cs, <sup>60</sup>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 Artificial Radionuclides in the Antarctic

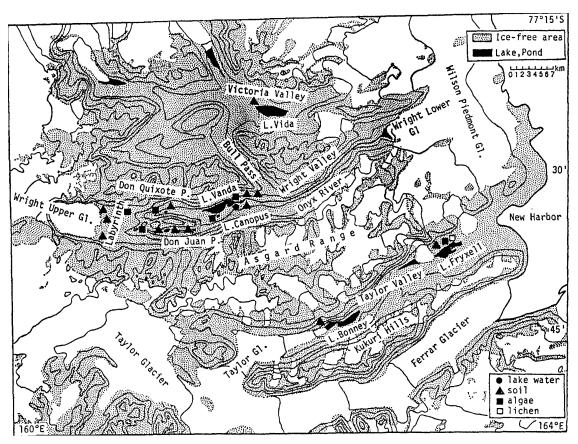


Fig. 1. Sampling location in the Dry Valleys, Antarctica.

# 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  $\alpha$ -ray spectrometry with the Si (Au) detector,  $\gamma$ -ray emitting nuclides were determined by  $\gamma$ -ray spectrometry with the Ge detector, and <sup>90</sup>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  $1\sigma$  error due to the counting statistics and no errors from other sources were taken into account.

### 3.1. Land water

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

Назнімото et al.

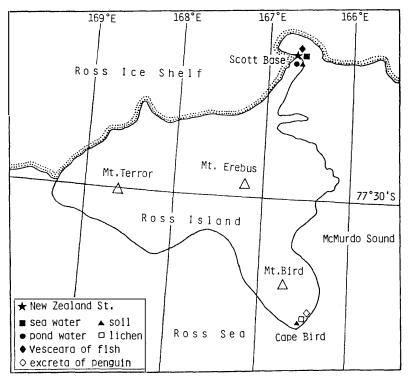


Fig. 2. Sampling location in Ross Island, Antarctica.

#### 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 <sup>90</sup>Sr, <sup>137</sup>Cs, <sup>239+240</sup>Pu and <sup>238</sup>Pu in algae and lichen were 2–10 times higher than in soil of Antarctica. Concentrations of <sup>137</sup>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 <sup>90</sup>Sr, <sup>137</sup>Cs and <sup>239+240</sup>Pu in algae collected at Lake Canopus during 3 years (<sup>90</sup>Sr: 0.96–1.3 Bq/kg-dry, <sup>137</sup>Cs: 21–24 Bq/kg-dry, <sup>239+240</sup>Pu: 0.48–0.52 Bq/kg-dry) were almost constant.

### 3.4. Sea water

Concentrations of <sup>90</sup>Sr and <sup>239+240</sup>Pu in sea water in the Antarctic were one order of magnitude lower than those in sea water around Japan and Northern Pacific Ocean

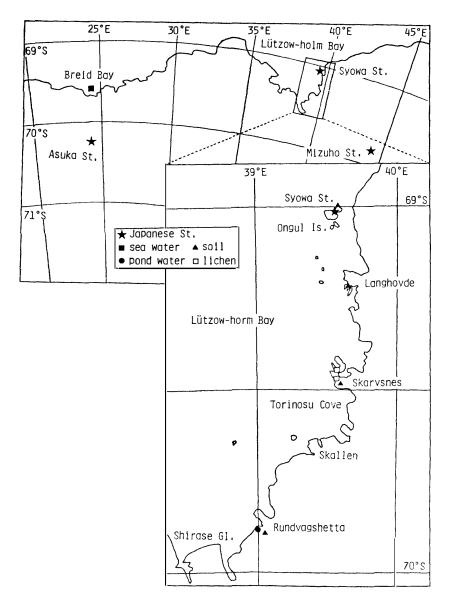


Fig. 3. Sampling location around Syowa Station, Antarctica.

( $^{90}$ 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 <sup>137</sup>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 <sup>239+240</sup>Pu in the land water seems to be supplied from meltwater of a glacier in which <sup>239+240</sup>Pu has been accumulated by nuclear explosion tests since 1950. <sup>238</sup>Pu,

## HASHIMOTO et al.

St.)   St.)   St.)   St.)   St.)   Tory Valley   St.	Sample	Area	Sample No.	Sampl date		Sampling location	Latitude (S)	Longitude (E)
and vater   Ross Is.   W 3   Dec. 19, '86   Crater Pond (near McMurdo St)   77°50′20''   166°40' 15 (37)     Dry Valley   W 4   Jan. 6, '87   Lake Vanda (near Vanda St.) from Sintase G1.)   77°32'   161°40'     Soil   Dry Valley   S 1   Dec. 9, '84   South Fork (VXE-6 Pond)   77°34'   161°21'     Soil   Dry Valley   S 1   Dec. 9, '84   South Fork (VXE-6 Pond)   77°34'   161°21'     S 2   Dec. 9, '84   Don Juan Pond (0~2 cm)   77°34'   161°11'     S 5   Dec. 18, '84   Don Quixote Pond (0~2 cm)   77°34'   161°11'     S 6   Dec. 18, '84   Don Quixote Pond (0~2 cm)   77°34'   161°11'     S 6   Dec. 11, '85   Lake Fryxell   77°51'   160°47'   15     S 10   Dec. 24, '85   Labyrinth (tear Mt. Electra)   77°31'   161°21'     S 11   Dec. 19, '86   Contar Dond (basin)   77°31'   161°12'     S 11   Dec. 19, '86   Don Juan Pond (chasin)   77°31'   161°11'     S 12   Jan. 1, '	Sea water	Ross Is.	<b>W</b> 1	Dec. 17,	<b>'</b> 86	Ross Sea (near Scott Base)	77°51′04″	166°45′23″
St.)   St.)   St.)   St.)   St.)   Tory Valley   St.		Syowa St.				•		
Syowa St.   W 5   Jan. 25, '86   Rundvågsheria (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'     Soil   Dry Valley   S   Dec. 9, '84   South Fork (SF-1 Pond)   77°34'   161°04'     S   Dec. 14, '84   Labyrinth (L-4 Pond)   77°34'   161°11'     S   Dec. 9, '84   Don Juan Pond (0~2 cm)   77°34'   161°11'     S   Dec. 18, '84   Don Quixote Pond (0~2 cm)   77°31'   161°09'     S   Dec. 11, '85   Lake Fryxell   77°31'   161°01'     S   Dec. 12, '85   Labyrinth (near Mt. Electra)   77°31'   161°11'     S   Dec. 29, '86   Don Juan Pond (basin)   77°34'   161°11'     S   11   Dec. 29, '86   Don Juan Pond (basin)   77°34'   161°11'     S   Jan. 1, '87   Taylor Valley (near Bull Pass)   77°31'   161°11'   161°11'     S   Jan. 1, '87   Caylor Valley (near Bull Pass) <td>Land water</td> <td>Ross Is.</td> <td><b>W</b> 3</td> <td></td> <td></td> <td>St.)</td> <td></td> <td></td>	Land water	Ross Is.	<b>W</b> 3			St.)		
from Shirase GL)     Soil   Dry Valley   S   1   Dec.   9, '84   South Fork (VSE-6 Pond)   77°34'   161°04'     Soil   Dry Valley   S   1   Dec.   9, '84   South Fork (VXE-6 Pond)   77°34'   161°21'     S   2   Dec.   9, '84   Don Juan Pond (0~2 cm)   77°34'   161°11'     S   5   Dec.   18, '84   Don Quixote Pond (0~2 cm)   77°31'   161°01'     S   7   Dec.   18, '84   Don Quixote Pond (0~2 cm)   77°31'   161°04'     S   7   Dec.   18, '84   Don Quixote Pond (0~2 cm)   77°31'   161°04'     S   10   Dec.   29, '86   Crater Pond (near McMurdo St.)   77°31'   161°12'     S   11   Dec.   19, '86   Crater Pond (near McMurdo St.)   77°31'   161°12'     S   12   Dec.   9, '87   Wright Valley (near terminal   77°34'   161°12'     S   13   Dec.   19, '86   Crater Pond (ne						· · · · · · · · · · · · · · · · · · ·		
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. 18, '84 Don Quixote Pond (0~2 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 (0~2 cm)   77'32'   161'09'     S 8   Dec. 11, '85 Lake Fryxell   77'34'   161'21'     S 10   Dec. 28, '85 Labyrinth (E-3 Pond)   77'34'   161'21'     S 11   Dec. 19, '86 Crater Pond (near McMurdo St.)   77'34'   161'21'     S 12   Dec. 29, '86 Don Juan Pond (basin)   77'34'   161'21'     S 13   Dec. 18, '84 Vale Valey (near Bull Lake)   77'31'   16'2'18'     S 14   Jan. 1, '87 Taylor Valey (near Bull Lake)   77'31'   16'2'18'     S 15.   Jan. 12, '87 Cape Bird   77'6'36''   166'23' &     S 20   Jan. 12, '87 Cape Bird   77'16'36'''   166'23' &     S 21   Jan.		Syowa St.	W 5	Jan. 25	, '86		69°54′	39°01′
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 Quixote Pond (0~2 cm)   77°34'   161°01'     S 6 Dec. 18, '84 Don Quixote Pond (2~5 cm)   77°34'   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 (1c=3 Pond)   77°34'   161°11'     S 10 Dec. 29, '86 Don Juan Pond (leasin)   77°34'   161°11'     S 11 Dec. 19, '86   Crater Pond (near McMurdo St.)   77°34'   161°11'     S 13 Dec. 29, '86 Don Juan Pond (leasin)   77°34'   161°11'     S 14 Jan.   1, '87 Taylor Valley (near terminal   77°34'   161°11'     S 15 Jan.   9, '87 Wright Valley (near Bull Pass)   77°31'   161°42'     S 15 Jan.   9, '87 Wright Valley (near Bull Pass)   77°31'   161°42'     S 14 Dac. 12, '87 Cape Bird   77°16'36'' 166°23' &   82'1'   39°40'1'     S 20 Jan. 12, '87 Cape Bird   77°16'36'' 166°23' &   82'2'   39°35'     S 2	Soil	Dry Valley						
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S   7   Dec.   18, '84   Don Quixote Pond (2~5cm)   77°37   161°09'     S   8   Dec.   11, '85   Lake Fryxell   77°31' 47''   160°44' 14     S 10   Dec.   24, '85   Labyrinth (Le3 Pond)   77°31' 21''   160°42' 13     S 11   Dec.   28, '85   Labyrinth (Le3 Pond)   77°31' 21''   160°42' 14     S 11   Dec.   29, '86   Don Juan Pond (east side)   77°34'   161°11'     S 12   Dec.   29, '86   Don Juan Pond (heast side)   77°34'   161°11'     S 14   Jan.   1, '87   Taylor Valley (near terminal)   77°34'   161°11'     S 15   Jan.   9, '87   Wright Valley (near Bull Lake)   77°31'   161°49'     S 15   Jan.   10, '87   Lake Vanda (east side)   77°31'   161°49'     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 20   J								
S 8   Dec. 11, '85   Lake Fryxell   77°36'   163°06'     S 9   Dec. 24, '85   Labyrinth (Le-3 Pond)   77°31' 21''   160°21' 13     S 11   Dec. 28, '85   Labyrinth (near Mt. Electra)   77°31' 21''   160°21' 13     S 12   Dec. 29, '86   Don Juan Pond (basin)   77°34'   161°12'     S 12   Dec. 29, '86   Don Juan Pond (basin)   77°34'   161°12'     S 14   Jan.   1, '87   Taylor Valley (near Bull Pass)   77°31'   161°20'     S 15   Jan.   9, '87   Wright Valley (near Bull Pass)   77°31'   161°40'     S 15   Jan.   9, '87   Wright Valley (near Bull Pass)   77°31'   161°40'     S 15   Jan.   10, '87   Lake Vanda (east side)   77°23'   166'49'     Ross Is.   S 19   Dec. 18, '84   Cape Bird   77°16'36''   166'23'     S 20   Jan. 12, '87   Cape Bird   77°16'36''   166'23'   8     S 20   Jan. 12, '86   Cape Bird   77°16'36''   166'23'   8								
S   9   Dec. 24, '85   Labyrinth (E-3 Pond)   77°31' 47" 160°44' 14     S10   Dec. 28, '85   Labyrinth (near ML Electra)   77°31' 21" 160°52' 13     S11   Dec. 19, '86   Crater Pond (near McMurdo St.)   77°53' 161°11'     S12   Dec. 29, '86   Don Juan Pond (basin)   77°34' 161°11'     S14   Jan.   1, '87   Taylor Valley (near terminal   77°34' 161°21'     S15   Jan.   9, '87   Wright Valley (near Bull Pass)   77°31' 161°42'     S15   Jan.   9, '87   Wright Valley (near Bull Lake)   77°31' 161°42'     S16   Jan.   10, '87   Lake Vanda (east side)   77°31' 161°42'     S17   Jan.   10, '87   Lake Vida (west side)   77°31' 161°42'     S19   Dec. 18, '84   Cape Bird   77°16' 36'' 166°23' &   8     S20   Jan.   12, '87   Cape Bird (near rookery)   77°16' 36'' 166°23' &   8     Syowa St.   S22   Jan.   12, '86   Canghovde (near Lake Nurume)   69°04' 25'' 39°35'   324   Jan   22, '84   South Fork (S								
S10   Dec. 28, %5   Labyrinth (near Mc, Electra)   77°31' 21" 160°52' 13     S11   Dec. 19, %6   Crater Pond (near McMurdo St.) 77°50' 20" 160°52' 13     S12   Dec. 29, %6   Don Juan Pond (east side)   77°34'   161°11'     S13   Dec. 29, %6   Don Juan Pond (basin)   77°34'   161°11'     S14   Jan. 1, '87   Taylor Valley (near terminal   77°34'   161°41'     S14   Jan. 10, '87   Lake Vanda (east side)   77°31'   161°42'     S15   Jan. 10, '87   Lake Vanda (east side)   77°32'   161°40'     S18   Jan. 10, '87   Lake Vanda (east side)   77°32'   166°42'     Ross Is.   S19   Dec. 18, '84   Cape Bird   77°16'36''   166°23'     Syowa St.   S22   Jan. 12, '87   Cape Bird (near rokery)   77°34'   161°04'     Syowa St.   S22   Jan. 12, '87   Cape Bird (near take Nurume)   69°14'   39°40' 15     Syowa St.   S22   Jan. 12, '86   Canghorde (near take Nurume)   69°14'   39°41'     Syowa St.								
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S14 Jan. 1, '87 Taylor Valley (near terminal of Tq°43' 162°18'   of Taylor GL) S15 Jan. 9, '87 Wright Valley (near Bull Pass) 77°31' 161°49'   S15 Jan. 9, '87 Wright Valley (near Bull Lake) 77°32' 161°40'   S18 Jan. 10, '87 Lake Vanda (east side) 77°32' 161°40'   S18 Jan. 10, '87 Lake Vanda (east side) 77°12' 166°42'   S19 Dec. 18, '84 Cape Bird 77°16' 36'' 166°23' 8   S20 Jan. 12, '87 Cape Bird 77°16' 36'' 166°23' 8   Syowa St. S22 Jan. 12, '86 Cape Bird 77°16' 36'' 166°23' 8   Syowa St. S22 Jan. 12, '86 Cape Bird 77°16' 36'' 166°23' 8   Syowa St. S22 Jan. 12, '86 Cape Bird 77°16' 36'' 160°27' 8 39°40'   Algae Dry Valley A Dec. 8, '84 South Fork (SF-1 Pond) 77°32' 161°04' A Dec. 1								
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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 Vanda (east side)   77°32'   166°49'     Ross Is.   S 19   Dec.   18, '84   Cape Bird   77°16' 36''   166°23'   8     Syowa St.   S 22   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°24'   39°40' 12     S 23   Jan.   12, '86   Karsvnes (near Torinosu Cove)   69°26'   39°35'   52     S 24   Jan.   2, '86   Ongul Is. (Miharasi Peak)   69°00' 25''   39°35'   52   Jan.   19, '84   North Fork (SF-1 Pond)   77°34'   161°04'     A 2   Dec.   19, '84   North Fork (1-2 Pond)   77°32'   161°28'     A 5   Dec.   2, '84   Lake Canopus   77°34'			S 15	Ian 9	'87		77°31'	161°49′
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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. 12, '87 Cape Bird (near rookery) 77°16' 36'' 166°23' 8   Syowa St. S 22 Jan. 12, '87 Cape Bird (near rookery) 77°16' 36'' 166°23' 8   Syowa St. S 22 Jan. 12, '87 Cape Bird (near rookery) 77°16' 36'' 166°23' 8   Algae Dry Valley A 1 Dec. 8, '84 South Fork (SF-1 Pond) 77°32' 161°04'   A 2 Dec. 19, '84 North Fork (1-2 Pond) 77°32' 161°04'   A 3 Dec. 17, '84 Labyrinth (E-5 Pond) 77°32' 161°04'   A 4 Dec. 20, '84 Lake Canopus 77°34' 161°04'   A 5 Dec. 28, '86 South Fork (near SF-1 Pond) 77°34' 161°04'								
Ross Is.   S 19   Dec. 18, '84   Cape Bird   77°16' 36"   166°23'   £     Subsect   S 20   Jan. 12, '87   Cape Bird   77°16' 36"   166°23'   £     Syowa St.   S 21   Jan. 12, '87   Cape Bird (near rookery)   77°16' 36"   166°23'   £     Syowa St.   S 22   Jan. 18, '86   Langhovde (near Lake Nurume)   69°14'   39°40' 12     Syowa St.   S 22   Jan. 12, '87   Cape Bird (near roninosu 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°00' 25"   39°36' 50     Algae   Dry Valley   A 1   Dec. 8, '84   South Fork (SF-1 Pond)   77°34'   161°04'     A 2   Dec. 19, '84   Lake Vanda (west side)   77°32'   161°28'   A     A 5   Dec. 20, '84   Lake Canopus   77°34'   161°04'     A 5   Dec. 28, '86   South Fork (near SF-1 Pond)   77°34'   161°04'     A 6 </td <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>								
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$		Ross Is						
Syowa St.   S21   Jan.   12, '87   Cape Bird (near rookery)   77°16'36''   166°23'   §     Syowa St.   S22   Jan.   18, '86   Langhovde (near Lake Nurume)   69°14'   39°40' 12     S23   Jan.   19, '86   Skarvsnes (near Torinosu Cove)   69°28'   39°35'     S23   Jan.   22, '86   Ongul Is. (Miharasi Peak)   69°00' 25''   39°36' 50     Algae   Dry Valley   A 1   Dec.   8, '84   South Fork (SF-1 Pond)   77°34'   161°04'     A 2   Dec.   19, '84   North Fork (I-2 Pond)   77°32'   161°04'     A 3   Dec.   17, '84   Labyrinth (E-5 Pond)   77°32'   161°04'     A 5   Dec.   26, '84   Lake Canopus   77°34'   161°04'     A 6   Dec.   18' 16' South Fork (near SF-1 Pond)   77°34'   161°04'     A 6   Dec.   28, '86   South Fork (near SF-1 Pond)   77°34'   161°04'     A 9   Dec.   28, '86   South Fork (near SF-1 Pond)   77°33'		10000 10.						
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'   39°35'   39°36' 50     S 24   Jan. 22, '86   Ongul Is. (Miharasi Peak)   69°00' 25''   39°36' 50     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     A 3   Dec. 17, '84   Labyrinth (E-5 Pond)   77°32'   161°04'     A 5   Dec. 20, '84   Lake Vanda (west side)   77°32'   161°04'     A 5   Dec. 28, '86   South Fork (near SF-1 Pond)   77°33'   161°28'     A 6   Dec. 11, '85   Lake Canopus   77°33'   161°31'     A 8   Dec. 28, '86   South Fork (near SF-1 Pond)   77°33'   161°31'     A 8   Dec. 28, '86   South Fork (east side of SF-1   77°34'   161°04'     A 9   Dec. 28, '86   South Fork (east side of SF-1   <								
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' 5(     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°04'     A 2   Dec. 19, '84   North Fork (1-2 Pond)   77°32'   161°04'     A 3   Dec. 17, '84   Labyrinth (E-5 Pond)   77°32'   161°04'     A 5   Dec. 20, '84   Lake Vanda (west side)   77°32'   161°04'     A 5   Dec. 26, '84   Lake Canopus   77°34'   161°04'     A 6   Dec. 11, '85   Lake Canopus   77°34'   161°04'     A 6   Dec. 28, '86   South Fork (near SF-1 Pond)   77°34'   161°04'     A 8   Dec. 28, '86   South Fork (near SF-1 Pond)   77°33'   161°04'     A 9   Dec. 28, '86   South Fork (near shore line)   77°33'   161°31'     A 10   Jan. 7, '87   Lak		Svowa St						
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A2Dec. 19, '84North Fork (1-2 Pond) $77^{\circ}32'$ $161^{\circ}06'$ A3Dec. 17, '84Labyrinth (E-5 Pond) $77^{\circ}32'$ $160^{\circ}50'$ A4Dec. 20, '84Lake Vanda (west side) $77^{\circ}32'$ $161^{\circ}28'$ A5Dec. 26, '84Lake Canopus $77^{\circ}34'$ $161^{\circ}04'$ A6Dec. 11, '85Lake Fryxell $77^{\circ}36'$ $163^{\circ}06'$ A7Jan. 5, '86Lake Canopus $77^{\circ}33'$ $161^{\circ}01'$ A8Dec. 28, '86South Fork (near SF-1 Pond) $77^{\circ}34'$ $161^{\circ}04'$ A9Dec. 28, '86South Fork (east side of SF-1 $77^{\circ}34'$ $161^{\circ}04'$ A9Dec. 28, '86South Fork (east side of SF-1 $77^{\circ}34'$ $161^{\circ}04'$ A9Dec. 28, '86South Fork (east side of SF-1 $77^{\circ}34'$ $161^{\circ}04'$ A9Dec. 28, '86South Fork (east side of SF-1 $77^{\circ}34'$ $161^{\circ}04'$ A9Dec. 28, '86South Fork (east side of SF-1 $77^{\circ}34'$ $161^{\circ}04'$ A9Dec. 28, '86South Fork (east side of SF-1 $77^{\circ}34'$ $161^{\circ}04'$ A9Dec. 28, '86South Fork (east side of SF-1 $77^{\circ}33'$ $161^{\circ}04'$ A9Dec. 28, '86South Fork (east side of SF-1 $77^{\circ}33'$ $161^{\circ}04'$ A9Dec. 28, '86South Fork (east side of SF-1 $77^{\circ}33'$ $161^{\circ}23'$ LichenDry ValleyL <td< td=""><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></td<>								
A 3Dec. 17, '84Labyrinth (E-5 Pond) $77^{\circ}32'$ $160^{\circ}50'$ A 4Dec. 20, '84Lake Vanda (west side) $77^{\circ}32'$ $161^{\circ}28'$ A 5Dec. 26, '84Lake Canopus $77^{\circ}34'$ $161^{\circ}04'$ A 6Dec. 11, '85Lake Fryxell $77^{\circ}36'$ $163^{\circ}06'$ A 7Jan. 5, '86Lake Canopus $77^{\circ}33'$ $161^{\circ}04'$ A 8Dec. 28, '86South Fork (near SF-1 Pond) $77^{\circ}34'$ $161^{\circ}04'$ A 9Dec. 28, '86South Fork (east side of SF-1 $77^{\circ}34'$ $161^{\circ}04'$ A 9Dec. 28, '86South Fork (east side of SF-1 $77^{\circ}34'$ $161^{\circ}04'$ A 9Dec. 28, '86South Fork (east side of SF-1 $77^{\circ}34'$ $161^{\circ}04'$ A 9Dec. 28, '86South Fork (east side of SF-1 $77^{\circ}34'$ $161^{\circ}04'$ A 9Dec. 28, '86South Fork (east side of SF-1 $77^{\circ}33'$ $161^{\circ}31'$ A10Jan. 7, '87Lake Canopus (in the water) $77^{\circ}33'$ $161^{\circ}31'$ A11Jan. 7, '87Lake Canopus (near shore line) $77^{\circ}36'$ $163^{\circ}06'$ Koss Is.L 2Jan. 12, '87Cape Bird (near hut) $77^{\circ}16'$ $36''$ $166^{\circ}23'$ Syowa St.L 3Jan. 19, '86Skarvsnes (near Torinosu Cove) $69^{\circ}28'$ $39^{\circ}35'$ Excreta of Ross Is.M 1Jan. 5, '86Ross Sea (near McMurdo St.) $77^{\circ}51'$ $166^{\circ}40'$ MawsoniiM 2Jan. 14, '87Ross Sea (near McMurdo St.) $77^{\circ}51'$ $1$	Algae	Dry Valley						
A 4Dec. 20, '84Lake Vanda (west side) $77^{\circ}32'$ $161^{\circ}28'$ A 5Dec. 26, '84Lake Canopus $77^{\circ}34'$ $161^{\circ}04'$ A 6Dec. 11, '85Lake Fryxell $77^{\circ}36'$ $163^{\circ}06'$ A 7Jan. 5, '86Lake Fryxell $77^{\circ}33'$ $161^{\circ}31'$ A 8Dec. 28, '86South Fork (near SF-1 Pond) $77^{\circ}34'$ $161^{\circ}04'$ A 9Dec. 28, '86South Fork (east side of SF-1 $77^{\circ}34'$ $161^{\circ}04'$ A 9Dec. 28, '86South Fork (east side of SF-1 $77^{\circ}34'$ $161^{\circ}04'$ A 10Jan. 7, '87Lake Canopus (in the water) $77^{\circ}33'$ $161^{\circ}31'$ A 11Jan. 7, '87Lake Canopus (near shore line) $77^{\circ}33'$ $161^{\circ}31'$ LichenDry ValleyL 1Nov. 26, '84Lake Fryxell $77^{\circ}36'$ $163^{\circ}06'$ Ross Is.L 2Jan. 12, '87Cape Bird (near hut) $77^{\circ}16'36''$ $166^{\circ}23'$ Syowa St.L 3Jan. 19, '86Skarvsnes (near Torinosu Cove) $69^{\circ}28'$ $39^{\circ}35'$ Excreta of Ross Is.P 1Jan. 12, '87Cape Bird (at penguin rookery) $77^{\circ}16'36''$ $166^{\circ}23'$ Viscera of Ross Is.M 1Jan. 5, '86Ross Sea (near McMurdo St.) $77^{\circ}51'$ $166^{\circ}40'$ MawsoniiM 2Jan. 14, '87Ross Sea (near McMurdo St.) $77^{\circ}51'$ $166^{\circ}40'$								
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 (near SF-1 Pond) 77°34' 161°04'   A 9 Dec. 28, '86 South Fork (east side of SF-1 77°34' 161°04'   A 9 Dec. 28, '86 South Fork (east side of SF-1 77°33' 161°04'   A 9 Dec. 28, '86 South Fork (east side of SF-1 77°33' 161°04'   A 9 Dec. 28, '86 South Fork (east side of SF-1 77°33' 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' 39°35'   Excreta of Ross Is. P 1 Jan. 12, '87 Cape Bird (at penguin rookery) 77°16'36'' 166°23'   Viscera of Ross Is. M 1 Jan. 5, '86 Ross Sea (near McMurdo St.) 77°51' 166°40'   Mawsonii <td< td=""><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></td<>								
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 77°33' 161°04'   A 9 Dec. 28, '86 South Fork (east side of SF-1 77°34' 161°04'   A 9 Dec. 28, '86 South Fork (east side of SF-1 77°33' 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' 39°35'   Excreta of Ross Is. P 1 Jan. 12, '87 Cape Bird (at penguin rookery) 77°16'36'' 166°23'   Viscera of Ross Is. M 1 Jan. 5, '86 Ross Sea (near McMurdo St.) 77°51' 166°40'   Mawsonii M 2 Jan. 14, '87 Ross Sea (near McMurdo St.) 77°51' 166°40'								
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 77°34' 161°04'   A 9 Dec. 28, '86 South Fork (east side of SF-1 77°34' 161°04'   Pond) A10 Jan. 7, '87 Lake Canopus (in the water) 77°33' 161°04'   A 10 Jan. 7, '87 Lake Canopus (in the water) 77°33' 161°31'   A11 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' 39°35'   Syowa St. L 3 Jan. 19, '86 Skarvsnes (near Lake Hunazoko) 69°25' 39°35' 164°23'   Excreta of Ross Is. P 1 Jan. 12, '87 Cape Bird (at penguin rookery) 77°16' 36'' 166°23'   Viscera of Ross Is. M 1 Jan. 5, '86 Ross Sea (near McMurdo St.) 77°51' 166°40'   Mawsonii M 2 Jan. 14, '87 Ross Sea (near McMurdo St.) 77°51' 166°40'								
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A10 Jan. 7, '87 Lake Canopus (in the water) 77°33' 161°31'   A11 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'   Syowa St. L 3 Jan. 19, '86 Skarvsnes (near Lake Hunazoko) 69°25' 39°35'   Excreta of Ross Is. P 1 Jan. 12, '87 Cape Bird (at penguin rookery) 77°16' 36'' 166°23'   Viscera of Ross Is. M 1 Jan. 5, '86 Ross Sea (near McMurdo St.) 77°51' 166°40'   Mawsonii M 1 Jan. 14, '87 Ross Sea (near McMurdo St.) 77°51' 166°40'						South Fork (east side of SF-1		
A11 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'   Syowa St. L 3 Jan. 19, '86 Skarvsnes (near Lake Hunazoko) 69°25' 39°35'   Excreta of Ross Is. P 1 Jan. 12, '87 Cape Bird (at penguin rookery) 77°16' 36'' 166°23'   Viscera of Ross Is. M 1 Jan. 5, '86 Ross Sea (near McMurdo St.) 77°51' 166°40'   Mawsonii M 1 Jan. 14, '87 Ross Sea (near McMurdo St.) 77°51' 166°40'			A 10	Jan	7. '87	,	77°33′	161°31′
Ross Is. L 2 Jan. 12, '87 Cape Bird (near hut) 77°16' 36'' 166°23' 39°35'   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 Ross Is. P 1 Jan. 12, '87 Cape Bird (at penguin rookery) 77°16' 36'' 166°23'   Viscera of Ross Is. M 1 Jan. 5, '86 Ross Sea (near McMurdo St.) 77°51' 166°40'   Mawsonii M 2 Jan. 14, '87 Ross Sea (near McMurdo St.) 77°51' 166°40'								
Ross Is. L 2 Jan. 12, '87 Cape Bird (near hut) 77°16' 36'' 166°23' 39°35'   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 Ross Is. P 1 Jan. 12, '87 Cape Bird (at penguin rookery) 77°16' 36'' 166°23'   Viscera of Ross Is. M 1 Jan. 5, '86 Ross Sea (near McMurdo St.) 77°51' 166°40'   Mawsonii M 2 Jan. 14, '87 Ross Sea (near McMurdo St.) 77°51' 166°40'	Lichen	Dry Valle	y L 1	Nov. 2	6, '84	Lake Fryxell	77°36′	163°06′
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 Ross Is.   P   1   Jan.   12, '87   Cape Bird (at penguin rookery)   77°16' 36"   166°23'     Viscera of Ross Is.   M   1   Jan.   5, '86   Ross Sea (near McMurdo St.)   77°51'   166°40'     Mawsonii   M   2   Jan.   14, '87   Ross Sea (near McMurdo St.)   77°51'   166°40'		•						
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Excreta of Ross Is. PenguinP 1Jan. 12, '87Cape Bird (at penguin rookery)77°16' 36"166°23'Viscera of Ross Is. MawsoniiM 1Jan. 5, '86Ross Sea (near McMurdo St.)77°51'166°40'MawsoniiM 2Jan. 14, '87Ross Sea (near McMurdo St.)77°51'166°40'								39°35′
Mawsonii   M 2   Jan. 14, '87   Ross Sea (near McMurdo St.)   77°51'   166°40'		f Ross Is.						
Mawsonii   M 2   Jan. 14, '87   Ross Sea (near McMurdo St.)   77°51'   166°40'	Viscera of	f Ross Is	M 1	Jan	5. '86	Ross Sea (near McMurdo St)	77°51′	166°40′
	Krill	•	K 1		-		61°	56°

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

$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c} 0.0003 \pm 0.0002 \\ \\ 0.0007 \pm 0.0003 \\ 0.0016 \pm 0.0004 \\ \text{ND} \\ OUBLICATION OF STATES OF STA$
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c}\\ 0.0007 \pm 0.0003\\ 0.0016 \pm 0.0004\\ ND\\ ND\\ ND\\ ND\\ ND\\ ND\\ ND\\ ND\\ ND\\ 0.016 \pm 0.007\\ 0.006 \pm 0.004\\ ND\\ ND\\ ND\\ ND\\ ND\\ ND\\ ND\\ ND\\ ND\\ ND$
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A 7 1.0 $\pm 0.1$ 21.5 $\pm 0.7$ 0.48 $\pm 0.03$	$0.13 \pm 0.02$
A 8 1.8 $\pm 0.2$ 5.9 $\pm 0.6$ 0.15 $\pm 0.02$	$0.041 \pm 0.009$
A 9 1.5 $\pm 0.2$ 4.8 $\pm 0.6$ 0.13 $\pm 0.01$	$0.023 \pm 0.006$
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A11 1.0 $\pm 0.2$ 24.1 $\pm 0.7$ 0.48 $\pm 0.04$	$0.11 \pm 0.01$
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L 2 2.1 $\pm 0.3$ 5.9 $\pm 0.4$ 0.10 $\pm 0.02$	ND
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P   1   5.9 $\pm 0.3$ 4.4 $\pm 0.5$ 0.21 $\pm 0.02$	$0.036 \pm 0.009$
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Table 2. Environmental radioactivity in McMurdo Sound area and around Syowa Station in the Antarctic.

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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168