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Research Article

Occurrence of various ingredients in the lake environments at Stornes Peninsula, Ingrid Christenson Coast, East Antarctica

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Abstract:

The Larsemann Hills is an ice-free area of approximately 50 km^2, located halfway between the Vestfold Hills and the Amery Ice Shelf on the south-eastern coast of Prydz Bay, Princess Elizabeth Land, East Antarctica (69°30'S, 76°19'58"E). The area consists of two major peninsulas Stornes and Broknes, four minor peninsulas, and approximately 130 near shore islands. There are more than 150 lakes on different peninsulas and islands.

Surface water samples were collected from two lakes on Stornes Peninsula during 30th Indian Scientific Expedition to Antarctica (ISEA) in mid-January 2011 and analysed for the physico-chemical parameters, major elements and trace metals. Lake waters were slightly acid, free from any colour, odour and turbidity, with dissolved oxygen close to saturation. Total dissolved solids were rather similar in both lakes, up to 71 mg/l and the dominant elements were Cl and Ca. Several minor and trace elements were very low or under detection limits. Total organic carbon was ca 0.7 mg C/l in both lakes and PO_4 was at 0.002 mg/level in one lake. Several pesticide residues were all under detection limits as well as alpha and beta radiation activities. Total bacterial count was 1.6×10^3 cfu/ml in lake ST-2 and lower in other lake while psychrophilic bacterial count was 1.6×10^2 cfu in the former lake. Also a Pseudomonas spp. was detected in the ST-2 lake sample.

Keywords: Water quality monitoring; Antarctic lakes; Larsemann Hills; water pollution

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1. Introduction

Aquatic ecosystems are often receptacles of point-source and non-point source pollutants from spills, sprays, or runoff events. While much emphasis is placed on aquatic ecosystem damage from pollutants, research has demonstrated that these unique systems have resilience and assimilative capacity in the mitigation of such pollutants. Lakes are important features 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 the purpose of drinking, irrigation, fishing, eco-tourism, etc. apart from the above advantages (Bharti and Niyogi, 2015a; Bharti and Niyogi, 2015b).

The different problems of lakes include excessive influx of sediments from their catchment, discharge of untreated or partially treated sewage and industrial waste waters/solid waste, entry of nutrients from diffuse sources like agriculture 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 & impacting the lake hydrology, deteriorating water quality, impacting biodiversity, bringing about climate changes etc. There is, therefore, an immediate need to know the pollution status of a lake at a given time so that necessary conservation activities may be undertaken to regain/improve the health of water body (Sharma et al., 2010; Chauhan et al., 2015).

High latitude lakes of Antarctica represent relatively unique ecosystems; however, they remain less intensely studied than temperate and tropical lakes, mainly because of their remoteness and the short summer open-water period (Vincent and Laybourn-Parry, 2008). Nevertheless, Antarctic lakes and also high altitude lakes are sensitive reference systems of global climatic change and other human impacts (Schmidt and Psenner, 1992, Quesada et al., 2006; Bhat et al., 2011). Concerning remote high altitude lakes, it has been stressed that although they 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 nutrients (Marchetto et al., 1995; Rogora et al., 2006), organic pollutants and heavy metals (Carrera et al., 2002). Due to the extreme environmental conditions (low temperature, strong solar radiation , mostly low buffering capacity and low nutrient levels), these ecosystems have a relatively simple food web and react more rapidly and more sensitively to environmental changes than other lakes (Psenner, 2002). Even minor impacts are able to significantly affect the physical and chemical properties of soft water high altitude and high latitude lakes, to induce changes in species composition and abundance of the biota and to cause accumulation of trace substances in higher trophic organisms (Hofer et al., 2001; Vincent and Laybourn-Parry, 2008; Bharti and Gajananda, 2013).

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 too 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 (Bharti and Niyogi, 2015a; Bharti and Niyogi, 2015c).

2. Material and Methods

2.1 Study Area

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, Broknes Peninsula, Stornes Peninsula, and several other islands, promontories, and nunataks (Fig. 1). Stornes Peninsula in the Larsemann Hills is part of a polar lowland periglacial environment between marine and glacial ecosystems (SIIR, 2012). The landscape is characterized by gently rolling hills and broad valleys interspersed with lakes formed in glacially scoured basins (Gillieson et al., 1990, Asthana et al, 2013).

Environmental monitoring and impact assessment studies were carried out during the austral summers of various Indian Scientific Expeditions to Antarctica since 2003. We analyzed the physicochemical parameters and the ionic constituents of water samples from two lakes on Stornes during 2010-11 during the construction of the third Indian Antarctic research station Bharti (Bharti, 2012).

Water samples were collected from two lakes and analysed for physico-chemical parameters, major and trace elements in lake water. The location map of study area is given in the Fig.1. Two sampling points were selected at significance difference, namely ST-1 and ST-2. Geo-coordinates and basic details of both sampling points are given in Table 1.

2.2 Sampling and storing

The samples of lake water were collected into the 1 L sterilized PET bottles (neatly cleaned and rinsed double Stoppard polyethylene bottles) on 15 January, 2011 from the littoral zone of lakes at a depth of 30 cm (approx.) in both sampling stations. Lakes were partially ice-covered at the time of sampling. Bottles were kept in ice-water bucket and brought to the laboratory where after adding 1 ml 70 % HNO_3 for preservation samples were kept at 4 ℃ during the completion of expedition. Back in India samples were analyzed for physico-chemical parameters, major elements, trace metals, microbiological parameters, pesticide residues and radiation contamination.

Gamma irradiated, clean and sterilized bottles (200 ml capacity) were used for the collection of lake water sample from Antarctica. For dechlorination sodium thiosulphate was added to the clean, dry sampling bottles before gamma sterilization in an amount to provide an approximate concentration of 100 mg/lit in the sample (Chauhan et al. 2015). Aseptic conditions were maintained during the collection of samples. The samples were kept in an ice pack to prevent any changes in the microbial flora of the samples during the transportation. The water samples were transported to the lab in vertical position maintaining the temperature 1–4 ℃ with ice pack enveloped conditions.

All the media were procured form Hi-Media Laboratory, Mumbai, India. Procured dehydrated media were used as per the instructions written on the box and growth promotion test of each media carried out before evaluation of samples. Sodium Chloride, Sodium thiosulphate and other chemicals were of analytical grade.Gram-Stain kit and other reagent procured from Difco Laboratories.

Serial Dilution Pour plate Method was used for the determination of Psychrophilic Bacterial Count.

For the detection of Pseudomonas sp. 250 ml water sample was passed through 0.45 micron filter and the filter paper was inoculated in cetrimide broth and then incubated at 4, 15, 22, 25, 37 ℃ for 48 h in individual tubes.

Subcultured on the plates of cetrimide agar. Plates were observed for characteristic green colonies, optimum growth were observed at 22 and 25 °C. Further confirmation was done by Gram's staining and Biochemical test as per the guidelines of IS: 13428:2005. Relevant methodology and protocol for microbiological study is given in table -3.

Figure 1 Location map of Stornes peninsula in Larsemann Hills area

2.3 Analytical Methods

Some of the physico-chemical characteristics of water including temperature, color, pH were determined *in situ* by mercury thermometer, visual observation and digital pH meter respectively, while dissolved oxygen, turbidity and total dissolved solids were analyzed using Orion onsite water quality monitoring kit.

Physico-chemical parameters were analysed using standard methodology. The concentrations of Cu, Pb, Cd, Zn and Cr were measured using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES). Pesticide residues were analysed using GC-MS & LC-MS. Detection of radiation contamination was done with the help of an automatic and portable radiation detector. Radioactivity analysis for Alpha particles, gross Beta particles and Cesium 137 was carried out using automatic radiation monitoring equipment onsite. Other parameters including metals were analyzed following the methods of APHA (2005) & Trivedi and Goel (1984).

3. Results and Discussion

Geo-coordinates of sampling locations are given in Table-1. Physico-chemical characteristics of lake water samples are given in Table-2. Water temperature was very low from 1.0 ℃ to 1.8 ℃ in both lakes

lakes at the depths of 30 cm (approx.). The lake water chemistry of the area is essentially influenced by chemistry of the host rock rather than precipitation and evaporation (e.g., Gibbs, 1970), the influence of of the latter has been found to be more substantial eastward, on lakes of Broknes (Gillieson et al., 1990). 1990). Numerous cases have appeared in the literature, 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 rock (Drever, 1988; Vincent & Laybourn-Parry, 2008).

3.1 General physico-chemical characteristics

Lake water was found to be free from any colour, odour or turbidity. pH of both samples were close to neutral, 6.7 and 6.8. Total hardness of water samples was found to be 14 mg/l and 13 mg/l respectively for ST-1 and ST-2 and alkalinity was 4 mg/l and 5 mg/l respectively for ST-1 and ST-2. Total dissolved solids of ST-1 and ST-2 lakes were recorded as 71 mg/l and 64 mg/l respectively, whereas dissolved oxygen was recorded 10.8 mg/l and 13.2 mg/l for ST-1 and ST-2 respectively. Total organic carbon of both samples was found to be 0.7 mg/l.

3.2 Dominant elements

Chlorides and calcium were found to be the dominant constituents among the lake water contents. Chloride was found to be 32 mg/l and 31 mg/l, while calcium was 3.6 mg/l and 1.3 mg/l at in ST-1 lake and ST-2 lake, respectively. Magnesium was found to be 1.3 mg/l at ST-1 lake and was nil in ST-2 lake. Boron was 0.007 mg/l at ST-2 lake site and nil in ST-1 lake.

Iron was found to be 0.02 mg/l in ST-1 lake water, while it was found below detection limit in ST-2 lake water.

3.3 Other inorganic and trace elements

Fluoride (0.1 mg/l in ST-1 lake), aluminum (0.006 mg/l in ST-1 & 0.007 mg/l in ST-2 lake) and manganese (0.003 mg/l at ST-2) were found in minor quantities Sulphate (1.0 mg/l) and phosphate (0.002 mg/l) were detected in sample ST-1 only.

Of trace metals cadmium was below detection level in both samples. Similar trend was observed for copper, mercury, selenium, arsenic, lead, zinc & chromium metals. 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 biota (Campbell et al., 1988).

3.4 Complex organic compounds

Phenolic compounds (as C_6H_5OH), anionic detergents (MBAS) and mineral oil were not detected in both lake water samples at Stornes peninsula.

3.5 Microbiology of lake water

Results of studies on microbiological parameters of lake water samples are given in Table-3. Total bacterial count was found to be less than 1 cfu (Colony Forming Unit) and 1.6×10^3 cfu in ST-1 and ST-2 lake water samples, while psychrophilic counts were found to be 66 cfu and 1.6×10^2 cfu in ST-1 and ST-2, respectively. No growth was observed for MPN coliform in any of the samples. Yeast & Moulds, Salmonella and Staphylococcus were absent in both of the lake water samples, while Pseudomonas spp. was detected in ST-2 lake water sample. Accordingly, the total organic carbon (TOC) was low in both lakes, ca 0.7 mg/l.

Table 1 Location of lake's water sampling points at Stornes Peninsula

S.N.	Sample ID	Sampling Date	Latitude (S)	Longitude (E)	Altitude (ft)
1	ST1	15.01.2011	69º 26' 45.4"S	76º 07' 20.6"E	155
2	ST2	15.01.2011	69º 24' 32.6"S	76º 07' 36.0"E	112

Table 2 Values of various physico-chemical parameters in lake's water collected from Stornes Peninsula

SN	Parameter	**IS: 10500-1991** Desirable (permissible)	ST1	ST2
1	Colour, Hazen unit	5, Max.	<5	<5
2	Odour	Unobjectionable (UO)	UO	UO
3	Turbidity, NTU	5, Max. (10)	<1	<1
4	pH	6.5-8.5	6.8	6.7
5	Total hardness (as $CaCO_3$), mg/l	300, Max. (600)	14	13
6	Iron (as Fe), mg/l	0.3, Max. (1.0)	0.02	<0.01
7	Chloride (as Cl), mg/l	250, Max. (1000)	32	31
8	Fluoride (as F), mg/l	1.0, Max. (1.5)	0.1	<0.1
9	Dissolved Solids, mg/l	500, Max. (2000)	71	64
10	Magnesium (as Mg), mg/l	30, Max. (100)	1.3	Nil
11	Calcium (as Ca), mg/l	75, Max. (200)	3.6	1.3
12	Copper (as Cu), mg/l	0.05, Max. (1.5)	<0.01	<0.01
13	Manganese (as Mn), mg/l	0.1, Max. (0.3)	<0.01	0.003
14	Sulphate (as SO_4), mg/l	200, Max.	1	<1
15	Nitrates (as NO_3), mg/l	45, Max	<1	<1
16	Phenolic Compounds (as C_6H_5OH), mg/l	0.002, Max	ND	ND
17	Mercury (as Hg), mg/l	0.001, Max.	<0.001	<0.001
18	Cadmium (as Cd), mg/l	0.01, Max.	<0.01	<0.01
19	Selenium (as Se), mg/l	0.01, Max.	<0.005	<0.005
20	Arsenic as As,mg/l	0.01, Max	<0.005	<0.005
21	Cyanide (as CN), mg/l	0.05, Max	<0.01	<0.01
22	Lead (as Pb), mg/l	0.05, Max	<0.01	<0.01
23	Zinc (as Zn), mg/l	5 Max. (15)	<0.01	<0.01
24	Anionic Detergents (MBAS) mg/l	0.2, Max	ND	ND
25	Chromium (as Cr^{+6}), mg/l	0.05, Max	<0.01	<0.01
26	Mineral Oil, mg/l	0.01, Max	ND	ND
27	Alkalinity (as $CaCO_3$), mg/l	200 Max.(600)	4	5
28	Aluminum (as Al), mg/l	0.2, Max	0.006	0.007
29	Phosphate (as PO4), mg/l	0.05, Max.	0.002	<0.002
30	Boron (as B), mg/l	1, Max (5)	<0.001	0.007
31	Total Organic Carbon (TOC), mg/l	-	0.735	0.711
32	Dissolved Oxygen (DO), mg/l	-	10.8	13.2

Table 3 Results of Microbiological Studies of lake water samples at Stornes (30th ISEA)

S.N.	Parameters	ST-1	ST-2
1	**Total Bacterial Count/ml**(As per guidelines of IS : 5402-2002, Reaff 2007)	1.6×10^2	1.6×10^3
2	**Psychrophillic Count/ml** (As per guidelines of IS: 1479 p-3, 1977, Reaff: 2003)	66 cfu	1.6×10^2
3	**MPN Coliform /100ml** (As per guidelines of IS:1622-1981, Reaff : 2003) Ed 2.4 (2003-05)	No growth observed	No growth observed
4	**Yeast & Mould Count/ml** (As per guidelines of IS: 5403 1999, Reaff: 2005)	Absent	Absent
5	**Salmonella/ 25ml** (As per guidelines of IS: 5887 (p-3) 1999 Reaff: 2005)	Absent	Absent
6	**Staphylococcus aureus/25ml** (As per guidelines of IS : 5887 P-2 1976 Reaff : 2005)	Absent	Absent
7	**Pseudomonas spp./10ml** (As per guidelines of IS:13428, Amn.D, 2005)	Absent	**Present**
8	**Macro-algae** (as per general microscopic examination)	Absent	Absent

Table 4 Analysis of Radiation Contamination Test in lake water at Stornes (30th ISEA)

Test Parameters and Protocol	Requirement	Samples ST-1	Samples ST-2
Radioactivity analysis:			
1) **Gross alpha** (including Radium – 226) As per IS:14194 (Part 2)	< 0.5 bq / l	<MDL	<MDL
2) **Gross beta Particle activity** As per IS: 14194 (Part 1)	< 1.9 bq / l	<MDL	<MDL
3) **Radioactive contamination analysis:** Cesium 137 content As per AERB Guidelines	< 1.9 bq / l	<MDL	<MDL

Minimum detection limit (MDL) of the instrument used:

Alpha counting system: 0.04 bq / liter

Beta counting system: 0.6 bq / liter

Gamma spectrometer with 1 k multi channel analyzer: 1.7 bq / l

3.6 Pesticide residues and radiation contamination

All pesticide residues (Dichlorvos, Propoxur, Dimethoate, Carbofuran, BHC (Benzene Hexa Chloride), Atrazine, Diazinon, Lindane, Phosphamidon, Methyl – Parathion, Fenitrothion, Aldrin, Malathion, Fenthion, Parathion, Endosulfan, Dieldrin, o,p DDT (di-chloro, di- phenyl, tri- chloroethane), Ethion, p,p DDT, Captafol, Phosalone, Permethrin, Cypermethrin, Fenvalerate, Deltamethrin, 2,4-D (Dichlorophenyle acetic acid), Isoproturon, Monocrotophos) were found below detection level in both lake water samples, while radiation contamination was also found less than Minimum detection limit (MDL) for Alpha, Beta and Cesium 137 content in both samples. Results for radiation contamination in lake water samples are given in Table-4.

4. Conclusion

After evaluating general physico-chemical parameters, heavy metals and organic compounds in lake water, it has been observed that both lakes have no pollution load and no impact of any anthropogenic activity. Low organic load in both lake water indicate the oligotrophic state of lake ecosystems. In oligotrophic lakes that are low in primary productivity as a result of low nutrient content, the chemistry depends mainly on lithology, precipitation, evaporation and retention time of water in the basin (Shrivastava et al., 2011). High dissolved oxygen content in lake water is advantageous to aquatic organisms. This is indeed very good and healthy condition for any aquatic ecosystem. Selected lake water samples were totally pesticide free and radiation contamination free. Lake water samples were found free from harmful pathogens and have a psychrophillic bacterial population in both lakes. Due to bacterial communities in lake, water may be considered harmful as drinking water according to Indian standards. However, as the observed microbial communities are psychrophilic in nature and survive in subzero conditions, they may not be survive in human stomach at 36 ℃. The presence of Pseudomonas spp. in ST-2 lake indicates the survival of new bacterium and its new strain in Antarctic lake water under subzero conditions. The bacterium may not be human induced as no permanent research station was there before sampling. Total dissolved solids are also very low, so the raw lake water can be recommended as drinking water, but not for long-time use. Still, quite a few Antarctic stations are continuously drinking water with similar or even lower salinity, compensating it by changing food and drink rations.

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