

## Chemical and Environmental Studies in Ice and Waters in and along Antarctica

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UTILIZING the unique opportunity provided by the First Indian Expedition to Antarctica during the austral summer of 1981-82 some chemical investigations were carried out on the ice and waters of the Antarctic continent and along a NE-SW transect in the southwestern Indian Ocean from 32° S latitude to the edge of the Antarctic continent.

These studies included estimations of several chemical components in ice and lake water on land and in waters of the Southern Ocean. The chemical components were: several essential nutrients, heavy metals and a few major elements. In addition, a study of aerosol were also conducted to examine the effect of areal transport of particles.

### (i) Ice shelf, freshwater lake and polynya

Chemical characteristics, such as, salinity, temperature, dissolved oxygen, phosphate-phosphorus, nitrate-nitrogen, nitrite-nitrogen, silicate-silicon, calcium, magnesium, potassium, fluoride, bromide, iodide, iron, zinc, copper manganese, nickel, cobalt, lead, and cadmium were measured upto 5 m depth in the ice shelf, in the surface waters of a freshwater lake and at several water depths in the polynya.

An increasing downward gradient was found in the ice in respect of most of the constituents. This was caused by the downward diffusion of salt in the ice. A reducing condition was observed at depths in the ice, caused by the gradual escape of gases upwards. Surface concentration of some of the elements appeared to be influenced by atmospheric transport and deposition. No significant difference was observed in the

constituents at some distance away from the edge of the ice shelf.

Concentrations of the heavy metals in the ice and in the lake and in a Himalayan glacier at varying heights were observed to be of a similar order (table 1). These features indicate that both Antarctica and the high altitudes of the Himalayas have clean and unpolluted environment.

Using these two as the southernmost and the northernmost datum points, a watch can be maintained on the health of the Indian Ocean.

Hydrochemical studies of the polynya in Antarctica indicate that the surface layers are influenced by melting of ice but an oceanic layer exists below 150 m depth. Chemical characteristics of the lower layers have many similarities with those of the deeper waters of the Southern Ocean. The height of the ice shelf was about 20 m above the sea surface and extended to about 150 m depth into the sea. Particulate matter resulting from the melting of ice probably adds to the reserves of nutrients and heavy metals of the sea water.

### (ii) Aerosol

Measurement of aerosol particles along a transect in the Western Indian Ocean, between 09° 45'N and 69° 59'S latitudes, showed a gradual decrease of particles towards Antarctica.

The concentration varied from  $65.3 \pm 1.9 \mu\text{g}/\text{m}^3$  air at 8° 37'N latitude to 0 in Antarctica. Peaks were recorded at places where the atmosphere was influenced by continental air. A peak was observed at the zone of Antarctic Convergence which may be the effect of the flow of surface air from Antarctica towards the equator. Katabatic wind is probably the cause of another peak observed near the Antarctic continent. An inverse relation has been observed between the wind speed and the aerosol content which is presumably due to scrubbing effect and dispersion.

### (iii) Southwestern Indian Ocean

Chemical parameters analysed in the water samples,

TABLE I

Concentrations of a few heavy metals (in  $\mu\text{g}/\text{l}$ ) in ice and water, Princess Astrid Coast, Antarctica and in a glacier in the Kashmir Himalayas.

Station	Fe	Zn	Cu	Mn	Ni	Co	Pb	Cd
Antarctic Ice	1.4	14.4	3.0	6.8	2.0	0	0	0
Antarctic Lake	50.5	13.6	3.4	5.6	3.2	0	0	0
Polynya - 10 m	2.0	46.8	3.1	0	3.7	1.4	2.6	1.5
Himalayan Glacier (mean)	82.5	4.5	4.1	17.0	1.8	1.1	3.1	0

collected upto a maximum depth of 4000 m at 17 oceanographic stations, were used to identify the regions of polar divergence, antarctic convergence and sub-tropical convergence. Within the limits of the available data, the polar divergence could be identified between 60° and 63° S. Antarctic convergence was observed slightly south of 52° S. Similarly, the boundary of the sub-tropical convergence was located at around 41° S. Downward gliding of the nutrient-rich water along the continental slope of Antarctica was also recorded.

The change in the oxidative ratios  $\Delta\text{AOU}$ :  $\Delta\text{Si}$ :  $\Delta\text{N}$ :  $\Delta\text{P}$  were 285:58:19:1 by atoms. A comparison of these with similar ratios from the Northern Indian Ocean indicated excesses of 19% nitrate and 45% silicate in the Southern Indian Ocean, while the phosphate concentrations in both these regions were found to be quite similar. Reserved fractions of phosphate and nitrate decreased significantly from the antarctic waters, south of the antarctic convergence, to the sub-antarctic waters found north of this region. This indicates that there is an increase in the intensity of oxidation from south to north. Similar values of reserved silicate in both the regions indicate their origin from oxidation and probably from other processes. Applying an empirical relationship between silicate and AOU, it was observed that the lower ranges of silicate concentrations were due to its consumption by siliceous algae, north of the polar divergence. Negative differences between the observed and calculated values of AOU suggest a transfer of oxygen from deeper to intermediate layers. Oxidative ratios do not indicate any difference in the rate of oxidation of organic matter in the Indian Ocean, north and south of the equator upto the zone of antarctic convergence.

### Biological Investigations in Antarctica Ecosystems

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FIRST (1981-82) and the second (1982-83) Indian Scientific Expedition to Antarctica, gave an unique opportunity for biotic characterization of a multitude of ecosystems (Oasis; freshwater lakes; fast ice (icy sea shelf and 'Polynya') pack ice; open ocean and a number of subantarctic islands from a scientifically little known area, between 37° to 72° south latitude and 5° to 45° east longitude.

Deploying the trophic ecology energy flow approach attempts were made to study the composition, distribution, abundance and productivity potentials of different ecosystems and their contribu-

tion to Antarctic food web. Accordingly, floral and faunal components, in relevance to environmental oscillations, were explored.

Biotic components included bacteria, mosses, lichens, phytoplankton, zooplankton, benthos, krill, seabirds and marine mammals and the associated life process characterization, such as, chlorophyll and pheophytin pigment content; estimation of particulate organic carbon (POC); measurement of live carbon or adenosine tri-phosphate (ATP) and the rate of biological production and utilization at different trophic levels in the terrestrial, limnetic, glacial and marine ecosystem.

Some of the important findings were as follows:

- i. Under the tremendous biennial fluctuations in light intensity, lack of organic soil, and wind chill stress, the microflora, dominated by petrophilous lichen (*Acrospora* sp.) and moss (*Bryum* sp.), flourishes in the crevices and pores of rocks and boulders, in the Oasis ecosystem of Dakshin Gangotri (Antarctica).
- ii. Ice free exorheic lakes, forming a self-contained ecosystem, supported a high bacterial population ( $12 \times 10^4 - 5.9 \times 10^6$ /ml), characterized by *Bacillus*, *Micrococcus* and *Corynebacterium*. Chlorophyll *a* content varying from 0.11 to 0.38  $\mu\text{g/l}$  supported a high rate of photosynthesis, ranging from 0.14 to 0.68  $\text{mgC/m}^3/\text{hr}$ .
- iii. Fast ice (icy shelf and Polynya) and pack ice, constituting an independent but complex ecosystem, is dominated by unicellular algal organisms, distinctly different from the planktonic flora. While the plant pigment concentration was rather poor (0.027-0.067  $\mu\text{g/l}$ ), the primary productivity (0.24-0.48  $\text{mgC/m}^3/\text{hr}$ ) was reasonably high. Sea ice was poor in POC and ATP content. Highest surface chlorophyll value of 1.5  $\text{mg/m}^3$  and a production rate of 2.65  $\text{mgC/m}^3/\text{day}$ , characterized the pack ice ecosystem.
- iv. Phytoplankton of the open sea environment, was contributed by 27 species of diatoms and 1 species each of dino and silicoflagellate, respectively. Average primary production rate of 3.72  $\text{mgC/m}^3/\text{day}$  in coastal waters was several times higher than that (0.95  $\text{mgC/m}^3/\text{day}$ ) in the off-shore areas. Bacterial counts and ATP content, displayed a direct relationship, with a significant part of POC, represented as detritus.
- v. The 68 species under 6 taxa, constituted the zooplankton. Standing crop, varied from 14 to 624  $\text{ml}/1000 \text{ m}^2$ . Secondary production, exhibiting a distinct zonality, fluctuated between 8.4