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Report on the Participation by the Bhabha Atomic Research Centre in the Tenth Indian Expedition to Antarctica

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Abstract

The Antarctic continent can be expected to provide reference levels for all environmental and pollution studies due to its remoteness and restricted human activities. The Bhabha Atomic Research Centre has participated in the Xth Expedition primarily to collect background baseline data on natural radioactivity, heavy metal concentration in soil and water, and biological specimens. While radioactivity data and some limited heavy metal concentration data have already been collected on air, water and soil samples from participation in 8th and 9th expeditions: this is the first time BARC made attempts to collect biological samples as well. Fairly complete data base has been built up on all these samples and these are presented in this report. The analytical procedures followed at BARC were mainly by the use of standard chemicals and approved standardisation techniques in case of inorganic parameters and standard reference gases, wherever required.

Introduction

Man's impact on the oceanic environment has always been the cause for great concern. Several investigations on the natural radioactivity levels and on the heavy metal concentrations over the ocean as well as on remote locations have been carried out by various nations in the world. In order to obtain a background baseline data over the South Indian ocean and on the Antarctic continent, extensive sampling has been carried out on air, water, soil, and other environmental samples from BARC participation in the Xth Expedition during November 27,1990 to March 26, 1991.

Natural Radioactivity Levels in the Atmosphere

Radon (Rn^{222}) and its short lived daughters are the most important radionuclides present in the ambient as well as in indoor atmosphere from the point of view of radiation risk to the population. Extensive measurements of natural radioactivity levels in the atmosphere due to Rn^{222} and Thoron (Rn^{220}) have been carried out enroute to and at Antarctic to obtain the Rn^{222} levels prevailing over Arabian sea and South Indian ocean region as well as around the Antarctic continent. The

measurement consists of collection of air particulate matter on a glass fiber filter of size 5 inch diameter (having a collection efficiency of 100 % for short-lived Rn daughters), for a known period of time (two hours duration) using a high volume sampler of 450 liters per minute, installed at the front foxil of the research vessel. This location is selected to avoid external contamination from the ship boilers and kitchen. The collected filter paper sample is counted for its gross alpha activity using a ZnS(Ag) counter of 35% counting efficiency, of 0.45 cpm as background. From the gross alpha counts, the Rn^{222} levels were estimated taking into account the collection time, flow rate, counting efficiency, the period of collection and also assuming radioactive equilibrium among the short lived daughters, which is valid over the ocean surfaces.

On an average, six to seven air particulate samples at periodic interval of time per day were collected and analysed. The overall errors due to sampling and processing is about ±25 %. The sampling was also carried out at Antarctica. In all 338 air particulate samples were collected during the cruise. Estimated ambient Rn^{222} levels are summarised in Table 1. Measured Rn^{222} levels were found to decrease steadily from 2.4 Bq m^{-3} at Goa, to 0.04 Bq m^{-3} at the equator and to 0.0159 Bq m^{-3} towards 70°S. Around Indian Antarctic station, Maitri, it varied from 0.02 to 0.030 Bq m^{-3} with a mean of 0.0296 Bq m^{-3}.

Extremely low concentration, observed consistently of the order of 0.037 Bq m^{-3} from 20° S downwards to South pole, is mainly due to the long path length and time taken for the air masses to travel to reach the South pole. This can also be due to the shift of south east trades below the equator and to the westerly wind towards 40° S. Extremely low concentrations of observed atmospheric radioactivity, due to Rn^{222} and its short-lived daughters, have to be taken into account while evaluating the budget of Rn^{222} in the atmosphere as well as the possible levels of pure maritime air. These are also very useful in evaluating the residence times and the continental components in maritime air due to mixing. Decreasing trend of Rn^{222} levels towards South pole shows the prevalence of maritime air with long trajectories over the

Table 1: Measured Rn^{222} Levels Over the Ocean and at Antarctica

Location	Mean (Bqm^{-3})	Location	Mean (Bq m^{-3})
15°N-13°N	2.22	20°S - 30°S	0.036
13°N - 10°N	1.258	30°S - 40°S	0.024
10°N - Equator	0.281	40°S - 50°S	0.033
0°S- 10°S	0.033	50°S - 60°S	0.019
10°S - 20°S	0.033	60°S - 70°S	0.0159
Antarctica - 0.296			

ocean. Reported levels by different countries over Antarctic stations vary from 0.020 to 0.058 Bq m^{-3} and are comparable to the concentrations observed around Indian station.

The above filter paper samples pooled together were analysed for the estimation of Be^7, the cosmogenic radionuclide and Cs^{137}, fallout radionuclide present in the atmosphere. Samples thus collected, were pressed in the form of a disc of 2 inch diameter and counted for their gamma activity concentration using a gamma spectrometry set up. The estimated concentration levels are given in Table 2. The observed levels of Be up to 19°S are close to the observed levels at Bombay while south of 20°S, the levels observed are less than the levels observed normally in Bombay. The observed levels of Cs^{137} are comparable with the levels observed in the mainland, Bombay.

Indoor Rn^{222} measurements around Antarctic continent were carried out by using passive detector technique. This involves exposing small strips of indigenously developed nuclear track detector foils of 2.5 cm x 2.5 cm size in the huts around Maitri for a period of 67 days in the bare mode. The dosimeter used consists of a film of above size mounted on a rectangular card such that it views a hemisphere of air of radius comparable to the range of alphas from Po^{214} and can be calibrated to measure the equilibrium equivalent Rn^{222} concentration

Table 2 : Measured Be^7 and Cs^{137} Concentration in the Antarctic and Indian Ocean Environment

Location	Concentration (in Bq/1000 m^3)	
	Be^7	Cs^{137}
15°N:73°E- 18°S:58°E	9.81	0.042
19°S;58°E- 34°S:47°E	8.08	0.051
35°S:47°E-70°S: 13°E	1.91	0.004
70°S: 13°E-70°S: 11 "E	0.61	0.000
Maitri (70° 45'S : 11° 45'E)		
70° S 11°E	2.61	0.000
70° S 11°E	2.50	0.009
70°S 11°E	2.65	0.000
70°S 11°E	1.35	0.008
70°S 11°E	2.20	0.013
70°S 11°E-39°S: 12°E	2.20	0.013
40°S 52°E - 20°S: 57°E	2.10	0.010
20°S 57°E -0°:67°E (equator)	0.95	0.010

(EEC_{Rn}), The EEC_{Rn} of a non equilibrium mixture of short lived Rn^{222} daughters in air is that activity concentration, which has the same potential alpha energy concentration (PAEC) to which the equilibrium equivalent concentration refers to.

The exposed dosimeters were chemically etched in a 2.5 N NaOH solution at 60°C for 90 minutes and the number of tracks registered were scanned by using a spark counter. Estimated track densities were then converted to the actual concentration using a calibration curve generated in the laboratory by way of carrying out controlled experiments. Using an occupancy factor of 0.67 and a dose conversion factor of 9 mSv/WLM and the following relation; the dose was evaluated.

EEC_{Rn} (Bq m^{-3}) = WLx 3700

The estimated dose to the dwellers is given in Table 3. The measured EEC_{Rn} levels at indoors varied from 1.7 to 21.3 mBqm^{-3} and the effective dose equivalent from 0.14 to 1.80 mSv/y in the dwellings studied. The over all errors due to sampling and measurement procedure has been estimated to be about ± 15 %. The details regarding the sampling and measurement procedure are given elsewhere (Ramachandran *et al,* 1992 and Eapen *et al,* 1992).

Natural Background Radiation Levels

Natural background radiation levels were studied using a scintillation survey meter to establish the background radiation dose rate levels at Antarctic continent. Integrated measurements using thermoluminescent dosimeters were also done. Measurements were carried out by using a portable gamma scintillation counter coupled to a 3" x 3" Nal(Tl) detector, operated in two ranges μR/hr and mR/hr. The minimum detection limit of the counter is 0.1 μR/hr. Though the error in the counting is energy dependent, it is found to be within ±20 %. The counter was almost completely weather proof and could be operated down to the temperature of -17°C. Measured outdoor radiation doses were found to be in the range 3 to 4.5 μR/hr, around Indian Station. Over enroute, the measured average background

Table 3 : Measured Indoor Rn^{222} Levels in Antarctic Environment

Location	Exposure period (days)	EEC_{Rn} levels (Bq m^{-3})	Eff. Dose Eq. (mSv/y)
1	67	21.3	1.8
2	67	6.0	0.50
3	67	1.7	0.14
4	67	14.7	1.24

Table 4 : Distribution of Gamma Dose Rate Around Schirmacher Oasis Environment

Subject	No. of measurements	Distribution function	AM/GM* (μR/hr)	SD/GSD* (μR/hr)
Open air	175	Normal	10.37	2.08
Pyroxine granulites	17	Normal	20.73	2.65
Pegmatites	68	Log. Normal	37.75	1.43
Gneisses	39	Log. Normal	12.79	1.73
Living room	180	Normal	13.90	1.80
In and Around Maitri	250	Normal	14.6	1.9

Note: (*) Parameters AM and GM are used in Normal distribution. While GM and GSD are used for Log Normal distribution. AM, GM and SD have units: GSD is a ratio.

radiation dose rate works out to be 7.7 μR/hr, while at the main land it is of the 5.8 μR/hr.

To know the distribution of external terrestrial gamma background radiation in and around Maitri, extensive survey of gamma exposure rates have been carried out using a scintillation survey meter. Measurements were carried out on the rock surfaces as well as in the surrounding environment. Estimated distribution of gamma dose rate in and around the Schirmacher oasis environment is given in Table 4. More than 6 to 7 measurements were carried in each location at a time and the observed readings were statistically tested for their distribution.

Uranium Content in Soil around Maitri Environment

Uranium is the main premordial radionuclide present in earth's crust throughout its history. Human activity in mining and milling is one of the channel for the transfer of underlying uranium to surface soil. Industrial activities involving earth materials can also result in the redistribution of radionuclides in the soil. So in a region free from human activities, the presence of uranium in soil is mainly due to the geochemical processes. To know the concentration of uranium in a remote location like Antarctica, measurements have been carried out using the highly reliable fission track detector technique.

Soil samples were collected around Maitri at a distance of about 2 km and were dried in an oven at 70°C for few hours. Dry soil samples were finely powdered and seived through a 100 mesh sieve. A homogeneous mixture of accurately weighed sample powder and methyl cellulose powder (used as binding material free from uranium) in the ratio 1:2 by weight was prepared. About 200 mg of this mixture was pressed into a thin and flat pellet of 1.3 cm diameter and 1 mm thickness using a

hydraulic pellet making machine. Pellets of standard glass of known uranium concentration (0.77 ± 0.006 ppm) were also made in exactly similar manner. Bach of the pellets was sandwiched between a pair of Makrofol-KG plastic nuclear track detector discs having the same diameter as that of the pellet. All these pellets were encapsulated in cylindrical aluminum cans of 1.5 cm dia. and 5 cm length, each containing pellets of the samples and standards.

These cans were then irradiated with thermal neutron dose of about 10^{15} (n vt) in a nuclear reactor. After the irradiation, the detectors were separated from the pel lets, washed in double distilled water and were chemically etched in 6.25 N KOH at 60°C for 20 min in a constant water bath to reveal the fission fragment tracks. Special care was taken to avoid using any material for treating, cleaning and mounting procedures with disturbing fissionable contaminations and causing track fading by over heating the plastic track detectors during irradiation in a reactor.

The uranium concentration was evaluated using the relation:

$$U_x = U_s\ (T_x/T_s)\ (I_s/I_x)$$

where the subscripts x and s stand for unknown and standard respectively, U is the uranium concentration, T is the fission track density and I is the isotopic abundance ratio of U^{235} and U^{238}. The over all errors due to sampling, sample preparation and measurement procedure have been estimated to be about ± 5 %.

The estimated uranium content in the soil around Maitri is found to vary from 0.036 to 0.364 ppm (Table 5), which is very small in comparison to the range of levels of 1.47 to 4.07 ppm estimated for various types of Indian soil (Mishra, 1970). The low level of uranium in soil samples from the Maitri region may be attributed to the absence of human intervention with the lithosphere in the region. The redistribution of the radionuclides takes place only by the natural geochemieal and geophysical process.

Table 5 : Estimated Uranium Content in Antarctic Soils by Fission Track Method

Location	U^{238} Content Range (ppm)
0.5 km South	0.129 -0.154
0.5 km North	0.036 - 0.043
1.0 km South	0.213-0.292
Lake side(2.0 km)	0.100-0.364
Around Maitri	0.093 - 0.357
1.0 km North	0.330 - 0.353

Heavy Metal Levels in Marine Environment

Several investigations on heavy metals in different waters and atmospheres have been reported in literature, but information from oceans and a remote place like Antarctica is rather limited. Comparison of the coastal data with the open sea data as well as the data on atmosphere at a remote location is necessary to understand the magnitude of human influences on the oceanic and remote environment. With this in view, measurements of air particulate matters, sea and fresh lake water and snow samples have been carried out for the analysis of heavy metal levels over the South Indian ocean and at Antarctica environment during the Tenth Expedition.

Air and sea water samples were collected at periodic intervals enroute to Antarctica during the cruise. Air particulate samples were collected by sucking air through a Whatman EPM-2000 filter paper at a flow rate of 100 Imp from the front foxil of the ship so as to ensure that external contamination due to the boiler releases and from the kitchen is not present. As the concentrations of the trace metals of interest viz. lead, cadmium, copper and zinc are expected to be very low at Antarctic environment compared to urban and other environment, each sampling was done for a duration of more than 24 hours. Sea and fresh lake water samples were also collected at periodic intervals from different locations during the cruise and kept in pretreated clean polythene containers to ensure that external contamination is negligible during the sampling and storing of the samples.

In all, 14 air filter samples at periodic intervals enroute and 11 samples at Antarctica have been collected. 28 sea water samples from different locations over the Indian ocean, right from Goa and 7 water samples from fresh water lakes around Indian station have also been collected. Air particulate and sea water and fresh lake water samples thus collected were decomposed by the method of acidic digestion using nitric, hydrochloric and perchloric acids. Volumetric measurements were carried out with Princeton Applied Research 174-A Polarographic analysis and voltammograms were recorded with PAR X-Y recorder. A static mercury drop electrode assembly was used with PARC-305 stirrer. Reliability and reproducibility of the measurement and standardization procedure of the estimation of heavy metals have been checked by analysing standard reference materials and the results obtained for the standards matched within ± 1-2 % of the certified values. The validity of the methods as well as of the data were checked by keeping low blanks, duplicate analysis and cross method checks. Details regarding the measurement procedure is given elsewhere (Khandekar *et al,* 1993). The over all error due to sampling and measurement procedure is estimated to be about ± 10%. The concentrations of lead and copper in the air particulate matter at various locations enroute to Antarctica are given in Table 6 along with the sampling locations and the volume of the sample collected.

From Table 6 it can be seen that the atmospheric lead values varied from 31.23 at Indian coast (Goa) to 0.21 ng m^{-3} at Polynya (70° 45' S; 11° 45' E) with a mean of 7.8 ng m^{-3} , while the levels of copper varied from 52.30 ng m^{-3} at Indian coast (Goa) to 0.45 ng m^{-3} at Polynya with a mean value of 15.0 ng m^{-3}. In the samples collected at Maitri, the values for lead are found to vary from 0.23 to 1.21 ng m^{-3} with a mean of 0.74 ng m^{-3} and that for copper varied from 0.63 to 4.23 ng m^{-3} with

Table 6 : Measured Concentration of Lead and Copper in Air Particulate Samples

Sr.No.	Location	Volume of Air Analysed (m^{-3})	Concentration (ng. m^{-3})	
			Lead	Copper
1	15°02'N:73°05'E	96.5	31.27	52.30
2	13°51'N:73°23'E	96.5	21.33	37.84
3	04°43'N:70°03'E	100.2	13.61	28.31
4	01°27'S:67°02'E	97.2	9.40	16.50
5	09°02'S:63°45'E	101.2	5.26	13.83
6	18°01'S:59°01'E	97.2	8.55	17.25
7	29°50'S:50°48'E	98.2	6.36	14.12
8	39°56'S:42°51'E	93.1	3.92	11.70
9	50°01'S:32°44'E	106.3	3.12	11.70
10	56°17'S:22°02'E	103.2	2.65	5.60
11	63°35'S:11°37'E	97.2	1.20	4.20
12	67°40'S:10°31'E	105.3	0.97	3.17
13	69°54'S:12°51'S	101.2	0.83	2.92
14	70°45'S:11°45'E	125.5	0.21	0.45
		Maitri (70°45'S:11°45'E)		
15	Maitri	127.6	0.23	0.63
16	Maitri	151.8	0.34	0.98
17	Maitri	125.5	0.29	0.67
18	Maitri	95.2	0.46	1.52
19	Maitri	97.2	0.81	2.57
20	Maitri	122.5	0.95	3.21
21	Maitri	132.7	0.73	1.89
22	Maitri	51.3	1.21	3.92
23	Maitri	90.1	1.07	3.47
24	Maitri	87.1	0.69	2.21
25	Maitri	88.1	1.40	4.23

a mean 2.3 ng m^{-3} . Observed levels of lead and copper can be compared with the reported levels in a remote location viz., 2.5 ng m^{-3} for lead and 1.2 ng m^{-3} for copper.

Levels of lead, cadmium and zinc in sea water samples from Indian coast, Goa, enroute to Antarctica are given in Table 7. Levels of the trace metals in sea water are found to be in the decreasing trend from Goa to Antarctica except near Mauritius, where the contribution due to (he local sources is a predominant factor. Lead levels were found to vary from 0.18 to 1.46 μgl^{-1} with a mean of 0.53 μg^{-1} . The cadmium concentration varied from below detection level of the detecting

Tablc 7 : Measured Lead, Cadmium and Zinc in Sea Water Samples from the Sampling Points Shown in Table 6

No.	Concentration (ng/1)		
	Lead	Cadmium	Zinc
1	0.26	0.02	6.94
2	0.16	0.008	15.97
3	1.43	0.075	89.24
4	0.26	nd	9.03
5	0.87	0.008	12 50
6	0.31	nd	3.96
7	0.42	nd	20.83
8	0.86	0.02	26.39
9	1.46	0.03	24.31
10	1.46	0.02	22.22
11	0.23	0.05	13.89
12	0.39	0.06	19.89
13	0.63	0.06	34.72
14	0.52	0.05	16.67
15	0.26	0.05	9.03
16	0.47	0.03	20.14
17	0.36	0.05	6.26
18	0.83	0.06	11.11
19	0.21	0.06	7.64
20	0.25	0.06	9.72
21	0.21	0.23	27.82
22	0.21	nd	22.92
23	0.18	nd	37.50

nd:-not detected

system to 0.23 ng l^{-1} with a mean of 0.052 ng l^{-1}, where as the zinc level is found to vary from 3.96 to 89.24 ng 1^{-1} with a mean of 20.38 ng l^{-1}. A number of measurements of the heavy metals have been carried out in Antarctica ice and fresh water samples and the results are given in Table 8.

From Table 8 it can be seen that in the ice samples, the mean concentrations of cadmium, lead and zinc are 1.25,0.68 and 87.48 µg l^{-1} respectively. In the fresh lake water samples, the mean concentrations of cadmium, lead, zinc and copper are respectively 0.023, 0.027, 7.81 and 1.07 µg l^{-1}. Maximum levels were found in the main lake mainly due to the human activities over the area. Reported levels of zinc in surface water at Antarctica by other investigators work out to be 23.3 u,g 1^{-1} which is close to the present finding (Khandekar *et al.*, 1992). Table 9 gives the results of

Table 8 : Measured Trace Metal Levels (µg/l) in Ice and Fresh Water Samples at Antarctica

No.	Sample	Date	Cadmium	Lead	Zinc	Copper
1	Ice	10.01.91	0.22	1.03	30,56	—
2	Ice	10.01.91	2.27	0.32	144.40	—
3	Lake water	31.12.90	0.05	0.026	6.25	0.64
4	Lake water	04.01.91	0.016	0.039	1.39	1,30
5	Lake water	04.01.91	0,004	0.007	19.44	1.21
6	Lake water	05.01.91	—	0.039	2.78	0,64
7	Lake water	06.01.91	—	0.039	12.15	1.69
8	Lake water	06.01.91	—	0.013	4.86	0.91

Table 9 : Trace Metal Concentration in Soils around Indian Antarctic Station

No.	Concentration in (P-g/g) of soil			
	Lead	Cadmium	Copper	Zinc
1	1.36	nd	6.03	4.5
2	1.14	nd	17.65	43.58
3	1.54	0.035	6.95	2,81
4	0.99	nd	12,85	28.52
5	1.02	0.03	10.83	27.45
6	1.15	nd	8.64	31.37
7	0.743	nd	13.65	—
8	1.465	0.013	12.24	—
9	0.791	0.012	20.04	—
10	0.766	nd	7.33	—

nd:-■ not detected

the measurements of trace metals in soil samples collected from Indian Antarctic Continent. Chemical parameters in soil samples have been analysed by the method suggested by Piper (1957). The elemental analysis is based on 48 hour HC1 digestion extract of the sample.

The average concentration of lead, cadmium, copper and zinc in soil samples near Maitri were found to be in the range of 0.78 to 1.54 µg/gm with a mean of 1. 1µg/gm of soil; 0.012 to 0.035 µg/gm with a mean of 0.01 µg/gm; 6.95 to 23.04 µg/gm with mean of 11.6 µg/gm of soil and 2.81 to 43.58 µg/gm with a mean of 23.04 µg/gm of soil respectively. These concentrations are 20 to 100 times less than the levels observed in Bombay soils (Khandekar, 1986).

Measurements of Atmospheric Ions and Particle Concentrations

To get the background level data on atmospheric ions and particle concentration at a remote location like Antarctica, extensive measurements were carried out both enroute and at the Antarctic continent. Concentration of aitken nuclei over the ocean gives a good picture of the life time and transport of the pollutants from the continental area. Atmospheric ions play an important role in the chemical and electrical phenomena in the lower atmosphere.

Concentrations of aitken nuclei were estimated using a small particle counter, which works on the principle of Wilson's cloud chamber. It measures the concen-

Table 10 : Measured Atmospheric Ions and Aitken Nuclei Levels and Radon over the Ocean and in Antarctica

Location	Ion Con.(Ions. cm^{-3})				Aitken		Radon
	Positive		Negative		Nuclei(cm^{-3})		($Bq\ m^{-3}$)
	GMC	GSD	CMC	GSD	CMC	GSD	
15°N-05°N	2200	1.3	2200	2.0	690	1.1	1.04
05°N-05°S	1900	1.3	2100	1.3	1200	1.1	0.09
05°S-15°S	2100	1.4	1300	2.3	730	1.9	0.04
15°N-25°S	1900	1.3	260	1.7	920	1.2	0.04
25°S-35°S	2.100	1.5	350	2.6	870	1.8	0.04
35°S-45°S	2300	1.4	240	2.4	570	1.5	0.03
45°S-55°S	2200	1.5	460	2.8	580	1.4	0.03
55°S-65°S	2200	1.5	650	2.6	360	1.6	0 03
60°S-70°S	2600	1.7	940	2.2	330	1.5	0.02
Maitri	3200	1.6	1400	1.7	490	1.7	0.03

GM: Geometric Mean; GSD: Geometric standard deviation

tration of sizes larger than I nm over a wide range of concentrations. Levels of positive and negative ions were measured by using an atmospheric ion and analyser type 134 A, Medicon, London. This unit measures the ion concentrations of both polarity with mobility greater than 0.04 cm^{-1} sec^{-1} cm^{-3} (Joshi, 1990). Measured positive ion, negative ions, the Rn^{222} levels and the particle concentration are given in Table 10.

The Particle concentrations were found to be on the higher side around Maitri compared to that over the ocean. The measured concentration levels were found to follow the same pattern as observed by several investigators all over the world. The details regarding the measurement procedure are discussed in detail elsewhere (Ramachandran, comm.).

Measurements of Methane in Antarctic Environment

Hydrocarbon gases are considered important as they play a major role in a variety of chemical reactions affecting the heat balance in the troposphere and ozone concentrations in the stratosphere. To obtain background levels of methane present over Antarctic continent, measurements were carried out to measure the levels of the same in the atmosphere. In all, 8 samples at Antarctic continent at periodic intervals were collected into an evacuated stainless steel canister and one sample each in both direction while cruising on the route. Concentrations of methane were estimated by gas chromatography at BARC on return. This was done by direct injection of 1 to 2 ml of the sampled air from the canister. Estimated methane levels over the Antarctic environment were found to vary from 1.372 to 2.401 ppm (Table 11). Measured levels were of the same order as observed in the earlier expeditions and were below the levels observed at Bombay. Experimental details of the measurement procedure are given elsewhere (Pandit *et al.,* 1992).

Table 11 : Measured Methane Levels around Antarctic Continent

Location	Concentration (ppm)
03°58'N : 69°44'E	1.417
70°03'S: 12°47'E	1.406
70°45'S : 11°45'E	2.401
70°45'S : 11 °45'E	1.486
70°45'S: 11°45'E	1.382
70°45'S : 12°47'E	1.436
69°57'S : 11°54'E	1.582
69°57'S: 11°54'E	1.424
69°57'S: 11°54'E	1.372
59°47'S : 35°28'E	1.470

Measurement of Katabatic Wind and Snow Particles

Major determinants of Antarctic weather are the snow and wind. Character and intensity of these are time dependent. Aerosols are always present in the atmosphere and their observed higher levels in space of time over large areas are generally due to the results of several physical and chemical influences and the interactions arising out from natural and anthropogenic sources. An attempt has been made to study the effect of Katabatic wind and snow over this continent based on the measurements of the particle concentration as well as the meteorological parameters. Assessment was made to study these fierce winds which carry large amount of snow particles to the sea in a vertical as well as in single longitudinal profile along the slope of the terrain. Based on the measurements, it has been observed that near Maitri, towards the ocean side, Fohen type of effect causes moderate to severe turbulence. It also helps in keeping the temperature warmer and the pressure low at the oasis as compared to the ice shelf or the plateau. Details pertaining to the measurement and analysis of the data are given elsewhere (Bassi *et al,* 1992a, 1992b).

Tritium Measurements in Marine Environment

To obtain the levels of tritium in sea and fresh water, extensive sampling of sea water over the South Indian Ocean and fresh water lakes around Maitri (70°, 45' S, 1 1^0 45'E) was carried out. A total of 36 surface sea water samples, spread over different latitudes and 6 fresh water samples around Maitri were collected in air tight polythene bottles (1 litre). The samples were distilled and enriched for their tritium content using electrolysis. Electrolysis was carried out in standardised glass cells kept in a constant temperature bath, whose temperature was maintained at 4°C and using Na_2O_2 (1 % W/V) as the electrolyte. The enriched samples were distilled to the last drop and analysed in an Ultra low level liquid scintillation spectrometer for long time counting (20 hrs) and using Instagel cocktail marketed by M/s Packard. The counting efficiency of this system has been determined with the help of tritiated water standard supplied by M/s Packard Instrument Company. For the partial spectrum of the tritium betas used for the estimation of the activity, the counting efficiency works out to be about 15 %, and the background counts using tritium free water are little less than 1 epm. The lowest detection limit for 600 min counting at 95 % confidence is 5 TU. Results of the samples analysed are given in Table 12.

The tritium levels present in the Southern hemisphere are expected to be low as compared to those existing in the Northern hemisphere. This is due to the fact that the contribution of tritium released to the atmosphere by fusion explosions in the Southern hemisphere is very small as compared to that in the Northern hemisphere. Three compartment model calculations indicate that in 1990 the average sea water tritium levels, ignoring spatial variations, in the Northern hemisphere were of the

Table 12 : Measured Tritium Levels in Antarctic Water

Sample No.	Date of collection	Location		Tritium content
		Lat	Long	TU*
BARC4	04.12.1990	15°-04.59'S	60° - 49.44'E	<5
BARC 17	16.12.1990	55°-58.51'S	22° - 37.00'E	<5
BARC 19	17.12.1990	60°- 07.70'S	15°- 10.02'E	<5
BARC 21	17.12.1990	62°- 00.32'S	13°- 14.09'E	<5
BARC 23	18.12.1990	64°- 14.24'S	10°-53.69'E	<5
BARC 26	19.12.1990	67°- 00.37'S	10°-09.28'E	<5
BARC 29	21.12.1990	70°-01.03'S	12°-55.19'E	<5

TU : Is a ratio of Tritium atoms to Hydrogen atoms present in a sample T/H $=10^{-18}$=1 TU and 1 TU =0.12Bq1^{-1}

order of 16 TU as compared to the levels of < 5 TU, as indicated by the samples analysed.

Phytochemical Components in Antarctic Samples

Lake bottom (Cyanophyceae) mats, Moss-Bryum sp., Lichen—*Parmelia* sp. from lakes (around Maitri) and Tetractinellid sponge (sea bottom) samples from Polynya were collected. Samples were room air dried and analysed for their fattyacids and sterol contents. Characterisation was done on the basis of gas liquid chromatography, Results of the analysis show that unsaturated fattyacids predominate over the saturted ones. Only sponge sample showed the presence of cholesterol. No other sterol were detected. The analytical results are based on the accurate experimentation and due precautions have been taken for the consistency of the results based on gas liquid chromatography. Table 13 gives the results of the analysis.

Table 13 : Phytochemical Components in Antarctic Samples (%)

Sample	Palmitic acid (16:0)	Stearic acid (18:0)	Palmito-leic acid (16:1)	Oleic acid (18:1)	Linoleic acid (18:2)	Linolenic acid (18:3)	Uniden-titled acids	Sterol (chol-esterol)
Lake bottom mats (Cyanophyceae)	25	4	26	13	7	11	14	Trace
Moss *(Bryum* sp.)	7	25	#	#	21	12	35	Trace
Lichen *(Parmelia* sp.)	10	#	#	10	79	#	1	Trace
Tetractinellid sponge	#	#	#	#	#	#	#	Present as a major steroid

Note: 16:0 and 18:0 Saturated acids. 16:1.18:1. 18:2 and 18:3 Unsaturated acids# Not detected

Physicochemical Analysis of Sea Water Samples

To study the physical parameters *(pH* and salinity) of sea water, sampling over South Indian Ocean at periodic intervals was made. Surface sea water samples for the estimation of *pH* and salinity were collected in 1 litre polythene bottles. Whereas for the trace element analysis 30 litre carbouys were filled and acidified. In all 36 sea water and 6 fresh lake water samples were collected and analysed. All parameters have been assayed by the prescribed procedure laid down in Standard methods for the examination of water, sewage and waste water APHA (1981). The results of the analysis show that the *pH* of the ocean water varied from 7.14 to 8.17, while the salinity ranged from 34.65 to 37.09 parts per thousand. In the fresh water lakes the *pH* varied from 5.5 to 7.26. Table 14 gives the results.

Table 14 : Physical Parameters *(pH &* Salinity) in Sea Water Samples

Sample No.	Geographical position		*pH*	Salinity *(%)*	Remarks
	Latitude	Longitude			
1.	00°11.46'N	68°03.13'E	7.93	37.09	
2.	05°01.58'S	65°51.74'E	8.03	36.44	
3.	10° 09.50'S	63°15.01'E	7.97	36.11	
4.	15°04.59'S	60°49.44'E	8.10	36.11	
5.	10°02.30'S	57°27.40'E	8.10	36.76	
6.	25°21.42'S	53°59.84'E	8.02	36.76	
7.	30°00.15'S	50°42.10'E	8.09	37.09	
8.	35°04.97'S	47°16.24'E	8.03	36.92	
9.	39°34.61'S	43°06.92'E	7.92	37.41	
10.	42° 47.92'S	40°53.51'E	7.89	35.46	
11.	44°38.10'S	39°27.96'E	7.81	35.30	
12.	46° 34.74'S	37°48.59'E	7.87	35.30	
13.	48° 06.41'S	35°39.93'E	7.81	35.30	
14.	49° 46.60'S	33°08.83'E	7.79	35.30	
15.	51°25.61'S	30°32.29'E	7.74	35.14	
16.	53°01.21'S	28°02.28'E	7.83	34.81	
17.	55°58.5l'S	22°37.00'E	7.82	35.30	
18.	57°47.29'S	19°17.85'E	7.86	35.14	
19.	60°07.70'S	15°10.02'E	7.74	35.14	
20.	61°03.12'S	14°09.13'E	7.88	35.46	

Contd...

Table 14: *Conld.*

Sample No.	Geographical position		*PH*	Salinity (%)	Remarks
	Latitude	Longitude			
21.	62°00.32'S	13°14.09'E	7.83	35.46	
22.	62°54.04'S	12°20.87'E	8.06	35.95	
23.	64°14.24'S	10°53.69'E	7.78	34.97	
24.	65°05.16'S	10°00.64'E	7.78	34.97	
25.	66°04.33'S	10°05.03'E	7.84	34.65	
26.	67°00.37'S	10°09.28'E	7.92	35.14	
27.	68°01.80'S	10°47.64'E	7.97	34.81	
28	69°38.76'S	12°35.57'E	7.81	35.46	
29	70°01.03'S	12°55.19'E	8.10	35.46	
30	70°02.22'S	11°56.73'E	7.71	29.61	Sea ice sample
31.	69°57.18'S	11°54.31'E	7.72	34.97	
32.	69°57.18'S	11°54.31'E	7.23	0.355	Shelf ice
33.	69°57.13'S	11°54.22'E	4.53	0.355	Fresh snow
34:	69°57.12'S	11°54.55'E	8.15	0.355	Drinking water
35.	69°57.03'S	11°53.53'E	—	—	Sea water for Lab work
	Smples collected from Northof Equator				
36.	03°45.19'N	68°17.78'E	8.14	35.79	
37.	08° 55.47'N	71°47.90'E	8.17	35.46	

Radioactivity Levels in Biotic Samples

To estimate the radioactivity levels due to uranium and thorium series as well as potassium in biotic samples, measurements have been carried out in moss and lichen samples from the Maitri lake (hand picked and cleaned in lake water) and in sponge and coral samples from sea bottom at Polynya (collected by Dredge). Samples thus collected were dried at 100°C to a constant weight, powdered, homogenised in a pestle and mortar. For gamma spectrometry, a 50 cc Coaxial HPGe detector coupled to a PC based 4K MCA was used to estimate the activity in various samples optimised to 95 gm each. In moss and lichen samples, the activity levels due to uranium series ranged from 0.016 to 0.031 Bq g^{-1} (dry weight), while that due to thorium series ranged from 0.006 to 0.041 Bq g^{-1} (dry weight). Potassium levels were found below detection. The activity due to fallout origin, Cs^{137} was of the order of 0.041 Bq g^{-1} (dry weight) in moss samples. In the samples collected from the sea bottom, the observed activity levels varied from 0.019 to 0.035 Bq g^{-1} (dry weight) and from 0.06 to 1.09 Bq g^{-1} (dry weight) due to uranium and thorium series respectively. Table 15 gives the results.

Table 15 : Radioactivity in Various Biological Samples

Sample & location	Activity in (Bq g^{-1} dry weight)							
	^{226}Ra	^{214}Pb	^{214}Bi	^{228}Ac	^{212}Pb	^{212}TI	40_K	^{137}Cs
Moss *(Bryum* sp) from Maitri Lake								
	#	0.016	0.031	#	0.041	#	#	1
Lichen *(Parmelia* sp) from Maitri Lake								
	#	#	0.025	#	0.006	#	#	#
Sponge from sea bottom								
	#	#	0.035	#	#	1.09	#	#
Coralline(ocean bottom)								
	#	#	0.022	#	#	#	#	#
	#	0.019	#	#	#	1.06	#	#

#Not detected. MDL for U^{238}, Th^{232}. K^{40} and Cs^{137} are 0.01, 0.006, 0.1 and 0.01 Bq g^{-1} dry respectively.

Radioactivity Levels in Abiotic Samples

To estimate the radioactivity levels due to uranium and thorium series in abiotic rock samples from Petermann, Humboldt and Nunatak region, as well as from lake bottom, around Maitri were collected and analysed. Lake bottom samples were dried to a constant weight at 100°C. Dried sediment and rock samples were powdered, homogenised in pestle and mortar, sieved through a wire mesh to obtain rock/sediment sample of uniform grain size of about 210 μm before counting, as outlined earlier for biotic samples. Obse ved radioactivity levels due to uranium series were found to vary from 0.032 to 1.78 Bq g^{-1} , 0.008 to 2.222 Bq g^{-1} and from 0.009 to 0.107 Bq g^{-1} (dry weight) respectively for Petermann, Humboldt and Nunatak region, while the activity due to thorium series ranged from 0.01 to 0.302 Bq g^{-1}; 0.038 to 1.75 Bq g^{-1} and 0.47 Bq g^{-1} (dry weight) respectively for the above mountain ranges. The estimated potassium in the above samples ranged from 0.791 to 3.17 Bq g^{-1} (dry weight). Table 16 gives the results of the measurements.

In the sediment samples collected from the lake bottom all from Schirmacher Oasis), the radioactivity levels due to uranium and thorium series and potassium were found to vary from 0.014 to 0.105 Bq g^{-1}; 0.008 to 0.102 Bq g^{-1} and from 0.33 to 0.775 Bq g^{-1} respectively (dry weight). The activity due to Cs^{137} varied between 0.01 to 0.025 Bq g^{-1} (dry weight). The activity levels observed in the samples were more or less equal to the general background of natural soils and rocks. The daughter activities of the uranium and thorium series were in radioactive equilibrium with their respective parent activity. Table 17 gives the results of the measurements.

Table 16: Radioactivity in Rock Samples

Sample & location	Activity of the sample (Bq g^{-1} dry weight)							
	^{226}Ra	^{214}Pb	^{214}Bi	^{228}Ac	^{212}Pb	^{208}TI	^{40}K	^{137}Cs
Petermann Mountain range								
(a)	0.051	0.034	0.026	0.064	0.011	0.302	0.893	#
(b)	1.78	0.50	0.407	0.075	0.13	0.208	2.4	1
(C)	0.117	#	#	0.046	0.112	0.11	2.148	#
(d)	1.43	0.041	0.032	0.066	0.035	#	#	#
Humboldt Mountain range								
(a)	2.22	1.06	0.139	0.125	#	0.067	3.17	#
(b)	#	0.11	0.008	0.044	#	0.71	#	#
c)	0.192	0.082	0.067	0.181	0.322	0.185	1.35	#
d)	0.210	0.049	0.040	#	0.318	1.75	1.8	#
(e)	0.062	0.013	0.03	#	#	#	0.79	#
(f)	0.279	0.121	0.101	#	0.137	#	0.88	#
(g)	#	0.042	1.040	#	0.038	#	0.93	#
Nunatak	#	0.107	0.009	#	#	0.47	#	#

Not detected. MDL for U^{238}, Th^{232}, K^{40} and Cs^{137} arc 0.01, 0.006, 0.1 and 0.01 Bq g^{-1} dry respectively.

Table 17 : Radioactivity in Lake Sediment Samples

	Activity of the sample (Bq g^{-1} dry weight)							
	^{226}Ra	^{214}Pb	^{214}Bi	^{228}Ac	^{212}pb	208_{Tl}	^{40}K	^{137}Cs
Priyadarshini Lake*								
	#	0.024	0.034	0.02	0.05	0.043	0.63	0.015
Lake II. 2.5 km from Maitri towards Russian camp*								
	0.05	0.02	0.038	0.035	0.077	0.102	0.78	0.01
Lake III, 2.0 km from Maitri towards Russian camp*								
	#	0.023	0.028	0.03	0.059	0.054	0.71	#
Lake IV, Glaciar lake feeding Priyadarshini*								
	0.017	#	0.023	0.52	0.042	0.039	0.69	#
Lake V, towards Trishul Peak*								
	#	0.014	0.025	0.008	0.044	0.048	0.61	#
Priyadarshini Lake (depth sediment)								
	0.105	0.075	0.051	#	0.09	#	#	#
Green House (Soil)-Maitri								
	0.083	0.025	0.032	#	0.044	#	0.33	0.025

*Coastal sediment. # Not detected. MDL for ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs are 0.01,0.006,0.1 and 0.01 Bq g^{-1} dry respectively.

Plankton Analysis

Plankton at Maitri lake was collected with the help of a conical net (9" Dia) of bolting silk cloth No. 20, having 164 meshes to a centimeter. The plankton collected in the net was transferred in a plastic bottle and preserved in 5% neutral formalin, where as plankton at Polynya was collected by standard plankton net of 20" Diameter operated by hydraulic winch. For the enumeration of plankton, drop method was adopted and the entire area of the cover glass was thoroughly examined under the microscope with different magnifications. For the identification of bigger forms, plankton concentrate was put on Sedgewich-Rafter counting cell and exam-

Table 18 : Qualitative Analysis of Plankton from Maitri Fresh Water Lake (70°45'S, 11°45'E)

A. Phytoplankton	B. Zooplankton
(1). Division Chrysophyta	Phylum Protozoa
Coscinodiscus sp.	*Oxytricha* sp.
Cyclotella sp.	*Trachelomonas* sp.
Melosira sp.	
Stephanodiscus sp.	Phylum Porifera
Biddulphia sp.	Gemmule (Fresh water sponge)
Fragilaria sp.	Phylum Nemathelminthes
Synedra sp.	*Aphelenchoides* sp.
Navicula sp.	*Teratocephalus* sp.
Pinnularia sp.	Phylum Rotatoria
Hantzschia sp.	*Philodina* sp.
Nitzschia sp.	*Proales* sp.
(2). Division Cyanophyta	*Diplois* sp.
Tolypothrix sp.	*Euchlanis* sp.
Oscillatoria sp.	Rotifer eggs
Phormidium sp.	Phylum Tardigrada
Anabaena sp.	*Hypsibius* sp.
Nostoc sp.	*Microbiotus* sp.
Synechocystis sp.	egg capsule of Tardigrada
Chroococcus sp.	Phylum Arthropoda
(3). Division Chlorophyta	Cyclopoid copepods
Cosmarium sp.	
Mesotaenium sp.	
Pediastrum sp.	
Unidentified filamentous algae	
Phylum Bryophyta	
Leptodictyum sp.	

ined under dissection microscope. Biological parameters have been assayed by the procedured laid down in standard methods for the examination of waters and waste water (APHA, 1981). In the fresh water samples collected from Maitri, 22 genera of phytoplankton and 14 genera of zooplankton have been observed. Table 18 gives the results of the observations.

Table 19 : Qualitative Analysis of Plankton from Polynya (Marine) - 69°57.20'S, 11°45.93'E

A. Phytoplankton	B. Zooplankton
(i) Division Chrysophyta	Phylum Protozoa
Coscinodiscus sp.	*Acanthometra* sp.
Melosira sp.	Unidentified radiolarians.
Cyclotella sp.	foraminiferans. ciliates
Rhizosolenia sp.	and flagellates were recorded
Chaetoceros sp.	
Biddulphia sp.	Phylum Arthropoda
Fragilaria sp.	Calanoid Copepods
Synedra sp.	Copepod eggs
Achnanthes sp.	*Nauplius* larvae
Gyrosigma sp.	*Metanauplius* larvae
Navicula sp.	*Lucifer* larvae
Neidium sp.	*Metazoea* larvae
Gomphoneis sp.	Ostracod
Bacillaria sp.	*Halocypris* sp.
Nitzschia sp.	Phylum Mollusca
Surirella sp.	Pteropods
Thalassiothrix sp.	*Veliger* larvae
Thalassiosira sp.	Gastropod egg capsule
Guinardia sp.	Phylum Vertebrata
Corethron sp.	Fish egg
Bacteriastrum sp.	
Hyalodiscus sp.	
(ii) Division Cyanophyta	
Oscillatoria sp.	
(iii) Division Chlorophyta	
Closterium sp.	
Closteriopsis sp.	
Halospheara sp.	
Pyramidomonas sp.	
(iv) Division Pyrrhophyta	
Peridinium sp.	
Gonysulax sp.	

In the marine plankton from Polynya, 29 genera of phytoplankton have been recorded. Zooplankton was found to be rich in larval crustaceans and gastropods. Table 19 gives the qualitative observations made. Presence of a large number of forms indicates the richness of shelf waters at Antarctica.

Conclusions

Results of the measurements carried out on the samples collected by Bhabha Atomic Research Center during the Tenth Indian Scientific Expedition to Antarctica (November 27, 1990 to March 26, 1991) are presented in this report. It is hoped that these results along with those obtained during earlier expeditions would provide a reliable data-base regarding the natural radioactivity levels present in air, water and in other environmental samples as well as heavy metal concentration present over South Indian ocean and at a remote location like Antarctica.

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