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Environmental Monitoring Studies at Indian Scientific Base, Maitri, East Antarctica

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ABSTRACT

During the austral Antarctic summer (November 2006 - February 2007), vital environmental data the Indian Scientific Base, Maitri in east Antarctica have been assessed. Extensive monitoring of air, surface water bodies and waste materials located in the proximity of Maitri station in particular and in the Schirmacher Oasis region in general was undertaken. The identified outputs from the activity include emissions to air, soil and ice hazardous and non-hazardous waste generations, mechanical actions, obstructions etc. A number of unavoidable impacts have been identified through the assessment, mainly of low and medium intensity. The impacts with both high probability and high intensity have also been identified and merit prioritisation in further mitigation effects. Sampling of water and wastewater emanating from different locations in and around Maitri was undertaken. Around~80 samples were collected so far. Sampling of waste oils emanating from Maitri Station and Novo Station was also done. Sampling of soil, sediments, oil spilled soils from Maitri and Novo Station was also undertaken. Air exhaust emissions, hazardous and non-hazardous waste generation and oil spillage were also studied. The present paper attempts to highlight the environmental parameters observed during austral Antarctica summer from November 2006 to February 2007.

INTRODUCTION

Antarctica is the coldest continent on the earth. The Indian Ocean, Pacific Ocean and Atlantic Ocean surround the continent. Antarctic continent covers 10% of the earth surface and has a surface area of nearly 14 million square kilometres. It also has 70% of the world‘s fresh water resources in the form of ice sheets. Thick ice sheets cover the whole continent (almost) 98%. As a result of the environmental conditions,

the remaining (~2%) portion without ice cover is basically the barren soil and rocks[1, 2].

The Antarctica Conservation Act (ACA) was made by USA in the year 1978 and is intended to conserve and protect the natural environment of Antarctica. It also addresses the proper material management especially of waste generated due to the interest by several countries to explore the potential of Antarctica in the wake of rising human activity. Further, the "Protocol on Environmental Protection to the Antarctica Treaty" made in year 1961, prohibits any industrial activity at Antarctica other than scientific research investigations. It also intends to conserve natural fauna and flora, managing wastes and preventing marine pollution.

Antarctica which is the last heritage of human kind and the continents of extremes has come to be known as the "Continent of Science". Even though it is difficult to survive in Antarctica, still scientists from all over the world have been engaged in the pursuit of scientific research in various fields. The investigations are essential not for the exploitation of natural resources buried under the region but for preservation of environment and ecology on earth; especially in the light of climate change. Countries that have set up scientific research stations include Australia, New Zealand, Argentina, Germany, United Kingdom, USA, Russia, etc. There are currently about 65 scientific research stations in summer and 30 research stations in winter, which are currently operating for carrying out scientific research. Around 4000 Scientists in summer and 1000 in winter from various countries are working in the harshest climate in Antarctica for scientific investigations. The major areas of investigations include earth sciences, communications, biosciences, atmospheric sciences, logistics, environmental studies, meteorological, seismic activity, etc.

The activities, which have minor and major impacts on the Antarctic environment are: operations of existing research stations, construction of new research stations, science projects operated from permanent research stations, rock or sediment drilling using drilling fluids, major deep ice core drilling projects, aviation and automobile operations.

Oil and fuel storage drums, gaseous emissions from operation of existing research station affect the Antarctic environment. Other main sources of waste materials in the environment at Antarctica may include emissions of carbon monoxide, oxides of nitrogen (NO_X), sulphur dioxide,

suspended particulate matter (SPM), waste incineration of research stations i.e. metals, aluminium cans plastic rubber waste etc; hazardous, non-hazardous, biodegradable and non-biodegradable waste generation etc. Further, the human activities on the earth have also caused major environmental impacts on Antarctica. For example, major problems such as "Ozone Hole" above the Antarctica which were mainly caused by the release of manmade chloroflorocarbons (CFCs). These CFCs have been extensively used in refrigerants and in industries both by developing and developed nations[4-12].

In the present work, during the austral Antarctic summer (November 2006-February 2007), vital data on environmental prospective were collected in and around the Indian Scientific Base, Maitri in east Antarctica. Sampling of water and wastewater, soil and sediments emanating from different locations was undertaken. Sampling of used oil, oil-spilled soils and water from Maitri and Novo station was also carried out. Around 40 sampling sites were covered. Around 40 samples of water and wastewater, 30 samples of soil and sediments were also collected. Further, the assessment of hazardous and non-hazardous waste materials emanating from various sources was carried out. The details are presented in paper.

OBJECTIVES AND SCOPE OF WORK

The main aim of the project was to carry out detailed environmental monitoring studies at the existing Indian Scientific Base, Maitri in east Antarctica. The scope of work involves:

- Sampling of hazardous oils and fuels conventionally being used and detailed analysis.
- Assessment of oil spillage.
- Assessment of air exhaust emission during operation of snow vehicles, incinerator, power generator etc.
- Sampling of water and waste water from different sources and their detailed characterization.
- Sampling of soils, sediments and rocks from different regions and their detailed analysis.
- Assessment of hazardous and non-hazardous waste material.

- Suggestions and recommendations to minimize waste material generation in and around the Indian Scientific Base, Maitri, east Antarctica.

Indian Scientific Base Maitri Station

The station is located at Latitude 70°45’ 0.165" South; Longitude 11° 43’ 0.145" East in the Schirmacher Oasis in Central Dronning Maud Land of east Antarctica. It is approximately 80 km from the ice edge. It is situated in an area of barren rock and is surrounded by a number of fresh water lakes. The closest station to Maitri is the Russian Station NOVOLAZAREVSKAYA. Maitri is relatively a large station complex, spanning an area of approx. 1000x500 meter**.**

Waste Disposal Policy at Maitri Station

Indian Scientific Base, Maitri has developed a waste management policy, which outlines ways to minimize waste and how specific waste materials should be disposed of in safer ways. Waste disposal policy at Maitri includes:

- Reduction of waste amount introduced toAntarctica to the minimum extent.
- All waste are separated into categories and clearly marked.
- All hazardous waste are not mixed with other non-hazardous waste and are kept in a separate container.
- Waste storage: Waste prepared after segregation are stored in the safe and marked container and transported back to either Indian or South Africa where it is scientifically disposed of.

MATERIAL AND METHOD

In this section, gathered data and applied methods have been described.

Sampling of Water and Waste Water and Its Characterization

Ice water samples were collected during austral Antarctica summer season from November 2006 to February 2007 in various parts of the Schirmacher Oasis of the Central Maud Donning of east Antarctica.

Sampling of water and waste water samples from Novo station was also carried out. Around ~ 35 samples were collected. The sample gathered for the present work is presented in Table 1. For all the analysis, the water samples were divided into physico-chemical and microbiological properties. A variety of analyses were performed on the collected water samples which include colour, pH, odour, turbidity, salinity, trace metal, chloride, sulphate, nitrate, dissolved solids, alkalinity and hardness.

Table 1–Types of Samples Collected

Sl. No	**Samples**	**Location**	**Sample Description**
1	Oil Samples	♦ Maitri Station ♦ Generator Complex ♦ Novo station ♦ Fuel Storage Tank ♦ Abandoned Drums, etc.	♦ Lubricating oil, ♦ ATF, Diesel ♦ Engine oil, ♦ Capacitor oil, ♦ waste oil,
2	Water/ice	♦ Pump House ♦ Priyadarshni Lake ♦ Wastewater discharge ♦ Land Locked Lake ♦ Glacier feeding lake's water ♦ Epishelf Lake ♦ Oil spilled water ♦ Novo Station ♦ Post Glacier Lakes, etc	♦ Drinking & bathing water ♦ Waste Discharge Water ♦ Glacier feeding lake's water ♦ Oil spilled water,
3	Ash	♦ Maitri Station	♦ Food incinerator ash, ♦ Toilet incinerator ash ♦ Open burning ash,
4	Soil/Sediments	♦ Generator Complex ♦ Vehicle Parking Area ♦ Land Locked Lake Summer Camp ♦ Empty oil drums ♦ Novo station etc.	♦ Oil spilled soil, ♦ Soil & sediments ♦ Waste water discharge

Sampling of Soil and Sediment and its Characterization

Soil and sediment plays a critical role in Antarctica ecosystem functioning. A critical assessment of soil sampling was undertaken in and around Maitri station. Soil samples were also collected in and around Novo station. The various types of samples collected are presented in Table 1. Around 32 samples representing various locations and activities including workshop, generator, oil-spilled soils etc. were collected.

RESULT AND DISCUSSION

Monitoring of Environmental Impact

The environmental monitoring and impacts assessment studies of the Maitri station was carried out keeping in view of various activities pertaining to the logistics and subsequent operations. The types of activities are presented in Table 2. A matrix was prepared to identify the impacts. Table 2 shows the interaction of various outputs of Maitri station with the environmental elements. These include use of polar

Table 2–Environmental Output of the Activity from Operations of Maitri Station: Output & Impact

Sl. No	Actions	Output					
		Air Pollutant Emissions	**Wastes**	**Noise**	**Oil Spills**	**Heat**	**Mech-anical**
1	Snow Vehicles/ Crane/ Pisten Bully	✓	✓	✓	✓	✓	✓
2	Generator	✓	✓	✓	✓	✓	✓
3	Incinerator	✓	✓	✓	✓	✓	✓
4	Helicopter	✓	✓	✓	✓	✓	✓
5	Field Equipment					✓	✓
6	Waste Disposal	✓	✓				
7	Human Activity			✓			✓
	Maitri Station	✓	✓	✓	✓	✓	✓

vehicles, power generations, incineration of food and toilet wastes, water effluent, wastewater discharge, helicopter, field equipment etc. Proper preventive and mitigation measures have also been proposed and are given in subsequent pages of the report.

Waste Management at Maitri Station

Proper waste management and disposal are given top priority at the Maitri station. The waste management at the Maitri Station is in accordance with Antarctica waste management. Since the total members of the Indian Scientific Expeditions to Antarctica varies from year to year, the amount of waste generated each year also varies accordingly. The Maitri station has comprehensive schemes for separating, storing and back loading of waste. The wastes at Maitri station are separated into different categories which are as follows:

- Bio-degradable waste : Food waste, human fecal waste, etc.
- General waste : paper and cardboard box packaging, wood, etc.
- Non-biodegradable waste: glass, aluminium, metal cans, etc.

Table 3–Hazardous and Non-Hazardous Waste Generation at Maitri station

Sl.No.	Waste Generated	Estimated (In Tons)		
		Monthly	Summer	Annual
1	Kitchen cum Food	0.4	2.0	4.5
2	Waste water effluent	50	250	700
3	Packaging waste	0.15	1.0	1.7
4	Glass waste	0.10	0.4	1
5	Waste oil	0.13	0.5	1.4
6	Ash	2.0	10	2.6
7	Chemical waste	0.08	0.5	1
8	Electrical / Electronic	0.1	0.5	1.2
9	Medical waste	0.01	0.04	0.11
10	Metal / Scrap	1.25	7	15
11	Misc.	0.83	4	10
	Total	**55.06**	**275.94**	**738.51**

- Hazardous wastes : Paints, oils and fuels, medical wastes, electronic waste, chemicals waste, battery, used oil, etc.
- Sewage effluent waste.
- Incinerated ash of toilet and food waste.

The ashes generated at Maitri station by incineration of food and toilet wastes are separated, collected in drums and brought out of Antarctica to India for appropriate disposal or recycling. Further, small non-combustible waste are separated and compacted for removal from Antarctica. The hazardous and non-hazardous waste materials generated at Maitri station are presented in Table 3. It gives an overview of the waste generation at the Maitri station.

Impact on Disposal of Waste Water / Sewage Effluent Waste

A system for purifying wastewater has been installed at the Maitri station. Sewage water from the Maitri station is treated by Klargester unit and discharged into a small pond. The treated effluent is periodically pumped from the settling pond into an ice-free area approx. 500-meter from the station.

The discharge of wastewater to the small pond is a minor and transit impact due to the small contaminant affects and also due to the dilution expected by the slow melting of ice. Moreover, the discharge wastewater from ice-free area is expected to reach near drinking water source i.e. Piryadarshni Lake.

It has also been observed that installed Klargester water effluent unit at the Maitri station was non-functional and there was no microbial disc. The sewage water was discharged into a small pond. Further, waste water from summer camp was discharged without treatment and may easily seep into the Piryadarshni Lake as it is situated ~30 m away from the lake.

Food and Toilet Waste Management

The station is equipped with incinerators for treatment of food and toilet waste. The food and toilet waste generated at the Maitri Station are burnt in oil fired incinerators at high temperature.

All food waste is incinerated in a designated area at the Maitri Station. Human toilet waste is incinerated once a day. ATF is used as fuel

for the incineration of food and toilet waste. Around ~4560 kg of food waste are incinerated per annum. Around ~400 kg of toilet waste ash are generated per annum during burning in toilet incinerators. The release of fuel gas from incineration of waste may contribute to environmental impact through emission released. It is estimated that around ~16848 L/ annum fuel is used for burning food and toilet waste items per annum.

The ashes from the incinerator are collected in drums, stored and transported out of Antarctica once a year. Samples of food and toilet waste ash were also collected and detailed analyses of ash samples were carried out at SRI. The results are presented in Table 4.

Table 4–Analysis of Ash samples

S. No.	Parameters	Food Incinerator ash	Toilet Incinerator ash	Open Burning ash
1	Loss on Ignition (%)	7.1	7.4	25.4
2	Silica (as SiO_2) by mass	16.5	7.4	22.2
3	Specific Gravity	2.68	3.14	2.18
4	Lead (as Pb) % by mass	0.014	0.004	1.3
5	Calcium as (Ca) % by mass	22.7	5.4	15.9
6	Iron as (Fe) % by mass	7.3	30.31	1.5
7	Cadmium as (Cd) % by mass	0.005	0.005	0.005
8	Aluminium as (Al) % by mass	1.5	0.05	0.71
9	Mercury as (Hg) % by mass	0.7	1.1	0.71
	Elemental Composition			
10	Carbon Content% by mass	3.80	N.D	7.31
11	Hydrogen Content% by mass	0.28	0.34	0.89
12	Nitrogen Content% by mass	ND	ND	ND
13	Sulphur Content% by mass	0.41	ND	0.69

Emission to Air from the Fuel Combustion

The internal combustion engine converts the chemical energy contained in the fuel into mechanical power. During the operation of the Maitri station, air emission produced from generator, incineration, snow vehicles etc., were estimated. The exhaust gas discharged from the

operation of snow vehicles, generator, incinerator etc. contain several gases and suspended particulate matter. These emissions comprise of Carbon dioxide (CO_2), Carbon monooxide (CO), Oxides of sulphur (SOx), Oxides of nitrogen (NOx) and other gases. The fuel consumption along with estimated air exhaust gases emissions of all activities of Maitri station of the generator, incinerator and snow vehicles etc. investigated are presented in Table 5. The estimation of air emission was done based on fuel consumption as per the guidelines in Manual of Antarctica.

Table 5–Fuel Consumption and Estimated Air Exhaust Emission of all activities at Maitri Station (Nov 2006-Feb 2007)

Sl. No.	Actions	Fuel			Air Emissions (Kg)					
		Hrs run	Lt.	Kg	CO_2	NOx	CO	HC	PM	SOx
1	Piston Bully/ Bulldozer/ Mantis Crane	3644	40,767	35,4674	110798	65	564	30.5	4	1.1
2	Power/ Generator	5454	51,386	44,706	139661	81.3	711	38.4	5.1	1.35
3	Food and Toilet Incinerator	1872	5616	4894	15288	9	77.8	4.2	06	0.15
	Total	**10970**	**97,769**	**85,067**	**2,65,747**	**155.3**	**1352.8**	**73.1**	**15.1**	**2.6**

However, the production of CO_2 as a result of combustion of fuel from operation of generator, incinerator, snow vehicles etc into the atmosphere is a cause of concern. The emission of CO_2 can contribute to the green house gases and are harmful to human health and also to the Antarctic environment. Further, combustible products settling on snow and ice-free surfaces could potentially affect the albedo, which with time could lead to further alternatives of physical environmental ablation rates. Deposited combustible compounds may in general affect ice quality. Moreover, the uptake of combustible products may in the long run inhibit growth of micro flora and fauna. These include emissions to the atmosphere such as exhaust gas, disturbance to the physical soil and ice environment such as tracks from movement of snow vehicles.

Further, environmental disturbance at Maitri station is an inevitable consequence of activities in Maitri station in Antarctica.

Effect of Scientific Research Operation

As research is the main purpose of Maitri station the scientific activities that are conducted in such a way that impacts are minimized. There are no effects on scientific research to be expected by the proposed activities.

Potential Impact of Oil Spills

Oil spills, unfortunately are common events in many parts of the Antarctica. Most of them are accidental, so no one can know when spills can happen on land, water, soil or ice at any time. The oil contamination poses a major threat to environment and ecosystem of Antarctica because the oil products are persistent and potentially toxic in the environment. Oil spills have diverse negative impact on the micro-organism. Oil spills pose the greatest environment risk in Antarctica.

The oil spillage at Maitri station was investigated in detail and areas contaminated by leakage/spillage of ATF fuel at Maitri station are mainly at four locations. These are mainly at generator complex, vehicle parking area, workshop, incinerator, and fuel storage tank area. The approximate oil spillage was found to be total area: 700 sq feet. These are described in Table 6. Oil spill in the Maitri station area may migrate in direction of freshwater reservoir under ice. It could also cause oil pollution of a coastline. Effects are mainly operational in the sense that

Table 6–Assessment of Oil Spillage

Sl. No.	Particulars	Oil Spillage	
		Area (Sq. feet)	Spillage (%)
1	Workshop	359	51.28
2	Generator complex	185	26.42
3	Fuel Storage Tank	100	14.28
4	Incinerator/Summer camp	50	7.14
	Total	**700**	**100**

drinking water will be exposed and potential made unusable. The oil spills on ice and soils may mobilise in groundsurface water, where it can migrate into lakes in Schrimacher Oasis and sea. Moreover, evaporative emissions occur during tank filling and in the form of diurnal losses from tanks. The fuel spill in Antarctica can cause long lasting environmental damage. The physical conditions in Antarctica retard the decomposition of the fuel products and cleanup efforts are made difficult by the conditioning. Moreover, oil spill may exert its effects directly, through fouling or poisoning

Table 7–Analysis of Waste Oil samples

S. No.	Parameters	Maitri Station		NOVO Station	Protocol Used
		Waste Oil (I)	Waste Oil (II)	Waste Oil	
1	Colour, ASTM Scale	> 8	> 8	> 8	ASTM D 1500
2	Flash Point °C (COC)	200	169	195	IS : 1448 (Pt 69)
3	K. Viscosity at 40 °C, cst	125.6	53.4	143.4	IS : 1448 (Pt 25)
4	Density g/ml at 25 °C	0.892	0.868	0.897	IS : 1448 (Pt 32)
5	Gross Calorific Value (Cal/gm)	11,140	11,170	11,130	IS : 1448 (Pt 6)
6	Ash Content at 600 C, (% by mass)	1.16	0.84	0.63	IS : 1448 (Pt 4)
7	Lead (as Pb), ppm	0.5	2.94	9.2	ASTM D 5184 Guidelines & ICP
8	Nickel (as Ni), ppm	< 0.1	< 0.1	0.1	ASTM D 5184 Guidelines & ICP
9	Iron (as Fe),ppm	1.7	23.8	9.1	ASTM D 5184 Guidelines & ICP
10	Cadmium(as Cd), ppm	< 0.1	0.1	< 0.1	ASTM D 5184 Guidelines & ICP
11	Zinc(as Zn), ppm	9.4	74	94	ASTM D 5184 Guidelines & ICP
12	Mercury (as Hg) ppm	—-	0.7	0.8	ASTM D 5184 Guidelines & ICP

Waste Oil

Around ~1400 L/annum of waste oil are generated per annum during operation and maintenance of generator, incinerator, snow vehicles etc., at Maitri station. These waste oil include lubricating oil, ATF, engine oil and waste oil that are stored in drums and are back loaded annually. Samples of waste oil were collected from Maitri and NOVO station. Detail analysis of waste oil samples was carried out at SRI laboratory and the results are presented in Table 7.

Characteristics of Lake Water and waste water samples

Water samples from land locked lakes, melted ice ponds, epishelf lakes, glacial lakes, Zub lake etc., were collected and analysed for the various parameters: pH, odour, alkalinity, turbidity, hardness, trace metals, nitrate, sulphate, chloride, oil and grease etc. The results are presented in Table 8-11. The average pH of water were found to be 6.7 in case of Zub lake, 7.1 in case of land locked lakes, 6.7 in case of epishelf lakes and 6.5 in case of proglacial lakes. The average turbidity of water were found to be 2.7 NTU in case of Zub Lake, 4 NTU in case of land locked lakes, 3.6 in case of epishelf lakes and 5 in case of pro glacial lakes. The average dissolved solids of water were found to be 150 ppm in case of land locked lakes, 94 ppm in case of epishelf lake and 20 ppm in case of pro glacial lakes. Further, *E-coli* were not detected in all the lakes water samples. The analytical data so obtained were compared with the permissible limits prescribed by BIS and WHO standards and the results suggested that the lake water were safe and uncontaminated.

Wastewater emanating from Maitri and NOVO station were also collected and analysed in detail. The results of wastewater discharge collected from Maitri and Novo station are presented in Table 12.

Potential Impacts of Noise

Noise pollution emanating from operation of generator, snow vehicles, incinerator, helicopter etc., at Maitri station shall have adverse impacts on the human beings, marine, life and also on Antarctic birds i.e., Skua and Penguin in the long run.

Table 8–Physico-Chemical Properties of Surface Zub Lake Water (Near Maitri Station)

S. No	Parameter	Desirable Limits as per IS 10500-1991	Zub Lake		
			South Side	East Side	North Side
1	Colour, Hazen unit	5 Max (25)	< 5	< 5	< 5
2	Odour	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable
3	Turbidity as NTU	5 Max	2	3	1
4	PH Value	6.5 to 8.5	6.7	6.6	6.9
5	Total Hardness (as CaCO3) mg/l	300 Max (600)	140	180	120
6	Dissolved Solids, mg/l	500 Max (2000)	365	509	310
7	Chloride (as Cl), mg/l	250 Max (1000)	10	20	10
8	Sulphate (as SO4) mg/l	200 Max (400)	10	10	24
9	Nitrates (as NO3) mg/l	45 Max	4	5	2
10	Oil and Grease, mg/l	0.01 Max	Nil	Nil	Nil
11	Alkalinity (as CaCO3,) mg/l	200 Max (600)	4	Nil	Nil
12	Test for detection of E Coli	Negative	Nil	Nil	Nil
13	MPN Coliform/100 ml	10 Max.	No growth observed	No growth observed	No growth observed
14	Iron (as Fe), mg/l	0.3 Max (1)	0.6	0.7	0.8
15	Magnesium (as Mg), mg/l	30 Max (100)	<0.01	<0.01	<0.01
16	Calcium (as Ca), mg/l	75 Max (200)	39	44	36
17	Copper (as Cu), mg/l	0.05 Max (1.5)	0.08	0.05	0.01
18	Manganese (as Mn), mg/l	0.1 Max (0.3)	<0.01	<0.01	<0.01
19	Mercury (as Hg)mg/l	0.001 Max	<0.001	<0.001	<0.001
20	Cadmium (as Cd)mg/l	0.01 Max	<0.01	<0.01	<0.01
21	Selenium (as Se)mg/l	0.01 Max	<0.01	<0.01	<0.01
22	Lead (as Pb) mg/l	0.05 Max	0.01	<0.01	<0.01
23	Zinc (as Zn) mg/l	5 Max	0.04	0.02	0.05
24	Chromium (as Cr) mg/l	0.05 Max	Nil	Nil	Nil
25	Aluminium (as Al) mg/l	0.03 Max (0.2)	0.01	0.01	0.05
26	Boron, (as B), mg/l	1.0 Max (5)	< 1	< 1	< 1

Table 9–Physico-Chemical Properties of Surface Antarctic Lake Water

S. No.	Parameter	Land Locked Lake		
		Lake 1	**Lake 2**	**Lake 3**
1	Colour, Hazen unit	< 5	< 5	< 5
2	Odour	Unobjectionable	Unobjectionable	Unobjectionable
3	Turbidity as NTU	3	2	2
4	pH	6.4	7.4	7.5
5	Total Hardness (as CaCO3) mg/l	6	50	76
6	Dissolved Solids, mg/l	14	13	23
7	Chloride (as Cl), mg/l	7	4	5
8	Sulphate (as SO4) mg/l	1	2	6
9	Nitrates (as NO3) mg/l	3	2	1
10	Oil and Grease, mg/l	Nil	Nil	Nil
11	Alkalinity (as CaCO3,) mg/l	20	46	31
12	Test for detection of E Coli	Nil	Nil	Nil
13	MPN Coliform /100 ml	No growth observed	No growth observed	No growth observed
14	Iron (as Fe)mg/l	0.07	0.03	0.08
15	Magnesium (as Mg) mg/l	<1	1	3
16	Calcium (as Ca) mg/l	10	2	15
17	Copper (as Cu)mg/l	0.03	0.03	0.01
18	Manganese (as Mn) mg/l	<0.01	<0.01	<0.01
19	Mercury (as Hg) mg/l	<0.001	<0.001	<0.001
20	Cadmium (asCd) mg/l	<0.01	<0.01	<0.01
21	Selenium (as Se) mg/l	<0.01	<0.01	<0.01
22	Lead (as Pb) mg/l	<0.01	<0.01	<0.01
23	Zinc (as Zn) mg/l	0.01	0.01	0.01
24	Chromium (as Cr) mg/l	0.01	0.01	0.01
25	Aluminium (as Al) mg/l	<0.01	<0.01	<0.01
26	Boron (as B) mg/l	< 1	< 1	< 1

Table 10–Physico-Chemical Properties of Surface Epishelf Lake Water

S. No	Parameter	Epishelf Lake		
		Lake 4	Lake 5	Lake 6
1	Colour, Hazen unit	< 5	< 5	< 5
2	Odour	Unobjectionable	Unobjectionable	Unobjectionable
3	Turbidity as NTU	3	2	4
4	pH	6.1	7.5	6.5
5	Total Hardness (as $CaCO_3$) mg/l	8	7	6
6	Dissolved Solids, mg/l	45	72	15
7	Chloride (as Cl), mg/l	13	30	5
8	Sulphate (as SO_4) mg/l	18	15	6
9	Nitrates (as NO_3) mg/l	1	2	1
10	Oil and Grease, mg/l	Nil	Nil	Nil
11	Alkalinity (as $CaCO_3$,) mg/l	2	4	8
12	Test for detection of E Coli	Nil	Nil	Nil
13	MPN Coli form/100 ml	No growth observed	No growth observed	No growth observed
14	Iron (as Fe)mg/l	0.07	0.09	0.08
15	Magnesium (as Mg) mg/l	1	1	3
16	Calcium (as Ca) mg/l	1	2	1
17	Copper (as Cu) mg/l	0.03	0.03	0.01
18	Manganese (as Mn) mg/l	<0.01	<0.01	<0.01
19	Mercury (as Hg) mg/l	<0.001	<0.001	<0.001
20	Cadmium (as Cd) mg/l	<0.01	<0.01	<0.01
21	Selenium (as Se) mg/l	<0.01	<0.01	<0.01
22	Lead (as Pb) mg/l	0.08	0.01	0.01
23	Zinc (as Zn) mg/l	0.01	0.04	0.01
24	Chromium (as Cr) mg/l	<0.01	<0.01	<0.01
25	Aluminium (as Al) mg/l	<0.01	<0.01	<0.01
26	Boron (as B) mg/l	<1	<1	<1

Table 11–Physico-Chemical Properties of Post Glacial Lake Surface Lake Water

S. No	Parameter	Post Glacial Lake		
		Lake 7	Lake 8	Lake 9
1	Colour, Hazen unit	< 5	< 5	< 5
2	Odour	Unobjectionable	Unobjectionable	Unobjectionable
3	Turbidity as NTU	1	3	5
4	pH	6.5	6.3	7.0
5	Total Hardness (as CaCO3) mg/l	80	30	24
6	Dissolved Solids, mg/l	12	10	47
7	Chloride (as Cl), mg/l	12	20	18
8	Sulphate (as SO4) mg/l	1	1	6
9	Nitrates (as NO3) mg/l	2	1	1
10	Oil and Grease, mg/l	<0.01	<0.01	<0.01
11	Alkalinity (as CaCO3,) mg/l	2	4	3
12	Test for detection of E Coli	Nil	Nil	Nil
13	MPN Coliform/100 ml	No growth observed	No growth observed	No growth observed
14	Iron (as Fe)mg/l	<0.01	<0.01	<0.01
15	Magnesium (as Mg) mg/l	<1	<1	<1
16	Calcium (as Ca) mg/l	1	2	1
17	Copper (as Cu)mg/l	0.03	0.03	0.01
18	Manganese (as Mn) mg/l	<0.01	<0.01	<0.01
19	Mercury (as Hg)mg/l	<0.001	<0.001	<0.001
20	Cadmium (as Cd)mg/l	<0.01	<0.01	<0.01
21	Selenium (as Se)mg/l	<0.01	<0.01	<0.01
22	Lead (as Pb)mg/l	<0.01	<0.01	<0.01
23	Zinc (as Zn)mg/l	0.09	0.01	0.05
24	Chromium (as Cr)mg/l	<0.01	<0.01	<0.01
25	Aluminium (as Al)mg/l	<0.01	<0.01	<0.01
26	Boron (as B)mg/l	< 1	< 1	< 1

Table 12–Physico-Chemical Properties of Waste Water Discharged from Maitri & Novo Station

S. No	Property	Waste Water Discharge		
		Maitri Station		Novo Station
		Sample 1	Sample 2	Sample 3
1	Colour, Hazen unit	Greyish	Greyish	Greyish
2	Odour	Objectionable	Objectionable	Objectionable
3	Turbidity as NTU	28	35	24
4	pH	7.6	8.3	7.6
5	Total Hardness (as CaCO3) mg/l	110	24	10
6	Dissolved Solids, mg/l	474	341	71
7	Chloride (as Cl), mg/l	240	61	80
8	Sulphate (as SO4) mg/l	77	18	2
9	Nitrates (as NO3) mg/l	45	11	11
10	Oil and Grease, mg/l	35	15	18
11	Alkalinity (as CaCO3,) mg/	125	112	22
12	Iron (as Fe) mg/l	0.5	0.2	0.8
13	Magnesium (as Mg) mg/l	0.05	0.02	0.01
14	Calcium (as Ca) mg/l	10	6	2
15	Copper (as Cu) mg/l	0.02	0.03	0.01
16	Manganese (as Mn) mg/l	0.05	0.01	0.01
17	Mercury (as Hg) mg/l	<0.001	<0.001	<0.001
18	Cadmium (as Cd) mg/l	<0.01	<0.01	<0.01
19	Selenium (as Se) mg/l	<.005	0.005	<.005
20	Lead (as Pb) mg/l	0.03	0.01	0.01
21	Zinc (as Zn) mg/l	0.3	0.02	0.01
22	Chromium (as Cr) mg/l	0.03	0.08	<.01
23	Aluminium (as Al) mg/l	0.01	0.01	0.01
24	Boron (as B) mg/l	<1	<1	<1

Emergency Response/Emission from Fire Fighting Equipment

The Maitri station is equipped with fire extinguishers and other fire fighting equipment. Halon and CO_2 extinguishing gases are being used for extinguishing fire. However, the emission of these gases from fire fighting equipment will not have a noticeable impact on the environment even if they are used during fire.

CONCLUSION

The environmental assessment studies carried out at the Indian Scientific Base, Maitri, station located in east Antarctica throws light on the status of air, 2222 water and soil quality and waste generated. Despite all care, there is always a possibility for accidental contamination as well as transport of solid and liquid waste into Schirmacher Oasis due to strong winds, which can directly or indirectly affect the quality of water, ice and soil. Further, the year round maintenance combined with increased scientific and logistics activity every year at the Maitri station results into waste generation. Anthropogenic activity of any kind is bound to disturb the fragile ecosystem in Antarctica continent in the near future.

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