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Water Quality Assessment of Velacherry Lake Using Remote Sensing and GIS Techniques

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Abstract: ***Lakes are major upholder of freshwater that supports the environment and its existence. It is evident that many inland water bodies are becoming obsolete with no steps taken towards its protection. A shallow lake in Velachery was tested for its quality with samples collected from 15 points. With urban agglomeration around the lake, it poses a threat to the eco system and its biotic community. Geographical Information System (GIS) which is widely recognized in water quality monitoring in conjunction with remote sensing was used to map the pollution extent of various parameters. It was explicitly seen that the lack of measures for diversion of untreated domestic waste from residential areas combined with dumping of solid discharge and effluents from industries has altered the physio-chemical parameters in an alarming rate.***

Keywords: Geographical Information Science; Parameters; Urban Agglomeration; Industrial Effluents Velacherry Lake; Water quality

1. Introduction

Lakes are an important feature of the Earth's landscape. They are extremely valuable ecosystems and provide a range of goods and services to humankind. However, anthropogenic pressures on lakes have increased rapidly in recent decades [13]. Major changes have occurred in the land use in their catchments where natural vegetation is cleared, and agricultural, urban and industrial activities are intensified. These anthropogenic activities (deforestation, agriculture, urban settlements and industries) have accelerated the aging process as increased amounts of sediments, nutrients and toxic substances enter lakes with the runoff.Most lakes are in different stages of degradation in various ways - through eutrophication, toxic pollution or habitat loss [10]. In addition the catchment based activities have been accompanied by encroachment on lake-shores by reclaiming shallow lake margins, sewage disposal, water abstraction, and diversification of in-lake recreational activities. All these activities directly cause rapid degradation of lakes.

Most important and common form of lake degradation is that of deterioration of water quality due to organic pollution from disposal of domestic wastewater and other solid wastes. Finally, equally important contribution to the degradation of lakes are human alteration in hydrology (excessive water abstraction), shoreline modification through landfill or beautification measure that remove natural vegetation and in-lake activities (bathing, washing, idol immersion and disposal of religious offerings).Their importance is ignored in the government and the public which has led to vast extinction in most of the areas. This not only affects the organisms present in it but also the other living beings.

2. Geographical Information Science

Geographic Information Systems is a computer-based tool that is used to analyze, store, manipulate and visualize geographic information, usually in the form of a map. GIS applicationsallow users to create and analyze spatial information, edit data in maps, and present the results of all the operations carried out. Modern GIS technologies use digital information, for which various digitized data creation methods are used [10]. GIS can also relate unrelated information by using location as the key variable. GIS accuracy depends upon source data provided with a high level of positional accuracy utilizing the GPS-derived positions. Aerial photography and satellite imagery are external sources that to the GIS output. Many disciplines can benefit from GIS technology GIS has evolved to show the development and implementation of hydrologic models at different levels.

3. Study Area

Velacherry Lake is one of the fresh water lakes in the city. The coordinates of the lake is 12.9885° N, 80.2130° E. The lake, once brimming with water catering to the needs of the public and being a source of irrigation, now presents a pathetic sight because of gross apathy. The lake, originally measured an area of 265.48 odd acres and the inhabitants of a vast area surrounding the lake, never faced water scarcity problems. Now, the lake has been encroached upon and the lake area has shrunk to a mere 57 acres. The study area is shown in Fig 1.

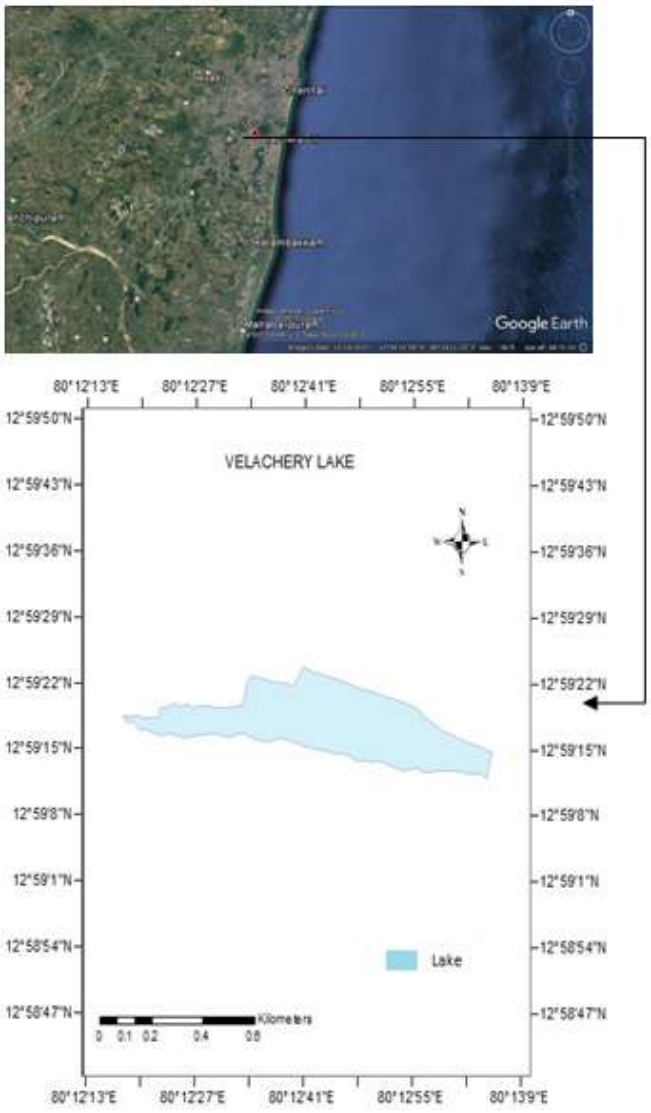

Figure 1: Study Area

4. Sample Collection and Analysis

The sample was collected from fifteen chosen points covering the accessible points and the entire stretch of the lake. Coordinates of each sample point location were recorded in field through GPS tracker [8].The water sample was collected in a one liter high density sterile polypropylene bottle required for the analysis to prevent atmospheric interaction with the collected samples. Winkler's solution A and B which arrests the alteration of oxygen content was prepared prior in the laboratory. The sampling locations are as shown in table 1

Table 1: Sampling Locations

Sample Points	Latitude (Decimal Unit)	Longitude (Decimal Unit)
S1	12.988163	80.216144
S2	12.9884	80.215744
S3	12.988817	80.21503056
S4	12.989308	80.21329722
S5	12.9896	80.20945
S6	12.988664	80.2090611
S7	12.988456	80.205125
S8	12.98845	80.206225
S9	12.987878	80.2069527
S10	12.987886	80.208725
S11	12.987806	80.21078889
S12	12.987486	80.2122222
S13	12.987003	80.21459722
S14	12.986831	80.21586667
S15	12.987311	80.21767778

For the analysis of Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD), sample was collected separately each in a glass bottle of 250ml capacity BOD sample was collected and stored for finding the BOD_5.To arrest the further reaction of obtained DO sample, 10 ml of Winkler's solution (A) followed by 10 ml of Winkler's solution (B) was added[1].The sampling was done in the month of August. The water quality parameters included Total Solids (TS), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Hydrogen Ion Concentration(pH), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), Salinity, Chloride and Alkalinity (TH) in this study.

These water quality parameters of each sample were analyzed in laboratory using appropriate standard methods avoiding storage of the collected sample and the obtained values are tabulated below in table 2.

Table 2: Attribute Table

SP (Decimal Unit)	TSS (mg/l)	TDS (mg/l)	pH	Salinity (mg/l)	BOD (mg/l)	COD (mg/l)	DO (mg/l)	TS (mg/l)	CHLORIDE (mg/l)	ALKALINITY (mg/l)
S1	1951	834	7.31	0.48	0.29	101.8	1.39	1647	243.5	363
S2	1551	821	7.21	0.69	0.82	101.8	0.98	974	453.89	391
S3	885	837	7.7	0.4	1.31	62.2	1.31	1179	221.41	351
S4	588	916	7.19	0.82	0.24	69.7	0.24	830	509.2	430
S5	594	824	7.26	1.17	1.31	46.6	1.31	1082	581.2	566
S6	358	821	7.64	0.9	0.33	132.2	1.47	1722	453.89	353
S7	1879	806	7.59	0.8	0.65	85.5	0.65	840	442.82	364
S8	258	1053	7.58	0.95	0	43.2	0.24	835	453.89	358
S9	22	801	7.69	0.8	2.2	85.5	4.33	2372	453.89	340
S10	26	512	7.62	0.81	6.24	62.2	8.82	2685	448.35	349
S11	1659	440	7.8	1.01	1.8	77.8	8.9	3270	453.89	347
S12	1459	825	7.67	0.62	1.02	77	1.02	1032	453.89	353

S13	2500	703	7.71	0.82	5.63	69.9	5.63	2480	453.89	359
S14	200	832	7.54	0.53	0.33	46.6	0.33	836	459.4	380
S15	8	827	7.6	0.83	0.69	69.9	1.71	2355	459.4	367

5. Methodology

A. Inverse Distance Weighted Method

Inverse distance weighted (IDW) interpolation explicitly makes the assumption that things that are close to one another are more alike than those that are farther apart. To predict a value for any unmeasured location, IDW uses the measured values surrounding the prediction location. The measured values closest to the prediction location have more influence on the predicted value than those farther away[2]. IDW assumes that each measured point has a local influence that diminishes with distance. It gives greater weights to points closest to the prediction location, and the weights diminish as a function of distance.

The optimal power (p) value is determined by minimizing the root mean square prediction error (RMSPE). The RMSPE is the statistic that is calculated from cross-validation. In cross-validation, each measured point is removed and compared to the predicted value for that location. The RMSPE is a summary statistic quantifying the error of the prediction surface [15]. Geostatistical Analyst tries several different powers for IDW to identify the power that produces the minimum RMSPE.

B. Interpolation Using IDW Method

1) Total Dissolved Solids

The average TDS value is less than 40 mg/l for freshwater bodies [2]. High Concentrations can cause damage to cell organisms. Turbidity reduces photosynthetic activity and increase the water temperature. Urban and fertilizer run-off, wastewater and septic effluent, soil erosion, decaying plants add on to the values [14]. Dissolved solids are also important to aquatic life by keeping cell density balanced. In distilled or deionized water, water will flow into an organism's cells, causing them to swell. In water with a very high TDS concentration, cells will shrink[1]. These changes can affect an organism's ability to move in a water column, causing it to float or sink beyond its normal range. It affects the planktons present. The distribution of Total Dissolved Solids in the lake is shown in Figure 2.

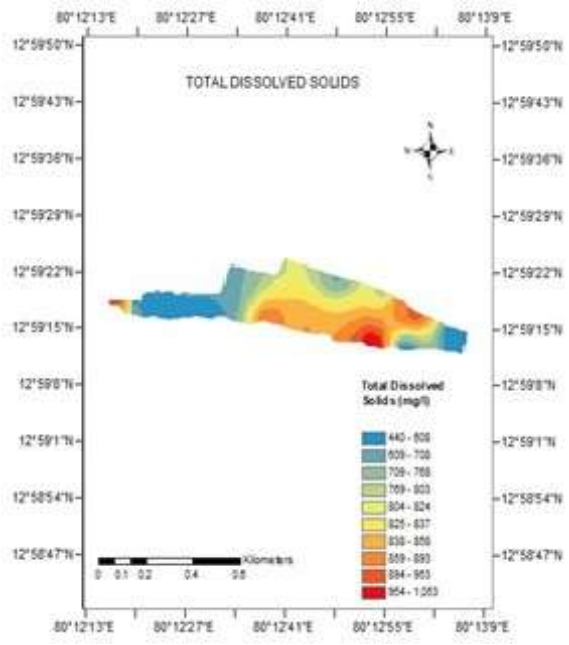

Figure 2: Spatial Distribution of TDS

2) Hydrogen Ion Concentration-pH.

The Hydrogen Ion Concentration (pH) is an indicator of the nature of the water. The process of photosynthesis by algae and plants uses hydrogen, thus increasing pH levels[4]. Likewise, respiration and decomposition can lower pH levels. It is found be in the nominal level with slight alkaline nature along the stretch of lake covering S10-S13 where there is an influence due to discharged waste.

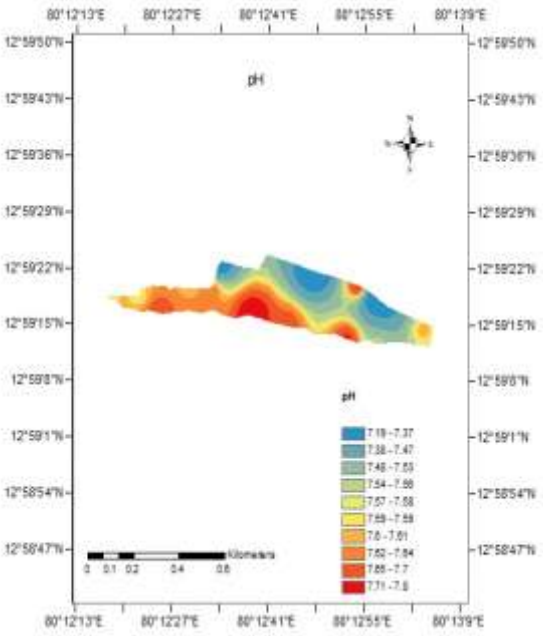

Figure 3: Spatial Distribution of pH

The concentration of Hydrogen ion is more or less uniform. A slight change in the pH range can increase the solubility of phosphorous and other nutrients [11]. This can cause the algal bloom resulting in Eutrophication.In case of

Velacherry lake which is shallow it can possibly cause a chain reaction. The variation of Hydrogen Ion concentration throughout the lake is as shown in Figure 3

3) Alkalinity

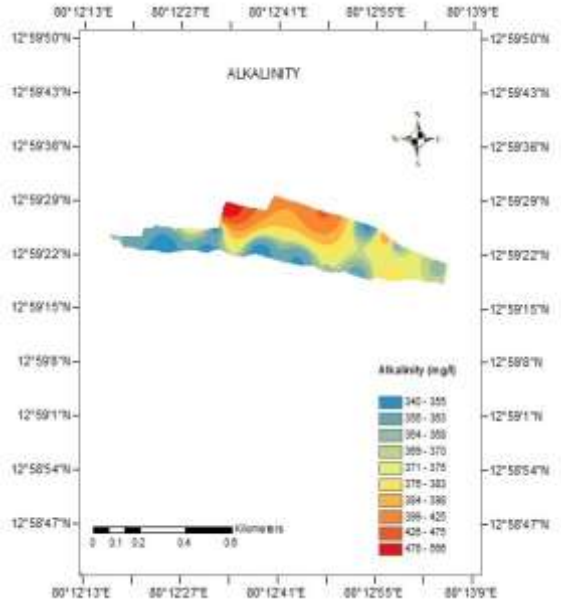

Figure 4: Spatial Distribution of Alkalinity

When a waterbody has a high alkalinity, it can limit pH changes due to acid rain, pollution or other factors[5]. The alkalinity of a stream or other body of water is increased by carbonate-rich soils (carbonates and bicarbonates) and decreased by sewage outflow and aerobic respiration.For the protection of aquatic life, the buffering capacity should be at least 20 mg/L. If alkalinity is naturally low, (less than 20 mg/L) there can be no greater than a 25% reduction in alkalinity. Higher the alkalinity higher is the prevention of pH change. According to Drinking Water Standards of BIS[11] , the desirable limit of Alkalinity is 200 mg/l and the permissible alkalinity limit is 600 mg/l. The spread of Alkalinity is seen in Figure 4.

4) Dissolved Oxygen

Oxygen in the dissolved state is a major component required for decomposition of matter and survival of organisms. When the value drops below 5 mg/l, the survival of fishes is questionable. In most of the parts it drops below 2 mg/l making it difficult for existence [1]. The amount of dissolved oxygen needed varies from creature to creature. Bottom feeders, crabs, oysters and worms need minimal amounts of oxygen (1-6 mg/L), while shallow water fish need higher levels (4-15 mg/l). In the lake in most of the locations it shows the deficiency of Oxygen i.e.below 4 mg/l [4]. Such highly varied value of Dissolved Oxygen leads to unfit condition of the aquatic organisms depends on it. The variation of DO in lake is seen in Figure 5.

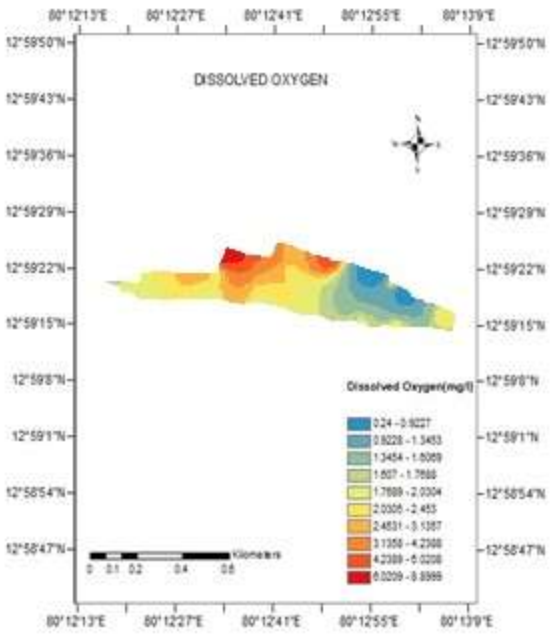

Figure 5: Spatial Distribution of DO

5) Total Solids

Total solids is a measure of the suspended and dissolved solids in water. It is a measurement that is often used in the water treatment industry [3]. A higher total solids level indicates that there is a high level of solid material in a water samples. Depending on the evaluation criteria, a high level of total solids could cause the sample to be considered contaminated. The standard for Total Solids in drinking water is 500mg/l. The TS values observed in the lake is extremely high compared to the required standard. If used for drinking purpose it will cause severe health issues. It is not consumable in any manner. Figure 6 shows its extent of pollution.

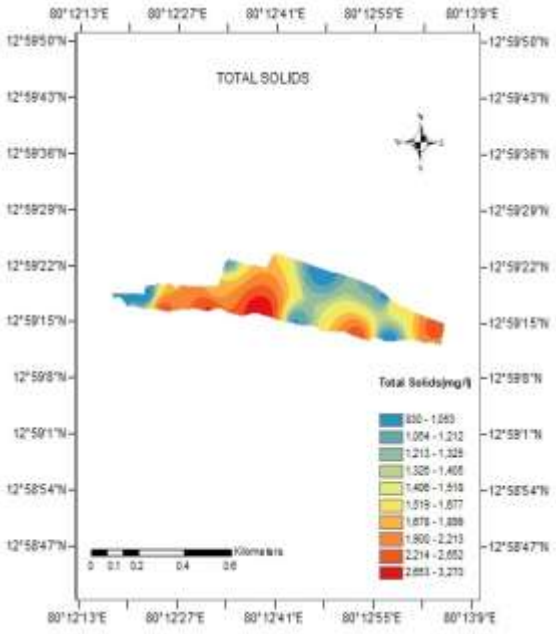

Figure 6: Spatial Distribution of TS

6) Chemical Oxygen Demand

COD is an index that shows the effect of discharged wastewater due to elevated oxygen demand due to chemicals [4]. An average value of 67.25 mg/l is observed. It is seen that it is within the limits of a freshwater body but high level makes it unsafe for direct usage.

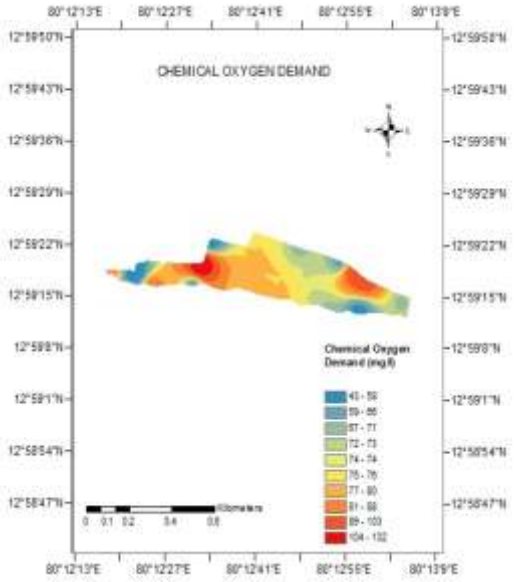

Figure 7: Spatial Distribution of COD

Small scale industries close by let in their effluent into lake (S1-S3).According to Environmental standards, the value of COD should be less than 250 mg/l for discharge[11]. However it is unfit for drinking purpose as the values should be as less as 2 or 3 mg/l. The distribution is shown in figure 7.

7) Biological Oxygen Demand

Biological Oxygen Demand is of importance as it directly signifies the extent of organic pollution present [9]. BOD value as high near the boundary of the lake (from S10-S13) with considerably low values in the interior. It is not suitable for drinking as not all the values fall within the permissible limits of 3-5 ppm [22].

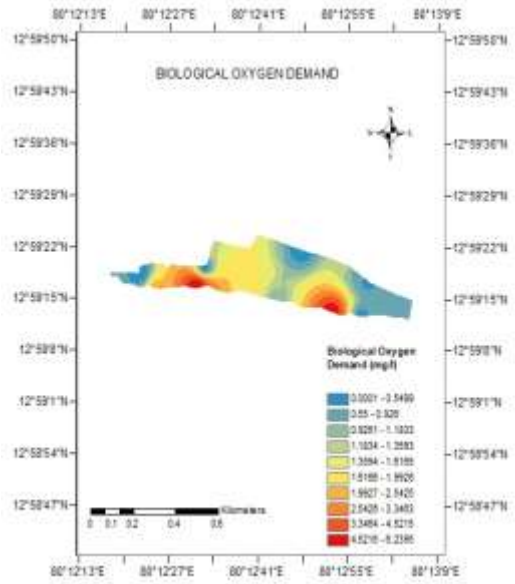

Figure 8: Spatial Distribution of BOD

This affects the aquatic organisms depriving them of available oxygen. When the oxygen is consumed, the oxygen available is less. Hence the BOD affects the fish life and the aquatic life as well. The spread of Biological Oxygen Demand throughout the Velacherry Lake is shown in the above figure 8.

6. Result and Inference

a) DO vs TDS

The principal application of TDS is in the study of water quality for streams, rivers and lakes, although TDS is generally considered not as a primary pollutant, but it is rather used as an indication of aesthetic characteristics of drinking water and as an aggregate indicator of presence of a broad array of chemical contaminants.

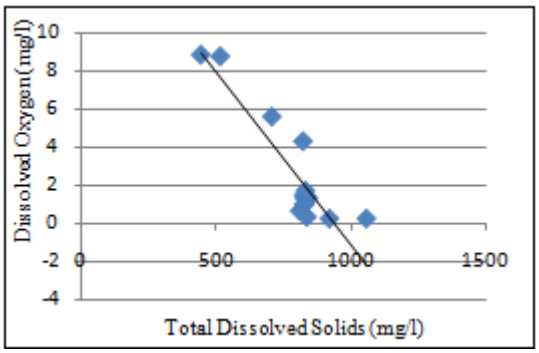

Figure 9: DO vs TDS

The amount of oxygen available for various purpose of the ecosystem largely depends on the Total Dissolved Solids. It is evident from the graph that as the solid content increases the Oxygen available decreases from Figure 9. The graph shows a negative correlation [14]. This is because the presence of solids in the water prevents the penetration of light to the deeper parts. This reduces the plant productivity due to insufficient light for photosynthesis. Ultimately, the Dissolved Oxygen content produced is very less. Further decomposition results in even less availability of Oxygen for the plants and the survival of the aquatic organisms.

b) pH vs Alkalinity

pH is basically a scale to measure whereas total alkalinity is a measurement of all alkaline substances dissolved in the water. In other words, total alkalinity is a measurement of the water's ability to resist change in pH.

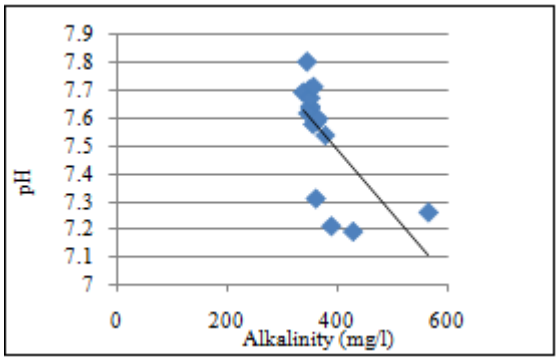

Figure 10: pH vs Alkalinity

This is seen from the Figure 10 which indicates a negative correlation. As the alkalinity reduces, the Hydrogen Ion concentration shows a hike due to the lack of availability of alkali for neutralization of the pH.

7. Conclusion

With rising population, effective disposal of enormous waste is a challenge [18]. The analyzed parameters TSS, TDS, BOD, COD, pH, DO and their variations from the standards is found dangerous to its aquatic biodiversity as well as plant life. The acquired results indicated the poor water quality and are unfit for usage as drinking water in most cases. Dissolved Oxygen and demand for oxygen are extremely unmatchable, the prime factor being urbanization and encroachment. The local authorities, public and the Government should be aware of the prevailing condition [16]. Efforts were taken by pollution control board supported by the government for its restoration but went in vain. Public Awareness on the poor quality, involvement and cooperation with the authorities for betterment is essential. Monitoring with proper planning for implementing scientific and feasible management system should be considered. This report showed the potential uses of remote sensing with GIS in efficient handling of the spatial data, field data contrary to the conventional method. Widening the horizon for GIS, RS and many more upcoming technologies must be ensured to face the real world challenges [15].

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