CHAPTER III

STUDY AREA & METHODOLOGY
The Sagar district occupies a central position in the map of India, extending from 23°10' - 24°27' N and 78°04' - 79°21' E at an average elevation of 457.2 - 533.4 m above the mean sea level. It lies in the rocky terrain of Vindhyan system of pre-cambrian era and the Deccan trap volcanic series. The district headquarter Sagar (Hindi, Sagar = Sea) is situated a few kilometers north of Tropic of Cancer, at an average height of 517 m above MSL.

The district is yet virgin as far as heavy industrialization is concerned, and is well known for its 'bidi' industry, which does not play any direct role in the deterioration of water quality as its wastes are not dumped directly into the water bodies for disposal. The studies in the district gains further importance, since the investigations could give a clear insight into the natural process of ageing and deterioration along with the human interference, barring the pollutional loads of heavy industries. In the present studies an attempt has been made to identify the amount of human interference and the key elements which result in the deterioration of water bodies, and the search for means and methods to curb and check it. To achieve this goal investigations were done on water bodies namely Sagar lake, Mila reservoir and Chittora reservoir which exhibit different trophic level and stage of eutrophication, largely
<table>
<thead>
<tr>
<th>Parameter</th>
<th>SAGAR LAKE</th>
<th>PILA RESERVOIR</th>
<th>WILTON RESERVOIR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>23°50' N 78°45' E</td>
<td>24°16' N 79°02' E</td>
<td>23°50' N 78°35' E</td>
</tr>
<tr>
<td>Altitude</td>
<td>517 m</td>
<td>445 m</td>
<td>522 m</td>
</tr>
<tr>
<td>Water spread</td>
<td>81 ha</td>
<td>1073 ha</td>
<td>20 ha</td>
</tr>
<tr>
<td>Catchment area</td>
<td>1410 ha</td>
<td>14366.5 ha</td>
<td>-</td>
</tr>
<tr>
<td>Max. depth</td>
<td>5.5 m</td>
<td>27 m</td>
<td>4 m</td>
</tr>
<tr>
<td>Nature of the bottom</td>
<td>Soft, muddy &amp; covered with macrophytes</td>
<td>Hard &amp; stony with clay pockets</td>
<td>Muddy, stony bed near embankment</td>
</tr>
<tr>
<td>Lithology of the area</td>
<td>Deccan basalt &amp; Vindhyan quartzite</td>
<td>Sandstone (Bijawar series)</td>
<td>Deccan basalt</td>
</tr>
<tr>
<td>Nature of the catchment</td>
<td>Surrounded by roads &amp; settlements. (Red &amp; black soils)</td>
<td>Forested (yellow, red soils)</td>
<td>Agricultural (black soils)</td>
</tr>
<tr>
<td>Level of human interference</td>
<td>High</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Water use pattern in order of relative importance</td>
<td>Washing, bathing, irrigation, sewage disposal, fisheries</td>
<td>navigation, Aqua. culture, wallowing by cattle, fish culture</td>
<td>Drinking, irrigation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SAGAR LAKE
INDEX MAP

CHAINS

FURLONGS

10 0 1 2 3 4

S = SAMPLING STATION, F = FORT
H = HOSPITAL, B = BUS STAND
• = GHAT, ☼ = MACROPHYTES
:: = TRAPA CULTIVATION
F = FEEDING CHANNEL

Fig. 1
INDEX MAP
BILA RESERVOIR
(----- = 1 MILE)

PICKUP WEIR

BILA RIVER

DAM

WATER SPREAD AREA

CATCHMENT AREA

SAGAR-CHATAPUR

SAGAR ROAD

Fig. 2
differing in usage potential and catchment area, and having various degrees of human interference (Table 1).

**Sagar Lake**

The Sagar lake, situated in the heart of Sagar city (23°50' N and 78°45' E) at an height of 517 m above mean, once a large and beautiful lake has now reduced to a shallow and eutrophic water body heavily infested with macrophytes (Fig. 1). The old records show the area of the lake to be 580 ha, which has now shrunk to the size of 62 ha, that too, including 14 ha of shallow wetland area on the southern side. This wetland is connected with the main lake through a narrow passage in the earthen Rithoria bund.

The main lake is surrounded on all its sides except southern side with stony fencing wall and houses, interspersed by many ghats. With the city bus-stand at the eastern side, and human settlements and hospital etc. around, the lake is very much subjected to human interference.

The lake is rainfed, with comparatively a small catchment area of 1410 ha. The north-western drainage of the lake agrees with the general north-westward drainage pattern of the district (Mishra, 1969). The rain water enters the lake through the canal in the west. The excess water flows out through the 'Kongha' (weir) built on the western side, to increase the water storage capacity of the lake.
Regarding the origin of the lake, the controversy, as usual, exists. According to Thakur (1897), the lake is an artificial one, constructed by Lakha Banjara in the 16th century; while others believe it to be a natural lake, maintained artificially. The lake has been formed by the damming of the north-westward drainage of the basin by an elongate lunate shaped Vindhyan outcrop, lying west-northwest of the lake (Mishra, 1969).

The controversy regarding the origin of the lake may live, but there are no two opinions regarding the death of this water body, in course of time; unfortunately the rate of which is very fast. The deteriorated state of the water of the lake makes it hard to believe that only 30 years ago the water was used as potable water.

The major portion of the lake is very shallow with an average depth of 2 m; the maximum depth, at present, is a mere 5.5 m at the Fort side. The infestation of macrophytes is so great that the differentiation of littoral and limnetic zones, on the basis of macrophytic growth at times becomes very difficult.

As the Fisheries Department has stopped stocking fishes in the lake, the local fishermen had to turn towards the macrophytes for the source of income. A good amount of Iraca cultivation for 'singhara' and Nelumbo cultivation for 'murar'
and 'kamal getta' is being carried out in the lake. A large number of betel vine plantations are also located in the south-western shore of the lake. Besides this, the lake is used for bathing, washing clothes, navigation and recreation. A large number of cattles can be seen wallowing in the lake disturbing the sediments and adding to the deterioration of water body.

SIMLA RESERVOIR

The Simla project is a medium irrigation scheme across Simla river in Dhasan sub-basin of W.R. The Simla reservoir (24°16' N and 79°02' E) is situated at an average height of 445 m above MSL in Banda Tehsil of Sagar district. The dam site is near village Uhhan approachable by a 3 km long metalled road towards left of mile 36 of Sagar-Kanpur interprovincial highway (Fig. 2).

The Simla river starts from the water shed near the village Dalpatpura, which is in mile 27 of Sagar-Kanpur road. During its flow in the northernly direction, various nullahs enter it. The reservoir formed due to the damming of Simla river encompasses a water spread area of 1073 ha. The dam is of composite type, consisting of central masonry dam of 593 ft with earthen dam on both sides of it, the right flank 2156 ft long, while left 1950 ft long.

The basin formed of ancient Bundelkhand granites of Si jawar
Series, consists of mainly rocky wasteland and shrub and sparse jungle. The vast catchment area of 14,866.5 ha consists of mixed dry deciduous forest.

The water in this main reservoir can be released through mechanical weir-gate in the masonry dam, which is then stored in the weir dam, about 14 km downstream. The water for irrigation purposes is released through two canals via this weir dam. The irrigation potential of the reservoir is about 30,300 acres, of which the majority 19,600 acres is in Chhatarpur district.

The reservoir is quite young being completed in 1973, and has no marked littoral and limnetic regions. The reservoir is also used for fisheries, and quite an appreciable amount of fishes are harvested from its basin. *Catla catla* and *Labeo rohita* are among the main fishes stocked. Being in a remote area, earlier famous for dacoity, the reservoir was yet least subjected to human interference; so much so that earlier to the commencement of the present investigation it was still virgin as far as limnological investigations are concerned. But lately, due to the practice of wheat cultivation in the exposed basin of the reservoir during drier season, and scouring of the basins for sheets of sandstones for various purposes by the local inhabitants, the ecology of the reservoir is disturbed, and the effects are already being reflected in its water quality.
The reservoir is fully devoid of macrophytic vegetation and hence, the organic input is through the phytoplankton and from the catchment through the leaf litter.

CHITTURA

Chittora reservoir (23°30' N and 78°35' E) is situated about 16 Kms from Sagar, on the National Highway No. 26 towards Narsinghpur, at an height of 522 m above MSL (Fig. 3). It is a small stretch of water with a water spread area of 20 ha formed by impounding the Bewas river. The river Bewas is an important tributary of Sonar river, which flows into the river Yamuna through the river Ken, and originates near the hills of Sagar district. This small river both in respect to length and volume, flowing through comparatively plain area covered with black soil, is the only major source of potable water for the city of Sagar. Two more dams are built on the same river far downstream.

The water of this reservoir is pumped through the M.I.I. Pump-house, just above the anicut, and is supplied to the Cantonment area. The anicut is built of masonry with alternate open spaces, the sluice gates, and has two vertical slots in the masonry for wooden logs to be fitted and filled with mud and sand to check the water flow. As the wooden logs are removed during rainy season, and again fitted in early winter for storage of water, the depth is maximum during late winter
and early summer. The storage pattern shows its reflection in the water quality, hence the reservoir behaves quite differently from the others.

The catchment of the reservoir is typically agricultural and the run off along with the interaction of the people living in the nearby villages plays an upper hand in controlling the water quality.

Though macrophytes have not yet fully established themselves near the anicut, but occasional stands of *Nitella*, *Najas*, *Myriophyllum* etc. indicate to its presence somewhere upstream. The sides of the reservoir have a good growth of *Ipomoea fistulosa* at its margin for quite a long distance.

**METEOROLOGY**

The climate of Jager is generally pleasant, and can conveniently be divided into three seasons, viz., monsoon, winter and summer. Each season generally comprises of four months duration, with monsoon from July to October, winter from November to February and summer from March to June; though late monsoon and extended summers are not very uncommon and such discrepancy plays a havoc with the ecology of the place. The monthly variations in rainfall and temperature for the year 1982-83, when the present study was conducted, are presented in Table 2. The atmospheric temperature showed marked
<table>
<thead>
<tr>
<th></th>
<th>Rainfall</th>
<th>Temperature (°C)</th>
<th>Humidity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of rainy days</td>
<td>Rainfall (mm)</td>
<td>Mean min.</td>
</tr>
<tr>
<td>June</td>
<td>4</td>
<td>48.7</td>
<td>26.0</td>
</tr>
<tr>
<td>July</td>
<td>16</td>
<td>229.5</td>
<td>24.3</td>
</tr>
<tr>
<td>August</td>
<td>27</td>
<td>1065.0</td>
<td>22.4</td>
</tr>
<tr>
<td>September</td>
<td>8</td>
<td>149.0</td>
<td>22.2</td>
</tr>
<tr>
<td>October</td>
<td>2</td>
<td>7.4</td>
<td>21.4</td>
</tr>
<tr>
<td>November</td>
<td>5</td>
<td>81.3</td>
<td>16.5</td>
</tr>
<tr>
<td>December</td>
<td>2</td>
<td>1.8</td>
<td>13.9</td>
</tr>
<tr>
<td>January</td>
<td>1</td>
<td>14.5</td>
<td>10.8</td>
</tr>
<tr>
<td>February</td>
<td>0</td>
<td>0.0</td>
<td>12.0</td>
</tr>
<tr>
<td>March</td>
<td>1</td>
<td>0.5</td>
<td>18.4</td>
</tr>
<tr>
<td>April</td>
<td>0</td>
<td>0.0</td>
<td>21.8</td>
</tr>
<tr>
<td>May</td>
<td>4</td>
<td>7.3</td>
<td>25.7</td>
</tr>
<tr>
<td>June</td>
<td>9</td>
<td>111.5</td>
<td>25.7</td>
</tr>
</tbody>
</table>
variations, with maximum during the summer months and minimum during the winter. The mean maximum reached as high as 39.9°C during May, with the mean minimum reaching the lowest limit of 10.8°C during January. The rainfall as expected was maximum during monsoon with 66.36% of the total rainfall just within a month (August), with less than 5% of the total in other months barring the monsoon season. The sky is heavily clouded during the monsoon, with generally clear or lightly clouded sky during the rest of the year. Both during summer and monsoon strong winds were experienced with the difference that in summer the humidity was low (not exceeding 37%), whereas during rains the humidity increased up to 86%.

**Sampling Scheme**

The limnological studies, as far as physico-chemical parameters and primary production are concerned, were started at all the three sites from March 1982. After the preliminary field surveys, during which the standardization of the methods too was done, two stations in Sagar lake and one each at Dils and Chittora reservoirs were selected for detailed studies. The data presented in the present text relate to the observations from July 1982 to June 1983, which covers all the three seasons - monsoon, winter and summer. Of the two stations selected at Sagar lake, station I was in the
littoral zone near the due stand amidst dense growth of macrophytes; and station II was near the jagar fort and was the representative of limnetic waters (Fig. 1). As the water quality of different sampling points in the other two reservoirs was not markedly different and they did not have any macrophytic growth and as such distinct littoral zone did not exist; only one station each, at both the reservoirs was studied round the year. At Chittora reservoir the sampling station was selected near the anicut, while at Wila reservoir the station was fixed arbitrarily at the centre of the reservoir.

All the three sites were visited regularly once in a month, and the sampling was started between 1000 - 1030 hrs. The surface water was collected directly, while the bottom water was sampled with the help of Huttner's sampler (2½ l capacity).

A part of the sample was taken in a 250 ml bottle, with due care avoiding bubbles and immediately winklerized for oxygen determination. After preserving a part of the sample with chloroform for nutrient determination in the laboratory, a majority of chemical parameters were analysed at the spot within 30 minutes of collection. Prior to the various chemical analyses, Secchi transparency, air and water temperatures were noted down. Necessary precautions were taken during the sampling, analyses and transportation of the water samples.
WATER ANALYSES

The following methods were used to analyse the different physico-chemical parameters:

**Transparency:** The transparency of water was measured using a standard Secchi disc of 20 cm diameter, having alternate black and white quadrants on the upper surface. The disc was gradually lowered in the water with the help of a graduated rope till it disappears and then lifted up slowly till it reappears. The average of the depths of disappearance and reappearance of the disc was taken as Secchi transparency. To maintain uniform conditions, the Secchi was always dipped in the water on the shaded protected side of the boat.

**Temperature:** The temperature of the atmosphere and water was taken by a good grade mercury thermometer having a least count of 0.2°C and a range of 0 - 50°C, avoiding direct exposure of the mercury bulb to the direct sunlight.

**Hydrogen Ion-Concentration:** The pH of the water was measured colorimetrically in a Lovibond-pH comparator box using NDM Universal pH indicator.

**Dissolved Oxygen:** The dissolved oxygen content of the water was analysed using modified Winkler's method (Ayyar, 1976). The samples were collected in 250 ml Winkler's bottles and immediately Winklerized by adding 1 ml of MnO₄⁻ solution
followed by 1 ml of alkaline potassium iodide-oxide solution. The brown precipitate of manganese hydroxide formed by the reaction with dissolved oxygen, releases an equal amount of iodine on acidification, with concentrated sulphuric acid. The iodine so liberated was estimated titrimetrically with N/40 sodium thiosulphate solution, using starch as an indicator.

**Per cent Oxygen saturation**: It was calculated according to Wolterman (1969). The solubility of oxygen at different temperatures was calculated with the help of table given by Montgomery et al. (1964). These solubility values of oxygen were modified for altitudinal correction of atmospheric pressure by multiplying a constant factor (Jussart and Francis-Boeuf, 1949). The values so obtained were for the altitude of the study sites. From these values, per cent oxygen saturation was calculated by the following formula:

\[
\% \text{ Oxygen Saturation} = \frac{\text{Observed O.U.} \times 100}{\text{St}}
\]

where,

\[
\text{St} = \text{St} \times \text{Cf}
\]

\[
\text{St} = \text{solubility of O}_2 \text{ at the temperature 't' of water sample}
\]

\[
\text{Cf} = \text{altitudinal correction factor}
\]
**Free Carbon dioxide:** The free carbon dioxide content of water was analysed immediately after the collection by titrating the sample with \(\frac{1}{44} \text{NaOH}\) using phenolphthalein as an indicator.

**Carbonate and Bicarbonate Alkalinity:** For the estimation of alkalinity the water sample was titrated with \(\frac{1}{50} \text{H}_2\text{SO}_4\) solution, with phenolphthalein and methyl orange as indicators. The carbonate and bicarbonate alkalinity was calculated from the results of phenolphthalein and methyl orange titrations, by the method as given in *APHA* (1976).

**Total Carbon dioxide:** The total carbon dioxide was computed from the values of free carbon dioxide, carbonate and bicarbonate alkalinity by the following formula:

\[
\text{Total } \omega_2 \text{ mg l}^{-1} = \text{mg l}^{-1} \text{ free } \omega_2 + 0.8 \times (A + B)
\]

where,

\[
A = \text{mg l}^{-1} \text{ of bicarbonate alkalinity}
\]

\[
B = \frac{\text{mg l}^{-1} \text{ of carbonate alkalinity}}{2}
\]

**Chloride:** The chloride content was estimated by Mohr's argentometric method (*APHA*, 1976). The sample was titrated with 0.0141 N silver nitrate solution using potassium chromate as an indicator.
**Total Hardness:** The total hardness was analysed by Compleximetric titration method (AWWA, 1976). The sample was titrated with standard solution of disodium salt of EDTA, using Eriochrome Black-T as indicator.

**Calcium Hardness:** The calcium hardness was also analysed following the compleximetric titration method, with standard solution of di-sodium salt of EDTA, using murexide mixture as indicator.

**Magnesium:** The magnesium content was calculated as following:

\[ \text{mg l}^{-1} \text{ Mg} = \text{Total hardness} - \text{Calcium hardness} \times 0.243 \]

**Phosphate:** It was determined spectrophotometrically by stannous Chloride method (AWWA, 1976). 2 ml of ammonium molybdate reagent was added to 50 ml of water sample. Then 3 to 4 drops of freshly prepared stannous chloride solution was added, which produced blue colour after some time. The per cent transmittance was recorded at 690 u wavelength in spectrophotometer, after 10 minutes against a distilled water blank. The exact concentration was obtained on comparison with the standard curve prepared earlier.

**Nitrate:** The nitrate content was measured spectrophotometrically by phenoldisulphonic acid method (AWWA, 1976). For this, 50 ml of water sample was evaporated
in a conical flask and the residue so obtained was dissolved in 2 ml phenol disulphonic acid. Approximately 3 ml of strong alkaline solution (NH$_4$OH or 12N NaOH) was added to the flask to neutralize the acidity and the content was diluted to 10 ml.

The optical density at 410 nm wavelength was noted against the distilled water blank and compared with the standard curve, to get the values.

**Carbohydrate:** The carbohydrate content was measured spectrophotometrically, using anthrone method as described by Goltenman (1969). 5 ml of anthrone solution was added to 1 ml of sample and heated in boiling water (in a bath) for 15 minutes. The sample was then immediately cooled in running water, and the optical density noted at 620 nm wavelength against a distilled water blank, which gave the exact concentration on comparison with the standard curve.

**PRODUCTION STUDIES**

The 'in situ' primary production was estimated using the 'light and dark bottle' technique, first described by Gaarder and Gran (1927), of measuring the rate of change of dissolved oxygen (titrimetrically by the Winkler's method) in samples enclosed in glass bottles. Since they can be returned to the same depth, maintained at the same temperature
and receive the same illumination as the surrounding water, an approximation may be obtained of the natural production rate.

To assess the production potential of the water bodies, light and dark bottles filled with water samples, were suspended in the lake to measure the oxygen changes resulting from the metabolism of the plankton. The water from surface was filled in one dark bottle (darkened by E.V.C. black plastic tape fixed all around) and 2 light bottles. One of the light bottles was immediately winklerized for the measurement of initial concentration of oxygen in water. The other two, tightly stoppered, were hanged in the lake just below the surface with the help of a rope on a fixed bamboo pole. After the lapse of 24 hr period, the bottles were taken out and the oxygen content was measured. The gross oxygen production (G.O.P.), net oxygen production (N.O.P.) and community respiratory rate or community oxygen consumption (C.O.C.) were measured as follows:

\[
\text{G.O.P.} = \text{O}_2 \text{ light bottle} - \text{O}_2 \text{ dark bottle} \\
\text{N.O.P.} = \text{O}_2 \text{ light bottle} - \text{Initial } \text{O}_2 \\
\text{C.O.C.} = \text{Initial } \text{O}_2 - \text{O}_2 \text{ dark bottle}
\]

The respective values so obtained in \( \text{O}_2 \text{ mg l}^{-1} \text{ d}^{-1} \) were converted to gross primary production (G.P.P.), net primary production (N.P.P.) and community respiration (C.R.) in gC
\( m^{-3} d^{-1} \) by multiplying with the factor 0.375 (Westlake, 1965).

The methods and techniques employed for the decomposition studies and benthic analysis have been dealt with in the respective chapters.