

Assessment of Pollution in a Freshwater Lake at Fisher Island, Larsemann Hills over East Antarctica

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ABSTRACT

Background and Objectives: The Larsemann Hills area (69°20'-69°28'S, 76°00'-76°30'E) is an ice-free oasis on the Ingrid Christensen Coast of Princess Elizabeth Land, East Antarctica, that includes Bharti Island, Fisher Island, McLeod Island, Broknes Peninsula, Stornes Peninsula and several other islands, promontories and nunataks. The Larsemann Hills is an ice-free area of approximately 50 km², located halfway between the Vestfold Hills and the Amery Ice Shelf on the South-Eastern coast of Prydz Bay, Princess Elizabeth Land, East Antarctica. The ice-free area consists of two major peninsulas (Stornes and Broknes), four minor peninsulas and approximately 130 near shore islands. The Larsemann Hills area contains more than 150 lakes at different islands and peninsulas. **Methodology:** Fisher Island of Larsemann Hills in east Antarctica was selected as a sampling site for the present study. Water sample was collected from a freshwater lake of Fisher Island during 30th Indian Scientific Expedition to Antarctica (ISEA) and analysed for the physico-chemical parameters, major elements and trace metal in surface lake water. Physico-chemical parameters were analysed using standard methodology. **Results:** The concentrations of metals Cu, Pb, Cd, Zn and Cr were measured using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES). Pesticide residues were also analysed using GC-MS and LC-MS. Radiation contamination was detected with the help of an automatic and handy radiation detector. Pesticide residues and radiation contamination was found below detection level of instruments in lake water sample. **Conclusion:** After evaluating general physico-chemical parameters, heavy metals and organic compounds in lake water, it has been observed that the lake water of lake has no pollution load and no impact of any anthropogenic activity.

Key words: Water quality monitoring, Antarctic lake, Fisher Island, water pollution

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INTRODUCTION

Lakes are important feature of the earth's landscape which are not only the source of precious water but provide valuable habitats to plants and animals, moderate hydrological cycles, influence microclimate, enhance the aesthetic beauty of the landscape and extend many recreational opportunities to humankind. The lakes are also used for drinking, irrigation, fishing, eco-tourism, etc., apart from the above advantages.

The different problems of the lake include excessive influx of sediments from the lake catchment, discharge of untreated or partially treated sewage and industrial waste waters/solid waste, entry of diffused nutrients

source from agricultural and forestry, improper management of storm water, over abstraction, over-exploitation of lake for activities like recreation, fishing, encroachments, land reclamation etc., causing lake water shrinkage, shoreline erosion and impacting the lake hydrology, deteriorating water quality, impacting bio diversity, bringing climate changes etc. There is, therefore, an immediate need to know the pollution status of a lake at given time so that necessary conservation activities may be undertaken to regain/improve the health of water body¹.

High altitude lakes of Antarctica continent represent a relatively unique ecosystem in general; however, they remain less intensely studied than lowland lakes, mainly because of their remoteness and the short summer open-water period². Nevertheless, Antarctic lakes are sensitive reference systems of global climatic change and

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other human impacts³. In fact, although remote high altitude lakes are in general protected from direct human impacts, in the last few decades they have been increasingly affected by airborne contaminants, such as acids and nutrients⁴, organic pollutants and heavy metals⁵.

Due to the extreme environmental conditions (low temperature, strong radiations, mostly low buffering capacity and low nutrient level) these ecosystems have a relatively simple food web and react more rapidly and more sensitively to environmental changes than other lakes⁶. Even minor impacts are able to significantly affect the physical and chemical properties of soft water high altitude lakes, to induce changes in species composition and abundance of the biota and to cause accumulation of trace substances in higher trophic organisms⁷. In spite of the socio-economic and ecological importance of these lakes, better knowledge of several ecological aspects (especially regarding species distribution patterns and biogeography, diversity and functional interaction among the different components of the food web) is needed for better understanding of their relationships with the environmental variables. These lakes have received little attention so far in terms of their limnology, diversity, conservation and water management but they are becoming increasingly important due to the possible consequences of the global climate change.

The Larsemann Hills area ($69^{\circ}20'–69^{\circ}28'S$, $76^{\circ}00'–76^{\circ}30'E$) is an ice-free oasis on the Ingrid Christensen Coast of Princess Elizabeth Land, East Antarctica, that includes Bharti Island, Fisher Island, McLeod Island, Broknes Peninsula, Stornes Peninsula and several other islands, promontories and nunataks (Fig. 1). The deglaciated terrain constitutes a transitional zone between marine and glacial ecosystems and includes gently rolling hills, glacially polished and striated bedrock hummocks (roches moutonnees), scoured surfaces and broad valleys interspersed with lakes of varying dimensions (Fig. 1). Indian scientific studies in the Larsemann Hills started in 2003 and the present study was carried out from 2010–2011 during the construction of the third Indian research station Bharti. To investigate lake water chemistry and characteristics in the area water sample was collected from a lake on Fisher Island.

Fisher Island in the Larsemann Hills is part of a polar lowland periglacial environment between marine and glacial ecosystems. However, this Island is almost surrounded by frozen sea. The landscape is characterized by gently rolling hills and broad valleys interspersed with lakes formed in glacially scoured basins⁸. Physicochemical parameters and the ionic constituents of water sample were analysed from a freshwater lake at Fisher Island.

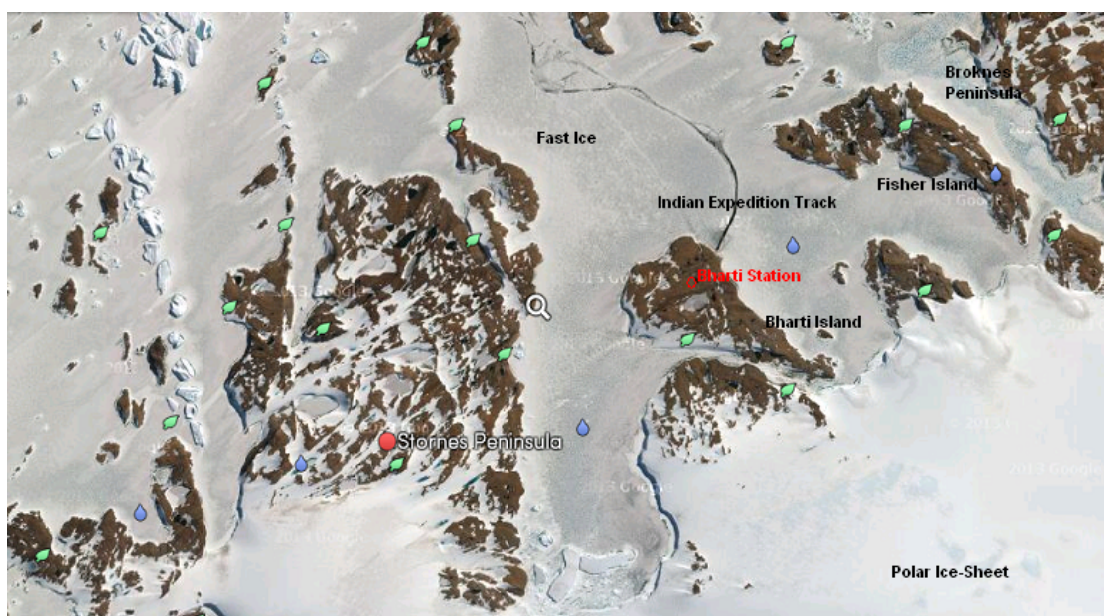


Fig. 1: Location map of the area and sampling sites

MATERIALS AND METHODS

Study area: Environmental monitoring and impact assessment studies were carried out in Antarctica during the austral summer seasons of various Indian Scientific Expeditions to Antarctica⁹.

Fisher Island of Larsemann Hills in east Antarctica was selected as a sampling site for the present study. Water sample was collected from selected lake of Fisher Island during 30th Indian Scientific Expedition to Antarctica (ISEA) and analysed for the physico-chemical parameters, major elements and trace metal in surface lake water¹⁰. The location map of study area is given in the Fig. 1. One sampling point F-1 was selected at Fisher Island, Larsemann hills in east Antarctica. Geo-coordinates of sampling point are given in Table 1.

Sampling: The sampling of lake water was carried out in the 1 L PET bottle and stored in a cold storage immediately after preservation by 1 mL 70% HNO₃. The samples were transported to the laboratory after completion of expedition and analyzed for further analysis of the physico-chemical parameters, major elements, trace metals, microbiological parameters, pesticide residues and radiation contamination.

Analytical methods: Temperature and pH of lake water samples were recorded onsite using thermometer and digital pH meter. Standard methods as described in APHA¹¹ were followed for the dilution and analysis for various parameters. Laboratory analysis work for metal analysis was carried out with the help of Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES).

Water sample was collected from sampling station on 15 January 2011. Neatly cleaned and rinsed double stoppered polyethylene bottles were used for collection of water samples. Bottles were kept in ice bucket and brought to the laboratory for further analysis. Some of the physico-chemical characteristics of water including water temperature, color, pH were determined onsite using mercury thermometer, visual, digital pH meter, respectively. While dissolved oxygen, turbidity and total dissolved solids were analyzed using Orion onsite water quality monitoring kit at the sampling stations. Separate samples were collected in sterile bottles for microbiological studies. Pesticide residues were analysed using GC-MS technique. Radioactivity analysis for alpha particles, gross beta particles and Cesium 137 was carried out using automatic radiation monitoring equipment. Other parameters including metals were analyzed in the laboratory following the standard methods^{11,12}.

RESULTS AND DISCUSSION

Geo-coordinates of sampling location are given in Table 1. Physico-chemical characteristics of lake water sample are given in Table 2. Lake water temperature was found in very low conditions i.e., 1.4°C. The lake water chemistry of the area is greatly influenced by chemistry of the host rock rather than precipitation and evaporation¹³. Numerous examples have appeared in the literatures which indeed support the idea that in an unpolluted environment, where anthropogenic activities are negligible, water quality can be correlated with minerals present in the bed rock⁸. In oligotrophic lakes

Table 1: Location of lake's water sampling site at Fisher Island

Sample ID	F-1
Date	15.01.2011
Latitude (S)	69° 23'37.7"
Longitude (E)	76°4' 06.3"
Altitude (m)	40

Table 2: Results of lake's water sample from Fisher Island

Parameter	IS: 10500-1991	F-1
Color (Hazen)	5, Max.	<5
Odor	Unobjectionable (UO)	UO
Turbidity, NTU	5, Max. (10)	<1
pH	6.5-8.5	6.6
Total hardness (CaCO ₃) (mg L ⁻¹)	300, Max. (600)	26
Iron (Fe) (mg L ⁻¹)	0.3, Max. (1.0)	0.04
Chloride (Cl) (mg L ⁻¹)	250, Max. (1000)	57
Fluoride (F) (mg L ⁻¹)	1.0, Max. (1.5)	0.1
Dissolved Solids (mg L ⁻¹)	500, Max. (2000)	126
Magnesium (Mg) (mg L ⁻¹)	30, Max. (100)	3.8
Calcium (Ca) (mg L ⁻¹)	75, Max. (200)	5.7
Copper (Cu) (mg L ⁻¹)	0.05, Max. (1.5)	<0.001
Manganese (Mn) (mg L ⁻¹)	0.1, Max. (0.3)	<0.001
Sulphate (SO ₄) (mg L ⁻¹)	200, Max.	3
Nitrates (NO ₃) (mg L ⁻¹)	45, Max	<1
Phenolic compounds (C ₆ H ₅ OH) (mg L ⁻¹)	0.002, Max	ND
Mercury (Hg) (mg L ⁻¹)	0.001, Max.	<0.001
Cadmium (Cd) (mg L ⁻¹)	0.01, Max.	<0.01
Selenium (Se) (mg L ⁻¹)	0.01, Max.	<0.005
Arsenic (As) (mg L ⁻¹)	0.01, Max	<0.005
Cyanide (CN) (mg L ⁻¹)	0.05, Max	<0.01
Lead (Pb) (mg L ⁻¹)	0.05, Max	<0.01
Zinc (Zn) (mg L ⁻¹)	5 Max. (15)	<0.01
Anionic detergents (MBAS) (mg L ⁻¹)	0.2, Max	ND
Chromium (Cr ⁺⁶) (mg L ⁻¹)	0.05, Max	<0.01
Mineral oil (mg L ⁻¹)	0.01, Max	ND
Alkalinity (CaCO ₃) (mg L ⁻¹)	200 Max.(600)	11
Aluminum (Al) (mg L ⁻¹)	0.2, Max	<0.02
Phosphate (PO ₄) (mg L ⁻¹)	0.05, Max.	0.014
Boron (B) (mg L ⁻¹)	1, Max (5)	<0.001
Total organic carbon (TOC) (mg L ⁻¹)	-	1.263
Dissolved oxygen (DO) (mg L ⁻¹)	-	11.4

that are low in primary productivity as a result of low nutrient content, the chemistry depends mainly on lithology, precipitation, evaporation and period of sojourn of water in the basin¹⁴.

General physico-chemical characteristics: Lake water was found to be free from any color, odor or turbidity. pH of selected freshwater lake sample was slightly acidic and found to be 6.6. Total hardness of lake water sample was found to be 26 mg L⁻¹ (Fig. 2), while alkalinity was found to be 11 mg L⁻¹. Total dissolved solids were recorded 126 mg L⁻¹ (Fig. 2), whereas dissolved oxygen was measured to be 11.4 mg L⁻¹. Total organic carbon in lake water sample was found 1.26 mg L⁻¹.

Dominant elements: Chlorides and calcium were found to be the dominant constituents among the lake water contents. Maximum chloride and calcium were found to be 57 and 5.7 mg L⁻¹. Magnesium was found to be 3.8 mg L⁻¹ while iron was found to be 0.04 mg L⁻¹. Sulphate was found to be 3.0 mg L⁻¹ in F-1 lake sample at Fisher Island near Bharti station at Larsemann Hills (Fig. 3).

Trace elements: Beside these, fluoride (0.1 mg L⁻¹) was also present in minor quantities in lake water

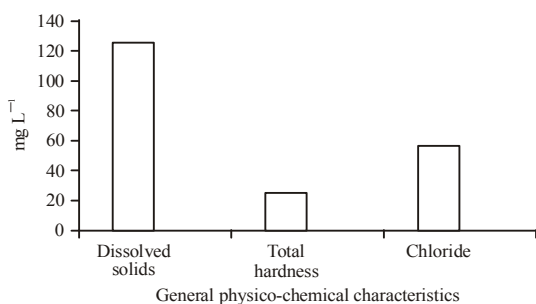


Fig. 2: Total dissolved solids, hardness and chlorides in lake water (mg L⁻¹)

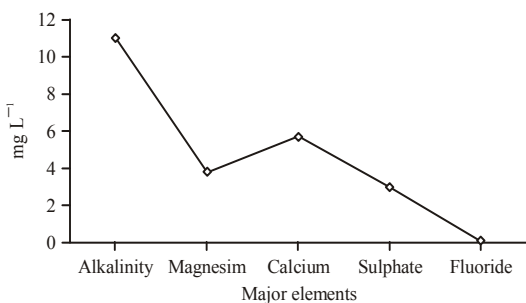


Fig. 3: Major elements in lake water (mg L⁻¹)

sample. Sulphate (3.0 mg L⁻¹) and phosphate (0.014 mg L⁻¹) were also detected in F-1 lake water sample. Trace metals like cadmium, aluminum and manganese were found below detection level in lake water sample. Similar trend was observed for copper, mercury, selenium, arsenic, lead, zinc and chromium metals in lake water sample collected from Fisher Island. Few metals are biologically essential to living organisms in trace quantities in aquatic ecosystems. These trace metals may re-circulate from sediment and became available for biota¹⁵.

Complex organic compounds: Phenolic compounds (as C₆H₅OH), anionic detergents (MBAS) and mineral oil were not detected in lake water sample at Fisher Island near Bharti station in east Antarctica.

Microbiology of lake water: Results for microbiological parameters of lake water samples are given in Table 3. Total bacterial count and psychrophillic counts were found to be less than 1 CFU (Colony Forming Unit). No growth was observed for MPN coliform in the sample. Yeast and moulds, *Salmonella*, *Staphylococcus* and *Pseudomonas* spp., were also found to be absent in freshwater lake water sample.

Pesticide residues and radiation contamination: All pesticide residues were found below detection level in selected lake water sample while radiation contamination was also found less than Minimum Detection Limit (MDL) for alpha, beta and cesium 137 content in lake water sample. Results for pesticide residues and radiation contamination in lake water sample are given in Table 4 and 5, respectively.

Table 3: Microbiological studies of lake water from Fisher Island (30th ISEA)

Sample ID	F-1
Total bacterial count mL ⁻¹ (As per guidelines of IS: 5402-2002, Reaff 2007)	Less than 1 CFU
Psychrophillic count mL ⁻¹ (As per guidelines of IS: 1479 p-3, 1977, Reaff: 2003)	Less than 1 CFU
MPN coliform/100 mL (As per guidelines of IS:1622-1981, Reaff: 2003) Ed 2.4 (2003-05)	No growth observed
Yeast and mould count mL ⁻¹ (As per guidelines of IS: 5403 1999, Reaff: 2005)	Absent
<i>Salmonella</i> 25/mL (As per guidelines of IS: 5887 (p-3) 1999 Reaff: 2005)	Absent
<i>Staphylococcus aureus</i> /25 mL (As per guidelines of IS: 5887 P-2 1976 Reaff: 2005)	Absent
<i>Pseudomonas</i> spp./10 mL (As per guidelines of IS:13428, Amn.D, 2005)	Absent
Macro-algae (as per general microscopic examination)	Absent

CFU: Colony forming unit

Table 4: Analysis of pesticide residues in lake water at Fisher Island (30th ISEA)

Tests pesticides	Detection limit (Mg L ⁻¹)	Protocol adopted	Sample marked as (F-1)
Dichlorvos	0.0002	GC-MS	BDL
Propoxur	0.0002	GC-MS	BDL
Dimethoate	0.0002	GC-MS	BDL
Carbofuran	0.0002	GC-MS	BDL
BHC (Benzene hexa chloride)	0.0002	GC-MS	BDL
Atrazine	0.0002	GC-MS	BDL
Diazinon	0.0002	GC-MS	BDL
Lindane	0.0002	GC-MS	BDL
Phosphamidon	0.0002	GC-MS	BDL
Methyl-parathion	0.0002	GC-MS	BDL
Fenitrothion	0.0002	GC-MS	BDL
Aldrin	0.0002	GC-MS	BDL
Malathion	0.0002	GC-MS	BDL
Fenthion	0.0002	GC-MS	BDL
Parathion	0.0002	GC-MS	BDL
Endosulfan	0.0002	GC-MS	BDL
Dieldrin	0.0002	GC-MS	BDL
o,p DDT (di-chloro, di-phenyl, tri-chloroethane)	0.0002	GC-MS	BDL
Ethion	0.0002	GC-MS	BDL
p,p DDT	0.0002	GC-MS	BDL
Captafol	0.0002	GC-MS	BDL
Phosalone	0.0002	GC-MS	BDL
Permethrin	0.0002	GC-MS	BDL
Cypermethrin	0.0002	GC-MS	BDL
Fenvalerate	0.0002	GC-MS	BDL
Deltamethrin	0.0002	GC-MS	BDL
2,4-D (Dichlorophenyle acetic acid)	0.0001	LC-MS	BDL
Isoproturon	0.0001	LC-MS	BDL
Monocrotophos	0.0001	LC-MS	BDL

BDL: Below detection limit

Table 5: Analysis of radiation contamination in water at Fisher Island (30th ISEA)

Test parameters and protocol	Requirement	Observed value (F-1)
Radioactivity analysis		
Gross alpha (including radium-226) As per IS:14194 (Part 2)	<0.5 bq L ⁻¹	<MDL
Gross beta particle activity As per IS: 14194 (Part 1)	<1.9 bq L ⁻¹	<MDL
Radioactive contamination analysis: Cesium 137 content As per AERB Guidelines	<1.9 bq L ⁻¹	<MDL

MDL: Minimum detection limit of the instrument used, Alpha counting system: 0.04 bq L⁻¹, Beta counting system: 0.6 bq L⁻¹. Minimum detection limit of the instrument used, Gamma spectrometer with 1 k multi channel analyzer, 1.7 bq L⁻¹

CONCLUSION

After evaluating general physico-chemical parameters, heavy metals and organic compounds in lake water, it has been observed that the lake water of lake has no pollution load and no impact of any anthropogenic activity. Low organic load in both lake water indicate the oligotrophic stage of lake ecosystems. High dissolved oxygen content in lake water will support to aquatic

organisms. This is indeed very good and healthy condition for any aquatic ecosystem. Selected lake water sample was almost pesticide free and radiation contamination free. Lake water sample was found free from harmful pathogens and has no psychrophillic bacterial population in lake water. Total dissolved solids are also very low, so the raw lake water can be considered as drinking water.

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