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Maitri-Environmental Perspective

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Aim

To carry out tasks designated by NEERI in its protocol "Proposed studies during XIVth IAE"

Introduction

In view of the protocol on environmental protection to the Antarctic treaty in 1991, it was obligatory to carry outproper Environmental Impact Assessment (EIA) studies and generate baseline parameters of Maitri station.

The objectives of the study undertaken by NEERI was the collection and collation of data on various components of environment viz. air, noise, water, biological and land, and to assess the likely impacts on environment.

Plan of Work

Following tasks during the study attempted

- Monitoring of exhaust gases from generator, vehicle, burning of sanitary wastes and also of ambient air
- Estimation of SPM in air due to movement of helicopters and road vehicles
- Monitoring program of Zub lake water as well as those of surface waters feeding Zub lake
- Evaluation of treatment efficiencies of two biodiscs in operation
- Monitoring of waste water discharges and seeped surface water at lower elevation
- Laboratory studies on impact of seeped surface water on lake plankton
- Collection and characterisation of soil contaminated by spillage/leakage of fuel and other sources

- Collection of data on solid and hazardous wastes
- Monitoring of levels of noise at various locations in and around Maitri station

Environmental Audit

Air

- Monitoring of smokes from generator, vehicle, burning of wastes generated from toilet, helicopter and also from control area
- Estimation of SPM in air due to movement of helicopters and road vehicles

Water

- Monitoring of Zub lake water and surface waters fed to Zub lake

Waste water

- Monitoring of waste waters discharged in ponds
- To find out sources of surface water at lower elevation of above ponds

Soil

- To measure the area contaminated by spillage/leakage of fuel
- To collect and characterize soils from different depths at contaminated and exposed sites

Soild waste

- To avail data towards quantification of different types of solid and hazardous wastes

EIA Studies

- In order to get total volume of water of Zub lake, scientific approach may be adopted through Survey of India (SOI) for measuring depths of water at different grids of the lake
- The bottom of the Zub lake is rocky. SOI can find out the area of sediment exposed to water, if any, for sampling and characterization
- Impact of drainage water from surface water channel on lake water can be studied in glass jars at different dilutions

To collect soil samples around the proposed site of garage for characterisation

A questionnaire prepared by NEERI to facilitate collection of information on activities at Maitri during expedition information on activities from Maitri.

Questionnaire

* Number of generators run
* Fuel consumption by generator (monthly)
* Hours helicopters run
* Fuel consumption by helicopters
* Hours of run of each type of vehicle
* Consumption of fuel of vehicles (monthly)
* Number of hours pump run for water intake from lake (monthly)
* Volume of water pumped per hour
* Number of boilers run
* Fuel consumption by boilers (monthly)
* Chemicals and quantity used in boilers
* Dates of pumping out of waste water from two ponds
* Quantity of waste water pumped out on each day (based on time and efficiency of pump used)
* Stock of different fuels and their containers
* Informations towards spillage/leakage of fuel
* Number of empty drums and their locations
* Quantity of paper waste burned open
* Quantity and type of food burned
* Numberofsealeddrumsforeachcategory of solid wastes. (Food scraps, plastics, metal, glass, ash, wood etc.)
* Quantityofliquidwastes(photographicchemicals,unserviceablelubricants, oil etc.) ear-marked for removal outside treaty area
* Any other information related to environment

Assessment of Quality of Air

(a) Monitoring of the fugitive emission and/or exhaust gases emerging out of Bhaskara generator room, Boiler room, Toilet incinerator, Helicopter and Ambient air quality.

(b) Measurement of levels of SPM due to helicopter movement. These experiments were carried out using high volume sampler keeping it atleast 5 meters away from the source both in upwind and downwind directions and at on height of 1 meter from the ground.

The generator, boiler and incinerator exhaust outlets are atleast 4-6 mtrs above ground levels. It was found that with the present instrumentation set up for air pollution monitoring could not be conducted effectively as due to high temperature gradient the flue gases go vertically up and hence at 1 meter height at which the sampling was done the results were as of ambient. Therefore the alternative adopted was to monitor the smoke inside the generator, boiler, incinerator rooms as due to leakages some amount of atmospheric pollution was observed in these working areas. This to a certain extent can be taken as a yard stick even-though it may not be the exact figures. Also the pollution caused by the burning of wastes in the incinerator. The burning of wastes are not continuous. It is daily fired only for 2-3 hours.

Hence the pollution calculations were scaled down accordingly.

Table: Levels of pollutants (SO_2, NO_x) at Maitri

S. No.	Location	Concentration ($\mu g/m^3$)	
		NO_x	SO_2
1.	Toilet incinerator	67	13
2.	Boiler	31	ND
3.	Generator	10	13

The air pollution due to incineration was monitored only for four hours i.e. during the period of firing, where as the helicopter exhaust was monitored from 10.15 a.m. to 6.25 p.m.

The measurement of SPM due to helicopter was carried out using the same instrumental set-up.

The emissions of SPM and the exhaust of helicopters are time variant as helicopters land periodically (periodicity varying from once every 40 mtrs to 90 mtrs). The maximum number of sorties undertaken in a day during the expedition was only eight i.e. 16 flights. Hence calculation for air assessment and SPM was scaled accordingly.

The SPM monitoring due to movement of vehicles could not be carried out due the following reasons:

a) The vehicles cannot be kept running continuously for 24 hrs as their engine life is at a premium.

b) This requires the presence of an operator continuously, which is not possible due to conditions existing in Antarctica.

c) Further these vehicles ply on convoy between Maitri and the shelf, taking about 14hrs one way and do not run near Maitri.

The results indicate high concentration of SPM from boiler and incinerator rooms.

Table: Ambient Air Quality at Maitri

S.No.	Location	SPM	NOx	SO_2
			($\mu g/m^3$)	
1.	Near refuse burning place	182	17	ND
2.	Near Helicopter	30	9	ND

Water

(A) Freshwater:

Water samples were collected from four lakes i.e. Priyadarshini, Control, Glacier to West and SE of Maitri. These samples were collected from 18 different locations and characterised for different parameters like physical, inorganic, nutrient, demand and organic parameters. These include *p*H, temperature, conductivity, turbidity, alkalinity, total hardness, chloride, sulphate, sodium, potassium, nitrate, nitrite ammonical nitrogen, total phosphate, dissolved oxygen, biochemical oxygen demand (BOD), chemical oxygen demand (COD), oil & grease, hydrocarbons and heavy metals like cadmium, copper, chromium, lead, iron & zinc.

Field parameters like *p*H, temperature, conductivity, turbidity, dissolved oxygen (DO) and BOD were analysed at Maitri station immediately after collecting the samples while samples for other parameters were preserved (with preservatives or at 4°C) and brought to the NEERI for analysis. Hydrocarbons and oil & grease extracts were carried out at Maitri station by extracting the samples with carbon tetrachloride and hexane respectively.

(B) Wastewater :

The samples at different times and the composite samples, both at the inlet and the outlet were collected from two biodiscs (B_1 & B_3). The following parameters were monitored.

1) The flow rate of wastewater discharges

2) BOD analysis of influent and effluent for both the biodiscs to study performance evaluating.

Hydrocarbons and oil-grease extractions were carried out using the standard procedures. BOD analysis was carried out for inlet raw water and outlet treated samples of both Klargesters at four dilutions viz. 5%, 1%, 0.5%, 0.1%.

The discharge of biodiscs B_1 and B_3 varied throughout the day. The wastewaters from inlet and outlet were collected at two different timings i.e. once when the discharge of wastewater is at it is peak for B_1 and lean for B_3 and the second time lean for B_1 and peak for B_3. (B_1 treating wastes from kitchen has got peak discharge during cooking/meal timings and for the rest of the time it is lean. B_3 treating wastes from bathroom/urinal/washing machine/wash-basins has got peak discharge during early morning and late evening when the members use these facilities and for rest of the time the discharge is lean).

There is negligible discharge between 2330 hrs and 0630 hrs as all supply and delivery pumps are shut down. Hence the effective supply of water to Klargesters are only for 17 hrs.

Measured discharge at two instances were as follows:

[A] B_1——————18 litres in 7 minutes

Hence approximate daily discharge

17 x 60x18/7 = 2600 LPD

B_3—————19 litres in 43 minutes

Hence approximate daily discharge

17x60x19/43 = 450 LPD

Therefore total volume of wastewater discharge is approximately 3050 LPD.

[B] B_1————19 litres in 32 minutes

Therefore approximate daily discharge

17 x 60 x 19/32 = 600 LPD

B_3———————195 litres in 8 minutes

Therefore approximate daily discharge

17x60x19.5/8 = 2500 LPD

Therefore total volume of waste water discharge is approximately 3100 LPD.

Hence the average discharge can be approximately taken as 3100 LPD.

The average demand for consumption of fresh water is approximately 3500 LPD.

It can be clearly seen that the outlet quantity of the biodiscs varies depending on the time of the day. During cooking and meal timing the respective biodisc's discharge is higher whereas during morning/evening the other biodisc's discharge is very high. The discharges from both these biodiscs are negligible from 2330 hrs to 0630 hrs, as there is no activity in station. Hence it can be safely presumed that the total volume of raw water consumption of fresh water sump is less than that of used for cooking/drinking gets converted to waste water. (The water is generally used for cooking/drinking/washing of plates/washing of clothes and bath).

Since the quantity of water is varying at different day times, sampling carried out at any instant of time will not give the correct picture. For getting an accurate picture, an empirical calculation as mentioned in previous paragraphs can be done or waste water will have to be collected physically for 24 hrs period. Moreover, when the warm water flows through the biodiscs because of very low humidity prevalent in Antarctica, there is bound to be heavy vaporization losses.

Moreover 24 hrs continuous monitoring cannot carried out without adequate arrangements in Antarctic weather.

The wastewater discharge pumps has got variable discharge between 60 LPM and 1000 LPM, which can be adjusted by —

(a) Changing the speed of the engine and hence the pump.

(b) Controlling the outlet orifice by closing/opening the control valve.

The periodicity of pumping out of wastewater from ponds are also not laid down. It is strictly on an "As is required" basis. The periodicity may be any thing between once in ten days to once in every month. There is always a dead stock in the pond, which cannot be pumped out as suction valve is to be always immersed in water. The pumped out water also leaks along the line. Moreover, over a period of time seepage does occur between the ponds and outside the channels.

It is seen that the accommodation is on a downward slope. Water is being taken in from downstream and sewage is pumped out to upstream, contrary to all existing universal norms. Because of the slope of the land, the untreated drainage and the sewage water from summer camps also flows freely down to the lake.

Another inherent defect was found in the duct heating system. The duct slopes away from the Maitri station downwards to the pump house. The duct heating system consists of methyl ethyl glycol (MEG): water leak from water heated mixture (60:40) being circulated in a closed loop. Any leakages in the circulation invariably has a MEG mixture leaking to the surrounding (may be into the lake also):

The main draw back is that such a highly toxic solvent like MEG should not be used under any circumstances in a circulation system which is not failure proof. The fixing of concentration of the mixture at 60:40 is also a sheer guess work as no charts of temperature vs. specific gravity for various concentrations of the MEG: water mixture are available. Hence the MEG or water may freeze as the concentration willnotbe60:40, which is supposed to be the concentration of the Anti-freeze mixture for use in the duct heating.

Since the concentration is fixed by trial and error, and because of the differential vaporization characteristics of water and MEG, the concentration of the solution continuously changes without any means to know and correct the concentration except by trial and error. This in 1994 August had lead to the breaking of the pipe, leading to leakage and water supply failure as the mixture froze in the duct circulation pipes. This was cleared forcibly by using high pressure air as well as opening the pipe line at pre-determined joints. Solidified. mixture did leak into the surroundings including lake. The frozen lake surface was mopped continuously to remove the frozen mixture to reduce contamination to the mixture extent possible. The approximate temperature on the day of the incident was -23°C to -28°C with wind speed of 35 to 45 knots.

The temperatures measured at the inlet and outlet of biodiscs B_1 and B_3 were as follows:

	Inlet	Outlet
B_1	34°C	35°C
B_3	34°C	30°C(Trace heater off)

The biodiscs are heated to maintain the temperature around 20 to 35°C. This is done because at this temperature the microorganism are active. Furthermore due to heating the density of water changes so that due to centrifugal action the heavier waste come out and accumulate on the sides.

The outlet temperatures of the biodiscs are always higher as the outlet pipe which is about 7 meter long is heated using trace heating elements to prevent freezing of water inside the pipe.

Soil

(A) Area contaminated by leakage/spillage of fuel is mainly at four locations:

(i) Fuel storage area behind Aditya complex is approximately = 200 x 400 sq. mtrs

(ii) Vehicle parking area approximately = 50 x 100 sq. mtrs

(iii) Fuel dumping area near dozer point approximately
= 150 x 150 sq. mtrs.

(iv) Various fuel tanks locations are:

a)	Aditya fuel tanks	2 x 1000 litres capacity
b)	Bhaskara fuel tanks	2 x 500 litres capacity
c)	Central fuel tanks for supplying to A block and boilers	2 x 5000 litres capacity

Approximate total area = 100 x 100 sq metres.

(B) Soil samples were collected from the area contaminated by leakage/spillage of fuel. The same could not be done at different depths as winter has already set in leading to frozen perma frost ground.

There was no flow of seepage water found from biodiscs outlet ponds to Priyadarshini lake. Hence samples were taken from water puddles before and after the road. The sediment samples were also taken from the area of water channel marks. The samples from the confluence point (Priyadarshini lake and water channels) were collected even though it may not give the correct picture due to following reasons:

a) The lean flow of water

b) Turbulence in lake due to heavy winds

c) The surface water in the lake started freezing.

Solid Waste

* Number of empty drums accounting approximately 1000 held
* Quantity of waste paper burned in open 50-60 kg/week
* Quantity and types of food burned, 20 kg/day consisting of cooked food waste, non-veg. food which is stale, and other un- usable food items
* Number of sealed drums of each category of solid wastes. (Food scraps, plastics, metal, glass, ash, wood etc.) 240 barrels and 1000 x 20 kgs garbage bags/year generated in 1994 and being carried back to India.
* Quantity of liquid wastes (photographic chemicals, unserviceable lubricants, oil etc.) earmarked for removal outside Treaty area - 200 litres/month is used for burning food items along with ATF.

Over and above, the following two chemicals are used for treating boiler feed water

a) Max-treat 3220 200 ml/3 days

b) Caustic soda 200 gms/3 days

This treatment of boiler water is to avoid formation of scales.

Stock position of various FOL (fuel, oil, lubricants) are as given below:

Type	Maximum	Minimum	Storage
ATF			
Bulk	400 kl	30 kl	Steel tanks
Barrels	200 kl	175 kl	Barrels of 200 Ltrs
LUBRICATING OIL			
15 W40	9001	2001	Brls of 501
10W 30	30001	4001	Brls of 2101
HYDRAULIC FLUID			
ATF66	20001	2001	-do-
J-26	14001	nil	-do-
GREASE			
Aeroshell avia	200 kgs	50 kgs	in 25 kg brls

Noise Measurement

Noise levels were measured in the generator complexes including the control rooms viz. Aditya and Bhaskara, Boiler room and Radio room.

The noise levels measured were as follows:

S.No.	Source	Noise level (dBA)
1.	Bhaskara	
	Generator room	102
	Control room	92
2.	Aditya	
	Generator room	102
	Control room	
	With open Doors	76
	With close Doors	62
3.	Between Aditya and Maitri	72
4.	Boiler room	78
5.	Noise due to wind with wind velocity 15-20 knots	76
6.	Radio room	65
7.	Lounge	64

Noise levels measured inside the Maitri building complex is ambiguous as the generators in block A (which is an extension of Maitri building) are not being run at present, and only Bhaskara and Aditya complexes are being used. It can be safely presumed that the noise levels in block A also being the same as that of Aditya/Bhaskara.

EIA Studies

(a) Total volume of water in Priyadarshini lake

The area of the lake as calculated from the map was 0.39 sq. km. The SOI didn't have any depth measurements of the lake. The maximum depth actually measured was 7 mtrs. Hence approximating this depth through out to an average of 3.5 mtrs (presuming the bottom of the lake to be uniform).

The total volume of the lake is approximately

$= 3.5 \times 0.39 \times 10^6$ cum

= 1365 million litres

(b) The sampling and characterization of lake bottom

No detailed data are available on depth measurements. Hence the area of sediment exposed to water cannot be calculated. However considering the maximum lake depth of 7 mtrs and 50 mtrs at the center of the lake, and using the empirical trignometrical formula the sediment are in the lake can be calculated.

Sediment area = $0.39/\cos[\tan^{-1}(7/50)]$ sq kms

= 0.39 sq kms

(c) The impact of drainage water from surface water channel

The water and sediment samples were collected from two locations for further studies. It is relevant to note here that the earlier points brought out pertaining to surface water flow.

(d) Soil samples have been collected from the proposed sites of garage for analysis

Conclusive Results/Observations

1. SPM monitoring using high volume sampler cannot be used in the present set-up. Modifications have to incorporated to increase the height of the stand.

2. The high volume sampling flow rate of air had to be scaled down or up depending on the parameters.

3. Since the burning of the wastes from toilet, boiler and emissions from helicopter, are not continuous the results may have to be vetted.

4. Fresh water control lake was changed as the designated control lake was found to be polluted by waste water/ATF leaks. Water samples from earlier designated control lake have been collected for further test.

5. Fresh water consumption was found to be approximately 3500 LPD.

6. The rate of waste water discharge is approximate for reasons already mentioned.

7. The seepage surface water flow was nil.

8. Untreated waste water from summer camp consisting kitchen, toilets, bath rooms easily seeps into the lake as they are situated within 20-30 mtrs of the lake periphery.

9. Sub-strata soil samples could not be taken due to reasons enumerated earlier.

10. The noise levels in the main building complex is found to be much higher when generators in block A are used.

11. High toxic MEG is being used for duct heating, the high probability rate of failure may leads to catastrophic results.

12. Copper pipes are being used for water distribution.

13. Fresh water is being taken from down stream and waste water is pumped out to upstream against all existing universal norms.

14. The incinerator facility at Maitri station is inadequate for the purpose for which it is designed due to the following reasons:

    a) The inlet of the incinerator is relatively small in size. The garbage which has to be burned freezes into a solid lumps at subzero temperatures prevalent in Antarctica. Afterwards these lumps cannot be broken for loading into the incinerator. Moreover the capacity of the incinerator is not commensurate with the garbage generated daily, Another significant point is during blizzard days there is no garbage burning carried out as the incinerators are located in the open. The accumulated garbage is too difficult to bum during subsequent days. The frozen lumps also require higher temperatures for a longer duration to burn it completely.

b) The incinerator temperature was not adequate to burn non- vegetarian wastes like fish, meat, bones etc.

15. Empty barrels in huge quantities are lying in and around Maitri station.
16. Maximum unserviceable stores are also lying in and around Maitri.
17. Construction materials over and above required levels are also lying around Maitri station.
18. The approximate volume of the Boiler room is 120 cum. (10 x 4 x 3 mtrs).

    Approximate consumption of MEG in 1994 was 800 litres. Hence the average consumption per week works out to be approximately 16 litres.

    As reported in literature the permitted occupation exposure standard is 100 mg of particulate matter NLD/cum, (long term), 60 mg of vapour/cum (long term), and 125 mg/cum (short term).

Here since the MEG mixture is heated for circulation and it is a closed loop the complete losses are only due to vaporization.

Hence the maximum permitted EG vapour in boiler room is approximately 120 x 60 mg (long term) = 7.2 kg

Presuming that the long term period is one week even then the MEG vapour content in boiler room is atleast more than double the permitted safe levels.

Hence this is a great health hazard to the operators who are permanently in the boiler room. (There is no ventilation in Maitri station due to its peculiar construction).

19. Many chemicals like acids, alkalis etc. are being brought every year in the station. The used chemicals are being thrown without any treatment or dilution. This may create harmful effect in the surrounding.

Additional Observations

1. Fire fighting systems in Maitri uses the HALON extinguishers
2. Transmitters, 2 x 5kW and 1 x 1kW are stationed inside the residential complex creating radiation health hazard
3. Additional information as given below have been obtained:

   * Number of generators running are two at a time out of 10 x 62.5 kva generators

* Fuel consumption by generator (monthly). 10 x 24 x 30 litres which is approx. 7500 lpm per generator. For two generators = 15 kl/month
* Hours helicopters run = 342 hrs
* Fuel consumption by helicopters = 62 kl
* Hours of run of each type of vehicle:

S.No.	Type	Nos.	Hours Run	Fuel Consumed
1.	Skidu scooter	3	nil	nil
2.	PB170	4	750 each	15 lph
3.	PB270	4	750 each	20 lph
4.	Dozer D40	1	300	20 lph
5.	Dozer D14	1	50	15 lph
6.	Liebher crane	1	200	20 lph
7.	Snow cat	2	100 each	10 lph
8.	APC Topaz	1	10	40 lph

* Consumption of fuel of vehicles (monthly). As above
* Number of hours pump ran for water intake from lake (monthly). 2 1/2 x 30 = 75 hrs
* Volume of water pumped per hour. 3500/21/2 = 1500 lph
* Number of boilers run, one out of four based on requirement. If temperature of circulation water goes down below preset values as given below:

Time of day	Clear Sky (°C)		Overcast Sky (°C)	
	Min	Max	Min	Max
Day	20	30	25	35
Night	25	35	30	40
Burner	on	off	on	off

* Fuel consumption by boilers (monthly) 10 kl
* Chemicals and quantity used in boilers

  (i) Caustic soda = 200 gm/3 days

  (ii) Max Treat 3220 = 200 ml/3 days
* Dates of pumping out of waste water from two ponds.

  "As is required basis" varies between once in ten days to once in a month.

* Quantity of waste water pumped out on each day (based on time and efficiency of pump used).

  The pump has got variable discharge between 60 - 1000 LPM as already brought out.

* Stock of different fuels and their containers.

* Informations towards spillage/leakage of fuel.NORMAL.

4. Highly toxic MEG (toxicity 2 fl oz.) is being used which can lead to catastrophic failures.
5. The refrigerators/deep freezers are using freon refrigerant, which is banned. Some of the freezers were non-functional due to gas leak (7 Nos.).
6. Lot of plastic containers for campacola etc. are found in Maitri. This may lead to inadvertent burning.
7. Bison fire proof panels of compressed asbestos is being used widely in Maitri. These are being used in toilets, living accommodation, generator container walls etc. As per existing data medically it has been proved that asbestos is highly detrimental to health and is a cause for various diseases of the lungs.
8. Effluents from cleanical laboratory is disposed to open space.
9. No catalysator is being used in Maitri.
10. No periodic measurement of emission gas is being done.
11. The treatment of drinking water is not carried out regularly.
12. Monitoring of water quality is not in practice.
13. No EMP is available in Maitri and hence not being handed over to successive teams.
14. Training on the environmental protection is required to be given to team members before proceeding on expedition.
15. No heavy duty compactors (Hydraulic/Electric) for compacting barrels/food/tins/glass/waste are available.

Deductions/Conclusions

1. Waste water disposal is not as per required environmental protocol
2. Bulk fuel is being stored in containers which are liable for failure
3. Noise levels in most of the areas of Maitri station are much above the acceptable limits.

Type	Day time (dBA)	Night time(dBA)
Industrial	75	65
Residential	55	45

(The generator/boiler complexes are being assumed to be industrial)

4. The transmitters are emitting health hazard radiation
5. The HALON fire extinguishers are being used against the international protocol where CFC usage has been banned
6. There is no "Dispomatic (macerator)" available in Maitri eventhough it is so mentioned in the ANN. VII to general guidelines issued by DOD
7. Waste water seepage (treated/untreated) is occurring into the Priyadarshini lake
8. Open burning of wastes are being resorted to
9. Fuel tanks are not double containment type, as recommended by Swedish inspection team in its report
10. Suitable fool proof collection system for waste water from biodiscs are not available
11. The whole Maitri area does not have an environmentally ecofriendly look

Recommendations/Suggestions

1. Fresh water pump house should be relocated upstream at the earliest with adequate redundancy
2. Use of MEG should be discontinued forthwith
3. HALON fire extinguishers should be banned
4. Refrigerant gas should be changed as per international CFC protocol
5. High power radio transmitters should be shifted out of living accommodation
6. Boiler and generator room should be adequately and acoustically sealed
7. Copper pipes being used for water distribution should be replaced by
8. Waste water sump of adequate capacity with in-built heating should be catered to prevent seepage/leakage/vaporization losses to surroundings
9. Double containment tanks for fuel storage as per Swedish inspection report should be catered
10. Summer camp kitchen/toilet/bathroom should have wastewater sumps with heating facility from where these can be disposed off

11. An environmental cleaning of Maitri should be done immediately
12. Incinerators with adequate capacity, temperature and all weather type should be immediately catered for
13. All plastic containers should be immediately changed to preferably metal/cans
14. To check the efficiency of the treatment plant, raw waste water and treatment waste water should be monitored regularly
15. Asbestos paneling should be replaced with suitable fire retardent/proof panels
16. Effluents from cleanical laboratory room should be disposed off after proper treatment
17. Catalysator to be installed
18. Measurement of gases emitted from different sources should be carried out regularly
19. Drinking water should be properly treated to make it potable
20. Water quality of Priyadarshini lake should be monitored
21. EMP should be made and handed over to each successive team
22. Adequate training on environment protection should be given to all expedition members
23. Suitable compactors should be installed immediately
24. The A block generators should be shifted away at the earliest

Recommendations for Further Work/Studies

1. NEERI should ensure that the following are monitored continuously during forthcoming expeditions, till an acceptable level of environmental management has been reached:
   a) Efficiency of treatment plant should be checked by monitoring raw and treated water regularly
   b) Storage and disposal of bulk fuel should be continuously monitored to conform to Antarctic protocol
   c) Disposal of food wastes should be monitored
2. Exhaustive environmental cleaning of Maitri complex should be carried out at the earliest
3. Noise level in living/working accommodation/areas should be monitored and brought down to safe levels

4. Transmission radiation hazards to the living population to be monitored and corrective actions be taken immediately
5. Refrigerants used to be monitored and changes over to eco- friendly gases/systems
6. Monitoring of fire fighting systems to have eco-friendly systems which are equally efficient and effective
7. Use of catalysator at Maitri
8. Periodic emission measurement of gases
9. Proper forced ventilation should be available in boiler room
10. All used/un-used chemicals should be taken out of Treaty area
11. An EMP talk should be delivered to each expedition team during briefing, preferably by NEERI to create requisite awareness
12. DOD guide line Standard Operating Procedure should be modified to include the detailed EMP as well as guide lines for proper environmental protection. To be precise an environmental manager be designated for each expedition by DOD in it's EMP who will be trained/briefed in various aspects and should be held accountable for environmental management
13. Suitable organization be tasked to measure the depths of Priyadarshini lake by suitable methods. This data as required by NEERI for making EIA studies, be passed on to them at the earliest.

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Table 1: Surface Water Sampling Locations

S.No.	Sampling location
	Priyadarshini Lake
1.	Western side of the lake (100 m from the bank)
2.	Southern side of the lake (100 m from the bank)
3.	Northern side of the lake (100 m from the lake)
4.	Western side of the lake (200 m from the lake)
5.	Northern side of the lake (200 m from the lake)
6.	Centre of the lake
7.	South-East side of the lake (200 m from the lake)
8.	North-Bast side of the lake (100 m from the lake)
9.	Eastern side of the lake (100 m from the lake)
	Control Lake
10.	Control lake No. 1 (North-West side of Maitri Station)
11.	Control lake No. 2 (North-West side of Maitri Station)
12.	Control lake No. 3 (North-West side of Maitri Station)
	Glacier Lake
1.	Northern side of glacier lake towards West of Maitri Station
2.	Western side of glacier lake towards West of Maitri Station
3.	Southern side of glacier lake towards West of Maitri Station
4.	Southern side of glacier lake towards South-East of Maitri Station
5.	Eastern side of glacier lake towards South-East of Maitri Station
6.	Northern side of glacier lake towards South-East of Maitri Station

Table 2: Surface Water Quality - Priyadarshini Lake, Control Lake Physical Parameters

S. No.	Sampling location	Temperature (°C)	*p*H	Conductivity (μs/cm)	Turbidity (NTU)
1.	Western side of the lake (100 m from the bank)	6.5	6.0	22.5	1.5
2.	Southern side of the lake (100 m from the bank)	4.5	6.1	18.0	1.0
3.	Northern side of the lake (100 m from the bank)	4.5	6.1	15.0	1.5
4.	Western side of the lake (200 m from the bank)	4.5	5.9	19.5	1.0
5.	Northern side of the lake (200 m from the bank)	4.5	5.8	18.5	1.0
6.	Centre of the lake	4.5	5.9	16.5	1.0
7.	South-east side of the lake (200 m from the bank)	4.5	5.4	20.5	1.0
8.	North-east side of the lake (100 m from the bank)	4.5	6.4	19.0	1.0

Contd.

Table 2 — *Contd.*

S.No.	Sampling location	Temperature (°C)	*p*H	Conductivity (µs/cm)	Turbidity (NTU)
9.	Eastern side of the lake (100 m from the bank)	4.5	6.2	13.0	1.0
10.	Control lake No. 1 (North-west side of Maitri station)	5.5	6.4	23.0	1.0
11.	Control lake No. 2 (North-west side of Maitri station)	4.0	6.3	34.5	1.0
12.	Control lake No. 3 (North-west side of Maitri station)	5.5	6.7	33.7	1.0

Table 3: Surface Water Quality - Priyadarshini Lake, Control Lake Inorganic Parameters

S.No.	Sampling location	Alkalinity	Total hardness	Calcium hardness	Chloride	Sulphate	Sodium	Potassium
		as	$CaCO_3$	(mg/1)		(mg/1)		
1.	Western side of the lake (100 m from the bank)	5.1	12.0	4.8	2.2	4.2	ND	ND
2.	Southern side of the lake (100 m from the bank)	4.7	12.0	2.4	3.3	4.2	ND	ND
3.	Northern side of the lake (100 m from the bank)	3.1	10.2	2.4	8.0	4.2	ND	ND
4.	Western side of the lake (200 m from the bank)	3.2	9.6	2.4	2.0	4.3	ND	ND
5.	Northern side of the lake (200m from the bank)	3.2	9.6	2.4	2.0	4.3	ND	ND
6.	Centre of the lake	4.9	9.6	2.4	8.0	4.9	ND	ND
7.	South-east side of the lake (200 m from the bank)	5.1	12.0	2.4	6.0	4.3	ND	ND
8.	North-east side of the lake (100 m from the bank)	4.8	12.0	2.4	6.0	4.6	ND	ND
9.	Eastern side of the lake (100 m from the bank)	5.1	9.2	2.4	8.0	4..6	ND	ND

Contd.

Table 3 — *Contd.*

S.No.	Sampling location	Alkalinity	Total hardness	Calcium hardness	Chloride	Sulphate	Sodium	Potassium
		as $CaCO_3$	(mg/l)			(mg/l)		
10.	Control lake No. 1(North-west side of Maitri station)	5.2	9.6	2.4	8.0	4.9	ND	ND
11.	Control lake No. 2(North-west side of Maitri station)	10.7	12.0	4.8	8.0	5.4	ND	ND
12.	Control lake No.3(North-west side of Maitri station)	20.6	18.4	19.2	7.2	5.8	ND	ND

ND: Not Detected

Table 4:Surface Water Quality - Priyadarshini Lake, Control Lake,Nutrient and Organic Parameters

S.No.	Sampling location	Nitrate NO_3-N	Nitrite NO_2-N	Ammonia as NH_3-N	Total phosphate	Dissolved oxygen	BOD	COD	Oil & grease	Hydrocarbon
		(mg/l)								(µg/l)
1.	Western side of the the lake (100 m from the bank)	ND	ND	ND	3.2	10.2	2.1	8.7	ND	ND
2.	Southern side of the lake (100 m from the bank)	2.7	ND	ND	3.9	10.5	2.3	4.0	ND	ND
3.	Northern side of the lake (100 m from the bank)	0.4	ND	ND	4.7	11.0	2.2	6.2	ND	ND
4.	Western side of the lake (200 m from the bank)	0.4	ND	ND	1.3	10.8	2.2	6.9	ND	ND

Contd.

Table 4 — *Contd.*

S.No.	Sampling location	Nitrate NO_3-N	Nitrite NO_2-N	Ammonia as NH_3-N	Total phosphate	Dissolved oxygen	BOD	COD	Oil & grease	Hydrocarbon
					(mg/l)					(µg/1)
5.	Northern side of the lake (200 m from the bank)	2.1	ND	ND	0.6	10.5	2.7	6.2	ND	ND
6.	Centre of the lake	1.2	ND	ND	0.8	10.9	3.9	5.3	0.8	0.14
7.	South-east side of the lake (200 m from the bank)	0.2	ND	ND	1.7	13.5	3.0	5.8	ND	ND
8.	North-east side of the lake (100m from the bank)	0.2	ND	ND	2.9	13.5	3.0	7.0	ND	ND
9.	Eastern side of the lake (100m from the bank)	1.4	ND	ND	4.2	10.7	1.4	4.0	ND	ND
10.	Control lake No. 1 (North-west side of Maitri station)	1.4	ND	ND	4.0	9.5	1.0	6.2	ND	ND
11.	Control lake No.2(North-west side of Maitri station)	1.4	ND	ND	0.5	9.4	1.6	2.8	ND	ND
12.	Control lake No.3(North-west side of Maitri station)	0.6	ND	ND	4.3	9.9	2.7	10.0	ND	ND

ND: Not Detected
BOD: Biochemical Oxygen Demand
COD: Chemical Oxygen Demand

Table 5: Surface Water Quality - Priyadarshini Lake, Control Lake Heavy Metals

S.No.	Sampling location	Cadmium	Copper	Chromium	Lead	Iron	Zinc
				(mg/l)			
1.	Western side of the lake (100 m from the bank)	ND	ND	ND	ND	0.07	0.04
2.	Southern side of the lake (100 m from the bank)	ND	ND	ND	ND	ND	ND
3.	Northern side of the lake (100 m from the bank)	ND	ND	ND	ND	ND	ND
4.	Western side of the lake (200 m from the bank)	ND	ND	ND	ND	ND	ND
5.	Northern side of the lake (200 m from the bank)	ND	ND	ND	ND	ND	ND
6.	Centre of the lake	ND	0.01	ND	ND	ND	ND
7.	South-east side of the lake (200 m from the bank)	ND	0.01	ND	ND	ND	ND
8.	North-east side of the lake (100 m from the bank)	ND	0.01	ND	ND	ND	ND
9.	Eastern side of the lake (100 m from the bank)	ND	ND	ND	ND	ND	ND
10.	Control lake No. 1 (North-west side of Maitri station)	ND	ND	ND	ND	ND	ND
11.	Control lake No.2(North-west side of Maitri station)	ND	ND	ND	ND	ND	ND
12.	Control lake, No. 3(North-west side of Maitri station)	ND	ND	ND	ND	ND	ND

ND: Not Detected

Table 6: Surface Water Quality - Glacier Lake Physical Parameters

S.No.	Sampling location	Temperature (°C)	*p*H	Conductivity (µs/cm)	Turbidity (NTU)
1.	Northern side of Glacier lake towards west of Maitri station	3.0	6.2	15.0	16.0
2.	Western side of Glacier lake towards west of Maitri station	3.0	6.0	17.0	4.0
3.	Southern side of Glacier lake towards west of Maitri station	3.0	6.0	14.5	3.0
4.	Western side of Glacier lake towards south-east of Maitri station	0.5	5.9	17.0	4.0

Contd.

Table 6 — *Contd.*

S.No.	Sampling location	Temperature	*p*H	Conductivity	Turbidity
		(°C)	(µs/cm)		(NTU)
5.	Eastern side of Glacier lake towards south-east of Maitri station	1.0	5.9	15.0	6.5
6.	Northern side of Glacier lake towards south-east of Maitri station	1.0	5.8	14.0	7.5

Table 7: Surface Water Quality - Glacier Lake Inorganic Parameters

S.No.	Sampling location	Alkalinity	Total hardness	Calcium hardness	Chloride	Sulphate	Sodium	Potassium
		as	$CaCO_3$	(mg/l)		(mg/l)		
1.	Nothern side of Glacier lake towards west of Maitri station	9.0	12.0	2.4	8	2.4	ND	ND
2.	Western side of Glacier lake towards west of Maitri station	6.4	12.0	2.4	6	4.7	ND	ND
3.	Southern side of Glacier lake towards west of Maitri station	6.4	9.6	2.4	10	4.7	ND	ND
4.	West of Glacier lake towards south-east of Maitri station	6.4	9.6	2.4	6	4.7	ND	ND
5.	East of Glacier lake towards south-east of Maitri station	6.4	12.0	2.4	6	4.7	ND	ND
6.	North of Glacier lake towards south-east of Maitri station	6.5	7.2	2.4	8	4.7	ND	ND

ND : Not Detected

Table 8: Surface Water Quality - Glacier Lake Nutrient and Organic Parameters

S.No.	Sampling location	Nitrate NO_3-N	Nitrite NO_2-N	Ammonia as NH_3-N	Total phosphate	Dissolved oxygen	BOD	COD	Oil & grease	Hydro carbon
		(mg/l)								(µg/l)
1.	Northern side of Glacier lake towards west of Maitri station	0.5	0.010	ND	1.2	8.5	ND	2.0	4.8	0.01
2.	Western side of Glacier lake towards west of Maitri station	ND	0.003	ND	1.1	8.1	ND	3.6	6.2	ND
3.	Southern side of Glacier lake towards west of Maitri station	0.5	ND	ND	1.3	8.7	ND	1.1	3.6	0.09
4.	West of Glacier of Glacier lake towards west of Maitri station	0.9	ND	ND	4.7	12.5	6.5	1.5	4.6	ND
5.	East of Glacier of Glacier lake towards west of Maitri station	0.2	ND	ND	0.8	10.8	4.1	4.8	4.4.	ND
6.	North of Glacier of Glacier lake towards west of Maitri station	ND	0.003	ND	3.1	13.1	ND	2.3	8.8	ND

ND::Not Detected
BOD: Biochemical Oxygen Demand
COD: Chemical Oxygen Demand

Table 9: Surface Water Quality - Glacier Lake Heavy Metals

S.No.	Sampling location	Cadmium	Copper	Chromium (me/1)	Lead	Iron	Zinc
1.	Northern side of Glacier lake towards west of Maitri station	ND	0.01	ND	ND	ND	ND
2.	Western side of Glacier lake towards west of Maitri station	ND	ND	ND	ND	ND	ND
3.	Southern side of Glacier lake towards west of Maitri station	ND	ND	ND	ND	ND	ND
4.	West of Glacier lake towards south-east of Maitri station	ND	0.01	ND	ND	0.03	0.09
5.	East of Glacier lake towards south-east of Maitri station	ND	0.01	ND	ND	0.06	0.11
6.	North of Glacier lake towards south-east of Maitri station	ND	0.01	ND	ND	0.03	0.02

ND: Not Detected

Table 10: Physico-chemical Characteristics of Surface Water

S.No	Sampling location	*pH*	Conducitivity (US/cm)	Alkalinity (mg/l)	Turbidity tNTU)	Total hardnes: (mg/1)	Calcium hardness	Sodium	Potassium (mg/1)	Nitrate	Nitrite	Ammonia
1.	Seepage water before road	7.8	640	53.4	2.5	69.6	38.4	52	4	3.5	0.017	3.0
2.	Seepage water after road	7.8	385	53.6	2.5	52.8	12.0	21	2	0.4	0.004	ND
3.	Control lake selected earlier	6.7	16	4.0	5.5	9.6	2.4	ND	ND	ND	ND	ND
4.	Tap water (Maitri station)	4.0	47	3.0	1.0	9.6	2.4	ND	ND	ND	ND	ND

ND: Not Detected

Table 11: Physico-chemical Characteristics of Wastewater

S.No.	Parameter	Biodisc (B_1) influent			Biodisc (B_1) effluent		
		Time t_1	Time t_2	Composite	Time t_1	Time t_2	Composite
1.	*p*H	4.4.	4.3	4.4	4.2	4.2	4.3
2.	Suspended solids (mg/1)	120	269	148	151	99	112
3.	Nitrate (mg/1)	10.2	9.4	9.3	13.0	11.6	10.6
4.	Nitrite (mg/1)	0.010	0.010	0.008	0.014	0.002	0.010
5.	Ammonia (mg/1)	2.5	2.5	2.5	2.5	2.5	2.5
6.	Biochemical oxygen demand (BOD) (mg/1)	860			444		
7.	Chemical oxygen demand (COD) (mg/1)	2586			1332		
8.	Oil & Grease (mg/1)	1.4	0.8	ND	ND	ND	ND
9.	Hydrocarbon (μg/l)	0.12	ND	ND	ND	ND	ND

ND: Not Detected

Table 12: Physico-chemical Characteristics of Wastewater

S.No.	Parameter	Biodisc (B_3) influent			Biodisc (B_3) effluent		
		Time t_1	Time t_2	Composite	Time t_1	Time t_2	Composite
1.	*p*H	7.8	7.9	7.9	7.6	7.9	7.9
2.	Suspended solids (mg/1)	68	61	53	63	46	53
3.	Nitrate (mg/1)	35.5	25.5	23.0	28.5	14.4	22.5
4.	Nitrite (mg/1)	0.04	0.01	0.01	0.06	0.03	0.03
5.	Ammonia (mg/1)	100	100	100	100	100	100
6.	Biochemical oxygen demand (BOD) (mg/1)	620	-	-	430	-	-
7.	Chemical oxygen demand (COD) (mg/1)	1832	-	-	1296	-	"
8.	Oil & Grease (mg/1)	14.2	0.8	12.8	2.0	2.0	5.2
9.	Hydrocarbon (μg/l)	1.3	1.9	3.0	1.9	2.9	1.8

Table 13: Biodisc Influent Wastewater Heavy Metals

S. No.	Sampling location	Cadmium	Copper	Chromium	Lead	Iron	Zinc
		(mg/1)					
1.	Biodisc sample collected at time t_1 B_{11}(I)	ND	0.01	ND	ND	0.02	0.01
2.	Biodisc sample collected at time t_2B_{12}(I)	ND	0.03	ND	ND	0.03	0.01
3.	Biodisc sample composite BIC (I)	ND	0.02	ND	0.01	1.40	0.23
4.	Biodisc sample collected at time t_1 B_{31}(I)	ND	0.03	ND	0.07	0.19	0.12
5.	Biodisc sample collected at time t_2B_{32}(I)	ND	0.04	ND	0.01	0.37	0.16
6.	Biodisc sample composite B_{3C}(I)	ND	0.01	ND	0.01	0.36	0.16

ND: Not Detected

Table 14: Biodisc Effluent Wastewater Heavy Metals

S.No.	Sampling location	Cadmium	Copper	Chromium	Lead	Iron	Zinc
		(mg/1)					
1.	Biodisc sample collected at time t_1 B_{11}(O)	ND	0.02	ND	0.01	5.09	0.15
2.	Biodisc sample collected at time t_2 B_{12}(O)	ND	0.07	ND	0.03	6.17	0.30
3.	Biodisc sample composite BIC (O)	ND	0.03	ND	0.01	0.06	0.01
4.	Biodisc sample collected at time t_1 B_{31}(O)	ND	0.03	ND	0.01	0.39	0.13
5.	Biodisc sample collected at time t_2 B_{32}(O)	ND	0.18	ND	ND	0.01	ND
6.	Biodisc sample composite B_{3C}(I)	ND	0.05	ND	0.02	0.24	0.12

ND: Not Detected

Table 15: Physical Properties of Soil

S-No	Sampling location	Particle size distribution %				Soil textural class	Water holding capacity (%)
		Coarse	Silt	Clay	Fine sand		
1.	Near oil tank	67.32	4.36	4.32	22.27	Sandy	24
2.	Near fuel tank	78.42	7.89	5.80	6.47	Loamy sand	26
3.	Opposite of fuel tank	69.16	14.92	6.32	8.45	Sandy	46
4.	Along wastewater seepage channel-1	68.92	5.63	5.00	19.19	Sandy	54
5.	Along wastewater seepage channels	73.52	4.65	4.40	17.43	Sandy	42
6.	Along roadside near wastewater seepage channel	74.18	8.72	6.20	9.89	Loamy sand	32

Table 16: Chemical Properties of Soil

S.No.	Sampling location	*p*H	Available nitrogen	Total nitrogen	Cation exchange capacity	Exchangeable cations				Percent organic matter
						Ca^{++}	Mg^{++}	Na^{++}	K^{+}	
1.	Near oil tank	6.6	4.04	5.68	20.37	10.1	4.7	3.6	1.1	5.60
2.	Near fuel tank	8.1	1.17	2.83	19.21	9.8	6.6	1.7	0.6	5.09
3.	Opposite of fuel tank	7.6	2.01	3.45	22.26	9.8	6.1	4.4	1.1	10.38
4.	Along wastewater seepage channel-1	8.3	2.18	3.47	34.55	16.9	10.3	4.1	1.1	3.92
5.	Along wastewater seepage channel-2	8.4	2.85	4.14	25.22	11.8	6.8	2.8	0.6	2.80
6.	Along roadside near wastewater seepage channel	7.9	1.51	2.98	27.21	12.3	7.0	3.9	2.8	3.36

Table 17: Soil Analysis - Oil and Grease and Hydrocarbons

S.No.	Sampling location	Oil and Grease (mg/g)	Hydrocarbons (μg/g)
1.	Near oil tank	6.01	1.62
2.	Near fuel tank	9.97	1.35
3.	Opposite of fuel tank	66.22	23.12
4.	Along wastewater seepage channel-1	4.61	0.55
5.	Along wastewater seepage channel-2	1.76	0.06
6.	Along roadside near wastewater seepage channel	1.14	0.04

Table 18: Chemical Characteristics of Sediments

S.No	Sampling location	Total carbon	Total nitrogen	Total sulphur
		Percentage (Air dry basis)		
1.	Waste water pond (B_3)	4.54	1.05	**ND**
2.	Priyadarshini lake inlet (Opposite of summer camp bathroom)	8.64	2.25	**ND**
3.	Sediment before mixing	3.16	2.05	**ND**
4.	Pump house	1.83	2.35	**ND**
5.	Priyadarshini lake (Opposite of summer camp urinal)	1.43	2.49	**ND**
6.	Seapage channel after road	2.98	2.69	**ND**
7.	Seapage channel before road	4.16	3.23	**ND**
8.	Waste water pond (B_1)	2.47	3.05	**ND**
9.	Confluence point	4.37	2.90	**ND**
10.	Priyadarshini lake (South-east of Maitri station)	2.82	2.84	**ND**
11.	Percolation pond	6.27	3.30	**ND**

ND: Not Detected

Table 19: Sediments Analysis - Oil & Grease and Hydrocarbons

S.No.	Sampling location	Oil & Grease (mg/g)	Hydrocarbons (µg/g)
1.	Waste water pond (B_3)	1.70	0.18
2.	Priyadarshini lake inlet (Opposite of summer camp bathroom)	1.56	0.14
3.	Sediment before mixing	1.63	0.25
4.	Pump house	0.71	0.18
5.	Priyadarshini lake (Opposite of summer camp urinal)	1.02	0.16
6.	Seepage channel after road	4.02	0.55
7.	Seepage channel before road	1.07	0.19
8.	Waste water pond (B_1)	1.03	0.07
9.	Confluence point (Lake and channel)	1.43	0.22
10.	Priyadarshini lake (South-east of Maitri station)	0.49	0.16
11.	Percolation pond	1.19	0.06

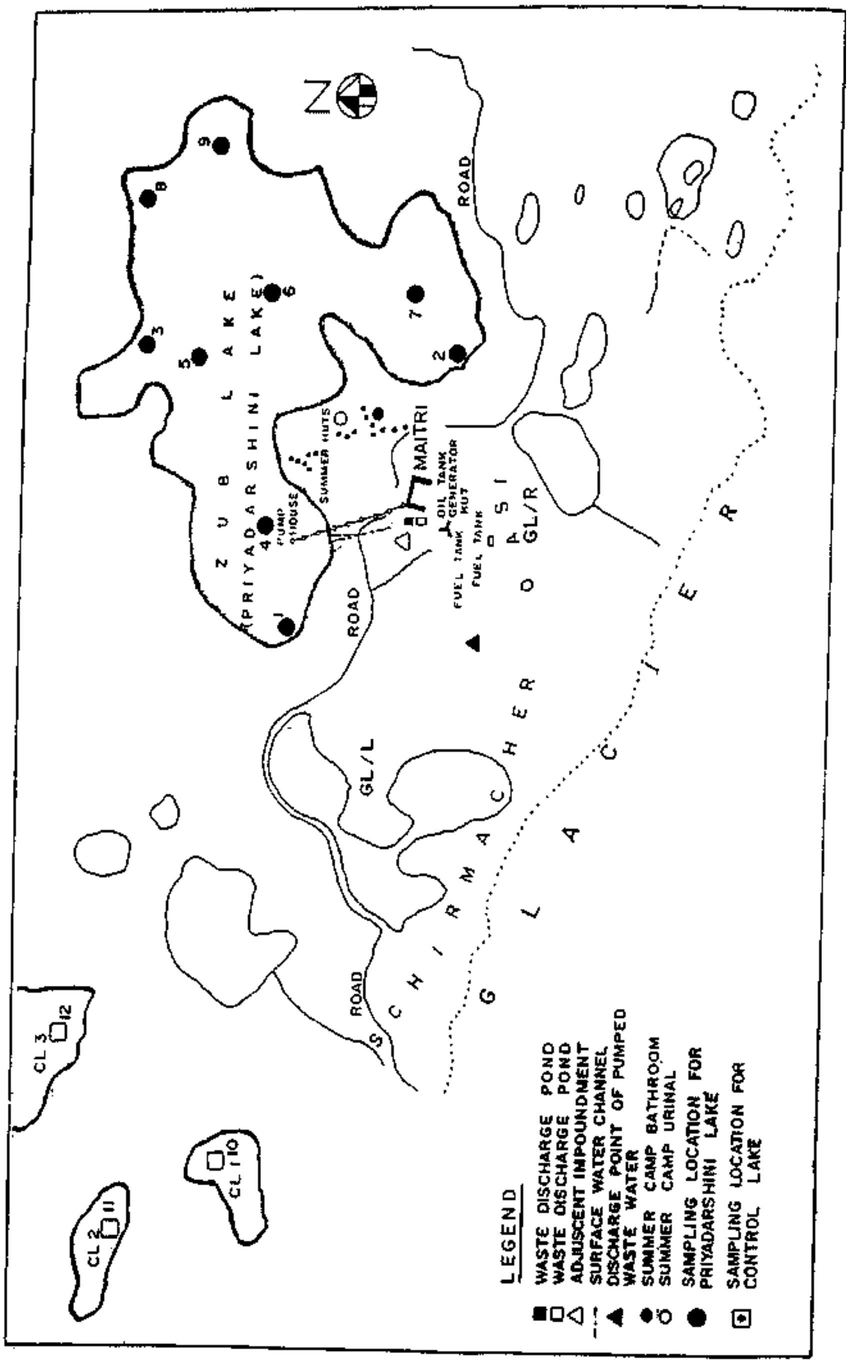

Fig.1.Locations Selected for Water Quality Monitoring (Priyadarshni lake, Control Lake)

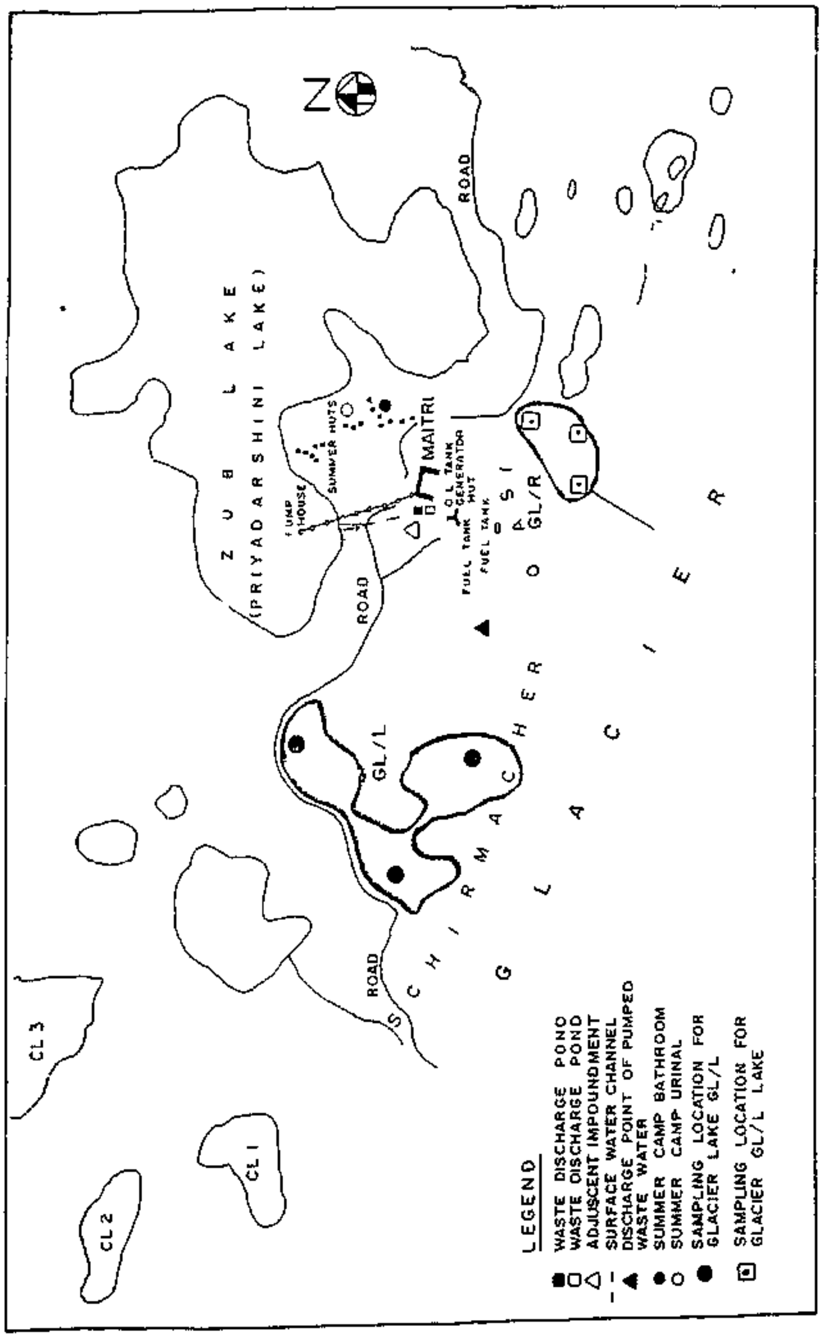

Fig 2 Locations Selected for Water Quality — Glacier Lake

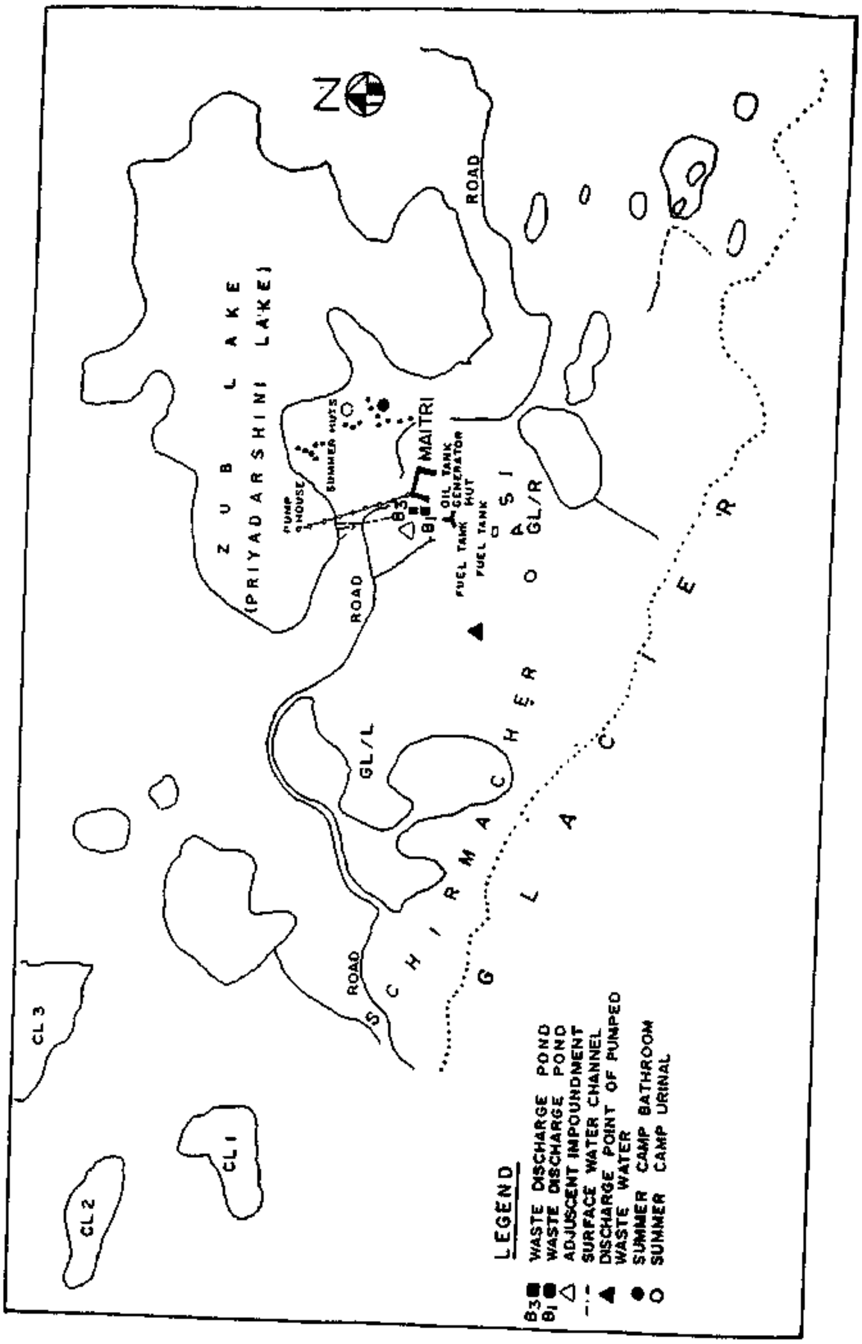

Fig 3: Locations Selected for Wastewater Characteristics

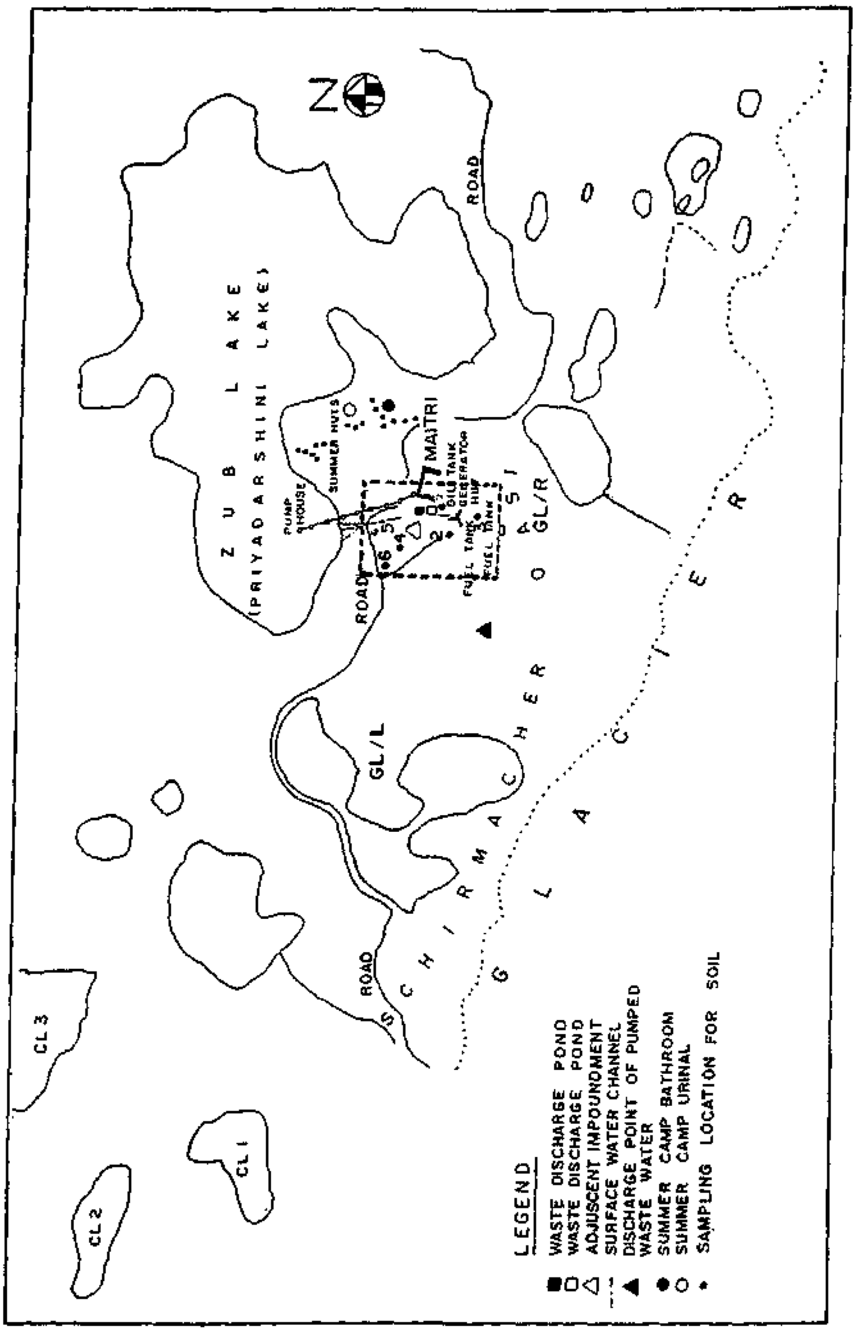

Fig.4: Locations Selected for Soil Quality

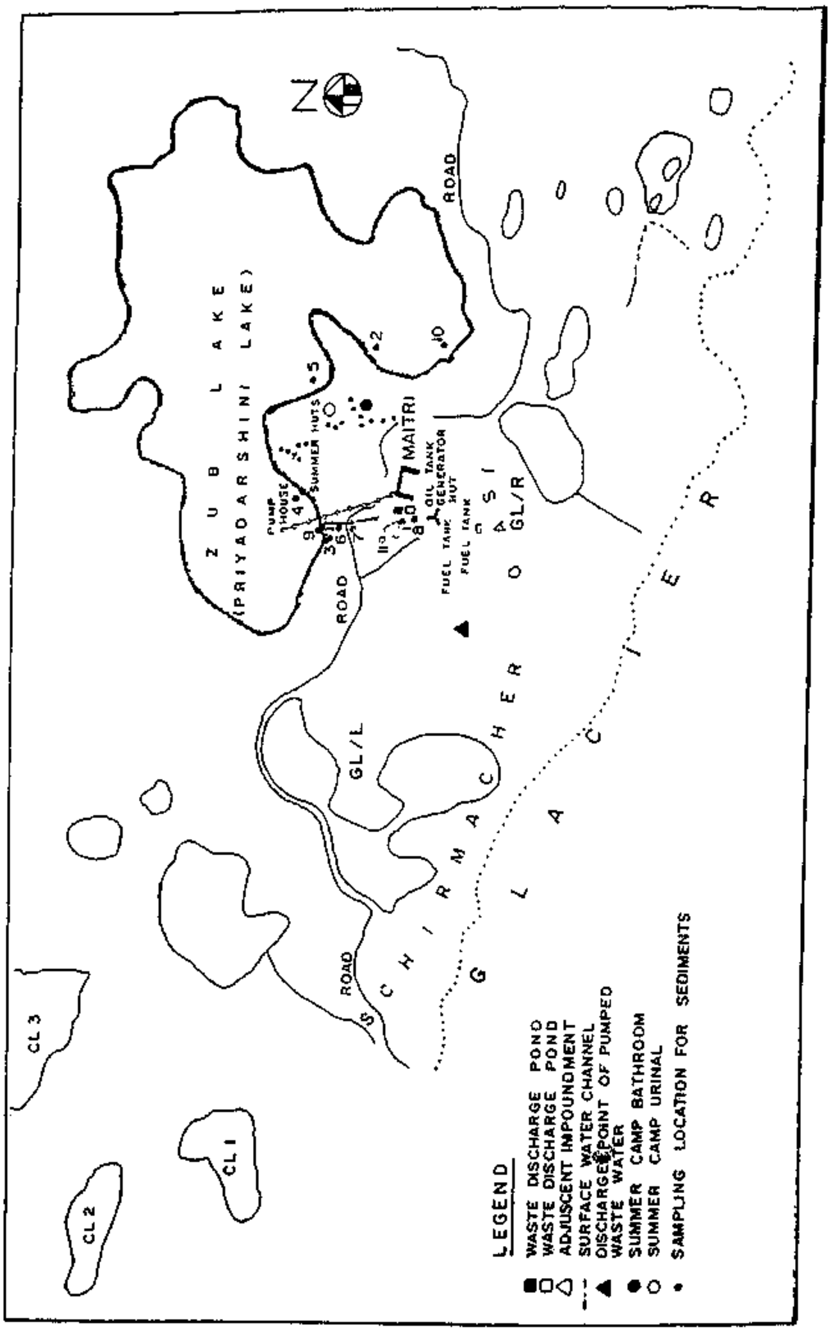

Fig. 5: Locations Selected for Sediment Quality