Water quality index of Kolleru Lake with applications of remote sensing and GIS Techniques

Gogireddy Somireddy
Department of Civil Engineering
St.Mary's Group of Institution, Guntur
Somireddy109@gmail.com
Balakrishna Penta
Department of Civil Engineering
Andhra University, Visakhapatnam
balakrishna.penta@gmail.com
K.V.Satyam
Department of Civil Engineering
kuna.satyam@gmail.com

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Abstract- Groundwater samples were gathered from Kolleru Lake, Andhra Pradesh in India. Concentrations of various physicochemical parameters including pH, Electrical Conductivity (EC), Total Solids (TS), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Total Hardness, Calcium Hardness, Turbidity Magnesium Hardness, Chlorides, Dissolved Oxygen (DO), Alkalinity and Biological Oxygen Demand (BOD), were determined in leachate samples. The fixations of Cl-, NO3-, SO42-, NH4+ were found to be in considerable levels in the groundwater samples particularly near to the landfill site of Kolleru region. The effect of depth and distance of the well from the pollution source was also investigated. The presence of these parameters included conductivity, total dissolved solids (TDS), chlorides, sulfates, Mn and F in groundwater cautions for the groundwater quality and in this way renders the related aquifer inconsistent for local water supply and other uses. Although certain parameters exceeded the WHO and BIS limits. The outcomes recommended the requirement for adjusting factors improving anaerobic biodegradation that prompt leachate stabilization in addition to continuous observing of the groundwater and leachate treatment processes. The groundwater zones and surface water bodies (ponds) around the Kolleru are usually affected by landfill leachate. Consequently, diseases such as, diarrhea, hepatitis, vomiting, abdominal pain, dysentery etc. have been frequently occurring in majority of the people residing adjacent to Kolleru area. In the present study, considering the gravity of the situation, the effects of leachate percolation and dispersion have been studied on the surrounding groundwater and surface water courses of Kolleru closed landfill site of AP.

Keywords: Ground water pollution, Heavy metals, groundwater, Kolleru Lake

1. INTRODUCTION

The Kolleru Lake is the largest fresh water body in India, located between the deltas of two major rivers Godavari and Krishna in the state of Andhra Pradesh, with very rich and varied of flora and fauna. In November 1999, the Government of Andhra Pradesh had declared the lake as Bird Sanctuary under India's Wild Life (Protection) Act, 1972. The RAMSAR convention for the conservation and sustainable utilization of wetlands designated Kolleru Lake, in November 2002, as a wetland of international importance (www.answers.com, accessed on 11 may 2007). Water samples have been collected throughout the lake, of three months of the year. For each sampling we have collected 3 samples around the lake. Samples were collected according to procedures prescribed in UNESCO document. The collected samples were labelled properly indicating the exact position where the samples are collected at the lake. Some field measurements are also done at the lake itself (D.O, pH, etc.) and then the remaining samples are brought to the laboratory in the bottles and analyzed for parameters such as chlorides, BOD, and total solids, TDS were by determined by standard methods (APHA 1998).

2. STUDY AREA

The lake serves as a natural flood-balancing reservoir for Krishna and Godavari Rivers and is fed with several inflowing rivers, canals, streams and agricultural drains of which Budameru and Tammileru are the biggest (www.godavari.org, accessed on May 11, 2007). The lake discharges its excess water into the Bay of Bengal through a 72 km long out-flowing brackish water canal called Upputeru (uppu = salt, eru = canal). There are 46 island villages and 76 shoreline villages consisting of about two hundred thousand (200,000) inhabitants around the lake and the main occupations of the inhabitants are aquaculture, agriculture and duck farming (Anjaneyulu Y, 2003; Rama Raju T S, 2003; Alagarswami K, 1994). The lake serves as a habitat and good breeding and feeding ground for thousands of migratory birds during winter months (Anjaneyulu Y, 2003).

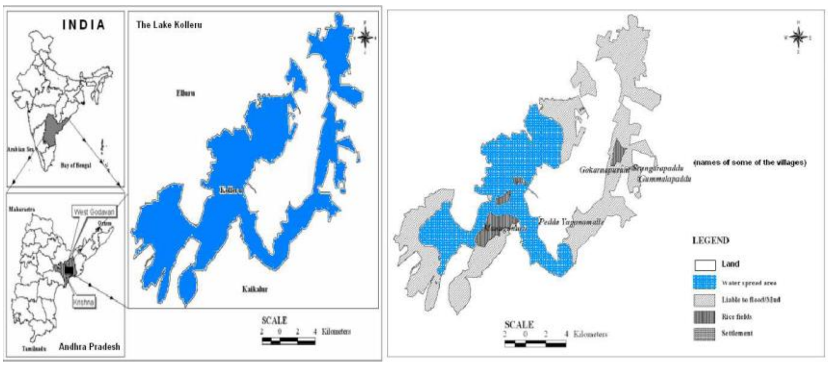

Fig.1 Location of Kolleru Lake in India Kolleru Lake land use map in 1967 (source: Marappan et.al.2006)

The status of the lake in 1967. Here the central part of the lake is covered with water (blue) (70.7 Km^2), remaining part as muddy ground (100.97 Km^2) which is liable to flood. However, a minor part of the lake is used for agriculture (8.4 Km^2) and human settlements (0.31 Km^2).

3. METRIALS and METHODS

Meteorologically the Kolleru basin falls under semi-arid climate class, with three seasons, namely summer, monsoon and winter. The basin enjoys rainfall from both southwest as well as northeast monsoons. The rainfall was found to vary widely across the years. The normal rainfall in the area is about 715 mm. Not mucvariation is seen in temperature across the seasons winter last for a period of three months (December – February) followed by summer, which lasts till June to mid-July. Dry situation have been reported frequently in the uplands of the basin due to failure or delayed monsoon. Similarly flood due to depression (in the Bay of Bengal) induced rainfall / storms are frequent in the basin generally during August to November

Scope

The present work is mainly to assess the impacts of pollution from domestic sewer lines and agricultural sources on physical chemical characteristics of water and also on soil sediments (Gavrilescu et al., 2015). The scope of work also includes GIS mapping for study area and physical, chemical analysis of water quality using Arc GIS 10.1 version (Aldaya et al., 2012). Study of other possible technologies to reduce the contamination in lake to promote sustainability in and around the study area (Mata et al., 2010).

Objective:

To access the physical and chemical analysis of kolleru lake water.

To identify the biological species and biological quality of lake water.

To conduct GIS mapping for physical, chemical analysis of water quality using Arc GIS 10.1 version.

4. ANALYSIS OF PHYSICAL AND CHEMICAL PARAMETERS

pH:

pH is governed by the equilibrium between carbon dioxide / bicarbonate / carbonate ions and ranges between 4.5 and 8.5 although mostly basic. It tends to increase during day largely due to the photosynthetic activity (consumption of carbon-di-oxide) and decreases during night due to respiratory activity. Wastewater and polluted natural waters have pH values lower or higher than 7 based on the nature of the pollutant.

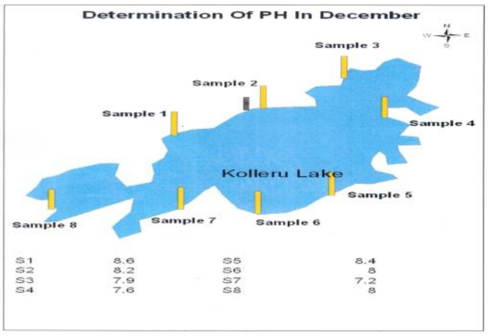

Fig.2 Determination of pH

Electrical Conductivity (EC)

Conductivity (specific conductance) is the numerical expression of the water's ability to conduct an electric current (Waxman and Smits 1968). It is measured in microsiemens per cm and depends on the total concentration, mobility, valence and the temperature of the solution of ions. Electrolytes in a solution disassociate into positive (cations) and negative (anions) ions and impart conductivity. Most dissolved inorganic substances are in the ionised form in water and contribute to conductance. The conductance of the samples gives rapid and practical estimate of the variation in dissolved mineral content of the water supply (Topp et al., 1980). Conductance is defined as the reciprocal of the resistance involved and expressed as mho or Siemen (s).

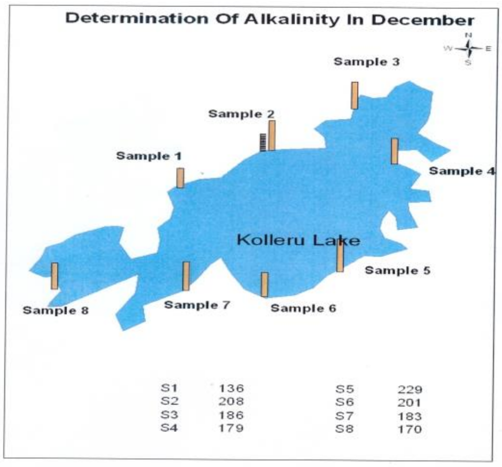

Fig.3 Determination of EC

Total Dissolved Solids

Dissolved solids are solids that are in dissolved state in solution. Waters with high dissolved solids generally are of inferior palatability and may induce an unfavourable physiological reaction in the transient consumer (Jothivenkatachalam et al., 2010).

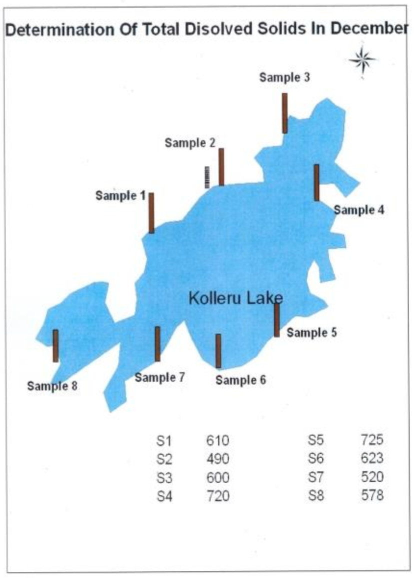

Fig.4 Determination of TDS

Total Suspended Solids

Suspended solids are the portions of solids that are retained on a filter of standard specified size (generally 2.0 µ) under specific conditions. Water with high-suspended solids is unsatisfactory for bathing, industrial and other purposes (Chapman and World Health Organization.1996).

Principle:

A well – mixed sample is filtered through a weighed standard glass fibre filter and the residue that is retained on the filter is dried to a constant weight at 103-105 ^{o}C. The increase in the weight of the filter determines the total suspended solids.

Procedure: The known volume of vigorously shaken sample (50ml) is filtered into a pre-weighed Porcelain dish, and Sample is dried for an hour at 103-105^{o}C in an oven, cooled in dessicator and weighed for constant weight.

Calculation:

$$\text{Total Suspended Solids (mg/l)} = \frac{(W1 - W2) \times (1000)}{\text{Sample volume (ml)}}$$

W_1 = Weight of dried glass fibre filter + residue, W_2 = Weight of glass fibre filter disk before filtering.

Total Hardness

Hardness is predominantly caused by divalent cat ions such as calcium, magnesium, alkaline earth metal such as iron, manganese, strontium, etc (Fakhru'l-Razi et al., 2009). The total hardness is defined as the sum of calcium and magnesium concentrations, both expressed as CaCO3 in mg/l. Carbonates and bicarbonates of calcium and magnesium cause temporary hardness. Sulphates and chlorides cause permanent hardness.

Calcium Hardness

The presence of calcium (fifth most abundant) in water results from passage through or over deposits of limestone, dolomite, gypsum and other calcium bearing rocks (Armienta et al., 2001). Calcium contributes to the total hardness of water and is an important micronutrient in aquatic environment and is especially needed in large quantities by molluscs and vertebrates. It is measured by EDTA titrimetric method. Small concentration of calcium carbonate prevents corrosion of metal pipes by laying down a protective coating. But increased amount of calcium precipitates on heating to form harmful scales in boilers, pipes and utensils (Shreir, 2013).

Calculation:

$$\text{Calcium hardness} \quad (\text{mg/l}) \text{ as CaCO3 } = \frac{\text{Normality of EDTA x T}}{\text{Volume of sample}}$$

Where, T = Volume of titrant consumed, V = Volume of sample

Magnesium Hardness

Magnesium is a relatively abundant element in the earth's crust, ranking eighth in abundance among the elements (Martin, 2006). It is found in all natural waters and its source lies in rocks, generally present in lower concentration than calcium. It is also an important element contributing to hardness and a necessary constituent of chlorophyll. Its concentration greater than 125 mg/l can influence cathartic and diuretic actions. High concentration of magnesium proves to be diuretic and laxative, and reduces the utility of water for domestic use while a concentration above 500 mg/l imparts an unpleasant taste to water and renders it unfit for drinking. Chemical softening, reverse osmosis and electro dialysis or ion exchange reduces the magnesium hardness to acceptable levels.

Principle:

Magnesium hardness can be calculated from the determined total hardness and calcium hardness.

Calculation:

Magnesium (mg/l) as $CaCo_3$ = Total hardness (mg/l) - Calcium hardness (mg/l)

Chlorides

The presence of chlorides in natural waters can mainly be attributed to dissolution of salt deposits in the form of ions (Cl^-). Otherwise, high concentrations may indicate pollution by sewage or some industrial wastes or intrusion of seawater or other saline water (Ghouili et al., 2018). It is the major form of inorganic anions in water for aquatic life. High chloride content has a deleterious effect on metallic pipes and structures, as well as agricultural plants. They are calculated by (Mohr's) *Argentometric method.*

Procedure:

A known volume of filtered sample (50ml) is taken in a conical flask, to which about 0.5ml of potassium chromate indicator is added and titrated against standard silver nitrate till silver dichromate ($AgCrO_4$) starts precipitating.

Calculation:

$$\text{Chlorides } (\text{Cl}-) = \frac{(\text{A}-\text{B}) \text{ x } (\text{N}) \text{ x } (35.45)}{\text{Sample taken in ml}}$$

Where, A - Volume of silver nitrate consumed by the sample

B - Volume of silver nitrate consumed by the blank

N - Normality of silver nitrate

Dissolved Oxygen

Oxygen dissolved in water is a very important parameter in water analysis as it serves as an indicator of the physical, chemical and biological activities of the water body. The two main sources of dissolved oxygen are diffusion of oxygen from the air and photosynthetic activity. Diffusion of oxygen from the air into water depends on the solubility of oxygen, and is influenced by many other factors like water movement, temperature, salinity, etc. Photosynthesis, a biological phenomenon carried out by the autotrophs, depends on the plankton population, light condition, gases, etc. Oxygen is considered to be the major limiting factor in water bodies with organic materials. Dissolved oxygen is calculated by many methods.

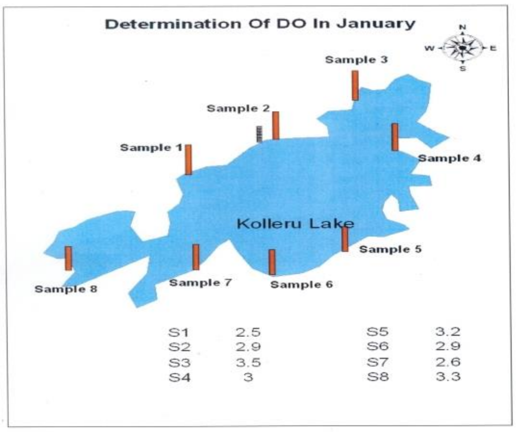

Fig.4 Determination of DO

Method: Winkler's method

Principle:

Oxygen present in the sample oxidizes the dispersed divalent manganous hydroxide to precipitate as a brown hydrated oxide after addition of potassium iodide and sodium hydroxide. Upon acidification, manganese reverts to its divalent state and liberates iodine from potassium iodide, equivalent to the original dissolved oxygen content of the sample. The liberated iodine is titrated against N/80 sodium thiosulphate using fresh iodine as an indicator.

Procedure:

The samples were collected in BOD bottles, to which 2ml of manganous sulphate and 2ml of potassium iodide were added and sealed. This was mixed well and the precipitate was allowed to settle down. At this stage 2ml of conc. sulphuric acid was added, and mixed well until all the precipitate dissolved. 203ml of the sample was measured into the conical flask and titrated against 0.025N sodium thiosulphate using starch as an indicator. The end point is the change of colour from blue to colourless.

Calculations:

203ml because (200) (300)/ (200-4) = 203ml.

1ml of 0.025N Sodium Thiosulphate = 0.2mg of Oxygen

Dissolved Oxygen (as mg/l) = (0.2) x (1000 ml of Sodium Thiosulphate)/200

Water Quality Index

Water Quality Index can be computed using the method proposed by Tiwari and Mishra, 1995. According to them, Quality rating (q) is calculated as

$$Qni = (Vactual – Videal) / Vstandard – Videal)* 100$$

Where, Qni = Quality rating of ith parameter for a total of n water quality parameters, Vactual = Value of the water quality parameter obtained from laboratory analysis, Factual = Value of that water quality parameter can be obtained from the standard tables, Videal for parameters it is equivalent to zero.

To determine the suitability of the water for drinking purposes, an indexing system called Water Quality Index (WQI) has been developed from this water quality rating which is formulated as,

$$WQI = (\sum qi\ Wi)/ \sum Wi\ i=1$$

Where Wi is unit weight for i th parameter Si (1=1,2..4) Refer to water quality parameters and K is constant of proportionality. For the sake simplicity we assume K=1.

Table 1: Standards for irrigation Water

S.No.	Parameter	Standard Value
1	Electrical Conductivity (milli mhos)	3000
2	Total Dissolved Solids (mg/l)	2100
3	Chlorides (mg/l)	600

(Source: Wastewater Treatment for Pollution Control by Soli J Arceivala p: 174)

Methods for biological assessment

Most organisms living in a water body are sensitive to any changes in their environment, whether natural (such as increased turbidity during floods) or unnatural (such as chemical contamination or decreased dissolved oxygen arising from sewage inputs). Different organisms respond in different ways. The most extreme responses include death or migration to another habitat. Less obvious responses include reduced reproductive capacity and inhibition of certain enzyme systems necessary for normal metabolism.

Biological assessment is often able to indicate whether there is an effect upon an ecosystem arising from a particular use of the water body. It can also help to determine the extent of ecological damage. Some kinds of damage may be clearly visible, such as unusual colour in the water, increased turbidity or the presence of dead fish. However, many forms of damage cannot be seen or detected without detailed examination of the aquatic biota. Microorganisms such as ciliated protozoa, algae or bacteria, reflect the water quality of only one or two weeks prior to their sampling and analysis, whereas insect larvae, worms, snails and other macro invertebrate organisms reflect more than a month, and possibly several years.

Methods for surface water analysis of Phytoplankton

The surface water sampling was carried by plankton net (bolting No 25) and the collections were preserved in 4% formalin. The collections were observed, under illuminating binocular microscope (Meopta, Czechoslovakia) and identified (using standard Taxonomic Manuals and Regional literature). The biological samples were broadly analyzed for various groups of phytoplankton and zooplankton present in the lake.

Microbiological methods:

The purpose of the MPN test is to estimate the number of pathogens in a sample of water as an index of the magnitude of pollution. MPN is a measure of the bacterial density of water and is a measure of the probable populations of pathogens in water. If MPN is more, the pathogens may cause several water borne diseases such as typhoid, cholera, dysentery, fevers, infectious hepatitis, and gastro-entireties. It is useful to assess the degree of contamination of receiving waters by domestic sewage. The series of MPN fermentation tube was inoculated with appropriate measured quantities of the water sample. Appropriate quantity of lactose broth was added in each tube. One Durham's vial is placed in inverted manner in each test tube. The tops are plugged with cotton. All the test tubes are placed in the incubator at 35-370C within 30 minutes. After 24 hrs, the tubes are examined carefully to check for whether the samples are MPN positive or MPN negative. The samples showed positive for the MPN test the samples are plated and the colonies observed. Eosin methylene blue (EMB) agar petri plates are prepared and the inoculum is streaked on the plates in such a way that the colonies are well separated. The plates were incubated at 370C for 24 hours. The plates were later examined for bacterial growth.

Enumeration of Bacteria by Serial Dilution Plate Technique

Principle:

The basic principle in this method is that a known quantity of water is prepared in the form of a suspension and the suspension is diluted several folds with sterile water to give a cell density of 1 to 10 per ml. This would give 100 to 300 colonies on plating one ml portion of this final dilution. By employing nutrient agar the total number of bacteria is enumerated.

Apparatus:

Saline, Sterile pipettes, Petri dishes and test tubes, Nutrient agar

Methods for serial dilution plate technique:

1ml of water sample was taken and dissolved in 9ml of sterile water. This is known as original solution. Taking 1ml of original solution and adding it to 9ml of saline in another test tube obtained a 10-fold dilution. This is 10-1 dilution. A serial dilution was made up to 10-10. 0.1ml aliquot from a highest i.e., 10-7 was transferred onto agar plates. Using a sterile glass spreader suspension on the agar surface was spread. The process was repeated by transferring 0.1ml aliquot from each of successive dilutions onto each of duplicated plates for each dilution. The Petri plates were incubated in an inverted position at 370C for 24 hours.

RESULTS AND DISCUSSION

Calculation of hydrological parameters of the Kolleru Lake

The catchments area of the lake is calculated with differential global positioning system and plannimeter and is worked out to be approximately 25 km^2. Similarly the effected area of the lake is worked to be 0.5 km^2. The average annual rainfall of the region is estimated as 650 mm. This is estimated on the basis of immediate 10 years average rainfall record of all nearest rain gauge station near to atapaka

The rainfall from the catchment's area is calculated by rational method

Runoff (R) = C*A*P

$= 0.6 * 25 * 10^6 * 0.65$

$= 9.75 * 10^{6\ m3} = 9.75\ m^3$

Where, C is the runoff coefficient which is assumed as 0.6 for this terrain

A is the area of the catchments

P is the precipitation (average annual rainfall)

The volume of the lake is worked out by multiplying area of the lake by average depth of the water 3M

Volume of the tank = $0.5 * 10^6 * 3$

$= 1.5 * 10^6 * 0.65$

= 1.5 million m^3

The study indicated that there was considerable organic pollution as reflected from the BOD values and also certain data analysis carried out indicated that certain pesticides were being discharged into the lake and thereby contaminating the lake waters.

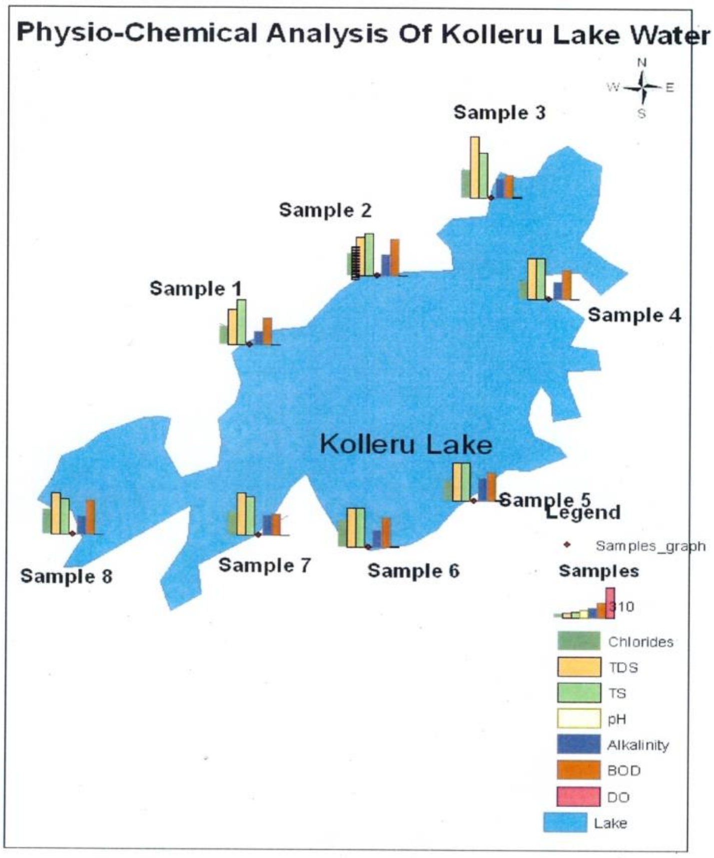

Fig.5. Physio-Chemical Analysis of Kolleru Lake Water

The predominant polluted contamination was done in the analysis. Considerable evidence was found which pointed that these two are being discharged into lake waters. Hence in order to rejuvenate the lake waters certain remedial measures as Waste Water Treatment. An assessment for physico-chemical and biological quality of waters, surrounding area was carried out. Certain remedial measures were undertaken and reported in this study. As a part of the study the water quality of the lake was assessed during three months for the variations.

The study included physico-chemical and biological parameters for water and suitable remediation methods. The samples were collected at various sampling points, which were identified, based on reachability and proximity of inlet and all around the lake. The water samples indicated high TDS values in the range of 600 to 900 mg/l. Similarly high Chlorides were observed. Polluted Lake Water must be done by primary, secondary and tertiary treatment. A low value of Dissolved Oxygen and high value of BOD was observed during all three months.

Environmental changes taking place in the lake should be monitored with the help of GIS and Satellite based image maps should be used as a basic input parameters for environmental mapping & monitoring of the lake environment. Geographical Information System technology must be used in their assessment of pollution as it useful to analyze and get the solution easily with more accuracy. Every citizen & every industrialist must be aware of the pollution & its effects and must be encouraged to follow the eco-friendly development.

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