Medical College and Hospital Project of Sri Lakshmiammal Education Trust at Agram, Pondicherry

# Environmental Impact Assessment and Management


Changi Constructions & Consultants

Environmental Management Division

Zenith T&S Mill, Husaini Lakda Bazar (Opp Alexandra Cinema)

Bellasis Rd; Mumbai 400 008

Phone: (022)3071527, Fax 8501206, changi_cc@yahoo.com

# Senior professionals associated with this report

## Group leader

Prof S. Basu, BChE, PhD
Professor Emeritus
Formerly professor at IIT Mumbai 1968-96
Professor Emeritus (AICTE) at Jadavpur University 1997-2002

## Team leaders

Ms A. Naseema, MS, PhD (USA)

Ms A. Tasneem, BTech, MS (UK)

Ms. A. Tarannum, BTech,

## Visiting consultant

Prof. F. I. Khan, MTech (IITR), PhD
Associate Professor,
The Memorial University of Newfoundland
Canada

# Contents

# List of Figures

# List of tables

# 1
# EXECUTIVE SUMMARY

The report presents an assessment of the water, air, and land environment at and around the site for a new hospital-cum-medical college proposed at Ulvaikkal Revenue Village, Agram, Pondicherry (RS No.s as in Appendix 1), by M/s Sri Lakshmiammal Education Trust. A 300-bed hospital is proposed to be established in conjunction with a medical college with the student intake capacity of 150 per year. On the basis of the environmental impact assessment we have prepared an environmental management plan.

As the site for the proposed institution is just across the road from the southern bank of Oussudu lake, great attention has been given to the assessment of the present status of the lake in view of the internationally recognized ecological importance of the lake. The environmental management plan (EMP) for the proposed hospital-cum-medical college has been drawn up to ensure that no adverse impact is caused to the lake in any manner due to the new institution.

The air, water, and soil environment at and around the project site has also been studied in detail and the findings have been documented in this report. The EMP aims at managing the project in a manner that the project doesn't adversely affect any of the dimensions of its environment.

Hence, the proposed establishment will not have adverse effect on air quality and water quality.

In addition to pollution control, the report gives specific recommendations for augmenting the water needs by rooftop harvesting and pond farming. Strategies to maximize water use and prevent any harmful accumulation of wastes have been delineated.

# 2
# THE PROJECT

M/s Sri Lakshmiammal Education Trust propose to set up a medical college-cum-hospital at Agaram village on the southern bank of Oussudu lake (Appendix 1). The institution, named Sri Lakshmi Narayana Institute of Medical Science, would include a 300-bed hospital and a medical college with a proposed student intake of 150 per year.

The campus of the proposed institution would encompass 26 acres, with about a fourth – 6 acres – of it as built area (Appendix 2).

The hospital is expected to begin with 62 doctors, 160 nurses/paramedics, and 51 non-technical personnel. The college would have initial faculty strength of 46 with a supporting crew of 72. in addition, a workforce of 46 would look after watch-and-ward, garden, and other estate matters.

Thus, all-in-all, the campus would have a staff strength of 437 in its first year and student strength of 150. These figures are expected to rise to 550 and 750 respectively by the fifth year.

The Trust proposes to draw its water from four bore wells and has secured permeission to extract 76.5 $m^3$ of water per day for its needs.

The energy requirements are proposed to be met with 500 KVA electrical power, augmented by 2 diesel-based generators of 120 HP each.

# 3
# LAND ENVIRONMENT

## 3.1 LAND USE

The watershed within which the proposed college-cum-hospital is sited, is located at11°57' North and 77°45' East near Oussudu village; 10 Km west of Pondicherry (Figure 1). The study area (~81.52 Km$^{2)}$ has diverse land use and land cover patterns (Table 1, Figure 1).

At present, about 43% of the land surface is in agricultural use and 6% is covered with settlements and other forms of urban land use. The remaining 51% is a mixture of water resources, open scrub, plantations, and open land (Figure 2).

### *3.1.1 Agriculture*

The predominant land use category of the catchment is agriculture. Considering the elevation contours of 40m and 20m above mean sea level, towards North and Northeast, there is a potential risk of run-off — rich in nutrients, pesticides and sediments — contaminating the lake.

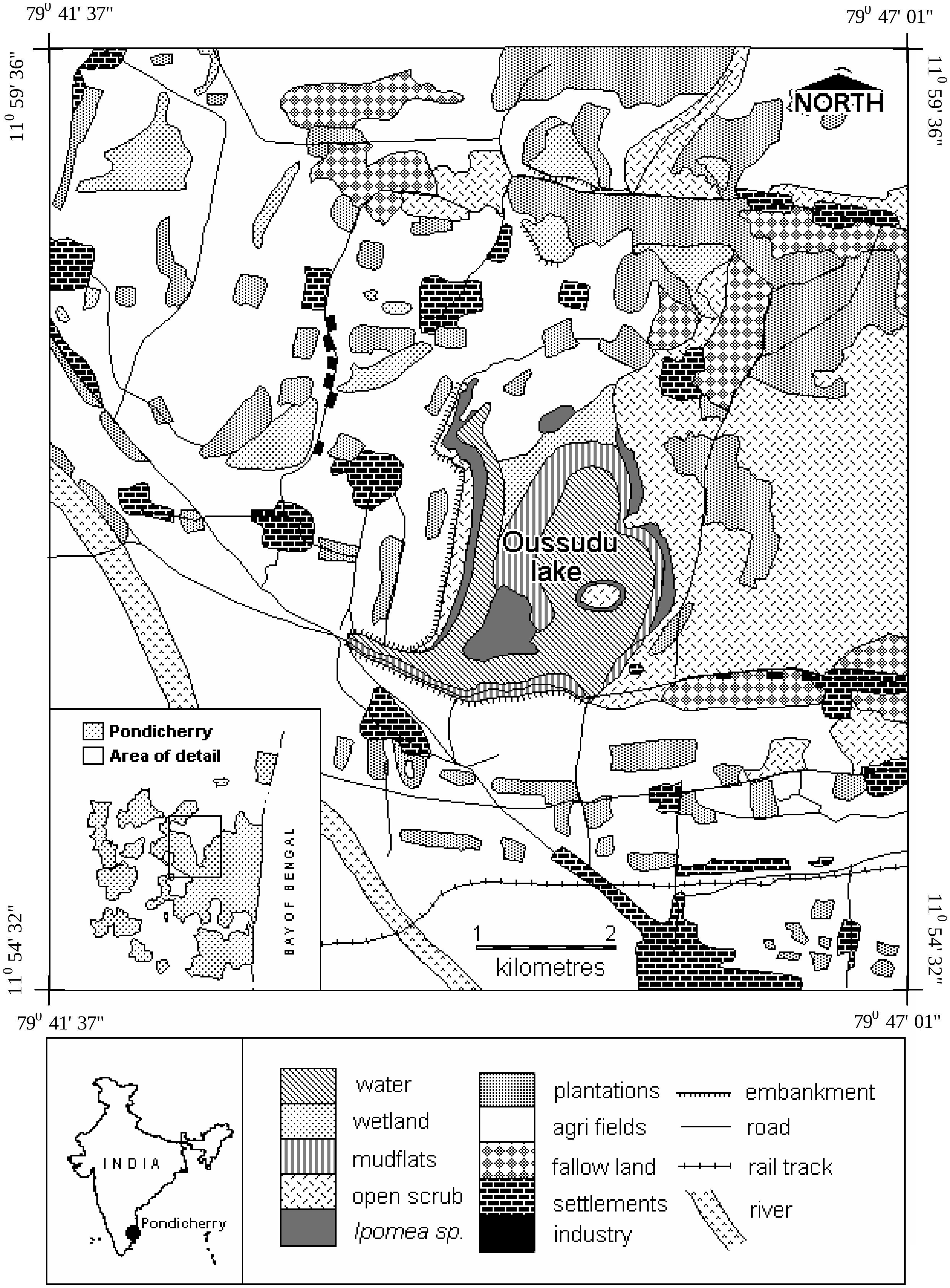



**Figure 1: Location and land use / land cover map of the watershed of the proposed project**

A few satellite ponds, found scattered around north and northwest of Oussudu lake, are extensively infested with wetland weeds and grasses. Some of the ponds near Katterikuppam and Sedarapet are used for cultivation of paddy (*Oryza sativa*) and sugarcane (*Sacharrum sp.*).

### *3.1.2 Plantations*

Plantations in the catchment area are chiefly that of *Casuarina sp.*, and *Cocus nucifera*, occupying an area of 11.92 $Km^2$ (15%).

**Table 1: Land cover and land use in the area around the proposed project**

| S.No | Category | | Watershed | Oussudu lake |
|---|---|---|---|---|
| | Level 1 | Level 2, level 3, level 4 | Area ($Km^2$) | Area ($Km^2$) |
| 1 | Water resources | Wetlands | 11.39 | 0.54 |
| | | Oussudu lake | 8.02 | |
| | | Water spread | 3.49 | 3.49 |
| 2 | Vegetation | Open scrub | 11.52 | 0.55 |
| | | Plantations | 11.92 | 0.15 |
| | | Agriculture | 34.82 | 0.33 |
| | | *Ipomea carnea* | 1.15 | 1.16 |
| 3 | Open land | - | 5.98 | 1.80 |
| 4 | Settlements | - | 4.73 | - |
| 5 | Road (Km) | - | (82.17) | - |
| 6 | Railway line (Km) | - | (5.26) | - |
| | Total (1 to 4) | | 81.52 | 8.03 |

### *3.1.3 Settlements*

The predominant settlements in the region are Villianur, Sedarapet and Katterikuppam. The rest of the settlements fall under Netapakkam, Agaram, Karasur, and Poothurai.

### *3.1.4 Industries*

There are two prominent industrial belts in the vicinity of Oussudu lake. The one lying in the Northwestern portion of the lake has a glass industry, a rubber industry and a coir industry; the other, located towards the road leading to Oussudu from Pondicherry town includes a cosmetic industry, a brewery, and a dairy. Very close (about ~500 m) to the proposed project is a plastic moulding based chair factory.

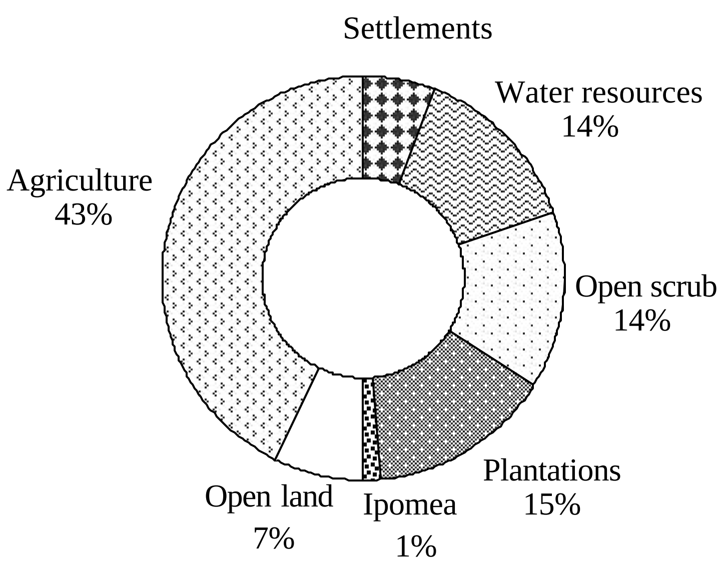



**Figure 2: Land use and land cover of Oussudu watershed**

### *3.1.5 Oussudu lake*

The medical college-cum-hospital is situated opposite the southern bank of Oussudu lake, and the impact of the project would be faced directly by the lake. Oussudu is an inter-state lake of which about 50 % of the water-spread lies in Pondicherry and the rest in Tamil Nadu (Figure 1). Oussudu plays a crucial role in recharging the ground water aquifers. It also harbours rich flora and fauna; indeed it is such an important wintering ground for migratory birds that it has been identified as one of the heritage sites by IUCN (International Union for Conservation of Nature) and has been ranked among the most important wetlands of Asia. In the recent past, Oussudu lake and its watershed have been subject to enormous pressures due to the increasing population, industrialization and urbanization.

Oussudu lake is now facing threats from many fronts: land reclamation, the practice of intensive agriculture *in-and-around* the lake, overgrazing by cattle, human interference, and poaching of birds. The lake is infested by the weed - *Ipomoea carnea* - covering about 14% of the lake area (Figure 3b). Encroachments in the form of rice paddies, land reclamation and plantations are on the increase. So are activities such as bathing and washing of clothes in the lake which can add substantial amounts of phosphate to the Oussudu water. The resulting stimulation in the growth of aquatic macrophytes and plankton, aggravating the status of eutrophication, is easy to witness. The ecologically sensitive zones such as roosting areas are in the proximity of human disturbance. Illegal fishing and poaching of birds is common. These trends if not checked soon can contribute to rapid eutrophication, siltation, and ultimate death of the lake.

The activities associated with agriculture and urban land use have brought about dramatic ecological changes affecting the quality of Oussudu watershed in terms of:

- ♦ direct destruction of natural habitat types;
- ♦ increased nutrient input to the watercourses and the lake through increased erosion, agriculture run-off and waste disposal;
- ♦ increased natural resource utilization such as gravel extraction, firewood harvest and fisheries.

These pressures have placed significant stress on the aquatic ecosystem of Oussudu. Large influxes of phosphorous generated primarily from agricultural activities and detergents remain a critical management concern. The primary productivity when compared with other lakes of India, is tending towards hyper-eutrophy.

The presence of agricultural fields around the lake have contributed copious amounts of N,P,K and pesticides through run-off. Oussudu has also witnessed the sad spectacle of industrial waste being dumped into it surreptitiously by the industries in the dead of night.

# 3.2 GEOLOGY

The landscape of this area is a product of the Cretaceous, Paleocene, Ecocene, Mio-Pliocene, of recent eras (Figure 3). The geology comprises of charnocklite overlain by a cover of sedimentary sequence. The thickness of this sub-horizontal sedimentary cover increases east to south-easterly up to 600 m near the coast. The landforms of the area are marine, fluvial and fluvio-marine regimes each sustaining individual soil assemblages.

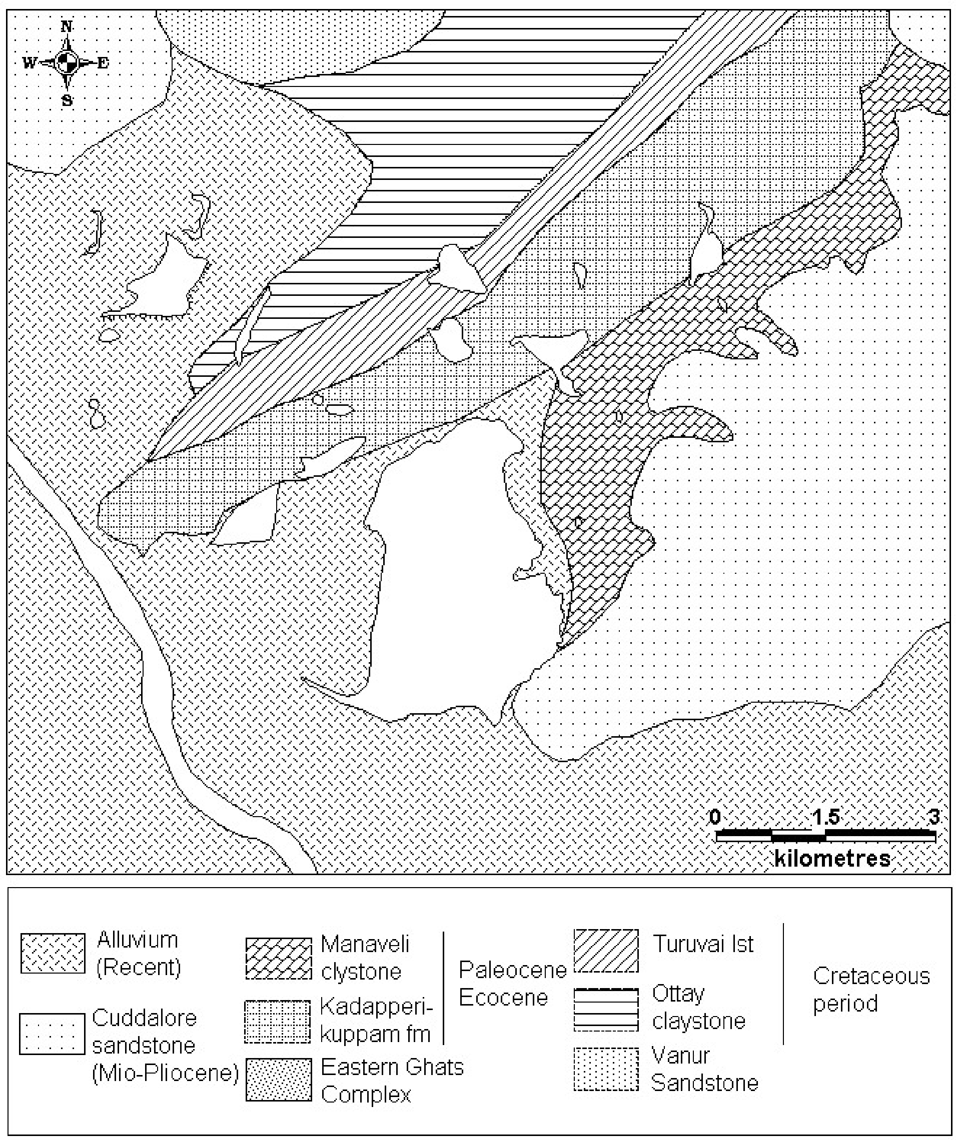



**Figure 3: Geological map of the area around the proposed project**

The Geological map (Figure 3) shows that Oussudu watershed comprises mostly of alluvium, manaveli clay stone, and vanur sand stone.

## 3.3 SOIL

### *3.3.1 Soil sampling*

Twenty eight soil samples were collected. The sites were carefully chosen to acquire a representation of the various land use and land cover patterns of the area (Figure 4).

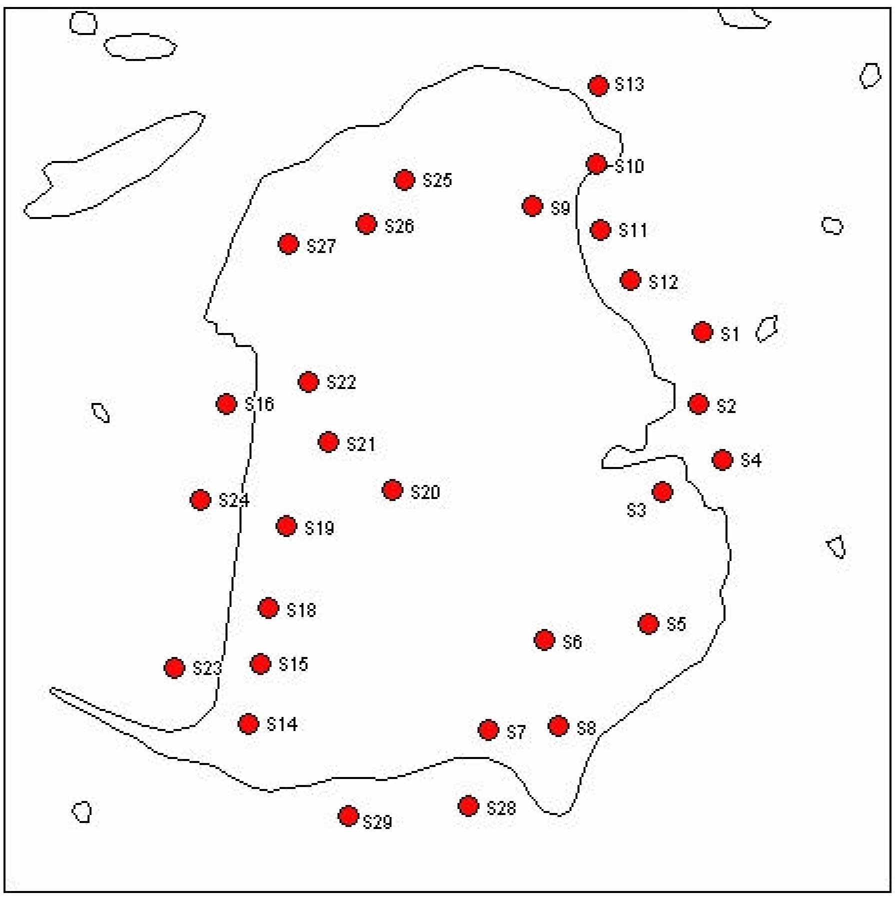



**Figure 4**: **Location of the sampling sites**

At each representative site a wooden quadrant (Plate 1), 15x15 cm, was placed randomly. The soil in the area falling under the quadrat was dug 15 cm deep. It was then excavated and homogenized. The soil chemistry was analyzed as per the procedures described by Okalebo et. al (1993).

**Plate 1: One of the soil sampling sites**

### *3.3.2 Soil quality*

The spatial distribution of the pH and EC of the soil has been presented as Figure 5.

Most of the soil samples belonged to class 1 and class 2, posing very low to moderate salinity hazard (Table 2, Figure 5).

Nearly 53% of the soil samples were moderately alkaline and 35% were mildly alkaline (Table 3, Figure 2). Alkalinity of the soils in this range indicates the presence of free $CaCO_3$ and may influence the availability of plant nutrients. These soils are known to increase the relative abundance of potassium and nitrogen, and restrict the mobility of phosphorous. Soils in the north-east and south-east extreme of the lake had an optimal pH range of 5.0 - 7.0, which are deemed suitable for agriculture.

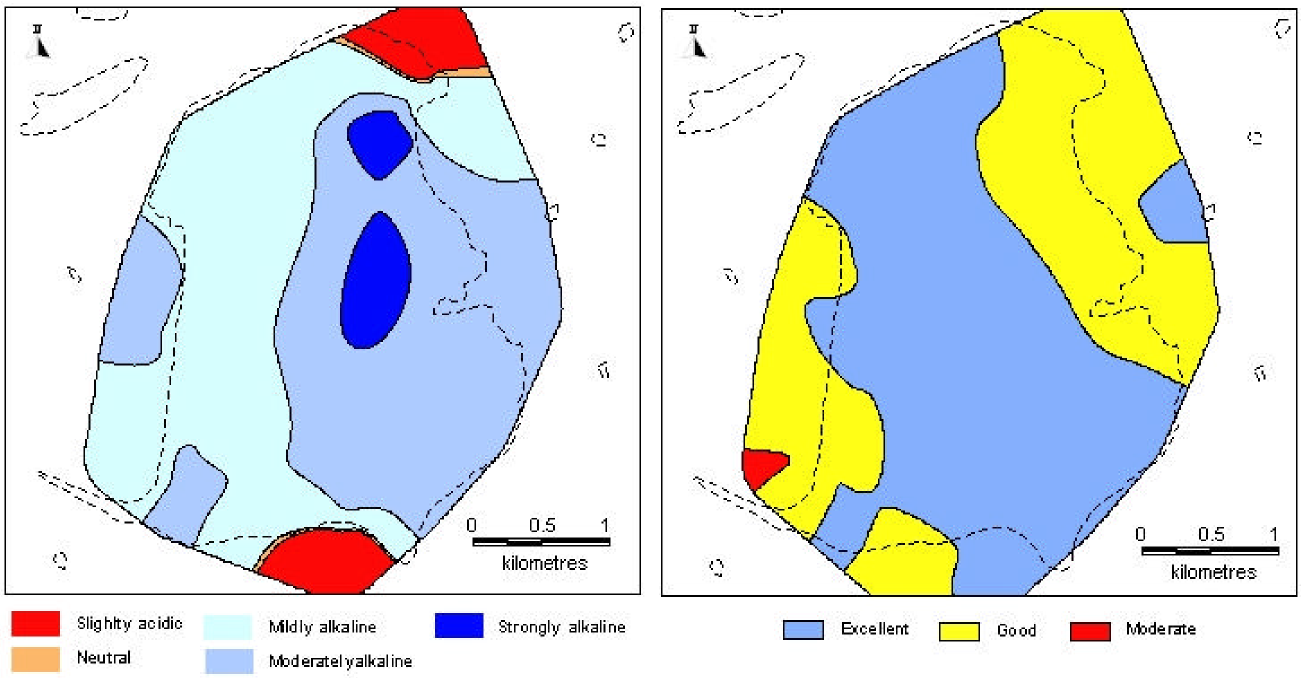



**Figure 5: The spatial distribution of soil quality: (a) pH and (b) EC**

**Table 2: Electrical conductivity of the soil samples**

| **EC (F mhos)** | **Class** @ | **Salinity hazard** | **Soil samples** |
|---|---|---|---|
| < 250 | Excellent (Class 1) | Low | S1, S5, S6, S7, S8, S14, S17, S19, S20, S21, S22, S25, S26, S27, S28 |
| 250 - 750 | Good (Class 2) | Moderate | S2, S3, S4, S9, S10, S11, S12, S13, S15, S16, S18, S24, S29 |
| 750 - 2250 | Moderate (Class 3) | Medium | S23 |
| 2250 - 4000 | Unsatisfactory (Class 4) | High | Nil |

| **EC (F mhos)** | **Class** [@] | **Salinity hazard** | **Soil samples** |
|---|---|---|---|
| > 4000 | Unfit (Class 5) | Very high | Nil |

**Table 3: pH of soil samples**

| **Soil category** | **pH range** [@] | **Soil samples** |
|---|---|---|
| Very strongly alkaline | > 9.0 | Nil |
| Strongly alkaline | 8.5 – 9.0 | S9 |
| Moderately alkaline | 7.9 – 8.4 | S1, S2, S3, S4, S5, S6, S7, S8, S12, S14, S15, S16, S20, S24 |
| Mildly alkaline | 7.1 – 7.8 | S10, S17, S18, S19, S21, S22, S23, S25, S26, S27 |
| Neutral | 7.0 | Nil |
| Slightly acid | 6.1 – 6.9 | S13, S28 |
| Medium acid | 5.6 – 6.0 | Nil |
| Strongly acid | 5.1 – 5.5 | Nil |
| Very strongly acid | 4.5 – 5.0 | Nil |
| Extremely acid | < 4.5 | Nil |

# 4
# WATER ENVIRONMENT

## 4.1 INTRODUCTION

The water environment of the study area is dominated by the Ossudu lake at the bank of which is situated the proposed project site. Indeed the proposed site is a part of the catchment area of the Ossudu eri.

An extensive study of the water environment was carried out in the context of the proposed project. This includes surface water quality, groundwater quality, and aquatic weeds.

## 4.2 ASSESSMENT OF SURFACE WATER QUALITY: PROCEDURE

### *4.2.1 The monitoring strategy*

Water quality of Ousteri was assessed for (i) the diurnal, seasonal and spatial variation, and (ii) the thermal and dissolved oxygen profiles across the depth of the lake. The water quality monitoring was done for all the three seasons that occur at Pondicherry – pre-monsoon (June to

September), winter or monsoon (October to January) and summer or post-monsoon (February to May).

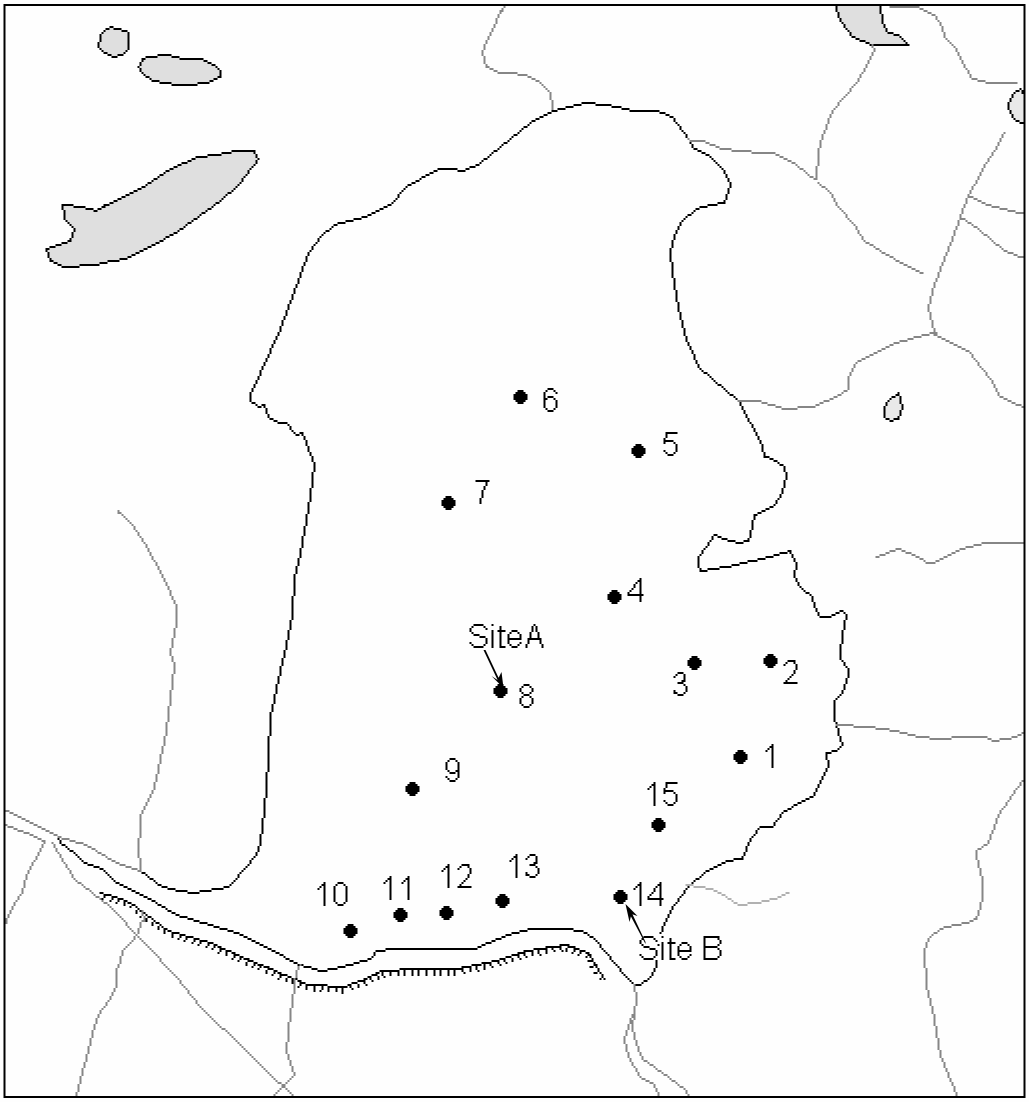



**Figure 6: Location of water quality monitoring stations in Oussudu lake. Site A (8) and Site B (14) were selected for diurnal variation of the water quality.**

Fifteen sampling sites that would represent the spatial variation of the lake were identified for the regular monitoring of the water quality (Figure 6). Based on the results of the initial surveys, two sampling sites, site A and site B, were selected for studying the diurnal variation of the water quality.

A country boat, made of wooden logs , was used for collecting the samples at various sampling sites with the help of a Van-Dorn water column sampler . The water samples from the *epilimnion* of the lake were collected 0.5 m below the surface water level of the lake; the water samples at *thermocline* were collected at the visible secchi depth; and the water samples from the *hypolimnion* of the lake were collected just above the bottom of the lake so as to avoid trapping of the sediments.

To study the diurnal variation of water quality variables, water samples were collected from the *epilimnion*, *thermocline* and *hypolimnion*, every one hour beginning from dawn (approximately 6.00 am) till dusk (approximately 6.00 pm).

All the samples were collected in plastic cans of 2 litre capacity and preserved for further analysis in a refrigerator.

For the analysis of phosphorus, a portion of the water samples were stored separately in plastic bottles coated with TFE, at 4 $^{o}$C. For the analysis of dissolved forms of phosphorus, part of the samples that were kept aside for the analysis of phosphorus were passed through 0.45 Φ membrane filters and were stored separately at 4 $^{o}$C.

For the analysis of heavy metals a small fraction of the samples, filtered through 0.45 Φ membrane filter, were acidified to < 2 pH and were stored separately.

### *4.2.2 The water quality variables studied*

Initially, a reconnoitory survey of the lake water quality was done. Nearly 25 water quality variables were studied. Based on these results, the most significant and essential water quality variables were chosen for analysis in the further surveys. For instance, agriculture being the most predominant land-use pattern in-and-around the lake, agricultural non-point source pollutants - nitrogen and phosphorus were considered for further analysis in detail. On the other hand, BOD and COD of the lake being within the permissible limits, were ignored for analyses in the further surveys. Sensitive parameters such as temperature, dissolved oxygen (DO) and electrical conductivity (EC) were analyzed *in-situ.*

The heavy metals - Cu, Cr, Cd and Zn (< 100 ppb) were analyzed by flameless AAS. In the case of Zn, where the concentrations were > 100 ppb, the samples were analyzed by flame AAS.

The analytical procedures used for the water quality analysis were as described in the APHA (1998) and Abbasi (1998). These confirm to the internationally accepted procedures, protocols, and analytical quality control.

## 4.3 ASSESSMENT OF SURFACE WATER QUALITY: FINDINGS

### *4.3.1 Diurnal variation of water quality*

Oussudu being a shallow lake, situated in the tropic, is expected to be highly sensitive to diurnal rhythm and hence, the study of diurnal variation was imperative.

The results for diurnal variation have been discussed with respect to the representative months of each season: July for pre-monsoon, January for monsoon and May for post-monsoon have been chosen as the representative months.

*a. Temperature*

| | epilimnion (range in °C) | hypolimnion (range in °C) |
|---|---|---|
| Post-monsoon | 25.0 - 30.0 | 36.5 - 32.0 |
| Pre-monsoon | 25.0 - 30.0 | 25.5 - 27.5 |
| Monsoon | 24.0 - 31.0 | 24.0 - 30.5 |

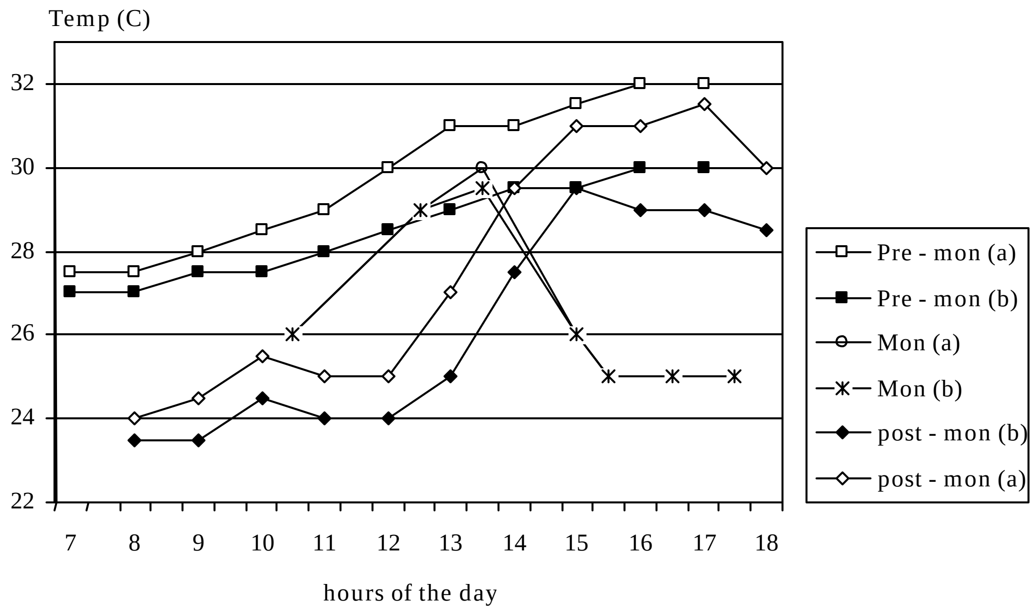



**Figure 7: Diurnal variation of water temperature (*a - epilimnion, b – hypolimnion)***

On an average, along the day, a change of ~ 5.5°C is observed in the epilimnion and ~ 4 °C in the hypolimnion of the lake.

During the monsoons, temperature of the lake rises gradually till 13 hrs of the day and then starts falling (Figure 7). Thus a change of about 5 °C was observed from dawn till dusk. As the lake is shallow, no significant difference was observed in the temperatures of epilimnion and hypolimnion.

During the post-monsoon and monsoon periods, the temperatures tend to follow a logistic pattern. The temperature gradually increases from dawn to mid-noon, then a sharp rise is observed from mid-noon till 15 hours of the day. Later, the temperatures remain more or less unchanged till evening. Thus, the maximum temperatures were observed at 15 hours. The range of fluctuation during pre-monsoon is narrower when compared to that of post-monsoon. The hypolimnion temperatures were less than the epilimnion by ~ 0.5 C.

*b. pH*

| | epilimnion (range in °C) | hypolimnion (range in °C) |
|---|---|---|
| Post-monsoon | 9.0 - 9.4 | 8.3 - 8.9 |
| Pre-monsoon | 8.8 - 9.0 | 8.8 - 9.0 |
| Monsoon | 8.4 - 9.1 | 8.3 - 8.9 |

On a typical day the pH value changes by ~ 0.4 units in the epilimnion and ~0.5 units in the hypolimnion. The change is however quite narrow and subtle. This can be attributed to the high alkaline nature of the lake which buffers the change of pH.

pH values during the pre-monson (July) were greater than monsoon (Jan), which in turn remain greater than post-monsoon (May). The pH curve along the day is convex during pre-monsoon (Figure 8) , more or less linear for monsoon and concave during post-monsoon.

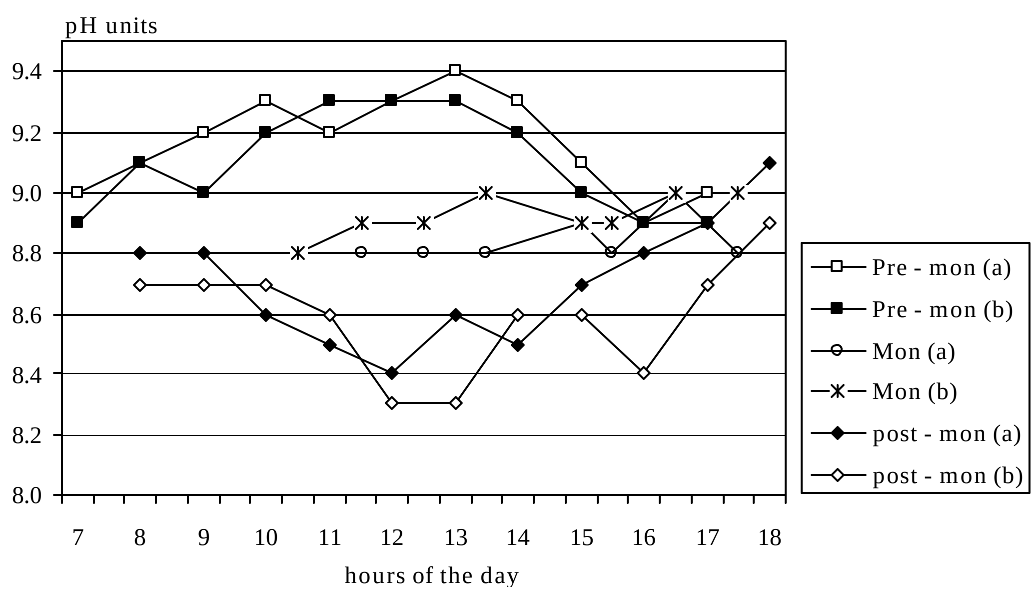



**Figure 8: Diurnal variation of pH (*a - epilimnion, b – hypolimnion)***

The pH values for hypolimnion follow a similar pattern as that of epilimnion.

*c. Electrical Conductivity (EC)*

| | epilimnion (range in *m* mhos) | Hypolimnion (range in *m* mhos) |
|---|---|---|
| Post-monsoon | 270 - 320 | 240 – 320 |
| Pre-monsoon | 200 - 230 | 200 – 230 |
| Monsoon | 220 - 280 | 210 – 270 |

The EC values during the post-monsoon and monsoon were more pronounced than the pre-monsoon. A change of about 55 *m*mhos has been observed in the epilimnion and ~ 70 *m*mhos in the case of hypolimnion. However, during pre-monsoon, the change remains very subtle with a variation of less than 30 *m*mhos.

The EC values along the day rise slowly as pH increases and reach the peak only during the late afternoons, by 14 hrs or 15 hrs (Figure 9).

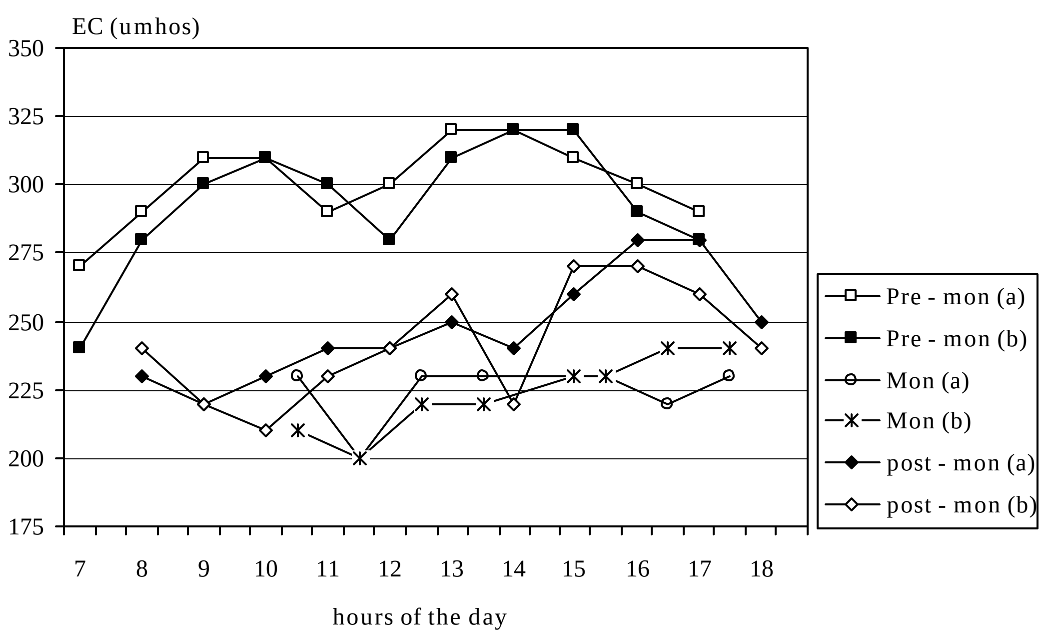



**Figure 9: Diurnal variation of EC (*a - epilimnion, b – hypolimnion)***

*d. Dissolved Oxygen (DO)*

| | epilimnion (range in ppm) | hypolimnion (range in ppm) |
|---|---|---|
| Post-monsoon | 5.3 - 7.3 | 4.6 - 6.3 |
| Pre-monsoon | 6.1 - 7.6 | 6.2 - 6.6 |
| Monsoon | 5.2 - 6.9 | 4.8 - 5.4 |

A change of about 2 ppm is observed during the post-monsoon and 0.5 ppm during the pre-monsoon in the epilimnion. The DO values tend to rise gradually as the day progress, due to the photosynthetic production of DO by the phytoplankton. The peak DO values were observed in the late-afternoon, at 13 hrs. (Figure 10). During monsoons, the variation of DO across the day is not very pronounced. The probable reason for this could be the thick cloud cover during these months. The higher cloud amount inhibits photosynthesis by the phytoplankton and macrophytes resulting in the lower diurnal variation of DO.

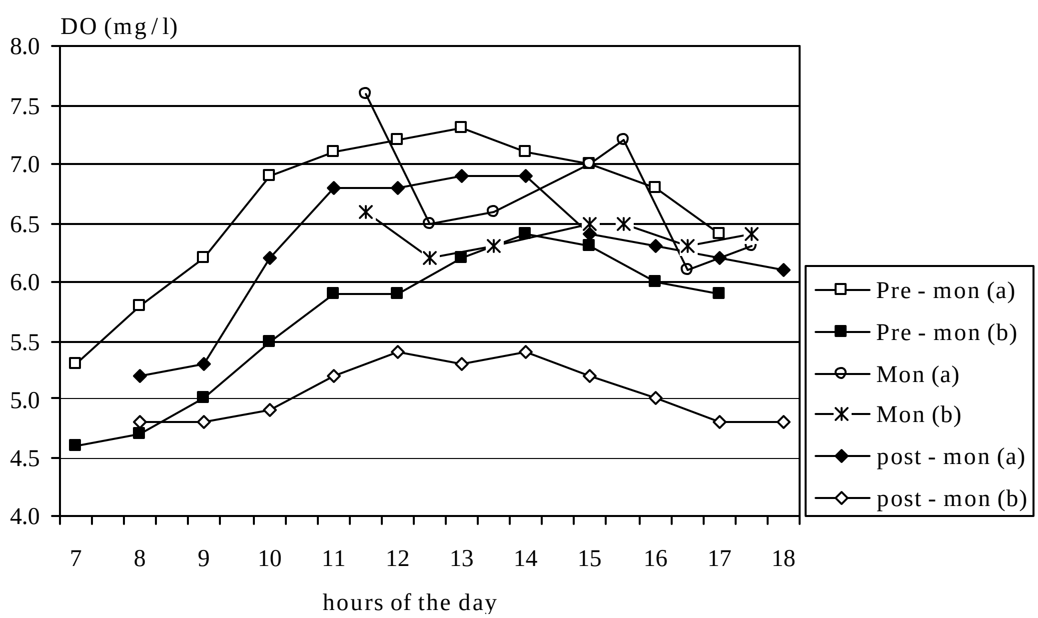



**Figure 10: Water quality of Oussudu lake – diurnal variation of DO (*a - epilimnion, b – hypolimnion)***

The DO variation in the hypolimnion is subtle, and the peak values were observed in the evenings, unlike in the case of epilimnion.

*e. Vertical Oxygen Profiles*

The vertical oxygen profiles of Oussudu lake, observed during the monsoon and post-monsoon, have been drawn as a function of time and depth of the lake (Figure 11).

The vertical oxygen profiles of Oussudu indicate slight variation of orthograde type with more or less uniform $O_2$ contents in the epilimnion and hypolimnion. Though the lake is eutrophic (the organic contents of phosphates corroborate this fact), the shallow nature of the lake and the strong wind currents mix up the lake water, resulting in weak and often no thermal stratification.

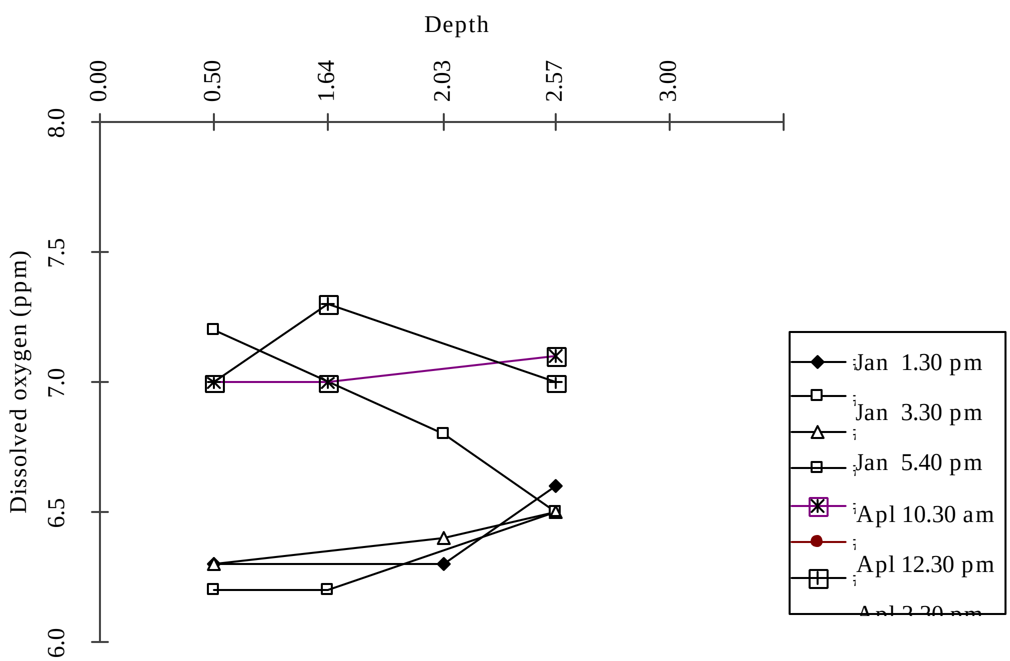



**Figure 11: Vertical profiles of dissolved oxygen**

*f. Alkalinity*

| | epilimnion (range in mg/l | hypolimnion (range in mg/l) |
|---|---|---|
| Post-monsoon | 84 - 90 | 84 - 92 |
| Pre-monsoon | 76 - 82 | 76 - 82 |
| Monsoon | 92 - 100 | 92 - 98 |

Unlike other water quality variables, the alkalinity values during pre-monsoon remain the lowest while during the monsoon it's comparatively higher. The change in alkalinity along the day was very insignificant (Figure 12).

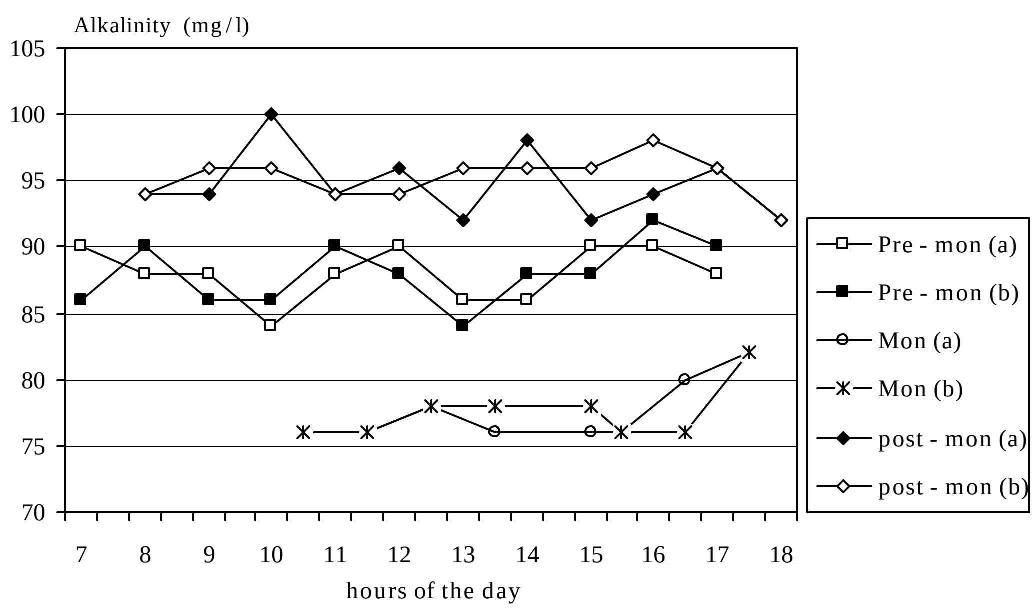



**Figure 12: Diurnal variation of alkalinity (*a - epilimnion, b – hypolimnion)***

*g. Chlorides*

During the period of post-monsoon a variation of ~ 5 mg/l was observed in the epilimnion and ~ 4 mg/l in the hypolimnion. However, the variation is quite less during monsoon and still lesser during the pre-monsoons (Figure 13). Apart from a typical '*dip*' during the deep noon no particular pattern in the diurnal variation was observed.

| | epilimnion (range in mg/l) | hypolimnion (range in mg/l) |
|---|---|---|
| Post-monsoon | 21 - 26 | 21 - 25 |
| Pre-monsoon | 10 - 14 | 11 - 12 |
| Monsoon | 16 - 18 | 14 - 17 |

The chloride values were usually higher in the epilimnion than the hypolimnion.

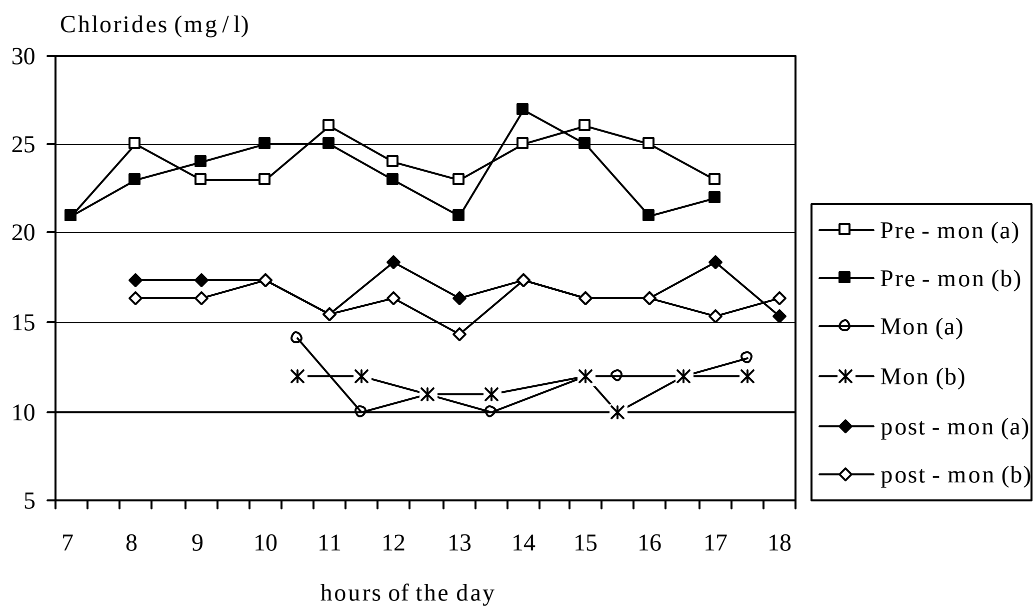



**Figure 13: Diurnal variation of chlorides (*a - epilimnion, b – hypolimnion)***

*h. Total Hardness*

A diurnal variation of 8 - 15 mg/l was observed in the epilimnion and 6 - 14 mg/l in the case of hypolimnion. The diurnal variation was more pronounced during monsoons and the least during post-monsoon (Figure 14).

| | epilimnion (range in mg/l) | hypolimnion (range in mg/l) |
|---|---|---|
| Post-monsoon | 62 - 73 | 62 - 74 |
| Pre-monsoon | 78 - 93 | 78 - 92 |
| Monsoon | 72 - 80 | 74 - 80 |

Total hardness in the hypolimnion was greater, though very marginally, than that of epilimnion. With the rest of the water quality variables, the post-monsoon total hardness values tend to correlate well with alkalinity, whereas the pre-monsoon values correlate well with that of pH.

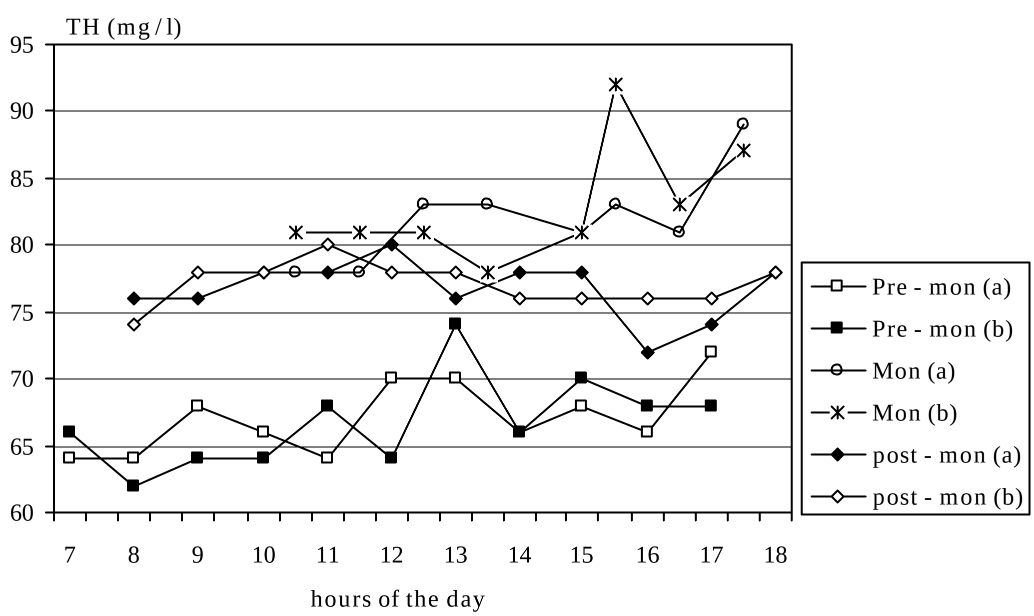



**Figure 14: Diurnal variation of TH (*a - epilimnion, b – hypolimnion)***

*i. Calcium Hardness*

The diurnal variation for calcium hardness was more pronounced during the pre-monsoon than post-monsoon and monsoon. During pre-monsoon a change of ~ 9.4 mg/l was observed in the epilimnion and ~ 10.2 mg/l in the hypolimnion (Figure 15).

| | epilimnion (range in mg/l) | hypolimnion (range in mg/l) |
|---|---|---|
| Post-monsoon | 13 - 22 | 17 - 27 |
| Pre-monsoon | 41 - 50 | 12 - 54 |
| Monsoon | 15 - 18 | 17 - 18 |

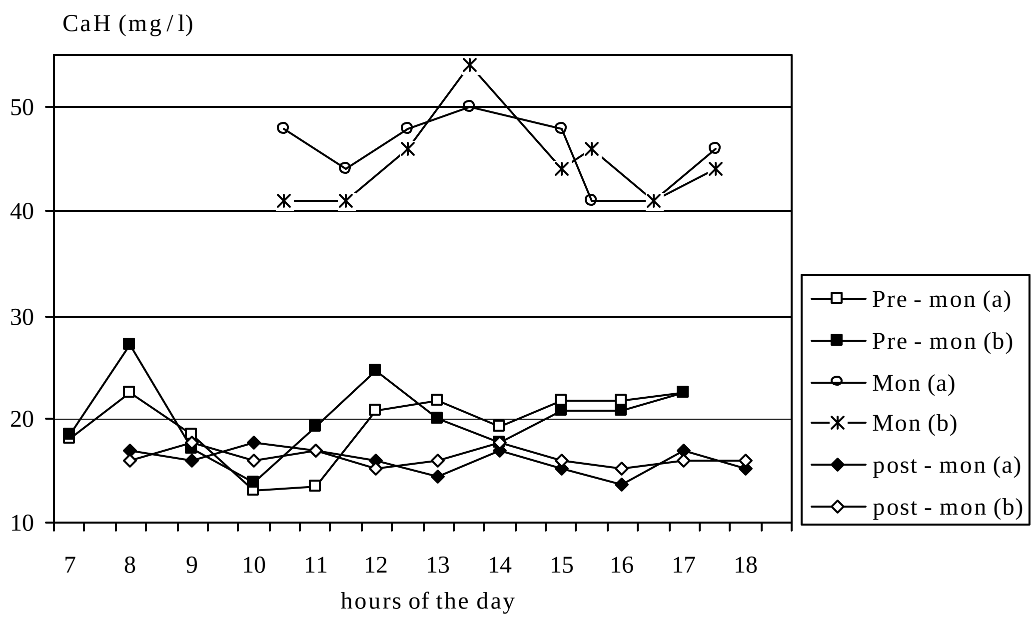



**Figure 15: Diurnal variation of calcium hardness (*a - epilimnion, b – hypolimnion)***

A difference of about 6 mg/l was observed in the value of epilimnion and ~18 mg/l in hypolimnion. The calcium hardness values correlate well with temperature during the monsoon and pre-monsoon, and with pH during the post-monsoon.

*j. Nitrogen (N)*

During the monsoon period, the levels of nitrite, nitrate and organic nitrogen in the epilimnion tend to be higher during the late evenings. Ammonical nitrogen however remains lower (Figures 16 and 17). In general, the hypolimnion has higher concentrations of all the forms of nitrogen than the epilimnion. When different species of nitrogen for a single time sampling (Jan I) were compared, the nitrites accounted for 12%, nitrates 82%, ammonical nitrogen 3%, and organic nitrogen 3% (Figure 17).

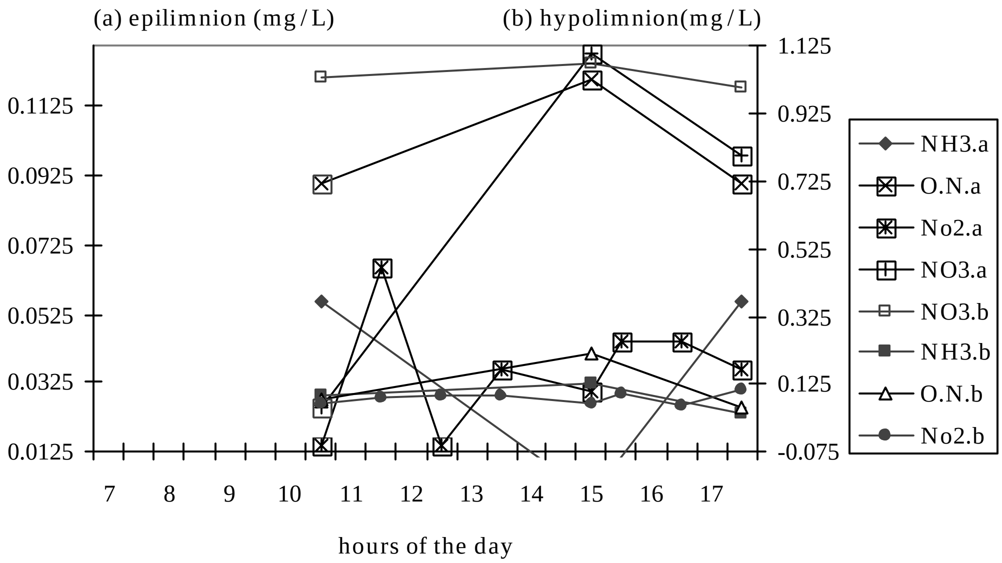



**Figure 16: Various forms of nitrogen along the day**

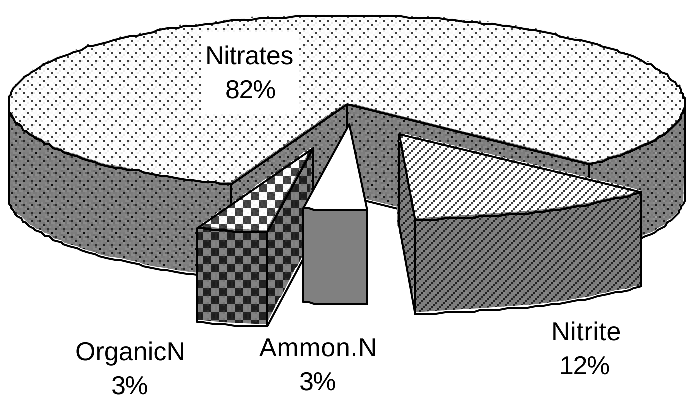



**Figure 17: Various forms of nitrogen during monsson (Jan)**

*k. Phosphorous (P)*

It was observed that monsoons have a predominant effect on the dynamics of phosphorus (P). Hence, phosphorous has been discussed in detail.

*Total Phosphorus:* The total phophorus (TP) tend to be at its peak by 12.30 hrs and later decrease. However, again a peak value of 0.02 mg/l is observed at 15.30 hours. In general, the TP concentrations remain higher during the peak noon hours. A 'flux' is observed in the TP concentrations between the epilimnion and hypolimnion. Thus, during the early morning and evening, concentration of phosphorous in the hypolimnion overtake that of the epilimnion.

A close look at the various forms of phosphorus - *reactive phosphorus* (RP), *hydrolysable phosphorus* (HP) and *organic phosphorous* (OP), reveal that most of these constituents remain stable throughout the day except the *total organic phosphorus* (TOP). It is due to the TOP, that an immense change in the diurnal variation of total phosphorous is reflected. And the source of this TOP can be attributed to the phytoplankton, zooplankton and the organic substances (Toombs, 1997). Because of the migratory movements of the plankton, a peak TP value was observed during the afternoons in the epilimnion. Later by evenings these plankton migrate to the hypolimnion (Goldman et. al., 1983) and hence the peak TP value in the hypolimnion is noticed late in the evening.

*Total Dissolved Phosphorous:* The total dissolved phosphorous (TDP) values in the epilimnion were more or less similar throughout the day. The hypolimnion values are lower than that of epilimnion during the early monsoons. As the noon progresses the values tend to override the epilimnion and fall back to the normal only by late evening.

As far as the various constituents of TDP are concerned, interestingly the *dissolved organic phosphorous* (DOP) marks the lowest of all, while the major chunk of the TDP has been accounted to the *dissolved hydrolysable phosphorous* (DHP). As a function of diurnal variation one observes a peak of DOP at 15.00 hours and DHP at 15.30 hours.

*n. Sulphates ($SO_4$)*

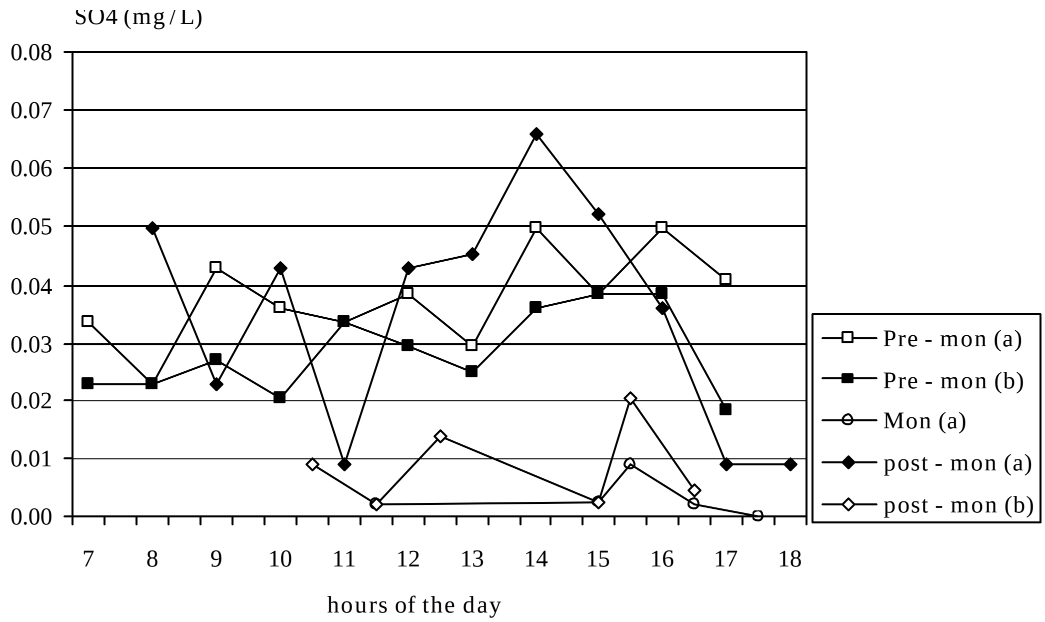



**Figure 18: Diurnal variation of sulphates (*a - epilimnion, b – hypolimnion)***

| | epilimnion (range in mg/l) | hypolimnion (range in mg/l) |
|---|---|---|
| Post-monsoon | 0.023 - 0.039 | 0.018 - 0.039 |
| Pre-monsoon | 0.002 - 0.009 | 0.002 - 0.020 |
| Monsoon | 0.009 - 0.060 | 0.018 - 0.080 |

The SO4 contents in the lake were quite insignificant and the change along the day is quite subtle and often erratic. However, during the pre-monsoon, values of SO4 follow the pattern of temperature, EC and alkalinity. The diurnal variation of SO4 is presented in the Figure 13 .

*o. Iron (Fe)*

The values of iron tend to rise by the late noon and then decrease gradually (Figure 14). A change of about 0.09 mg/l for epilimnion and ~ 0.07 mg/l for hypolimnion was observed, during the day.

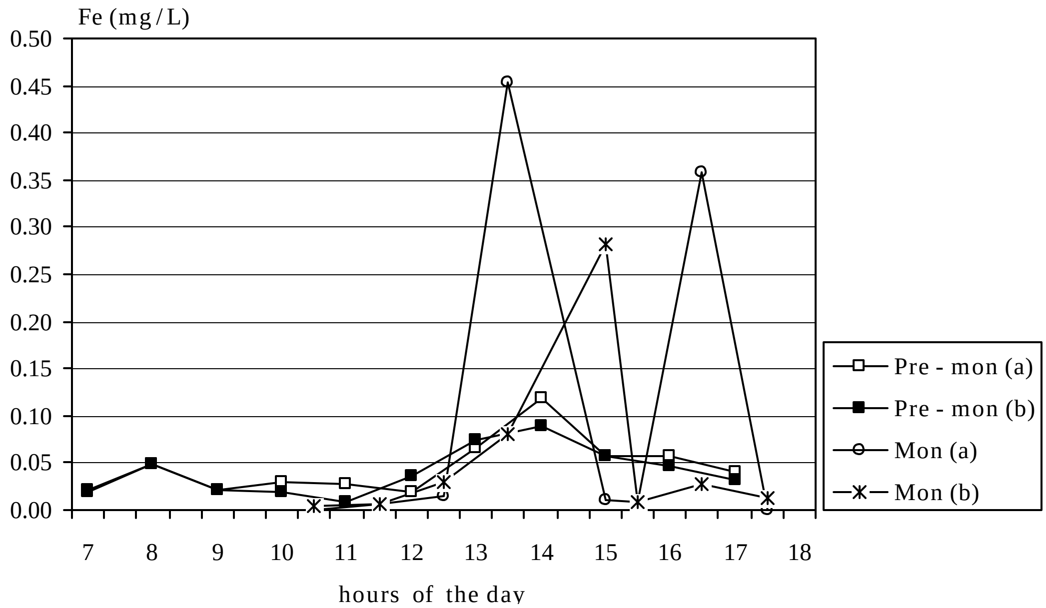



**Figure 19: Diurnal variation of iron (*a - epilimnion, b – hypolimnion)***

No significant change was observed in the concentrations of epilimnion and hypolimnion. The iron values correlate positively with that of temperature, pH, EC and partly with alkalinity and total hardness.

### *4.3.2 Seasonal variation of water quality*

The seasonal variation of water quality of Oussudu lake has been discussed vis-à-vis the governing factors such as rainfall (Figure 15), cloud amount (Figure 16), runoff, evaporation and water level (Figure 15) of the lake. The water quality variables were also compared with the standards of BIS and WHO for the utility of drinking water, fisheries and aquatic life, and swimming pools.

*a. Temperature*

The temperature of Oussudu lake varies between ~27 $^{o}$C (Dec, Jan, monsoon) and ~35 $^{o}$C (Sept, pre-monsoon), with an average of ~29 $^{o}$C ± 2.6. This range is quite typical of a tropical lake and can influence several water quality parameters. During the peak of the summer months (May – June), diurnal temperatures fluctuate by ~3°C.

The thermal behaviour of a water body in the tropical belt is primarily influenced by several atmospheric conditions such as cloud coverage, wind velocity, and ambient temperature (Rajashree, 1996). Apart form the ambient conditions, water exchange and bathymetry of a lake also influence the thermal behavior of a water body (Borego & Borego, 1982). It was observed that all the above factors play a crucial role in influencing the temperature of water of Oussudu lake (Figure 15 and 16).

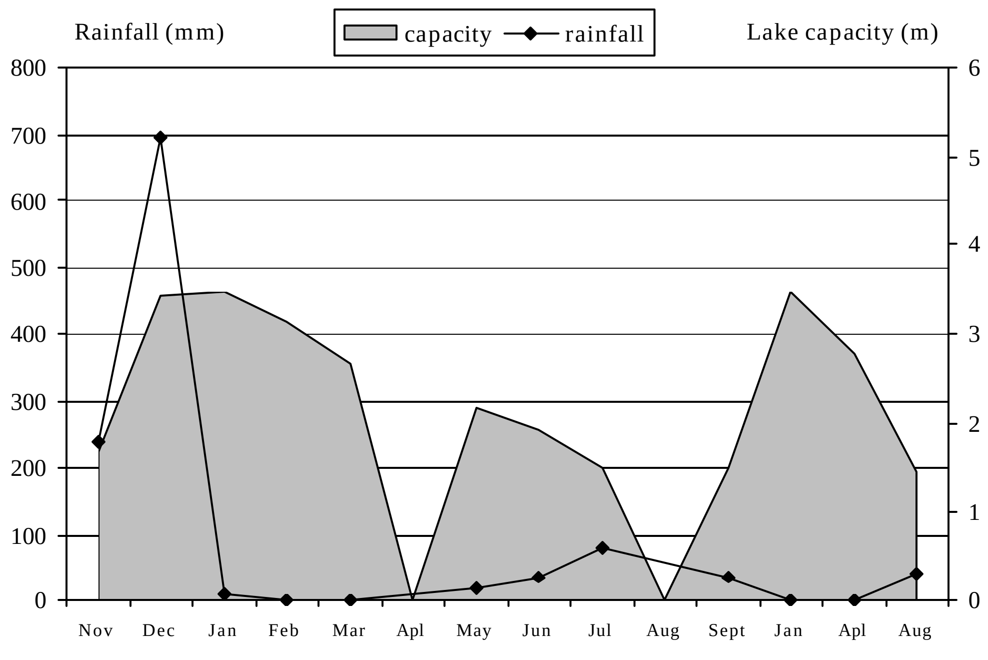



**Figure 20: Rainfall at the site and the capacity of Oussudu lake**

*b. pH*

The pH varies within a range of 7.6 (Dec, monsoon) and 9.6 units (Sept, pre-monsoon), with an average of 8.8 units ± 0.5.

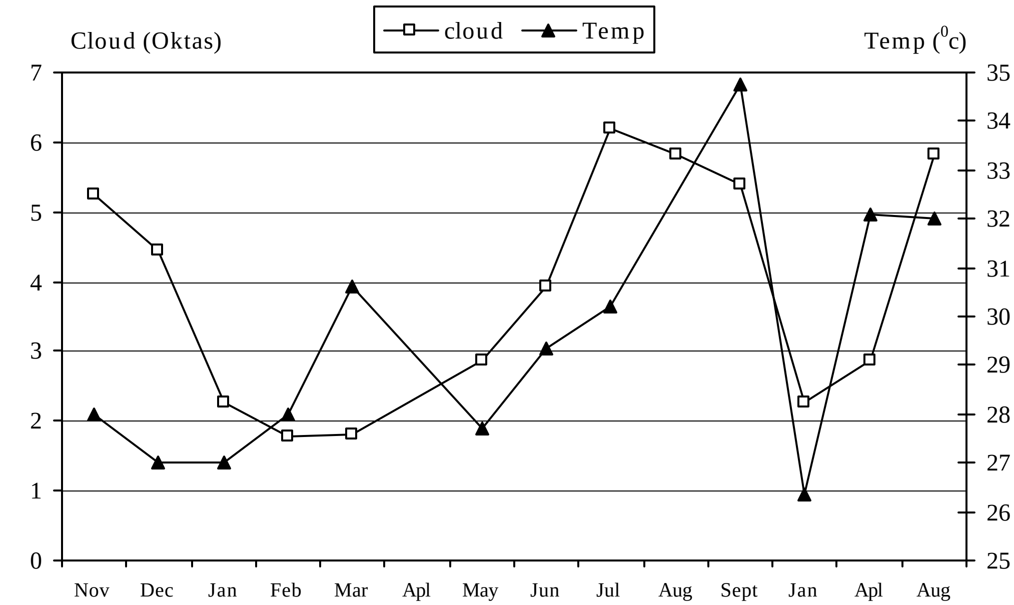



**Figure 21: Mean monthly cloud amount of Pondicherry and the average temperature of Oussudu surface water**

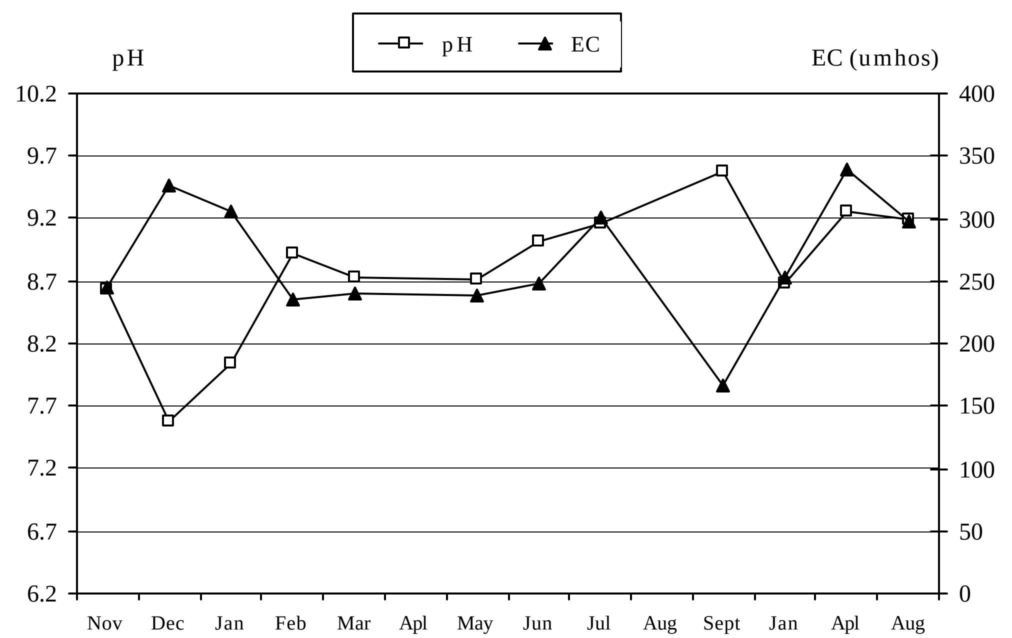



**Figure 22: Seasonal variation of pH and EC**

pH values of the lake were lower during the monsoon, which gradually rise as the lake dries up (Figure 17), due to the increase in substances that increase alkalinity.

pH of the lake is ideal for drinking purpose, fisheries and aquatic life for only a brief period of time, during the months of Dec and Jan. It was during this period that the lake has received the first spell of rain after a prolonged period of dryness. In the subsequent months, pH value of the lake is beyond the desirable limits for all the above mentioned purposes.

The pH of Oussudu lake is favorable for the growth of phytoplankton. Similar observations were made by Bhatt & Negi (1985) and Mahajan & Kanhere (1995).

*c. Electrical Conductivity (EC)*

The EC values range between 238 µmhos (May I, post-monsoon) and 326 µmhos (Dec, monsoon). The seasonal average is 273 µmhos ± 40 (Figure 17).

The surface runoff from the catchment of Oussudu contributes significantly to the EC of the lake, The values reach as much as 326 µmhos (Abbasi, 1997b). During the monsoon, EC values correlate positively with rainfall, as the rainfall increases the EC tends to increase. Once the post-monsoon approaches, the EC values start falling sharply to as low as 235 Φmhos. During the period of post-monsoon and pre-monsoon, the EC values tend to increase because of the increased evaporation loss contributing to the rise in TDS concentration (Abbasi, 1997; Rajashree 1996).

Thus, EC in the lake is affected because of the two factors: surface run-off during the monsoons and evaporation loss during the months of pre-monsoon and post-monsoon.

*d. Alkalinity*

The alkalinity values vary within a range of 80 mg/l (April, post-monsoon) and 130 mg/l (Nov, monsoon), the seasonal average being 96 mg/l ± 14.

The peak values of alkalinity were observed when the lake was totally dry and has received the first drizzle of rainfall (Figure 18). Alkalinity values correlate positively with the pattern of rainfall. This implies that, surface run-off from the Oussudu contains substances which contributes to the alkalinity.

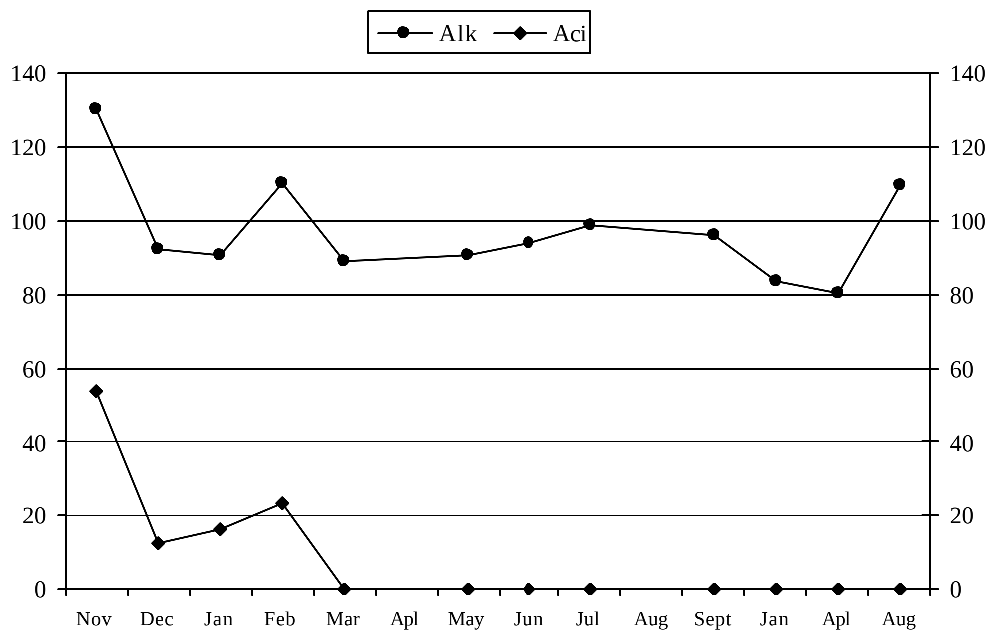



**Figure 23: Seasonal variation of alkalinity and acidity**

The alkalinity values in general were very close to 100 mg/l. Thus Oussudu lake would very soon reach the category of *hardwater* as per the classification of Philipose (1960) and Moyle (1946) based on alkalinity. Moreover, as the alkalinity in the lake is mostly contributed by calcium and magnesium, the lake can be considered as nutritionally rich (Sarwar and Rifet, 1991). Alkalinity values correlate positively with total hardness and chlorides.

The water of Oussudu lake meets the criteria set for fisheries and aquatic life (BIS, 1994), and swimming pools (BIS, 1993).

*e. Acidity*

As the lake receives its first rainfall, after the brief period of dryness, peak value of acidity, reaching 80 mg/l has been observed. Later, the acidity values fell sharply to a *zilch* within a span of 3 to 4 months (Figure 18). Thus the lake remains *acidic* for a very brief period.
The brief period of acidity again corroborates the fact that the lake is generally alkaline in nature, alkaline enough to buffer the change in acidity because of $CO_2$, a major constituent in freshwater lakes contributing to the acidity.

Thus, acidity in the lake during the months of Nov to May can be attributed to the high concentrations of hydrolysable salts such as iron etc., contributed by the surface runoff or due to the sediments of the lake itself, which upon dissolving in the rain water would have contributed to the acidity.

Acidity values correlate positively with alkalinity, total hardness and dissolved oxygen.

*f. Total Hardness (TH)*

During the study period, the seasonal average of TH was 80 mg/l ± 8, with a range of 68 mg/l (June, pre-monsoon) and 93 mg/l (Feb, post-monsoon).

Precipitation seems to be the sole factor influencing the fluctuating TH values. The TH values rise during the monsoon period to as high as 93 mg/l. Very soon, during the post-monsoon months, the values start falling steeply. Again, the values increase during the southwest monsoons, i.e., during the period of pre-monsoon (Figure 19).

The TH values correlate positively with calcium hardness, nitrites, sulphates, iron and capacity of the lake.

Water quality of Oussudu lake fits the permissible limits of drinking water (BIS, 1991; WHO, 1984).

*g. Calcium Hardness (CaH)*

The CaH values varied within a range of 14 mg/l (May, post-monsoon) and 47 mg/l (Jan, Monsoon) with a seasonal average of 26 mg/l ±12 (Figure 19).

The CaH values correlate, positively with $NO_3$, total hardness, EC and rainfall pattern; and negatively correlate with $SO_4$ and Fe unlike that of total hardness.

As per the set standards of BIS (1991), water quality of Oussudu lake fits the drinking water criteria.

*h. Dissolved Oxygen (DO)*

DO levels in the lake varied within a range of 5.3 ppm during the monsoon (Jan) and 7.6 ppm during the early post-monsoon (Feb), with a seasonal average of about 6 ppm ± 0.9 (Figure 20).

The DO curve indicates a bimodal oscillation, with peak values during the early monsoon and early post-monsoon (Figure 20). During the early monsoons an initial rise in DO levels was followed by a sudden decrease to 5.3 ppm. Again during the early post-monsoon a sharp rise in DO levels has been observed followed by a gradual decline throughout the rest of the post-monsoon and pre-monsoon. However, sporadic rains during the pre-monsoon, in the month of June do contribute to the some amount of DO.

The peak levels of DO during the early post-monsoon could be attributed to the rapid phytoplanktonic growth, which would have contributed to the photosynthetic oxygen. Also, the increase in temperature during the early post-monsoons could have accelerated the photosynthetic oxygen production, which intern would have increased the DO.

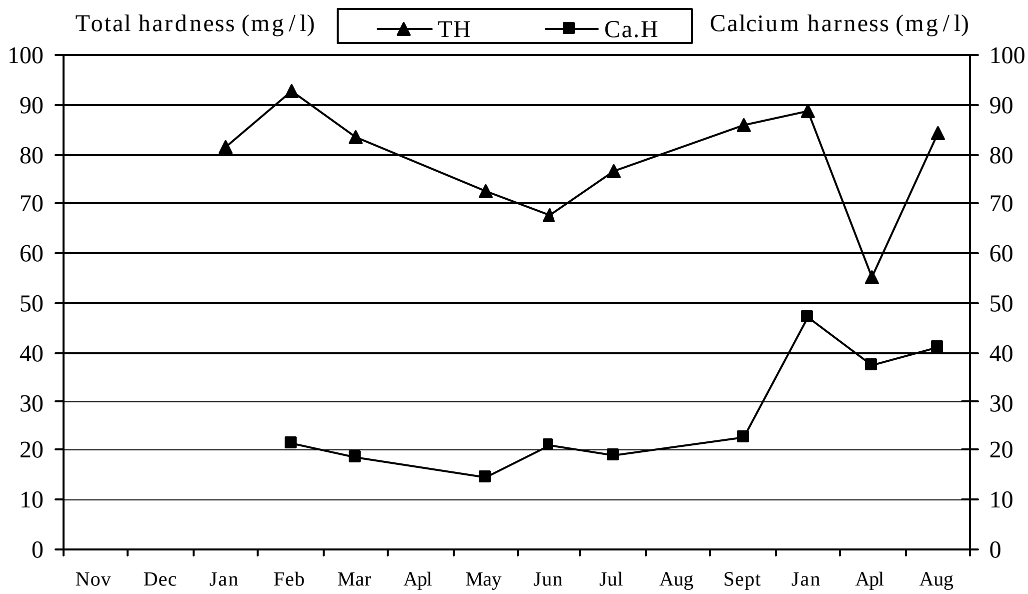



**Figure 24: Seasonal variation of total hardness and calcium hardness**

The increasing levels of DO during the early monsoon and post-monsoon can be because of the heavy rains and the ensuing dilution of the organic substances, including the dead phytoplankton and hydrophytes. Studies conducted elsewhere also corroborate these findings (Rajashree, 1996; and Saxena & Chauhan, 1993).

The decline in DO levels during the post-monsoon and pre-monsoon could be attributed to the increased concentration of organic wastes (degrading phytoplankton and hydrophytes) and to the receding levels of water in the lake.

The DO values correlate positively with temperature, alkalinity, total hardness, total phosphorus and dissolved phosphorus, nitrites and sulphates.

As per the standards of BIS (1994), and WHO (1984) the DO levels were within the desirable limits for fisheries and aquatic life.

*i. Chlorides ($Cl^-$)*

The seasonal average for chlorides was 20 mg/l ± 7, ranging between 13 mg/l (Feb, post monsoon) and 33 mg/l (Nov, monsoon). The peak chloride values during the early monsoon tends to decrease sharply till the post-monsoon approaches (Figure 20). During the period of post-monsoon and pre-monsoon the chloride values increase gradually.

The peak monsoon values of chlorides can be attributed to the surface runoff, rich in animal origin and organic waste. Sarwar & Rifet (1991) have made similar observations in their study of a fresh water lotic ecosystem of Kashmir.

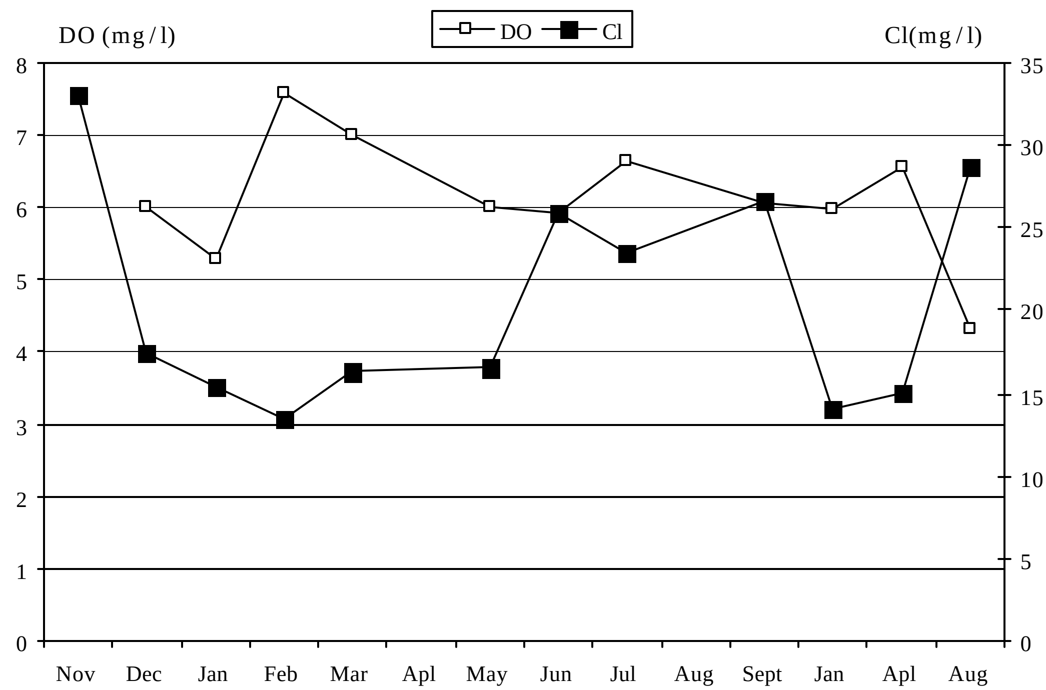



**Figure 25: Seasonal variation of dissolved oxygen and chloride**

The chloride values correlate well with total hardness. The chloride levels were within the standards for drinking water criteria (BIS, 1991; WHO 1984), and swimming pools (BIS, 1993).

*j.Nitrogen (N)*

***Nitrites:*** The minimum concentration of nitrites were found during the monsoon (0.0002 mg/l, Nov) and maximum during the pre-monsoon (0.09 mg/l, Feb and Apr); the seasonal average being 0.03 mg/l ± 0.04.

Nutrient economy, in the lakes is primarily controlled by the influx of surface runoff (Baker et. al., 1993), phytoplankton uptake (Shankaranarayanan & Quasim, 1969; Desouza et al., 1981; Chandran & Ramamoorthi, 1984; Upadhya, 1988; Rajashree & Panigrahy, 1992), and grazing intensity in the catchment (Heathwaite & Johnes, 1996).

Thus, the peak values during the monsoons can be attributed to the surface runoff resulting from the catchment, influenced by the varied land-use and grazing intensity. However, the low contents of nitrite nitrogen ($NO_2$-N) in the lake could be due to (i) utilization by the phytoplankton and macrophytes for photosynthesis, and (ii) the denitrifying bacteria which are quite active at higher temperatures during the summer months (Mahajan & Kanhere, 1995).

***Nitrates:*** During the month of Jan (monsoon) an average of 0.92 mg/l was observed which is within the permissible limits of drinking water (BIS, 1991) and, fisheries and aquatic life (BIS, 1994).

***Ammonical nitrogen***: An average of 0.125 mg/l was observed during the month of Jan, late monsoon, which is within the permissible limits for fisheries and aquatic life (BIS, 1991).

***Organic nitrogen***: During the month of Jan an average of 0.22 mg/l was observed.

*k. Phosphorus (P)*

***Total phosphorus:*** Total phosphorus (TP) values of Oussudu lake varied between 0.003 mg/l (Nov) and 0.115 mg/l (April), with a seasonal average of 0.05 mg/l ± 0.04 (Figure 21).

The total phosphorus (TP) values correlate positively with the capacity of the lake. The values rise sharply by the end of monsoons, as the lake fills up to its full capacity. Later, the TP values decline as the water level of the lake recedes. Again, during the pre-monsoon months TP values rise depending on the intensity of the precipitation, which directly governs the potential runoff from the catchment.

***Total orthophosphorus:*** Total orthophosphorus (TOP) constitutes nearly 12% of the total phosphorus (TP). The average value of OP was 0.008 mg/l (Figure 22). The peak values were observed during the monsoons and early pre-monsoons (Figure 21). Surface runoff is the main source contributing to the TOP budget.

***Total condensed phosphorus:*** The concentration of the condensed phosphorus reach peak values during the late monsoon (Jan), late pre-monsoon (May), and pre-monsoon(Jul). The receding level of water in the lake make the fluctuation much more pronounced. Total condensed phosphates measure about 0.037 mg/l, a 32% of the total phosphorus budget (Figure 23).

The major source contributing to the condensed phosphorus could probably be the laundry washing and cleaning activities that are carried-out in the lake.

***Total organic phosphorus:*** The high total organic phosphorus (TOP) were observed during the monsoons. The sources of TOP can be attributed to the heavy grazing activity and the ensuing cattle feces, fecal droppings of the avifauna, and human defecation inside the lake, when it is dry. Also, some TOP would come to the lake as surface run-off.

The peak TOP values during the late post-monsoon and the early pre-monsoon can be attributed to the high primary productivity of the lake due to the increase in the phytoplankton growth.

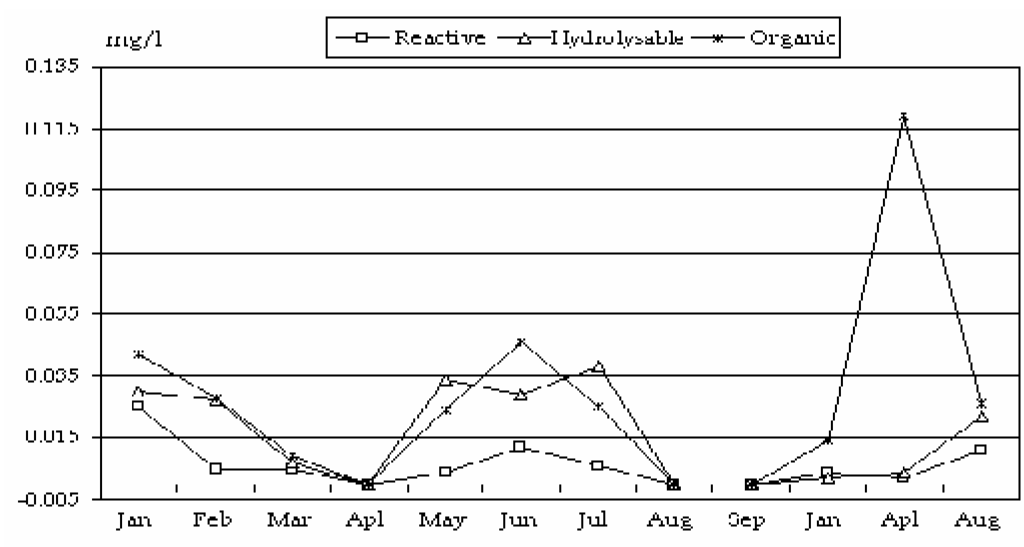



**Figure 26: Seasonal variation of total organic phosphorous**

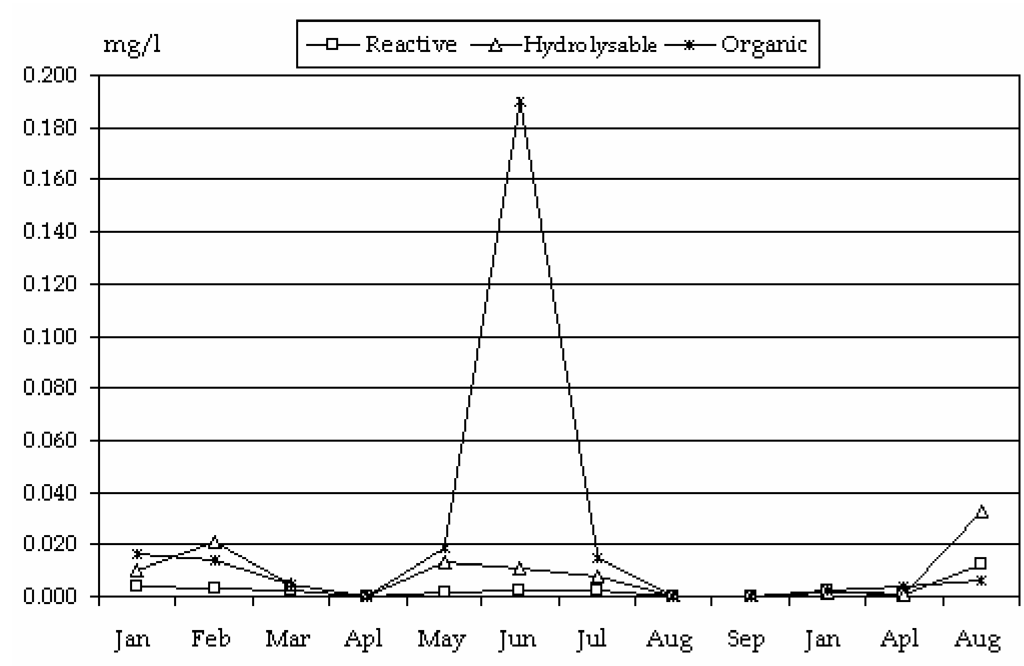



**Figure 27: Seasonal variation of total dissolved phosphorous**

TOP constitute an average of 0.037 mg/l, a 56% of total phosphorus (Figure 26). The exceptionally high value of TOP during the post-monsoon (April) can be attributed to the biodegradation of hugemass of hydrophytes and the receding water level in the lake.

***Total dissolved phosphorus:*** The total dissolved phosphorus (TDP) values follow similar pattern as that of total phosphorus, with a seasonal average of 0.024 mg/l and a range of 0.003 mg/l (Jan, monsoon) and 0.04 mg/l (Feb, post-monsoon). The peak values were observed during the monsoons and pre-monsoons, while there was a decline during the post-monsoon (Figure 27).

***Dissolved orthophosphorus:*** Dissolved orthophosphorus (DOP) constitute 13% of the total phosphorus, with an average of 0.0034 mg/l. The trend is more linear unlike that of TOP.

*Dissolved condensed phosphorus*: It is the most dominant form of all the dissolved phosphorus during the early monsoons. The condensed and organic forms follow a similar pattern right from the middle of the post monsoon till the next monsoon (Figure 27). However, for the subsequent monsoon the pattern changes. Condensed phosphorus remains lowest during the months of monsoon and post monsoon. When the values shoot up sharply during the months of pre-monsoon due to the receding water levels and peak cleaning activities in the lake.

***Suspended phosphorous:*** Suspended organic phosphorus (SOP) is higher than the other forms of dissolved phosphorus, constituting about 40% of the total phosphorus (Figure 28). SOP is a result of the *biomass*, both living and dead organic matter. This points towards the highly productive nature of the lake.

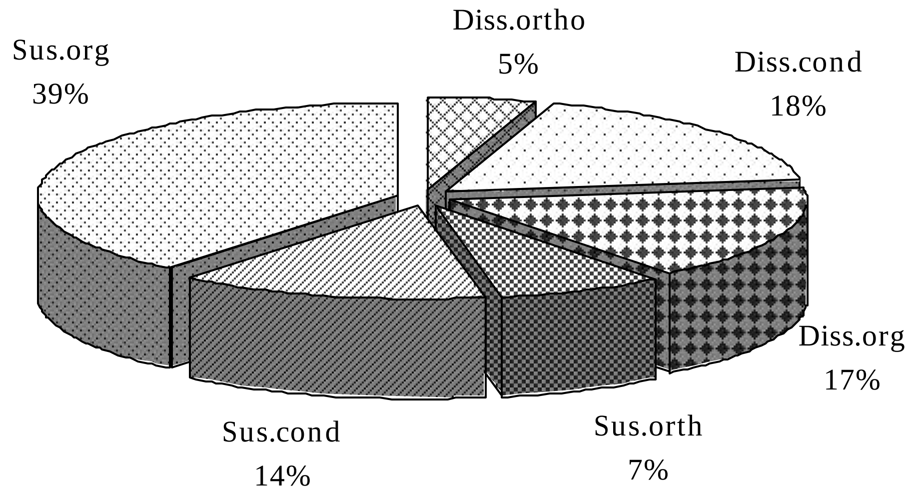



**Figure 28: Seasonal average of various forms of phosphorous**

*l. Sulphates ($SO_4$)*

The seasonal average of sulphates was 0.06 mg/l ± 0.05 with a minimum of 0.02 mg/l January (first phase of sampling) and a maximum of 0.08 mg/l during January (second phase of sampling).

The $SO_4$ values tend to fluctuate within a very narrow range. The factors governing the changes were (i) lower $SO_4$ values due to the dilution factor during monsoons when the precipitation is less intense, not enough to generate the surface runoff (ii) the higher values of $SO_4$ during the monsoons with intense precipitation resulting in the surface run-off; which brings with it the constituents of $SO_4$, and (iii) higher $SO_4$ values during summer due to the evapo-transpiration resulting in the higher concentrations. Thus, the peak values during Jan II could be attributed to the low water levels in the lake and again in Jan I because of the heavy flooding (Figure 29).

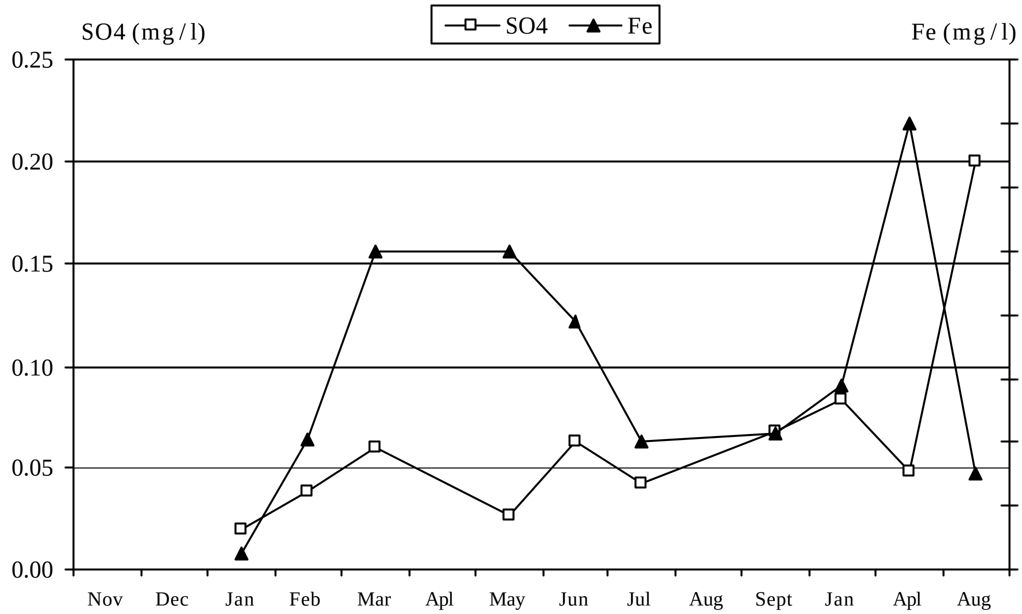



**Figure 29: Seasonal variation of sulphates and iron**

The $SO_4$ values were within the desirable limits set by BIS (1991) and WHO (1984) for the drinking water criteria.

*m. Iron (Fe)*

The seasonal average for Iron was 0.06 mg/l. Iron values varied within a range of 0.005 mg/l during the post-monsoon (March) and 0.14 mg/l during the post monsoon (Apl). the predominant factor affecting the iron values are the monsoons (Figure 29), as a dilution factor. Thus, the monsoon period had low iron values, while the peak values were observed during the post-monsoon. During the pre-monsoons with sporadic rains, about 0.04 mg/l of iron was witnessed.

The iron values correlate highly with temperature, total phosphorus and dissolved phosphorus.

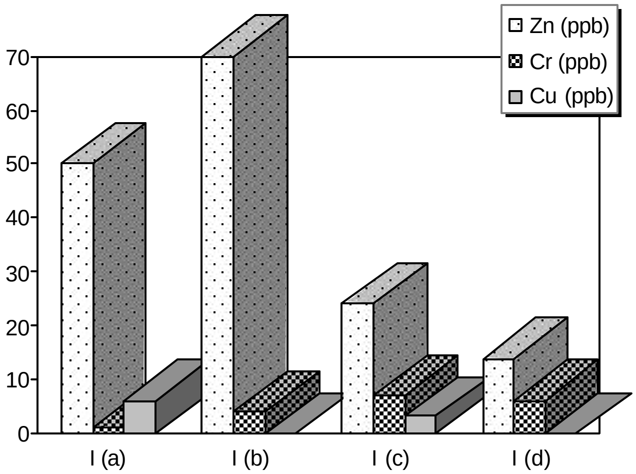
The values of iron were within the standards prescribed for drinking water (BIS, 1991; WHO, 1984) and, fisheries and aquaculture of (BIS, 1994).

*n. Heavy metals*

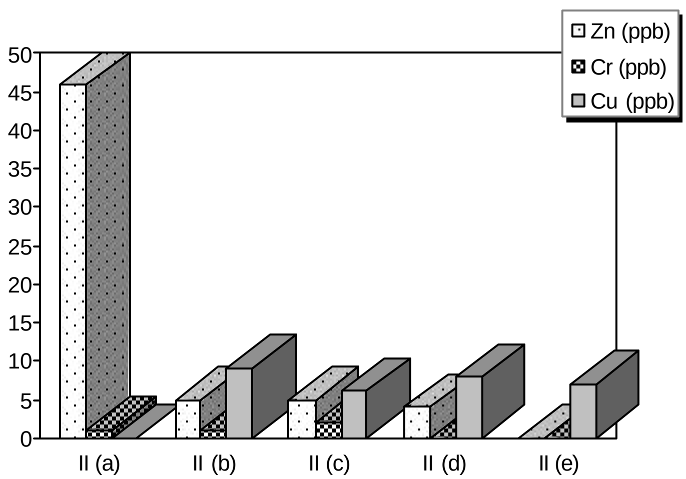
The dissolved heavy metals - Zn, Cu, Cd, and Cr - were studied to identify: (i) the contribution of the watersheds, if any, (ii) the seasonal patterns, and (iii) whether the heavy metals were within the desirable limits of the criteria of drinking and irrigation water.

The salient findings of the study were:

1. The concentration of Cd was below the detectable limits (#1 ppb).
2. All the heavy metals studied were within the desirable limits of drinking water (BIS, 1991), and fisheries and aquaculture (BIS, 1994).
3. A very significant finding of the study is that the levels of Zn and Cu were higher at the surface of the lake than at the bottom of the lake (Figure 30 and 31). This is contrary to the normal, expected trend, and indicates that these metals are being contributed by the run-in received by the lake.
4. Higher concentrations of Cr were found in the feeder channel than in the lake. This indicates that the feeder channel may be contributing Cr to the lake rather than the surface run-off (Figure 30 and 31).
5. The concentration of Zn and Cr were 3 times higher during pre-monsoon (summer) compared to their monsoon concentrations. This can be attributed to the evapo-transpiration loss of water in the lake during summer leading to the increased concentration of the heavy metals (Figure 32).




I (a) Composite diurnal surface samples, Site
I (b) Composite diurnal bottom samples, Site A
I (c) Integrated surface grab samples: A5a, A5b, S1, S2, S3
I (d) Feeder channel, 11B




II (a) Composite diurnal surface samples, 1A, 1B, 2A, 3A, 4A,5A, and 6A
II (b) Composite diurnal bottom samples, 1A, 1B, 2A, 3A, 4A,5A, and 6A
II (c) Composite diurnal surface samples, 1B, 2B, 3B, 4B, 5B, 6B, 7B, and 8B
II (d) Integrated surface grab samples, S2, S3, S4, S5, S6, and S7
II (e) Feeder channel, 11B

**Figure 30: Heavy metals in surface water during monsoon and post-monsoon**

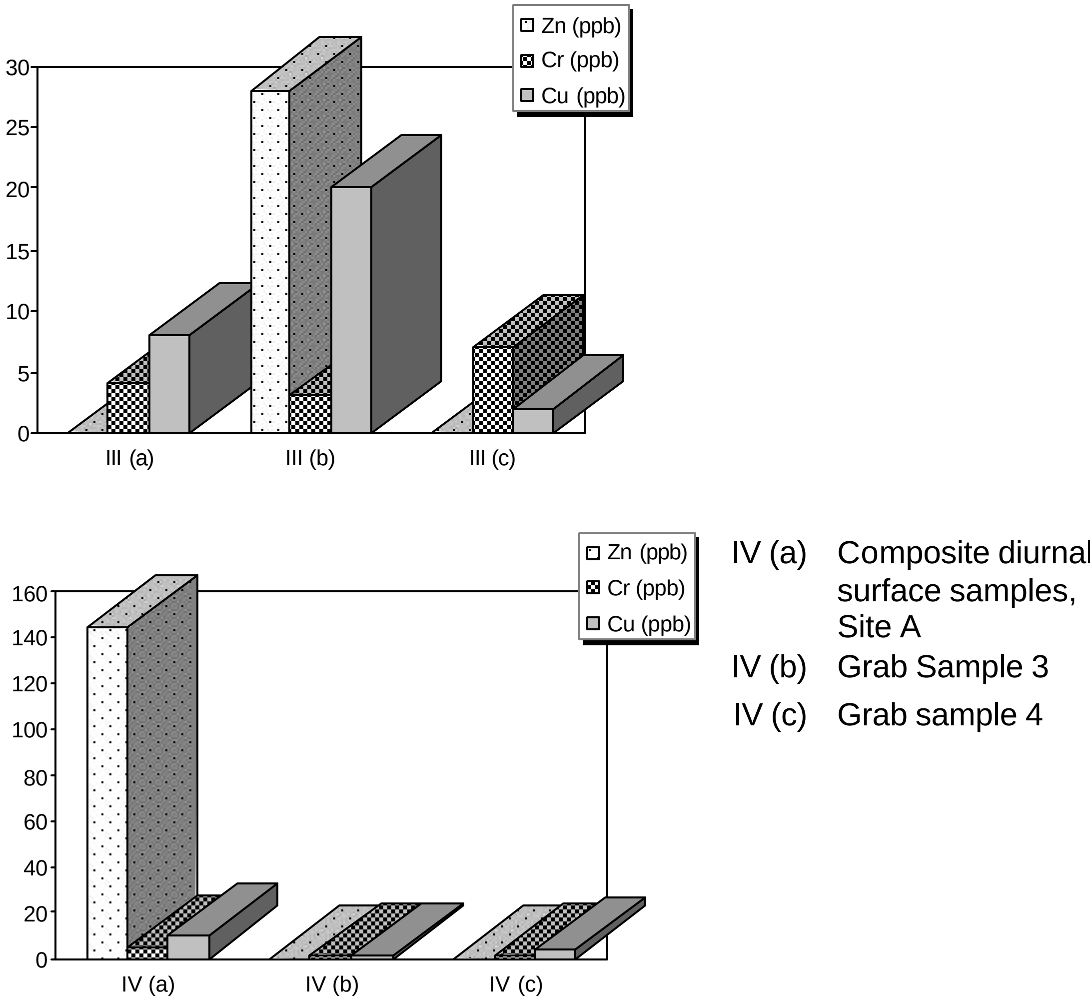



**Figure 31: Heavy metals in surface water during pre-monsoon**

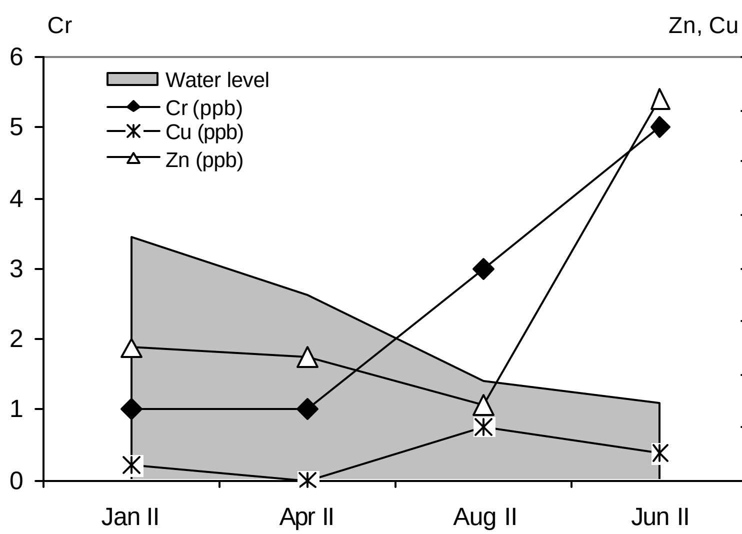



**Figure 32: Seasonal variation of heavy metals**

# 4.4 THE GROUNDWATER QUALITY

For groundwater quality assessment, samples were collected from bore-wells and dug-wells that were in the vicinity of the soil sampling locations ( Figure 33).

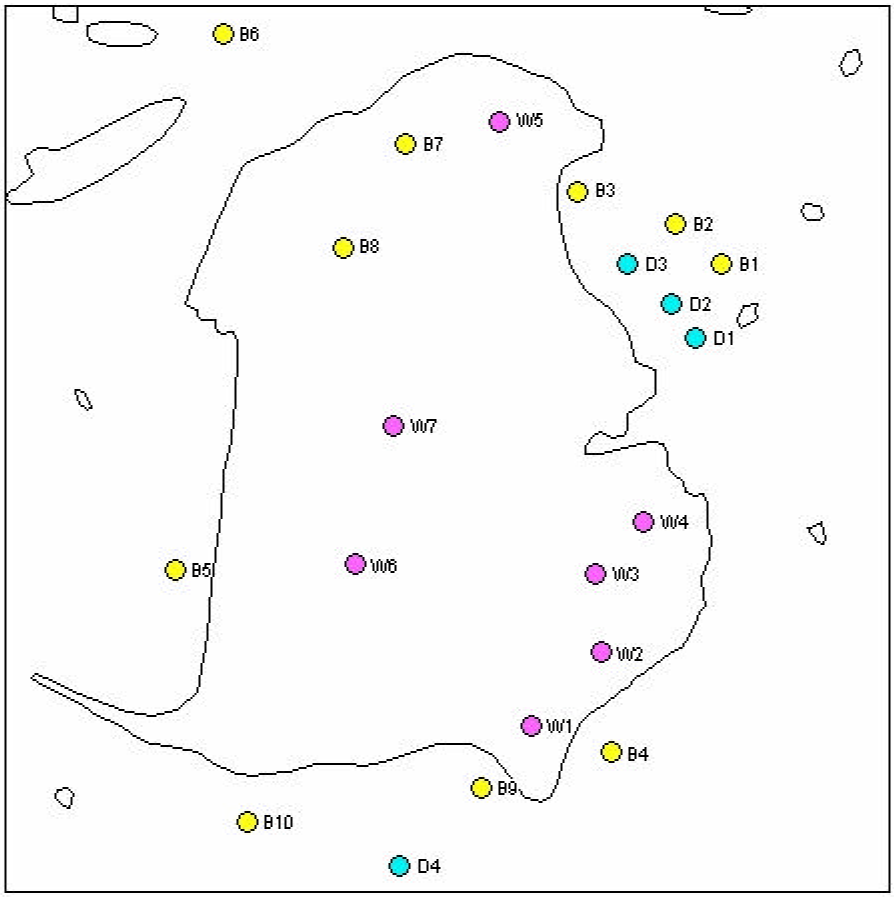



**Figure 33: Location of the sampling sites: ground water: dug wells - D1 to D4, bore wells - B1 to B10.**

The spatial distribution of the pH and EC of the ground water has been presented as Figure 34. Except one sampling site, rest of the bore-well samples were of class 3, with medium salinity hazard (Table 4). pH of the bore-well water in-and-around the lake varied from being mild to moderately alkalinity (Table 5, Figure 34).

The dug-well water of the region varied between moderate salinity and mild to moderately alkaline pH (Table 4). The pH and EC of the soil positively correlate with the corresponding values of these parameters of the bore-well water, and negatively correlate with that of the dug-well water (Table 6).

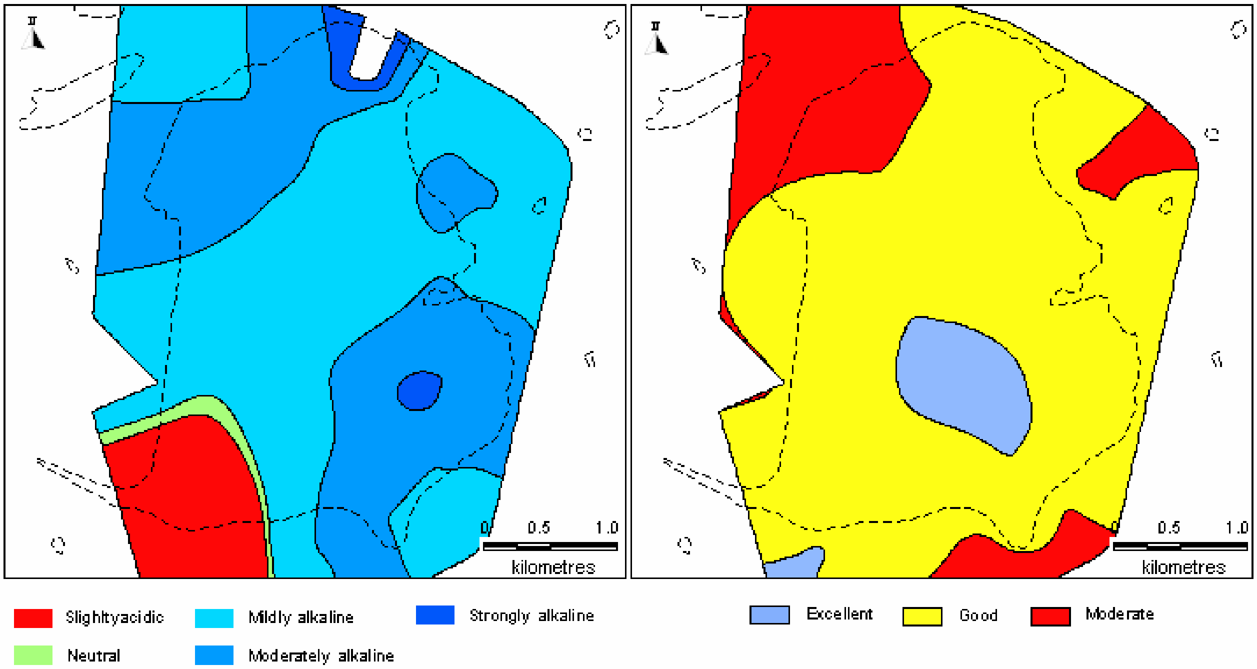



**Figure 34: The spatial distribution of water quality: (a) pH and (b) EC**

**Table 4: Electrical conductivity of soil and water samples of Oussudu**

| **EC (F mhos)** | **Class** [@] | **Salinity hazard** | **Water samples** [#] |
|---|---|---|---|
| < 250 | Excellent (Class 1) | Low | B10 |
| 250 - 750 | Good (Class 2) | Moderate | B3, W1, W2, W3, W4, W5, W6, W7, D1 |
| 750 - 2250 | Moderate (Class 3) | Medium | B1, B2, B4, B5, B6, B7, B8, B9, D2, D3, D4 |
| 2250 - 4000 | Unsatisfactory (Class 4) | High | Nil |
| > 4000 | Unfit (Class 5) | Very high | Nil |

[@] Classification of water based on EC, after Grag et. al., (1980)

[#] B: bore-well, D : dug-well, W : surface water sample, S : soil sample

**Table 5: pH of soil and water samples**

| **Soil category** | **pH range** [@] | **Soil samples** | **Water samples** [#] |
|---|---|---|---|
| Very strongly alkaline | > 9.0 | Nil | W5 |
| Strongly alkaline | 8.5 – 9.0 | S9 | W3 |
| Moderately alkaline | 7.9 – 8.4 | S1, S2, S3, S4, S5, S6, S7, S8, S12, S14, S15, S16, S20, S24 | W1, W2, W4, D2, D3, B7, B8, B9 |
| Mildly alkaline | 7.1 – 7.8 | S10, S17, S18, S19, S21, S22, S23, S25, S26, S27 | B1, B2, B3, B4, B5, B6, W6, W7, D1, D4 |
| Neutral | 7.0 | Nil | Nil |
| Slightly acid | 6.1 – 6.9 | S13, S28 | B10 |
| Medium acid | 5.6 – 6.0 | Nil | Nil |
| Strongly acid | 5.1 – 5.5 | Nil | Nil |
| Very strongly acid | 4.5 – 5.0 | Nil | Nil |
| Extremely acid | < 4.5 | Nil | Nil |

[@] Classification of water based on pH range, after Briggs et. al., (1987)

[#] B: bore-well, D : dug-well, W : surface water sample, S : soil sample

**Table 6: Correlation of pH and EC of soil and water quality**

| | Soil pH | Soil EC | Bore-well pH | Bore-well EC | Dug-well pH | Dug-well EC |
|---|---|---|---|---|---|---|
| Soil pH | 1 | 0.1139 | 0.9042 | 0.1747 | -0.7145 | -0.8919 |
| Soil EC | | 1 | 0.9666 | 0.76906 | -0.9973 | -0.9731 |
| Bore-well EC | | | 1 | 0.3462 | -0.9445 | -0.9996 |
| Dug-well pH | | | | 1 | -0.8137 | -0.9996 |
| Dug-well EC | | | | | 1 | 1 |

# 5
# FLORA AND FAUNA

## 5.1 INTRODUCTION

The study area supports diverse, rich and rare flora and fauna . The area due to the extreme hydrological fluctuations across the annual cycle, gives rise to interesting pattern of flora and fauna in the lake. The northeast monsoons leave Ousteri flooded during the winter months, while the scorching summers leave it totally dry.

## 5.2 THE FLORA

The natural vegetation, altered much by human agencies, consist of over 220 species belonging to 63 families. A complete checklist of all plants in the watershed has been presented in the Table 7.

The flora represents a wide range of habit and habitats. Species such as *Agave americana, Barleria buxifolia, Calotropis gijantia,* and *Lepidanthus cristata* represent the dry terrains. While the species such as *Coldenia procumbens* - the prostrate herb, *Hybanthus enneaspermus, Arundo dondax,* and *Scirpus lacustrus* represent the wetland habitat.

Species representing rare habitats were: *Dichrostachys cineri* - the leguminous shrub of scrub forests; *Dalbergia panicula* - the tree of deciduous forests; *Hugonia mystax* - the climbing shrub of dry forests; *Ficus hispida* - the species representing evergreen and the generally damp environmental conditions; *Cassia auriculata* - the leguminous shrub, leaves of which are used for tanning leather, also an indicator of black cotton soils; and Canthium parviflorum - the thorny shrub representing scrub forests, which has a strong affinity for the laterite soils.

**Table 7: Flora identified in the watershed**

| | Family | Species | Significance / utility |
|---|---|---|---|
| 1 | Acanthaceae | Asystasis gangetica | |
| 2 | Acanthaceae | Barleria buxifolia | |
| 3 | Acanthaceae | Crossandra infundibuliforms | |
| 4 | Acanthaceae | Ecbolium viride | |
| 5 | Acanthaceae | Justicia simplex | |
| 6 | Acanthaceae | Lepidagathis cristata | |
| 8 | Acanthaceae | Asystasis gangetica | |
| 9 | Acanthaceae | Barleria buxifolia | |
| 10 | Acanthaceae | Crossandra infundibuliforms | |
| 11 | Acanthaceae | Ecbolium viride | |
| 12 | Acanthaceae | Justicia simplex | |
| 13 | Acanthaceae | Lepidagathis cristata | |
| 14 | Aizoaceae | Glinus oppositifolius | Medicinal |
| 15 | Aizoaceae | Mollugo disticha | |
| 16 | Aizoaceae | Mollugo pentaphylla | |
| 17 | Amaranthaceae | Achyranthes aspera | |
| 18 | Amaranthaceae | Aerva lanata | |
| 19 | Amaranthaceae | Amaranthus spinosus | Edible |
| 20 | Amaranthaceae | Celosia argentea | |

| | Family | Species | Significance / utility |
|---|---|---|---|
| 21 | Amaranthaceae | Gomphrena celosioides | |
| 22 | Amaranthaceae | Gomphrena globosa | Ornamental |
| 23 | Amaranthaceae | Trichurus monsoniae | |
| 24 | Anacardiaceae | Buchanania axillaris | |
| 25 | Anacardiaceae | Lannea coromandelica | |
| 26 | Apocynaceae | Carissa spinarum | |
| 27 | Apocynaceae | Ichnocarpus frutescens | Hedge plant |
| 28 | Apocynaceae | Wrightia tinctoria | Sculpture, dye-yielding plant |
| 29 | Asclepiadaceae | Calotropis gigantia | |
| 30 | Asclepiadaceae | Hrmidesmus indicus | |
| 31 | Asclepiadaceae | Leptadenia reticulata | Hedge plant |
| 32 | Asclepiadaceae | Pergularia daemia | |
| 33 | Asclepiadaceae | Sarcostemma acidum | |
| 34 | Asclepiadaceae | Wattakaka volubilis | |
| 35 | Agavaceae | Agave americana | Ornamental |
| 36 | Aristolochiaceae | Aristolochia bracteolata | |
| 37 | Boraginaceae | Carmona retusa | |
| 38 | Boraginaceae | Coldenia procumbens | |
| 39 | Boraginaceae | Ehretia pubescebs | |
| 40 | Boraginaceae | Heliotropium sp. | |
| 41 | Cactaceae | Opuntia dillenii | |
| 42 | Capparaceae | Cadaba fruticose | |
| 43 | Capparaceae | Capparis brevispina | |
| 44 | Capparaceae | Capparis sepiaria . | |
| 45 | Capparaceae | Capparis sp. | |
| 46 | Capparaceae | Cleome aspera | |
| 47 | Capparaceae | Cleome viscosa | |
| 48 | Capparaceae | Maerua oblongifolia | |

| | Family | Species | Significance / utility |
|---|---|---|---|
| 49 | Caryophyllaceae | Polycarpon prostratum | |
| 50 | Ceratophyllaceae | Ceratophyllum demersum | |
| 51 | Celastraceae | Cassine glauca | |
| 52 | Celastraceae | Celastrus paniculatus | |
| 53 | Celastraceae | Maytenus energinata | |
| 54 | Celastraceae | Reissantia indica | |
| 55 | Clusiaceae | Garcinia spicata | |
| 56 | Clusiaceae | Garcinia talbottii | |
| 57 | Convolvulaceae | Evolvulus alsinoidus | |
| 58 | Combretaceae | Terminalia bellirica | Tanning |
| 59 | Commelinaceae | Commelina sp. | |
| 60 | Commelinaceae | Cyanotis tuberose | |
| 61 | Compositae | Eclipta alba | |
| 62 | Compositae | Synedrella nodiflora | |
| 63 | Compositae | Ipomoea carnea sp. | Ornamental |
| 64 | Compositae | Ipomoea pascaprae | Sand-fixer |
| 65 | Compositae | Ipomoea pestigridis | Hedge plant |
| 66 | Compositae | Merremia emarginata | |
| 67 | Compositae | Merremia tridentata | |
| 68 | Compositae | Parthenium sp. | |
| 69 | Compositae | Tridax procumbens | |
| 70 | Cyperaceae | Cyperus sp. | |
| 71 | Cyperaceae | Fimbristylis sp. | |
| 72 | Cyperaceae | Scirpus lacustrus | |
| 73 | Ebenaceae | Diospyros ferrea Var. buxifolia | |
| 74 | Euphorbiaceae | Acalypha indica | |
| 75 | Euphorbiaceae | Breynia vitis-ideae | |
| 76 | Euphorbiaceae | Croton bonplandianus | |

| | Family | Species | Significance / utility |
|---|---|---|---|
| 77 | Euphorbiaceae | Dryeres sepiaria | |
| 78 | Euphorbiaceae | Euphorbia hirta . | |
| 79 | Euphorbiaceae | Euphorobia rosea | |
| 80 | Euphorbiaceae | Jatropha curcas . | |
| 81 | Euphorbiaceae | Jatropa gossipifolia | |
| 82 | Euphorbiaceae | Mallotus philippinensis | |
| 83 | Euphorbiaceae | Micrococca mercurialis | |
| 84 | Euphorbiaceae | Phyllanthus gardeniarianus | |
| 85 | Euphorbiaceae | Phyllanthus reticulatus | |
| 86 | Euphorbiaceae | Phyllanthus rotundifolius | |
| 87 | Euphorbiaceae | Phyllanthus neruri | |
| 88 | Euphorbiaceae | Phyllanthus amarus | |
| 89 | Euphorbiaceae | Ricinis communis | |
| 90 | Euphorbiaceae | Sebastiana Chamaelea | |
| 91 | Euphorbiaceae | Securinega Leucopyrus | |
| 92 | Euphorbiaceae | Tragia involucrata Var. rheediana Muell | |
| 93 | Fabaceae (Caesalpiniodae) | Bauhinia racemosa | |
| 94 | Caesalpiniodae | Cassia auriculate . | |
| 95 | Caesalpiniodae | Cassia fistula | |
| 96 | Caesalpiniodae | Cassia occidentalis | |
| 97 | Caesalpiniodae | Parkinsonia aculeata | |
| 98 | Caesalpiniodae | Tamarindus indica | |
| 99 | (Mimosoidae) | Acacia chundra | |
| 100 | Mimosoidae | Acadua keyciogkiea . | |
| 101 | Mimosoidae | Acacia nilotica | |
| 102 | Mimosoidae | Dichrostachys cinerea | |
| 103 | Mimosoidae | Pithecellobium dulce | |

| | Family | Species | Significance / utility |
|---|---|---|---|
| 104 | Mimosoidae | Prosopis juliflora | |
| 105 | Papilionoidae (Faboidae) | Abrus praecatorius | |
| 106 | Faboidae | Alysicarpus vaginalis | |
| 107 | Faboidae | Atylosia sp. | |
| 108 | Faboidae | Butea monosperma | |
| 109 | Faboidae | Canavallia virosa | Tanning |
| 110 | Faboidae | Crotalaria medicagenia | |
| 111 | Faboidae | Dalbergia paniculata | |
| 112 | Faboidae | Derris scandens . | |
| 113 | Faboidae | Derris sp. | |
| 114 | Faboidae | Desmodium biarticulatum | |
| 115 | Faboidae | Indigofera hirsute | |
| 116 | Faboidae | Indigopera limneuii | |
| 117 | Faboidae | Ormacarpum sennoides | |
| 118 | Faboidae | Phaseolus sp. | |
| 119 | Faboidae | Pithecanthus sp. | |
| 120 | Faboidae | Sesbania sp. | Ornamental |
| 121 | Faboidae | Stylosanthes fruticosa | Sand-fixer |
| 122 | Faboidae | Tephrosia pulcherrima | Hedge plant |
| 123 | Faboidae | Zornia gibbosa spanoghe | |
| 124 | Flacourtiaceae | Flacourtia indica | |
| 125 | Graminae | Apluda mitica | |
| 126 | Graminae | Arundo dondax | |
| 127 | Graminae | Cynodon dactylon | Fodder |
| 128 | Graminae | Dendrocalanmus strictus | Fencing |
| 129 | Graminae | Sachharum sp. | |
| 130 | Hippocrataceae | Salacia chinesis | |
| 131 | Hydrocharidaceae | Hydrilla verticillata | |

| | Family | Species | Significance / utility |
|---|---|---|---|
| 132 | Hydrocharidaceae | Vallisneria spiralis | |
| 133 | Labiaceae | Hyptis suaveolens | |
| 134 | Labiaceae | Leucas aspera | |
| 135 | Labiaceae | Ocimum tenuifolium | |
| 136 | Labiaceae | Ocimum sanctum | |
| 137 | Labiaceae | Pogostemon sp. | |
| 138 | Lauraceae | Cassytha filiformis. | |
| 139 | Lauraceae | Cassytha siam | |
| 140 | Liliaceae | Glorisa superba | |
| 141 | Liliaceae | Sanseviera sp. | |
| 142 | Linaceae | Hugonia mystax | |
| 143 | Loganiaceae | Strychnos colubrina | |
| 144 | Malvaceae | Abutilon indicum | |
| 145 | Malvaceae | Abutilon sp. | |
| 146 | Malvaceae | Bombax mori | |
| 147 | Malvaceae | Malvastrum coromandelianum | |
| 148 | Malvaceae | Sida sp. | |
| 149 | Melastomataceae | Memecylon lushingtonii | |
| 150 | Melastomataceae | Memecylon umbellatum | |
| 151 | Meliaceae | Azadirachta indica | Medicinal, edible |
| 152 | Menispermaceae | Cissampelos Pareira Var hirsuta | |
| 153 | | Cocculus hirsutus | |
| 154 | Moraceae | Ficus benghalensis | Fencing |
| 155 | Moraceae | Ficus hispida | |
| 156 | Moraceae | Ficus religiosa | Fencing |
| 157 | Myrtaceae | Syzygium caryophyllatum | |
| 158 | Myrtaceae | Syzygium cumini | |
| 159 | Nyctaginaceae | Boerhavia diffusa | |

| | Family | Species | Significance / utility |
|---|---|---|---|
| 160 | Ochnaceae | Ochna obtusata | |
| 161 | Oleaceae | Jasminum sp. | |
| 163 | Orchidaceae | Eulophia nuda Lindi | |
| 164 | Palmae | Borassus flabellifer | Building, thatching, edible |
| 165 | Palmae | Corypha umbraculifera | Ornamental, thatching |
| 166 | Palmae | Phoenix loureirii | |
| 167 | Palmae | Phoenix sylvestris | Edible |
| 168 | Pandanaceae | Pandanus odoratissimus | Medicinal, hedge, edible |
| 169 | Passifloraceae | Passiflora foetida | |
| 170 | Plumbaginaceae | Plumbago Zeylanica | Medicinal |
| 171 | Polygalaceae | Polygala arvensis | |
| 172 | Polygalaceae | Polygla Javana | |
| 173 | Portulacaceae | Portulaca oleracea | |
| 174 | Rhamnaceae | Zizyphys mauritiana | |
| 175 | Rhamnaceae | Zizyphus oenoplia | |
| 176 | Rhamnaceae | Ziziphus xylopyrus | Fodder fencing |
| 178 | Rubiaceae | Benkara malabarica | |
| 179 | Rubiaceae | Borreria sp. | Fencing |
| 180 | Rubiaceae | Canthium parviflorum | |
| 181 | Rubiaceae | Ixora paverra | |
| 182 | Rubiaceae | Morinda coreia | |
| 183 | Rubiaceae | Oldenlandia sp. | |
| 184 | Rubiaceae | Pavetta indica | |
| 185 | Rubiaceae | Randia brandisii | |
| 186 | Rubiaceae | Randia dumetorum | Fencing, hedge |
| 187 | Rubiaceae | Randia malabarica | |

| | Family | Species | Significance / utility |
|---|---|---|---|
| 188 | Rubiaceae | Spermacoce hispida | |
| 189 | Rubiaceae | Tarenna asiatica | |
| 190 | Rutaceae | Atalantia monophylla | |
| 191 | Rutaceae | Citrus sp. | |
| 192 | Rutaceae | Clausena dentate | |
| 193 | Rutaceae | Glycosmis mauritiana | |
| 194 | Rutaceae | Toddalia asiatica | |
| 195 | Sapindaceae | Allophyllus serratus | |
| 196 | Sapindaceae | Cardiospermum halicacabum | |
| 197 | Sapindaceae | Dodonaea Viscosa | Hedge |
| 198 | Sapindaceae | Lepisanthes tetraphyalla | |
| 199 | Sapindaceae | Sapindus emarginata | Soap |
| 200 | Sapotraceae | Madhuca longifolia | |
| 201 | Scrophulariaceae | Lindernia sp. | |
| 202 | Scrophulariaceae | Striga asiatica | |
| 203 | Solanaceae | Datura metel . | |
| 204 | Solanaceae | Solanum surattense | |
| 205 | Solanaceae | Solanum sp. | |
| 206 | Sterculiaceae | Pterospermum suberifolium | |
| 207 | Sterculiaceae | Waltheria indica | |
| 208 | Tiliaceae | Corchorus sp. | |
| 209 | Tiliaceae | Grewia tenax | |
| 210 | Typhaceae | Typha angustata | |
| 211 | Verbenaceae | Gmelina asiatica | Fencing |
| 212 | Verbenaceae | Lantana Camara | |
| 213 | Verbenaceae | Phyla nodiflora | |
| 214 | Verbenaceae | Stachytarpheta | |

| | Family | Species | Significance / utility |
|---|---|---|---|
| | | Jamaicensis | |
| 215 | Verbenaceae | Viter | |
| 216 | Violaceae | Hybanthes enneaspermus | |
| 217 | Vitaceae | Cissus quadrangularis | |
| 218 | Vitaceae | Cissus setosa | |
| 219 | Vitaceae | Cissus vitiginea | |
| 220 | Zygophyllaceae | Tribulus terrestris | |

The ornamental plants commonly encountered during the study were: Agave americana, Gamphrena globosa, Fistula sp, and Corypha umbraculifera.

Among the plants of medicinal importance the following are the most common: Jatropa curcasa, Phyllanthus rotundifolins, Tamarindus indica, Azadirachta indica, and Pandanus odoratissimus.

### *5.2.1 Arborescent species*

This comprises essentially the trees planted on the bunds of rice fields such as *Borassus flabellifer* (Palmyra palm); *Acacia arabica* (Babul tree) - a spiny evergreen tree with black bark, generally adapts well to the soils saturated with water; a few plantations of *Casuarina sp.* scattered here and there amidst rice fields and towards the northeast of Oussudu lake; and C*ocus nucifera,* the coconut palm.

*a. The avenue trees*

The most common avenue trees, that were planted along the road side are: *Enterolobium samen, Morinda sp, Acacia sp., Bombax mori; Cansjera rheedi* and *Delonix regia.* Here and there one could also notice a few trees of *Ficus benghalensis,* (banyan tree), *Ficus religiosa* (peepal tree), and *ficus hispida*.

*b. Shrubs*

Among the shrubs *Stachytarpheta sp.* and *Proscopis juliflora* represent wetland types growing in the damp environment. Species such as *Achyranthus aspera*, *Zizyphus sp.*, *Hyptis suaveolens*, *Croton bonplandianum*, *Calotropis prosera*, *Jatropa gossipifolia* and *Lantana camara*, are the shrubs which generally grow abundantly in the wastelands. Usually these plants are found scattered along the bunds.

A special mention maybe made of the presence of certain unique species such as *Waltheria indica* and *Abutilon indicum*, the aggressive colonizers of disturbed grounds and fallow lands. Also, one can find *Ipomea sp.*, the terrestrial and aquatic weed spreading about 60% of the lake.

*c. Herbaceous Vegetation*

*Boerhavia sp., Coldenia procumbens, Cleome viscosa, Phyllanthus amarus*, and *Ammonia baccifera* are the hygroscopic herbaceous species which prefer the soils with mild moisture in and around the lake.

The presence of *Eclipta alba* - the perennial herb which colonizes arable clay soils, *Chrozophora rottleri, Argemone mexicana, Tridax procumbens, Leucus aspera, Phyllanthus amaras, Aerva lantana*, *Phyla nodiflora*, and *Parthenium sp.*, are indicative of the disturbed nature of the lake bed. Most of these are weeds colonize arable and fallow lands.

### *5.2.2 Hydrophytes*

The area is found to be heavily infested with *Ceratophyllum demersum* and *Hydrilla verticillata* – two of the world's most dominant submersed weeds. The weeds form such dense mats in some parts of Ousteri that it is impossible to cast dragnets for capturing fishes.

The species, *Ceratophyllum*, was the most widespread and present at all the sites (Table 7, Figure 35). The fresh weight of this species varied between 268 g $m^{-2}$ and 2576 g $m^{-2}$, with an average of 999 g $m^{-2}$. The dry weight varied between 31 g $m^{-2}$ and 317 g $m^{-2}$, with an average of 122 g $m^{-2}$ . The moisture content, with respect to fresh weight, varied between 89.4% and 87.67%, with an average of 88.1%.

Like *Ranuncules*, *Nymphea*, and *Vallisneria*, *Ceratophyllum* is known to precipitate lime. Also, this species is capable of utilizing bicarbonate ions as a source of carbon (Gupta, 1987).
The other aquatic weed, *Hydrilla verticillata*, was found at the sites M1 and M2 (Table 7, and Figure 35). The fresh weight of the species varied between 5 g $m^{-2}$ and 676 g $m^{-2}$, with an average of 340 g $m^{-2}$. The dry weight varied between 0.75 g $m^{-2}$ and 74 g $m^{-2}$, with an average of 37 g $m^{-2}$. The moisture content, with respect to fresh weight, varied between 85.6% and 89.07%, with an average of 87.3% .

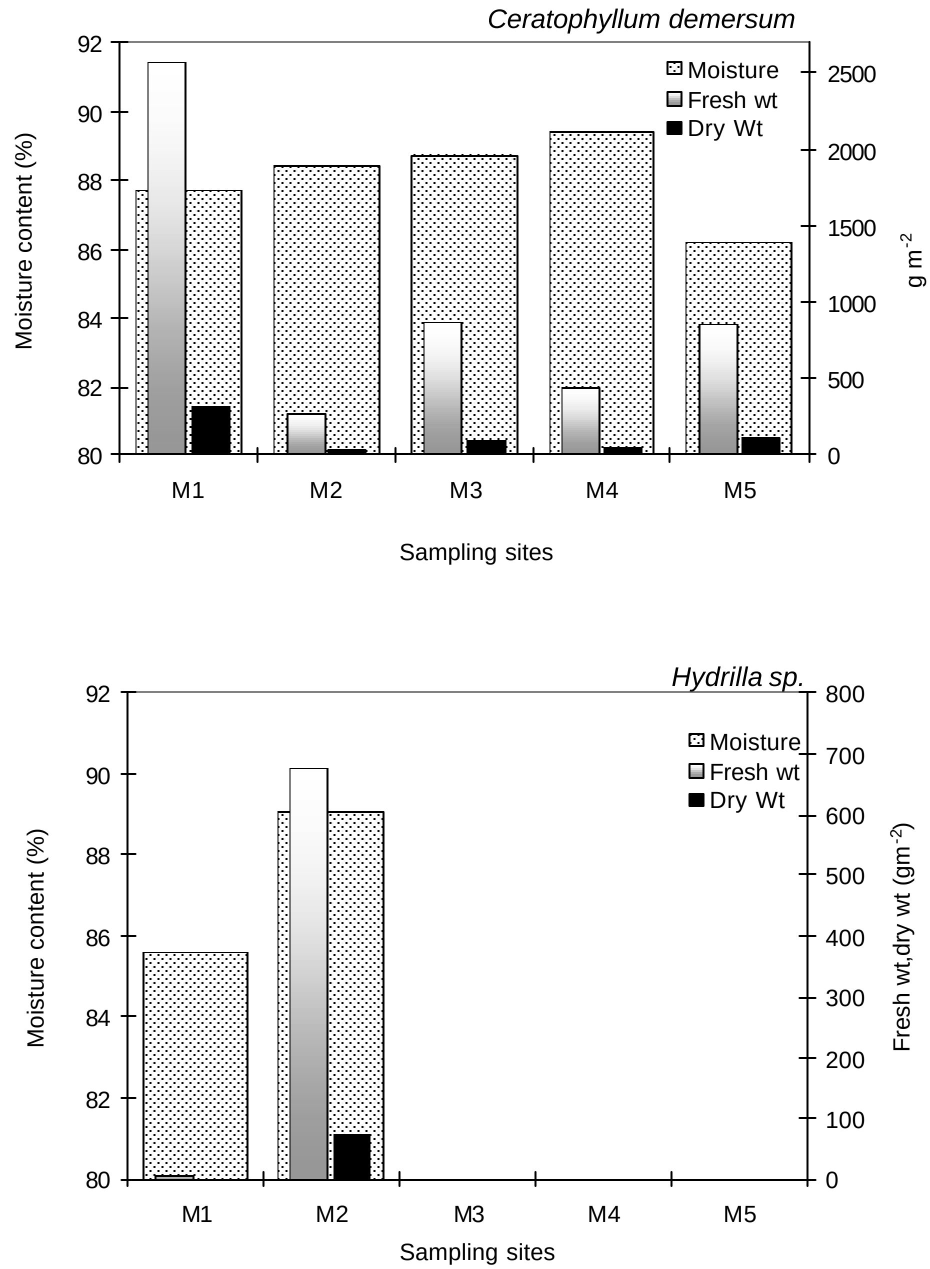



**Figure 35: The distribution of the macrophytes, *Ceratophyllum sp.* and *Hydrilla sp.*, at various sites**

*Hydrilla*, due to its low light compensation, 10 -12 Einsteins $m^{-2}$ $sec^{-1}$, is known to grow even at depths where no other plant life is known to occur in the aquatic habitats (Gupta, 1987). Hence, the spread of *Hydrilla* showed a positive correlation with the water depth of the lake.

The mixed phytomass sample collected at site M3, weighed 555 g $m^{-2}$ when fresh, and 61 g $m^{-2}$, when oven-dried. The moisture content measured 89% of the fresh weight. According to the remote sensing and GIS studies carried out, *Ipomoea* covered 1.16 $Km^{2}$, which is 14% of the land-cover of Oussudu lake.

The presence of rampaging mats of terrestrial and aquatic weeds in Oussudu indicates that the lake is highly polluted and is, as a result, becoming eutrophic or 'obese' (Abbasi, 1997; Chari, 1997, 1998;).

### *5.2.3 Grasses*

Among grasses, few species whose presence is noteworthy are: rushes such as *Eleocharis sp.*, and S*cirpus lacustrus;* culms such as *Arundo dondax*, the reed like erect herb; *Cynodon dactylon*, the most frequently encountered common grass in the arable and fallow lands; and *Sporobolous diander.*

## 5.3 THE FAUNA

During the study period, 54 species of birds were identified belonging to 22 families (Table 8). Most of the species were represented by Anatidae (10 species), Aradeidae (eight species), Charadridae (four species) and Accipitridae (four species). Twenty-four species are local migrants, representing 45% of the total (Figure 36). Of these, the waterfowl are represented by only two species: spot-billed duck (Anas poecilorhyncha) and mallard (Anas platyrhnchos).

The migratory birds are represented mostly by geese and ducks (seven species), sandpipers (one species) and raptors (one species). Some birds such as fantail snipe, stints, plovers, lapwing and sandpipers come to Oussudu from as far away as Africa and Northern Europe (Abbasi, 1997). The most frequent migratory species is northern pintail (Anas acuta), sighted throughout the study period. The less frequent visitors are northern shovelor (Anas clypeata) sighted in January 1993, tufted duck (Aythya fugila) and pale marsh harrier (Circus macrourus) sighted in 1994, and wood sandpiper (Tringa glareola) sighted in 1995. Of the migratory species, the common pochard (Aythya ferna) is more abundant in Northern India, but less so in Eastern and Southern India (Ali, 1996).

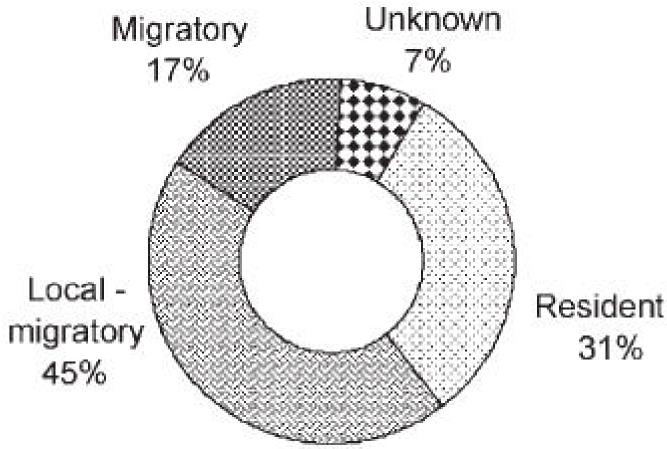



**Figure 36: Locational status of the Oussudu bird community. The 'local-migratory' refers to the birds that migrate within the geographical limits of India; 'unknown', refers to the birds that could not be identified during the study.**

In terms of abundance, the Eurasian wigeon (Anas penelope) outscores all other species (an average of 1117 individuals were sighted each year).

Birds of prey found in the area include the common paraiah kite (Milvus migrans) and the brahmini kite (Haliaster indus). There is a rich variety of small birds of open plains such as pale marsh harrier (Circus macrourus), pied koel (Eudynamus scolopacea), common myna (Acridotheres tristis), black drongo (Dicrurus adsimilis), spotted dove (Streptopelia chinensis), red-vented bulbul (Pycnonotus cafer), palm swift (Cypsiurus parvus) associated with palmyra palm, and skylark (Alauda gulgula). The water level and the availability of exposed ground in the middle of the water seems to be a major influencing factor for the spatial and temporal occurrence of several species of birds. High water levels (41.9 m), favour geese and ducks, and to some extent rails and gullinules. Lower water levels favor birds such as gulls, terns and skimmers, herons and egrets, grebes and storks.

**Table 8: Bird counts of Oussudu**

| | Jan '93 | Mar '94 | Jan '95 | Jan '96 | Jan |
|---|---|---|---|---|---|
| **GREBES** | | | | | |
| Little grebe *Tachybaptus ruficollis* | 936 | 72 | 91 | 331 | 76 |
| Unidentified grebes | — | 20 | — | — | — |
| **CORMORANTS** | | | | | |
| Little cormorant *Phalocrocorax niger* | 81 | 517 | 752 | — | 7 |
| Great cormorant *Phalacrocorax carbo* | — | 1 | — | — | — |
| **HERONS & EGRETS** | | | | | |
| Indian pond heron *Ardeola grayii* | 195 | 145 | 491 | 86 | 171 |
| Cattle egret *Bubulcus ibis* | 48 | — | — | — | — |
| Little egret *Egretta garzetta* | 110 | 123 | 236 | 457 | 10[illegible] |
| Intermediate (smaller) egret *Egretta intermedia* | 282 | 242 | — | 172 | 93 |
| Great egret *Egretta alba* | 135 | — | — | 68 | — |
| Grey heron *Ardea cinerea* | 12 | — | 2 | — | — |
| Striated (little green) heron *Butorides striatus* | — | 7 | — | — | — |
| Unidentified herons and egrets | 43 | — | — | — | 32 |
| **STORKS** | | | | | |
| Asian openbill *Anastomus oscitans* | 389 | — | 153 | 292 | — |
| **GEESE & DUCKS** | | | | | |
| Indian cotton teal *Nettapus coromandelianus* | 141 | 203 | 843 | 52 | 67 |
| Eurasian wigeon *Anas penelope* | 3295 | 362 | 1786 | — | 14[illegible] |
| Gadwall *Anas strepera* | 346 | 244 | 1038 | — | — |
| Mallard *Anas platyrhynchos* | 3176 | — | 740 | 76 | — |
| Northern pintail *Anas acuta* | 52 | 2419 | 1420 | 4 | 21 |
| Spot-billed duck *Anas poecilorhyncha* | — | — | — | — | 42 |
| Northern shoveler *Anas clypeata* | 336 | — | — | — | — |
| Garganey *Anas querquedula* | — | 670 | — | — | 4 |
| Common pochard *Aythya ferina* | — | 1713 | 1943 | — | — |
| Tufted duck *Aythya fugila* | — | 1455 | | — | — |
| Unidentified ducks | — | 462 | 894 | — | — |

| | Jan '93 | Mar '94 | Jan '95 | Jan '96 | Jan |
|---|---|---|---|---|---|
| **RAILS, MOORHENS & COOTS** | | | | | |
| White-breasted waterhen | | | | | |
| *Amaurornis phoenicurus* | — | — | 52 | — | — |
| Moorhen | | | | | |
| *Gallinula chloropus* | — | — | 1763 | — | — |
| Purple swamphen | | | | | |
| *Porphyrio porphyrio* | — | — | — | 3 | — |
| Common coot | | | | | |
| *Fulica atra* | 442 | 342 | 870 | 30 | 246 |
| **JACANAS** | | | | | |
| Pheasant-tailed jacana | | | | | |
| *Hydrophasianus chirurgus* | 62 | — | — | 6 | 14 |
| **PLOVERS & LAPWINGS** | | | | | |
| Little ringed plover | | | | | |
| *Charadrius dubius* | — | — | — | — | 23 |
| Common snipe | | | | | |
| *Gallinago gallinago* | — | — | 39 | — | — |
| Red-wattled lapwing | | | | | |
| *Vanellus cinereus* | 187 | 94 | 89 | 102 | 28 |
| Little stint | | | | | |
| *Calidris minuta* | 381 | - | - | 12 | 36 |
| Black-winged stilt | | | | | |
| *Himantopus himantopus* | 150 | - | 97 | 71 | 47 |
| **SANDPIPERS** | | | | | |
| Common sandpiper | | | | | |
| *Actitis hypoluecos* | — | 217 | — | — | 46 |
| Wood sandpiper | | | | | |
| *Tringa glareola* | — | — | 54 | — | - |
| Unidentified sandpipers | — | — | — | — | 247 |
| **TERNS** | | | | | |
| Whiskered tern | | | | | |
| *Chlidonias hybridus* | 1840 | 504 | - | 122 | 642 |
| Little tern | | | | | |
| *Sterna albifrons* | — | — | 843 | — | — |
| **KINGFISHERS** | | | | | |
| White breasted kingfisher | | | | | |
| *Halcyon smyrnensis* | 54 | — | — | — | — |
| Small blue king fisher | | | | | |
| *Alcedo atthis* | 8 | — | — | — | — |
| **RAPTORS** | | | | | |
| Black-winged kite | | | | | |
| *Elanus caeruleus* | 4 | — | — | — | — |
| Paraiah kite | | | | | |
| *Milvus migrans* | 24 | — | 7 | 36 | — |
| Brahminy kite | | | | | |
| *Haliaster indus* | 14 | — | 2 | — | — |
| Pale marsh harrier | | | | | |
| *Circus macrourus* | — | — | 4 | — | — |

| | Jan '93 | Mar '94 | Jan '95 | Jan '96 | Jan '97 |
|---|---|---|---|---|---|
| **OTHERS** | | | | | |
| Green bee-eater | | | | | |
| *Merops orientalis* | 144 | — | — | — | — |
| Eastern sky lark | | | | | |
| *Alauda gulgula* | 188 | — | — | — | — |
| Palm swift | | | | | |
| *Cypsiurus parvus* | 243 | — | — | — | — |
| Yellow wagtail | | | | | |
| *Motocilla flava* | 8 | — | — | — | — |
| Red-vented bulbul | | | | | |
| *Pycnonotus cafer* | 16 | — | — | — | — |
| Spotted dove | | | | | |
| *Streptopelia chinensis* | 19 | — | — | — | — |
| Black drongo | | | | | |
| *Dicrurus adsimilis* | 24 | — | — | — | — |
| Common mynah | | | | | |
| *Acridotheres tristis* | 47 | — | — | — | — |
| Pied koel | | | | | |
| *Eudynamys scolopacea* | 2 | — | — | — | — |

# 6
# AIR ENVIRONMENT

## 6.1 AMBIENT AIR QUALITY MONITORING

Ambient air quality was assessed by setting up a network of 5 air quality monitoring stations. These were at the project site, and at distances 1 Km from the project site in four directions – north, south, east, and west (Table 9.

High volume air samplers were set up as per standard norms and three consecutive 8 hr samples were taken in each assessment. A total of 11 assessments comprising of 264 hours of high volume air sampling were made (Table 9).

The area being dominated by Oussudu lake, the air quality is by-and-large very good. All the samples had air pollutants well within the limits set for industrial and residential areas by the Central Pollution Control Board (CPCB; Table 10). As a hospital is being put up at the project site, the site comes under ‘sensitive’ category. For this category of location, the $SO_x$ and $NO_x$ values are well within the limits of 30 $\mu g/m^3$. The SPM is also within the limits of 100 $\mu/m^3$ but is close to, or just about exceeding, this limit (Table 9). Hence utmost care will be needed to keep the project site dust free and with lots of trees to prevent the SPM from exceeding its limit.

**Table 9:Ambient air quality at and around the proposed site (Average of 3 consecutive 8 hr samples)**

| *Station* | | *SPM* | *$SO_x$* | *$NO_x$* |
|---|---|---|---|---|
| Project Site | Assessment I | 99.9 | 10.8 | 9.9 |
| | Assessment II | 100.5 | 8.3 | 12.6 |
| | Assessment III | 96.4 | 9.7 | 10.3 |
| One Km north | Assessment I | 123 | 16.5 | 8.8 |
| | Assessment II | 127 | 21.2 | 13.8 |
| One Km south | Assessment I | 106.5 | 9.6 | 10.5 |
| | Assessment I | 117.2 | 9.2 | 12.3 |
| One Km east | Assessment I | 133 | 19.6 | 15.8 |
| | Assessment II | 85 | 20.3 | 13.7 |
| One Km west | Assessment I | 129 | 11.8 | 9.4 |
| | Assessment II | 115 | 13.6 | 11.3 |

**Table 10: Maximum permissible levels of air pollutants as per CPCB norms**

| Type of location | Permissible limits, $\mu g/m^3$ | | |
|---|---|---|---|
| | $SO_x$ | $NO_x$ | SPM |
| Industrial | 120 | 120 | 500 |
| Residential | 80 | 80 | 200 |
| Sensitive | 30 | 30 | 100 |

# 7
# THE ENVIRONMENTAL MANAGEMENT PLAN

## 7.1 WATER REQUIREMENT

As the proposed project includes a medical college which will admit about 150 students per year, its resource requirements would grow rapidly during the first five years as new classes and staff would be added till a relatively steady state would reach after about 5 years.

The permission now available to the Trust is to draw 76.5 $m^3$ of water per day. After about 5 years the water requirements per day would be as follows; these have been computed on the basis of the guidelines of the Government of India (*Manual on Water Supply and Treatment*, Ministry of Urban Development, Government of India):

1. Hospital @ 450 litres/day per bed, 300 beds : 135 $m^3$
2. College (assuming only day population, no hostels or quarters)
   - 750 students @ 45 litres/day : 33.75 $m^3$
   - 150 staff @ 45 litres/day : 6.75 $m^3$

3. Residential staff (assuming that 150 persons may be residing in the campus by the fifth year, inclusive of nursing, watch-and-ward, night duty doctors)

| | |
|---|---|
| 150 staff @ 135 litres/day | : 20.25 $m^3$ |
| Total | :195.75 $m^3$, per day |

Thus it is realistic to plan for a water availability of 200 $m^3$/day, and a wastewater treatment plant of 0.8 times this flow (as per GOI norms) i.e., 160 $m^3$.

## 7.2 NEED FOR AUGMENTING AND ENHANCING WATER USE

As the water requirement, when the institution reaches its peak capacity, is of the order of 200 $m^3$ per day as against the initial provision of only 76.5 $m^3$, the institution would need auxiliary water supply in the years to come.

In addition, the institution would need to harvest all the rainwater that falls on its 26 acre campus besides reusing its water to the maximum.

But there are limits to both getting an auxiliary supply and on harvesting/reuse. Hence the institution would need to take great care in its water management programme.

## 7.3 REUSE STRATEGY

### *7.3.1 Use of sprinkler and drip irrigation systems and provision for ground water recharge*

As nearly 160 $m^3$ of treated water would be generated each day, only a fraction of it can be realistically used for gardening. Indeed, by use of wastage-saving sprinklers and drip irrigation devices the institution is required to reduce wastage of treated water for gardening purpose. Further, the terrain needs to be prepared so that the water used for gardening also contributes to groundwater recharge.

### *7.3.2 Separate overhead tanks and disposal lines for the use of treated water*

The remaining treated water should be fully utilized in toilet flushing. To achieve this, separate overhead tanks and connections need to be installed so that only the water coming out of the treatment plant is used for this purpose.

## 7.4 RAINWATER HARVESTING

### *7.4.1 Rooftop harvesting*

The entire rooftop area should be so designed so that it maximizes rainwater harvesting and directs the harvest to filters and then to collection sumps. Arrangements should also be in place to either pump the harvested water to the tanks made for the storage/distribution of reuse water, or for turbidity removal plus disinfection so that it can be used for drinking and cleaning.

### *7.4.2 Collection of surface run off*

The terrain of the entire campus should be prepared so that the run off is channelized to suitable located ponds and lined tanks. This water may also be coagulated – filtered and disinfected for use as freshwater.

If these measures are taken carefully and implemented properly, it may be possible for the institution to run with even less than the presently permitted groundwater withdrawal. This is indicated by the following calculation.

*1. Rainwater that can be realistically utilizable with rooftop collection*

Total built area (6 acre) : 24281 $m^2$
Average annual rainfall : 2.1 m
Utilizable harvested water (20% of the rooftop catch) : 10200 $m^3$/year or ~46.5 $m^3$/day

*2. Rainwater that can be realistically utilizable with surface collection*

Total catchments (20 acres) : 80940 $m^3$
Average annual rainfall : 2.1 m
Utilizable harvested water (10% of the surface catch) : 16997 $m^3$/year or ~26.5 $m^3$/day

Thus, at least 73 $m^3$/day of water can be obtained by meticulous rainwater harvesting. Further, by proper catchment management, much of the un-harvested rainfall can be directed for groundwater recharge.

### *7.4.3 Treatment*

Therefore installation should be made to treat harvested rainwater with the following, for eventual use in drinking, cooking, cleaning, etc:

a) coagulation
b) filtration
c) disinfection

## 7.5 WASTEWATER TREATMENT SYSTEM

The quantity of wastewater estimated to be generated from the proposed hospital-cum-college is 160 $m^3$/day (Section 7.1). The wastewater is expected to have the following characteristics:

BOD : 200-300 mg/l

COD : 300-750 mg/l

SS : 100-350 mg/l

The wastewater is to be treated to such levels so as to make it fit for use for gardening and for flushing toilets. It should be brought to a COD of 30 mg/l or lesser. The treatment plant should accordingly consist of the following steps (Figure 37):

### *7.5.1 Screen*

The screens should be capable of removing floating debris and other coarse material typically found in sewage. This would prevent clogging of pipes and damage to downstream equipment such as pumps.

### *7.5.2 Equalization tank*

An equalization tank should be provided to ensure near-constant flow-rate in order to overcome the operational problems that are caused by flow-rate variations.

### *7.5.3 Primary sedimentation unit*

A typical circular primary sedimentation tank may be employed for the removal of the readily settable solids from the sewage.

### *7.5.4 Biological treatment unit*

The biodegradation of the organic matter content may be carried out by using either the activated sludge process or a rotating biological contactor, depending on the space and power considerations.

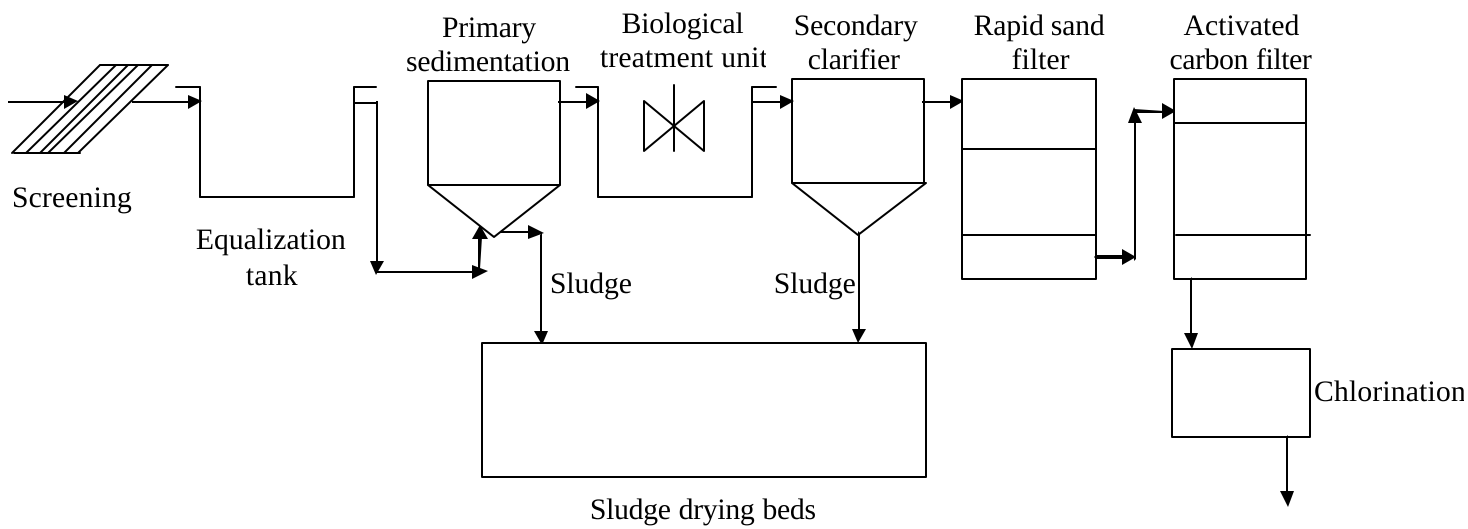



**Figure 37: Layout of the proposed waste-water treatment system**

### *7.5.5 Secondary clarifier*

A lamella clarifier may be used to settle the biomass contained in the effluent from the biological treatment unit. The sludge from this unit should be sent to the sludge drying beds. The dried sludge may be composted and used as manure in the gardens.

### *7.5.6 Rapid sand filter*

The remaining suspended solids in the wastewater have to be removed by passing the wastewater through the rapid sand filter.

### *7.5.7 Activated carbon filter*

This unit is essential for removing the colour and odour from the wastewater, along with removal of the remaining biodegradable and non-biodegradable organics and heavy metals that may be present.

### *7.5.8 Chlorination*

The treated wastewater should be disinfected by chlorination.

### *7.5.9 Control of total dissolved solids and hardness in recycled water*

As it is proposed to reuse the treated water, build-up of total dissolved solids (TDS) and hardness may occur with each reuse cycle. The institution should, therefore, periodically monitor the TDS and hardness of the water being reused and keep it within limits by augmenting it with softened and de-ionised water as and when necessary.

## 7.6 AIR POLLUTION CONTROL

### *7.6.1 From the incinerator*

There will be two sources of air pollution during the operation of the incinerator. One would be the emission of $SO_x$, $CO_x$ and $NO_x$ due to the use of diesel at the rate of 8 to 10 litres per hour of operation; the other would be the combustion products of the hazardous medical wastes. The incinerator should be equipped with appropriate air pollution control devices (scrubbers, adsorbers, catalytic converters etc.) to handle dioxins, furans, and such other highly toxic micro constituents of incinerator exhaust. The treated gaseous emissions should be discharged from stacks at least 30 m high.

### *7.6.2 From the generator*

The Trust proposes to use a 120 HP diesel-based generator; another generator of identical capacity is proposed to be kept as a permanent standby.

The generator is rated to consume 16-18 litre of diesel per hour. This is equivalent to diesel consumption by 3-4 buses per hour. Considering that the location is a 'sensitive area' (as detailed in Chapter 6) and the $SO_x$ and $NO_x$ levels must be kept below 30 $\mu g/m^3$, the Trust should install a scrubber and a catalytic converter before directing the exhaust through a 30 m tall stack to ensure that $SO_x$ and $NO_x$ levels at the point of exit of the generator exhaust are well below 30 $\mu g/m^3$. The $CO_x$ levels should also be accordingly controlled.

## 7.7 BIO-MEDICAL (HAZARDOUS) WASTES

There are two categories of solid waste which would be generated at the hospital – the typical solid wastes generated in an institution and the hazardous bio-medical wastes.

The bio-medical wastes will be collected, segregated and disposed as per the specifications of Bio-medical Waste (management and handling) Rules, 1998.

The medical wastes will be burnt in the hospital incinerator. The diesel-fired incinerator has a capacity of 100 kg. A schematic diagram of the incinerator is presented in Figure 38. The incinerator bottoms (ash and un-burnt wastes), which are hazardous, are to be collected and stored onsite till they can be transferred to the government hazardous waste disposal site which is due to come up.

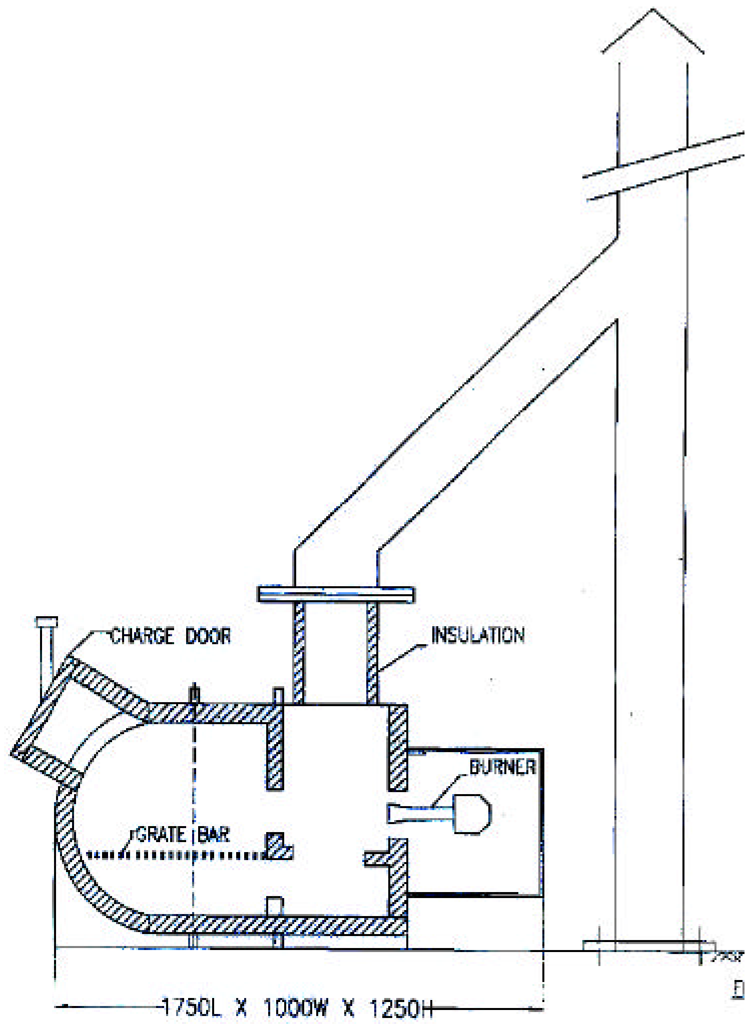



**Figure 38: Schematic of the incinerator**

## 7.8 MANAGEMENT OF TYPICAL SOLID WASTES

The total amount of typical solid wastes (~0.3 kg per person per day, consisting of paper, food, kitchen wastes, clothing etc) generated in the proposed institution would be ~225 kg/day. The waste would have to be segregated into compostible and non-compostible fractions. The compostibles may include kitchen wastes, food wastes, paper, and vegetation. These will be composted on site. The composted waste should be used as fertilizer in the gardens. The non-compostible fraction, such as plastics, paper, metal parts, batteries, etc. would have to be collected and stored onsite till they can be transferred to the government hazardous waste disposal site which is due to come up.

## 7.9 NOISE MANAGEMENT

As detailed in Chapter 5, Ousteri lake continues to attract a large number of migratory birds of diverse species and the lake is due to be identified as a Heritage Site by the International Union for Conservation of Nature (IUCN). Hence it is imperative that during construction phase noise pollution is avoided by a) Doing the crushing and grinding operations well away from Ousteri, b)using only low-decibel machinery on site, and c) adapting other measures to absorb noise.

It is also recommended that multi-species trees are developed in the campus, (and not just Accacia, Casuarina or Eucalyptus) which will control particulates, attenuate noise to some extent, balance the micrometeorology of the area, and provide habitat for the avifauna.