Physicochemical studies of water quality with special reference to ancient lakes of Udaipur City, Tripura, India.

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Abstract- Present work was designed to study the physicochemical parameters of four lakes of Udaipur known as the "City of Lakes" of Tripura state. The studied lakes are Amar Sagar (AS), Dhani Sagar (DS), Jagannath Dighi (JD) and Mahadeb Dighi (MD). To evaluate the water quality of the lakes and to identify the pollution sources random sampling was done during the month of April, 2014. Collected samples were analyzed according to APHA (2005) for different physicochemical parameters and the results were compared with standard values prescribed by WHO (1997) and BIS (1991). Obtained results of physicochemical water quality parameters of studied lakes revealed the fact of pollution load in the lakes. Average Biochemical Oxygen Demand (BOD) as well as the value of ammoniacal nitrogen (NH_3-N) is found high during analysis which conveys high bacteriological load, organic matter disposal and animal waste contamination into the lakes. The main pollution sources are identified as, four numbers of canals flowing municipality waste into the AS and one in DS, organic waste disposal into the lakes by local residents, agriculture practice inside the AS during dry season and contamination of domestic waste from run over drains in various parts of different lakes. Consequences of such human activities and discharge of sewage water makes the existence of the lakes more vulnerable. It is the prime necessary to take immediate remedial action to prevent all anthropogenic activities in the studied lakes or else the lakes will become biologically barren and will be lost forever.

Index Terms- Udaipur, Physico-chemical, Water quality, Bacteriological load, BOD, Ammoniacal-nitrogen

I. INTRODUCTION

From time immemorial ancient lakes has played a great role in human civilization as a precious life sustaining water resource. Antique architect and city planners were very much aware about the fact that lakes can improve the life quality of human civilization (Naselli-Flores, 2008). Thus they have usually constructed big lakes in almost all developed cities for great many purposes such as drinking water source, bathing and cleaning, agricultural irrigation, fishery, sustainable use for industry, boosting of natural ground water level, aesthetic value and many other livelihood. A healthy lake eco-system could conserve natural and social balance by contributing healthy environment of its location. Nowadays naturally existing dynamic equilibrium of water bodies like rivers, lakes and estuaries are affected by the human activities (Tamiru, 2004; Mahananda et al. 2010; Mehari and Mulu, 2013). In present scenario urban lakes are under direct threat of qualitative and quantitive degradation by means of pollution from both fixed-point and non-point sources. There are numerous sources of pollutants that could deteriorate the quality of water resources (Tamiru, 2004). Factors that are directly or indirectly polluting the lake ecosystems includes population growth, unplanned growth of city area, urbanization, agricultural land expansion and lack of awareness among the local residents. All such activities and pollution causing factors are decreasing the utility of water day by day (Tank and Chippa, 2013). Accessible man maid urban lakes and all other natural wetlands have gained the thrust of conservation in recent years due to their important functions in different hydrological processes. To take decisions and formulate policies concerning conservation, management and sustainable use of lakes and water resources, accurate spatial inventory is required (Finlayson and Davidson, 1999). Thus, sequential and continuous interpretation of physical, chemical and biological status of water quality and characterisation of the pollution sources along with quantitative contribution of significant pollution causing parameters is important for demeanour pollution control management of urban lakes (Zhou et al., 2011). This will generate baseline data of water resources to evaluate the rate of change in water quality over a period of time.

In this view the present study was conducted to study the physicochemical parameters of four ancient lakes of Udaipur city, Tripura, North-East India. Review of literature suggested that very limited study on water quality has been done in Tripura state, whereas the state is rich in inland fresh water lakes and wetlands including a Ramsar site (Ramsar site no. 1572). Therefore, this present study generates a important baseline database for lakes of the Tripura state which would be helpful to evaluate the status of the water quality and degree of change in water quality of studied lakes over a time gap.

II. Materials Methods

Study Area:

Udaipur was the former capital of Tripura state (latitude 22°57' to 24°33' N and longitude 91°10' to 92°20' E) in the 14th centaury till 1760 A.D. Udaipur is located between 23°53'N and 91°48'E in Gomati district of Tripura. Udaipur is famous for the Tripura Sundari temple and the artificial lakes located here. Four ancient lakes namely Amar Sagar (AS) [23°32'.02.50"N, 91°29'.37.67"E], Dhani Sagar (DS) [23°31'.51.42"N, 91°30'.07.14"E], Jagannath Dighi (JD) [23°31'.51.42"N, 91°30'.07.14"E] and Mahadeb Dighi (MD) [23°32'.13.72"N, 91°29'.55.26"E] were surveyed to study the physico-chemical parameters of the water (Figure 1). Each of the studied lake was located in the heart of the city. Among the lakes AS is the biggest one (3684×906 ft^2) followed by DS (2400×720 ft^2), JD (1650×400 ft^2) and MD (750×450 ft^2).

Sample Collection:

Water samples were collected from four different sites (S_1, S_2, S_3, and S_4) of each lake (AS, DS, JD and MD) during the month of April, 2014. The samples were collected in plastic container between 10:00 am to 4:00 pm and brought to the laboratory in an icebox jar to avoid unusual change in water quality. Standard methods for sample collection and preservation were followed during the study (APHA, 2005). Some physical data like, temperature, pH were recorded in the field at the time of sample collection. Geo coordinates for the studied lakes were taken by the GPS system.

Analysis:

Water samples were collected from 16 different sites (4 sites in each lake) and are analysed for 17 different physico-chemical parameters of water quality, followed by standard methodologies of APHA (2005). That includes 7 physical and 10 chemical parameters such as pH, temperature, Electrical conductivity (EC), total dissolve solids (TDS), total suspended solids (TSS), dissolve oxygen (DO), biochemical oxygen demand (BOD), total hardness (TH), alkalinity, chloride etc. Obtained results of the different parameters are compared with standard value prescribed by BIS (1991) and WHO (1997). Results of the parameters are presented in Table 1.

III. Result and Discussion

Natural water body contains uniform water solution which undergoes unremitting physicochemical transformation due to circulation in the environment that greatly affects the water quality composition. Variation in results is found between different lakes as well as within different sites of the lakes. However there could be always a chance for difference in test result in different laboratories because of laboratory approach, sample preservation, quality of chemicals used and testing methods applied (Weldemarim, 2013). Results of the physicochemical parameters obtained from this study are discussed bellow-

Temperature:

Temperature is one of the essential physical parameter of water quality to measure because it influences the aquatic life by alter the dissolve oxygen (DO) concentration in the water making oxygen less available for respiration and metabolic activity of aquatic organisms (Tank and Chippa, 2013; Jalal and Sanalkumar, 2012). Water temperature is an affective factor to control the chemical reactions and its rate within the water body that determines the usefulness of the water (Metcalf and Eddy, 2003). Temperature of the studied water bodies were measured by digital thermometer during sample collection and average temperature is recorded between 28.25^{o}C to 31.50^{o}C. The standard temperature for sustaining aquatic life varies between 28.00^{o}C to 30.00^{o}C (Weldermeriam, 2013). The average water temperature is found highest (31.50^{o}C) in AS whereas lowest average temperature (28.25^{o}C) is recorded in MD. High temperature of AS among the studied lakes is might be due to contamination of municipality sewage (Figure.2) which is supported by the study of Gopalkrushna (2011) in Akot city, Maharastra, India.

pH:

pH that maintain the acidic or basic property, is a vital characteristic of any aquatic ecosystem since all the biochemical activities and retention of physico-chemical attributes of the water are greatly depend on pH of the surrounding water (Jalal and Sanal Kumar, 2013) . Most of the similar study suggested that water samples are slightly alkaline due to presence of carbonates and bicarbonates (Tank and Chippa, 2013; Gopalkrushna, 2011; Verma et al., 2012). The higher range of pH indicates higher productivity of water (Gopalkrushna, 2011) because availability of carbonates and bicarbonates in water enhance dissolve carbon dioxide level by dissociation and acts as a raw material for photosynthesis. The pH value of all the studied water samples is measured by digital pH meter and average pH is recorded between 8.12 to 8.66 which was found very approximate to the high limit (6.5 to 8.5) prescribed by the BIS (Bureau of Indian Standard). The highest and lowest pH is recorded in DS (8.66) and AS (8.12) respectively.

Colour:

Colour is an optical parameter that absorbs a fraction of visible spectrum and is reflected by the dissolved substances, colloidal substances and suspended particles present in the water. Colour of any water body is depended on the natural vegetation (decay of plant matter, algae, plankton etc.) and also altered by different anthropogenic sources viz. effluents from industries and mills. Colour of water in not an important parameter for health effect but responsible for humiliate aesthetic value. Colours of the studied lakes are found yellowish green to pale green and average value is measured between 1.73 to 3.93 HU.

Turbidity, Total Suspended Solids (TSS) and Total Dissolve Solids (TDS):

Turbidity of water is the expression of optical property by which light is scattered by the colloidal particles present in the water. Phytoplankton, microscopic organisms, clay, slit and other organic matter makes a lake turbid (Das and Shrivastaba, 2003). High turbidity signify presence of large amount of suspended solids (Verma et al. 2012), this is again indicate the high rate of siltation so as to decrease the depth of the water body. Turbidity of the studied lakes are measured by the Turbidity meter and average value is recorded between minimum 7.57 NTU in MD to maximum 62.55 NTU in AS. Obtained turbidity is very high in all the studied lakes and found above the prescribed limits by BIS (10500-91). Comparatively high turbidity in AS may be due to the contagion of large amount of sewage water and organic pollutants from the surrounding locality. The increase in turbidity by organic pollutants resulting eutrophication of water bodies which consequently dwindle the light transmission into water and thus gradually condense overall productivity. Total suspended solids (TSS) are the composition of carbonates, bicarbonates, chlorides, phosphates, nitrates of alkali and alkaline earth metals, organic matter, salt and other particles. Water with high suspended solids is not suitable for bathing (Trivedy, 1990; Gay and Proop, 1993). Among the studied lakes average TSS is recorded 5 mg/l, 10 mg/l, 18 mg/l, 71.5 mg/l and in MD, JD, DS and AS respectively which are within the standard limit (150 mg/lit) prescribed by WHO in terms of inland surface water. Type and quantity of TDS define the color and electrical conductivity of the water body (Tank and Chippa, 2013). The amount of total dissolve solids (TDS) in water indicates salinity of water and may also be used as an indicator for rapid plankton growth and sewage contamination. In this study average TDS value is measured 162 mg/l, 336 mg/l, 348.5 mg/l, and 428.5 mg/l in DS, JD, MD and AS respectively.

Electrical Conductivity (EC):

EC is the measure of the ability of an aqueous solution to transmit an electric current. Conductivity depends upon the presence of cations and anions, their total concentration, mobility, valence and temperature of water which is a good measure of total amount of salt present in water. In the present study the average EC is recorded as 14.43 μS/cm, 14.68 μS/cm, 16.95 μS/cm and 20.60 μS/cm for JD, MD, AS and DS respectively.

Alkalinity:

Alkalinity express the buffering capacity of the water which appreciably maintain the pH by absorbing access H^+ ions and protects the water body from pH fluctuation. The main species responsible for alkalinity are carbonates, bicarbonates, hydroxide ions, ammonia, organic acid etc. Alkalinity acts as a buffer against rapid pH change. Alkalinity is recorded within prescribed range and found to be related with hardness of the water because water contains metallic carbonates (mostly $CaCO_3$) is high in alkalinity as well as hardness because metals like Ca, Mg are the main contributor of water hardness. Whereas carbonates and bicarbonates associated with sodium and potassium contribute only alkalinity not hardness because of incapability of sodium and potassium to form complex with electron donor ligands. Average value of alkalinity is obtained 60.68 mg/l, 76.72 mg/l, 97.33 mg/l and 116.79 in MD, JD, DS and AS respectively.

Total Hardness (TH):

Hardness is caused due to presence of cations like Ca^{+2}, Mg^{+2}, Fe^{+3} etc. This is the property of water to precipitate soap by formation of complex with calcium, magnesium present on water. TH of the studied lakes are found within prescribed limit and the average value is recorded 27.08 mg/l, 28.15 mg/l, 28.63 mg/l and 36.64 mg/l in DS, MD, JD and AS respectively which is the measure of total amount of Ca^{+2} and Mg^{+2} ions.

Calcium (Ca^{+2}) and Magnesium (Mg^{+2}):

Calcium and magnesium are exists in surface and ground water mainly as carbonates and bicarbonates. Lake water contributed calcium as due to higher proportion of calcium in the surrounding rocks and soils which is essential for plant precipitation of lime, bone building etc. The main source of magnesium is sewage inflows and minerals generate from soil erosion and are important for enzyme activation, growth of chlorophyll and phytoplankton (Ramesh and Seeta, 2013; Verma et.al, 2012). According to the result obtained in the present study calcium and magnesium content is found within the permissible limit given by BIS.

Dissolved Oxygen:

Dissolve oxygen which indicates the health of the ecosystem refers to the volume of oxygen present in water body. It is an important water quality parameter to be measure because it prevail biological and physicochemical attributes of surrounding water. Oxygen enters into the water by aerial diffusion and as a photosynthetic byproduct of aquatic plants and algae. The DO depends upon the temperature, salinity and pressure of the water. The DO value indicates the degree of pollution in the water bodies (Gupalkrushna, 2011). The aquatic life distressed when DO levels drops to 4-2 mg/lit. (Francis and Floyd, 2003) and as DO level falls undesirable changes in odor, taste and color reduce the usefulness of water (Tank and chippa, 2013). In this study the average DO is measured between 5.27 to 6.96 mg/lit whereas the highest concentration in MD is found 7.56 mg/ lit. and lowest concentration in DS is 4.77 mg/ lit.. DO level of studied water bodies are found within the prescribed range of BIS.

Biochemical Oxygen demand (BOD):

Biochemical oxygen demand (BOD) is an important parameter of water quality which measures the quantity of oxygen consumption by microorganisms during decomposition of organic matter. BOD is usually used for determining the oxygen demand of municipal or industrial discharge. High BOD indicates high scale contamination of organic matter in the water. Though high BOD is always accompanied by low DO level, counter result is obtained in our study which is comparable to the study of Anhwange on river Benue, Nigeria (Anhwange et al. 2012). High BOD than the prescribed value is found in all of the studied lakes where the maximum average value is found 22.90 mg/l in AS and lowest is found in MD (3.20 mg/l). Water can only hold a limited supply of dissolve oxygen in a water body and is fluctuate with diurnal cycle of the aquatic ecosystem. The probable reasons for high BOD as well as normal DO in the studied lakes suggested that there is high nitrogenous oxygen demand (NOD) than carbonaceous biochemical oxygen demand (CBOD). NOD is the result of the breakdown of proteins into ammonia, which is readily converted to nitrate in the environment. The conversion of ammonia to nitrate requires more than four times the amount of oxygen as the conversion of an equal amount of hydrocarbons to carbon dioxide and water. Agricultural practice and sewage runoff in AS increase nutrients such as nitrate and phosphate in the water which endorses the growth of aquatic plants eventually, leads to an increase in plant decay and a greater move to and fro in the diurnal dissolved oxygen level. We collected the samples between the mid hours of a day (1000 to 1600 hrs), so normal DO despite high BOD is acceptable in the studied lakes where sewage runoff and agricultural run off as well as domestic waste contamination are the main problem.

Ammoniacal Nitrogen (NH_3-N):

Ammonia in surface water can be of various sources like organic origin, inorganic origin and the air deposition. This is one of several forms of nitrogen and considered as most important indicator for soil contamination (excessive use of ammonia rich fertilizer), excretion of nitrogenous wastes from animals, and sewage contamination in aquatic environments. Although ammonia is a nutrient required for life, it is toxic for aquatic organism and excess of ammonia can accumulate in the organism cause alteration in metabolism or increase body pH. NH_3-N of the studied lakes are found higher than the prescribed value of BIS and average value is ranges between 0.06 to 3.20 mg/l. Highest value in AS is recorded 4.20 mg/l whereas lowest in MD is obtained 0.00 mg/l. High NH_3-N level in AS and DS evidently signify the affect of remarkable sewage contamination as well as significant organic effluence into the lakes.

Chloride ($Cl^{-)}$):

Chloride is present in all natural surface and ground water from as low concentration to high concentration. Chlorides are mainly come from inorganic salts like NaCl, KCl and $CaCl_2$ etc. which are generally provided by soil, natural layers of chloride salts, municipal and industrial sewage and animal wastes (Gopalkrushna, 2011). Chloride is not harmful to humans but high concentration of chloride increase the corrosive property of water. The chloride content of studied water samples were within permissible limit prescribed by BIS and average values are recorded as 26.13 mg/l, 28.40 mg/l, 30.67 mg/l and 36.35 mg/l, for JD, MD, DS and AS respectively.

Nitrate (NO_3^-):

Inorganic nitrogen that present in water as Nitrate (NO_3^-) is the main nutrient that accelerates the growth of hydrophytes and algae. Nitrate occurs in water from various natural sources and due to human activities like food production, agriculture and manure disposal of domestic and industrial sewage. High level of nitrates is found in rural areas because of extensive application of nitrogenous fertilizers in agriculture. In urban areas sewage water rich in nitrates contaminate surface water thus increases the nitrate amount. (Tank, 2013; Gopalkrushna, 2011). A small amount of nitrate is common in all kinds of surface water. In this study relatively larger amount of nitrate is found in the studied lakes though obtained levels are within range prescribed by BIS. Nitrate stimulates the growth of hydrophytes and phytoplankton that consequently increase the nutrient in water body leading to eutrophication. The average nitrate value in studied lakes is found between 9.82 mg/lit to 48.30 mg/lit where minimum and maximum is obtained in MD and AS respectively.

Phosphate (PO_4^{-3}):

Phosphate has a limited source in nature and also acts as a limiting factor for productivity of water body. Phosphate may occur in lake as result of domestic waste, detergent and agricultural run off containing fertilizer (Gopalkrusna, 2011). The average value of phosphate recorded in the studied lakes ranges between 0.05 to 0.37 mg/l. Comparatively high amount of phosphate is recorded in AS (0.37 mg/l) and in DS (0.11 mg/l) which is might be due to discharge of municipality sewage and dumping of domestic waste into the lakes (Benjamin et al, 1996).

Sources of Pollution in the Lakes:

During the study so many pollution sources are found which are badly affecting the water quality of the studied lakes. Four number of municipality drains were found discharging municipality sewage in the AS on western side of the lake. In northeastern corner agriculture practice was also evidenced in a dry plot of AS. Local peoples are found depositing domestic waste into all of the studied lakes. On the west corner of DS the biomedical waste is discharge into the lake from the district hospital. Anthropogenic pressure is found moderate in JD and MD.

IV. Conclusion

The results obtained from this study revealed that BOD, NH_3 –N and Turbidity are above desirable limit suggested by BIS. The results show that the lakes of Udaipur city receives very high amount of pollutants from the surroundings and the lake water is highly contaminated by sewage effluents. Local peoples are ignorantly polluting the lakes and the dreadful conditions of the lakes are also visible from the satellite photo. Due to high organic matter contamination hydrophytes are growing drastically and deposited into the lake after death which consequently reducing the depth of the lake day by day. If present condition is continue for the longer period, very soon the lakes will become ecologically barren. So concern authority should take firm decision on urgent basis to resolve the problems of the lakes of Udaipur city.

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Figure 1. Location Map of Lakes of Udaipur City

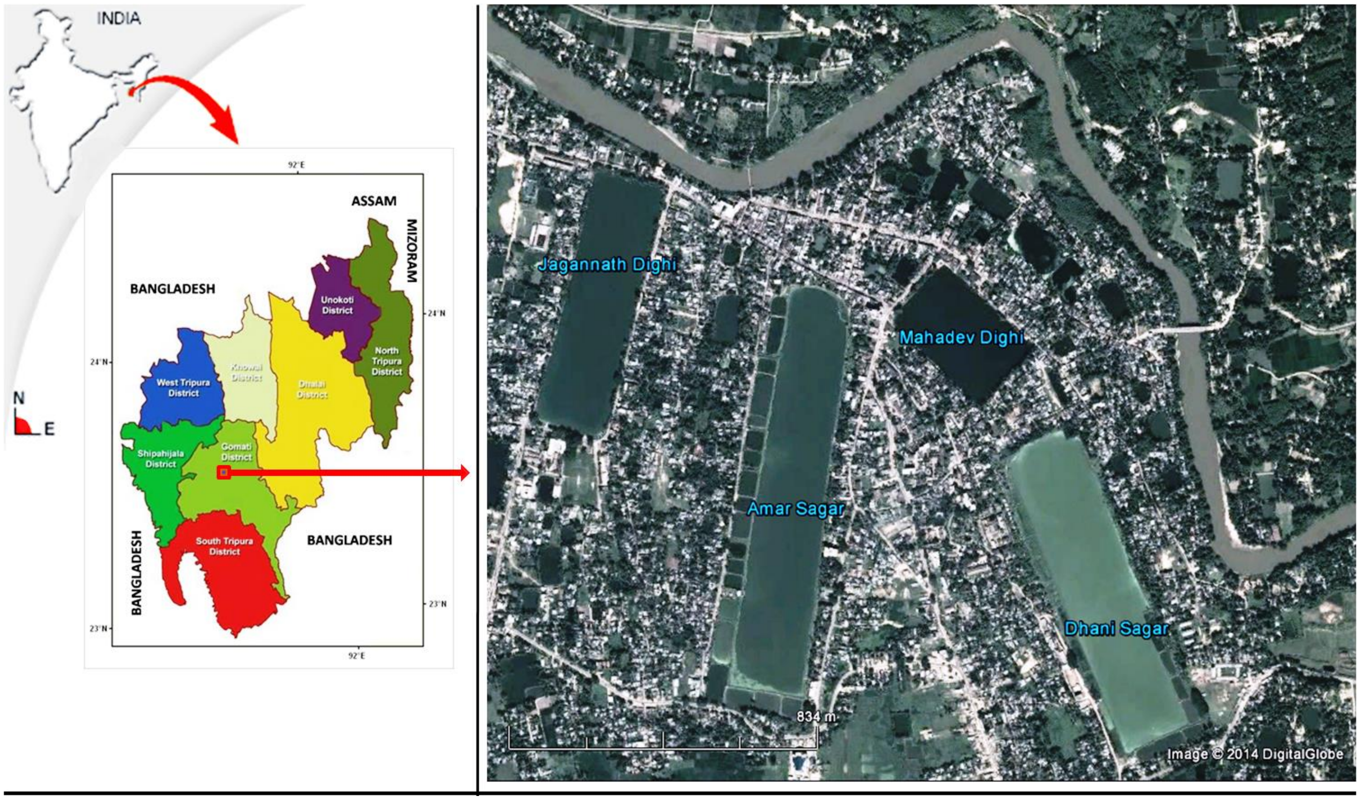

Figure 2. Sewage discharging canal into Amar Sagar (AS)

Table I: Results of the physic-chemical parameters of different sites of the studied lakes in Udaipur city

Parameters		Amar Sagar					Dhani Sagar					Jagannath Dighi					Mahadeb Dighi				
		S1	S2	S3	S4	Avg.	S1	S2	S3	S4	Avg.	S1	S2	S3	S4	Avg.	S1	S2	S3	S4	Avg.
PHYSICAL	Temparature (°C)	30.00	32.00	32.00	32.00	31.50	29.00	30.00	30.00	28.00	29.25	29.00	29.00	28.00	29.00	28.75	28.00	29.00	28.00	28.00	28.25
	pH	8.52	8.11	8.12	7.71	8.12	9.05	8.51	8.59	8.48	8.66	8.21	7.79	8.49	8.49	8.25	8.32	8.78	8.34	8.39	8.46
	Colour (1/m)	4.00	3.40	1.20	2.50	2.78	4.40	5.50	2.60	3.20	3.93	3.20	2.30	3.60	3.30	3.10	0.90	1.50	3.30	1.20	1.73
	Turbidity (NTU)	104.00	34.90	34.90	76.40	62.55	42.00	55.10	52.50	59.10	52.18	17.40	27.00	16.00	21.40	20.45	8.52	6.37	7.78	7.59	7.57
	TSS (mg/l)	32.00	64.00	88.00	102.00	71.50	36.00	4.00	16.00	16.00	18.00	8.00	24.00	4.00	4.00	10.00	4.00	0.00	12.00	4.00	5.00
	TDS (mg/l)	392	380	444	498	428.50	168	148	164	168	162	324	321	344	352	336	316	288	392	398	348.50
	Conductivity (µS/cm)	19.14	18.82	18.99	10.84	16.95	20.70	21.10	20.30	20.30	20.60	14.88	14.51	14.08	14.26	14.43	14.44	14.61	14.78	14.90	14.68
CHEMICAL	Alkalinity (mg/l)	119.08	114.50	114.50	119.08	116.79	91.60	96.18	96.18	105.34	97.33	68.70	68.70	100.76	68.70	76.72	73.24	59.54	54.96	54.96	60.68
	Total Hardness (mg/l)	36.64	36.64	32.06	41.22	36.64	32.06	22.09	22.09	32.06	27.08	32.06	27.48	27.48	27.48	28.63	27.12	26.89	31.10	27.48	28.15
	Ca^{+2} (mg/l)	11.01	9.17	11.01	11.01	10.55	9.17	9.17	7.34	7.34	8.26	11.01	9.17	7.34	7.34	8.72	9.17	7.34	9.17	9.17	8.71
	Mg^{+2} (mg/l)	2.22	3.33	1.11	3.33	2.50	2.22	1.11	1.11	3.33	1.94	1.11	2.22	1.11	2.22	1.67	3.33	3.33	2.22	2.22	2.78
	DO (mg/l)	4.99	5.20	5.32	5.55	5.27	7.46	4.87	5.77	4.77	5.72	5.97	5.37	5.87	5.87	5.77	6.16	7.06	7.56	7.06	6.96
	BOD (mg/l)	23.20	22.00	20.60	25.80	22.90	19.70	15.30	15.90	24.10	18.75	4.98	5.02	4.98	5.18	5.04	3.59	1.93	3.53	3.73	3.20
	NH_3-N (mg/l)	3.60	2.90	4.20	2.10	3.20	1.63	2.52	2.37	2.12	2.16	0.98	0.84	1.12	0.72	0.92	0.12	0.00	0.00	0.11	0.06
	Chloride (mg/l)	40.89	36.35	31.80	36.35	36.35	31.80	31.80	27.26	31.80	30.67	27.26	22.72	27.26	27.26	26.13	27.26	27.26	31.80	27.26	28.40
	NO_3^{-1} (mg/l)	42.08	48.30	44.88	43.56	44.71	39.67	42.74	40.80	39.95	40.79	16.89	18.84	17.21	16.43	17.34	12.20	11.42	9.82	10.43	10.97
	PO_4^{-3} (mg/l)	0.39	0.36	0.31	0.40	0.37	0.02	0.12	0.23	0.09	0.11	0.02	0.01	0.06	0.09	0.05	0.10	0.03	0.09	0.05	0.07