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Qualitative Evaluation of Sasthamkotta Lake by Using GIS

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ABSTRACT
Sasthamkotta Lake, also categorized as a designated wetland of international importance under the Ramsar Convention since November 2002 is the largest fresh water lake in Kerala, a state of India on the south of the West Coast and one among the nineteen wetlands identified for conservation and management by the ministry of environment and forests under the national wetland conservation program. It meets the drinking water needs of half a million people of Kollam district in Kerala and also provides fishing resources. The lake is facing degradation due to anthropogenic activities such as directing human waste, soil erosion due to destruction of vegetation, changes in land use pattern etc. thus leading to the deterioration of environmental quality as well as a decrease in the surface area and depth. The present study is to assess the quality of the water in Sasthamkotta Lake by GIS interpolation and to predict the future pollution level and its impact.
Keywords - Biological parameters, Chemical parameters, Fresh water lakes, GIS Interpolation, Physical parameters, Statistical analysis Water Quality Analysis

I. INTRODUCTION

Water is an essential natural resource for sustaining life and environment that we have always thought to be available in abundance and the free gift of nature. However, the chemical composition of surface and subsurface water is one of the prime factors on which the suitability for domestic, industrial or agriculture purpose depends. Natural, readily available water such as shallow groundwater, surface water, water from the boreholes and springs are the main sources for drinking water production [1].Though surface water contributes only 0.3% of the total water resources on earth, it is one of the major and preferred sources of drinking water in rural as well as urban areas, particularly in the developing countries like India. But in the era of economic growth, surface water is getting polluted due to urbanization and industrialization [2].

Water quality is a term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose [3].

GIS technology integrates common database operations with unique visualization. The advantage of GIS compared to other information systems is the highest power of analyzing of spatial data and handling large spatial databases. GIS serves as a decision support system for management of land, resources or any spatially distributed activities or phenomenon. Thus GIS found to be an efficient tool for spatial assessment of pollutions[4]. Pollution concentration maps prepared using GIS are spatial distribution maps showing variation of surface water pollutants such as total dissolved solids, heavy metals, nitrates etc. over the considered area [5].

The State's largest freshwater lake and one of the 26 Ramsar sites in the country, Sasathamkotta Lake in the Kollam district is fast becoming grassland (The Hindu, April 9, 2013). Even as it is feared that Sasthamkotta Lake is shrinking to death, a recent study by the Kerala Sasthra Sahithya Parishad (KSSP) brings the relief that the State's largest freshwater lake is not in danger of extinction. The study submitted to the State government shows that water level of the lake fell to alarming levels in 2004 and 2009.

Many research studies had been done regarding hydrological features of the lake. But most of them are not concentrated on water quality and other environmental features. Very few studies reveal the physical, chemical and biological characteristics of the lake. After detailed review of literature it has been understood that GIS interpolation can effectively utilized for assessing the pollution level of the lake. So the present study was envisaged to have a detailed assessment of water quality of the Sasthamkotta Lake by using GIS.

The objective of the study is to assess the quality of the water in Sasthamkotta Lake by using GIS mapping after analyzing the physical, chemical and biological parameters and finally to predict the future pollution level and its impacts.

II. MATERIALS AND METHODS

2.1 STUDY AREA SELECTION

The Sasthamkotta lake is located physiographically in the midland region between 9º0'- 9º 5'N latitude and 76º 35'-76º 46'E longitude at an elevation of 33 m above mean sea level. The Lake has a catchment area of 934.56 hectares, an average depth *of* 6.7 m and a maximum depth of 13.9 m.

2.2 SAMPLING AND DATA COLLECTION

The samples were taken from 8 stations (Figure 1) during the months from October 2012 to July 2013.The collections were made during day time. Maximum care was taken for the collection of samples, their preservation and storage as per the APHA standards [7].Latitude and Longitude of the sampling stations are also marked by using GPS. The previous water quality data of Sasthamkotta Lake were obtained from the Kerala Water Authority, Q.C Division.

2.3 MEASUREMENT AND ANALYSIS OF WATER QUALITY PARAMETERS

Water quality was analyzed for physical, chemical and biological parameters such as DO, BOD, COD, Turbidity, Total Solids, Electrical conductivity, Acidity, Alkanity, Sulphate, Total Hardness, Calcium, Magnesium, Chloride, Fluoride, Iron, pH, Total coliform and Fecal coliform for more accurate value of Water Quality Index. These parameters were measured as per standard method APHA.

2.4 STATISTICAL ANALYSIS OF DATA

Water quality data were statistically analyzed by using R software. To find out the most significant parameters among the quality variables, Pearson's correlation studies were conducted between water quality index and parameters. Those parameters having coefficient of correlation nearer to one are more significant and the P-value should be less than 0.05.

2.5 WATER QUALITY MAPPING USING GIS

To represent WQI of the lake, GIS tool was used. The method used was Inverse Distance Weighted interpolation. IDW interpolation explicitly implements 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 will use the measured values surrounding the predicted location. Those measured values closest to the prediction location will have more influence on the predicted value than those farther away. Thus, IDW assumes that each measured point has a local influence that diminishes with distance. It weights the points closer to the prediction location greater than those farther away, hence the name inverse distance weighted.

III. RESULTS AND DISCUSSION

3.1 GENERAL

After conducting detailed survey, identified the main contamination stations (Figure 1) and latitude and longitude of the stations also marked (Table 1). The samples were taken from the stations from the months of October 2012 to July 2013 and the characterizations of the samples in pre monsoon, monsoon and post monsoon seasons are shown in Table 2, 3 and 4.

Fig. 1 sampling points(Source: Salin Peter et al. 2013)

3.2 WATER QUALITY ANALYSIS

Seasonal analysis of water quality was done by using the average value of the parameters obtained from all the stations (Table 2, 3 and4).

3.2.1 DISSOLVED OXYGEN

Variations in the concentration of dissolved oxygen at pre monsoon, monsoon and post monsoon seasons from the eight sampling stations were, presented in Table 2, 3, 4 respectively and the graphical representation showed in Fig. 2. The average value of dissolved oxygen at pre monsoon season ranged from a minimum of 6.6 mg/L in sampling station 1 (S1) to a maximum of 7.2 mg/L in sampling station 8 (S8).At monsoon season it ranges from 7.6 mg/L in sampling station 6 (S6) to 8.54 mg/L in sampling station 8 (S8) and post monsoon season it ranges from 7.6 mg/L in sampling station 3 (S3) to 8.4 mg/L in sampling station 8 (S8). Seasonal mean showed that dissolved oxygen is sufficient (> 5.0 mg/l) at all stations and highest during monsoon and post monsoon seasons than pre monsoon.

3.2.2 BIOLOGICAL OXYGEN DEMAND

The observed variations of biological oxygen demand at pre monsoon, monsoon and post monsoon seasons were illustrated in Table 2, 3, 4 respectively and the graphical representation in Fig. 3.The minimum BOD of 4 mg/L at pre monsoon season was recorded from sampling stations 2 and 8 (S_2 and S_8) and highest BOD of 10 mg/L was from sampling station 5 (S_5).At monsoon season the BOD ranges from a minimum value of 5 mg/L in sampling station 4 (S_4) to a maximum of 12 mg/L in sampling stations 5 and 7 (S_5 and S_7) and at post monsoon season the minimum value of 4 mg/L at sampling station 4 (S_4) to a maximum of 15 mg/L in sampling station 7 (S_7). The maximum BOD was observed in sampling station 7 (S_7) at post monsoon season because of the direct discharge of waste water from Saathamkotta and nearby areas.

3.2.3 CHEMICAL OXYGEN DEMAND

The observed variations of mean chemical oxygen demand values were illustrated in Table 2, 3, 4 and Fig. 4. At pre monsoon season the COD ranges from a minimum of 30 mg/L in sampling stations 2, 3 and 8 (S_2, S_3 and S_8) to a maximum of 197 mg/L in sampling station 6 (S_6).At monsoon season it ranges from 30 mg/L in sampling stations 2, 3 and 8(S_2, S_3 and S_8) to 197 mg/L in sampling station 6 (S_6) and at post monsoon season 30 mg/L in sampling station 8 (S_8) to 197 mg/L in sampling station 3 (S_3). In sampling stations 3 and 6 (S3 and S_6), COD value is very high because of the waste agricultural chemicals discharged into the lake from rubber plantations at Rajagiri, Bharanikkavu and the adjoining areas. All other stations COD value is high because of the waste agricultural chemicals discharged into the lake from rubber plantations at Sasthamkotta and nearby areas and the direct discharge of drainage water from Sasthamkotta, Bharanikkavu and nearby areas.

TABLE 1 LIST OF SAMPLING STATIONS (Source: Salin Peter et al. 2013)

Sampling Stations	Coordinates	Remarks
S1	9^0 2' 30.28" N 76^0 37' 20.56" E	Effluent from water treatment plant
S2	9^0 2' 33.77" N 76^0 37' 23.43" E	Soil erosion and agricultural activities
S3	9^0 3' 22.73" N 76^0 38' 16.83" E	Wastewater discharge from Bharanikkavu town
S4	$9^0$1'58.76"N 76^0 38' 8.70" E	The destruction of the hillocks, intense soil erosion and deposition of mud in the lake
S5	9^0 1' 48.18" N 76^0 36' 48.30" E	Nutrient rich water flow from the Karali marshlands
S6	9^0 2' 20.35" N 76^0 37' 02.25" E	Wastewater discharge from rubber estate
S7	9^0 2' 40.87" N 76^0 37' 40.65" E	Wastewater discharge from Sasthamkotta town
S8	9^0 2' 15.68" N 76^0 37' 41.78" E	Centre of the lake

TABLE 2 CHARACTERIZATION OF WATER SAMPLE IN PRE MONSOON SEASON (Source: Salin Peter et al. 2013)

Parameters	Units	Sampling Stations							
		S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
DO	mg/L	6.6	7.1	7.2	6.8	7.1	7.2	6.9	7.2
BOD	mg/L	5	4	7	5	10	5	7	4
COD	mg/L	190	30	30	110	120	197	140	30
Turbidity	NTU	7.2	5.8	7.2	7.1	7.3	5.8	6.9	5
Temperature	^{0}C	30.1	30	29.9	29.8	29.9	29.8	30.1	29.9
Total Solids	mg/L	43.2	42.1	42.5	43.1	44.2	42.1	43.5	38
pH		6.79	6.82	6.71	6.9	6.9	6.82	6.71	6.9
Iron	mg/L	0.46	0.41	0.37	0.45	0.32	0.41	0.38	0.03
Fluoride	mg/L	0.41	0.37	0.36	0.47	0.31	0.37	0.40	0.2
Potassium	mg/L	1	1.2	1	1.3	1.3	1.2	1.3	1
Total coliform	No.of coliforms/100ml	1100	800	1000	1100	1100	467	1100	467
E coli	No.of coliforms/100ml	120	120	120	67	120	120	120	30

TABLE3CHARACTERIZATION OF WATER SAMPLE IN MONSOON SEASON (Source: Salin Peter et al. 2013)

Parameters	Units	Sampling Stations							
		S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
DO	mg/L	8.1	8.3	7.8	8.5	8.4	7.6	7.9	8.54
BOD	mg/L	9	9	10	5	12	7	12	6
COD	mg/L	190	30	30	110	120	197	140	30
Turbidity	NTU	14	10	16	8	10	14	18	8
Temperature	^{0}C	27	26.9	26.9	27	26.8	27	27.1	26.8
Total Solids	mg/L	46	42	52	44	46	44	60	42
pH		7.2	7.3	7.1	6.9	7.4	7.2	7.2	7.1
Iron	mg/L	0.45	0.40	0.42	0.47	0.41	0.38	0.40	0.1
Fluoride	mg/L	0.42	0.37	0.38	0.44	0.30	0.39	0.42	0.2
Potassium	mg/L	1.2	1.4	1.2	1.3	1.3	1.1	1.4	1.2
Total coliform	No. of coliforms/100ml	1100	1100	1100	1100	1100	1100	1100	1100
E coli	No. of coliforms/100ml	140	160	260	260	140	260	260	140

TABLE 4 CHARACTERIZATION OF WATER SAMPLE IN POST MONSOON SEASON (Source: Salin Peter et al. 2013)

Parameters	Units	Sampling Stations							
		S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
DO	mg/L	8.0	8.3	7.6	8.3	8.3	7.7	7.9	8.4
BOD	mg/L	10	9	12	4	12	8	15	5
COD	mg/L	160	195	197	110	80	190	160	30
Turbidity	NTU	12	9.6	20	6.8	9.2	12	18	6.7
Temperature	^{0}C	27.4	27.5	27.4	27.2	27.3	27.1	27.4	27.2
Total Solids	mg/L	45.5	43	62	42.1	45.1	44	58	40
pH		7.2	7.1	6.9	7.2	7.6	7.1	7.2	7.1
Iron	mg/L	0.44	0.37	0.42	0.46	0.32	0.36	0.42	0.1
Fluoride	mg/L	0.38	0.36	0.42	0.36	0.20	0.4	0.42	0.2
Potassium	mg/L	1.2	1.3	1.2	1.2	1	1.3	1.3	1
Total coliform	No.of coliforms/100ml	1100	1100	1100	1100	1100	1100	1100	1000
E coli	No.of coliforms/100ml	160	120	260	260	160	260	260	120

3.2.4 TURBIDITY

The observed variations in turbidity values were illustrated in Table 2, 3, 4 and Fig. 5.The turbidity values ranged between 5 NTU in sampling station 8 (S_8) to 7.3 NTU in sampling station 5 (S_5) at the pre monsoon, 8 NTU in sampling stations 4 and 8(S_4 and S_8) to 18 NTU at sampling station 7 (S_7) at monsoon and at post monsoon season it was 6.7 NTU in sampling station 8(S_8) to 20 NTU in sampling station 3(S_3). The seasonal mean values of turbidity showed that minimum was observed during pre monsoon and maximum during monsoon and post monsoon season. In station S_7 turbidity value is very high in the monsoon and post monsoon season because of the direct discharge of drainage water from Sasthamkotta and nearby areas.

3.2.5 SURFACE WATER TEMPERATURE

Surface water temperature measured and the seasonal analysis during the period of study was given in Table 2, 3, 4 and Fig. 6**.** The average temperature ranges from 29.8^{0}C in sampling stations 4 and 6(S_4 and S_6) to 30.1^{0}C in sampling stations 1 and 7 (S_1 and S_7) at pre monsoon season. At monsoon season it ranged from 26.8^{0}C from sampling stations 5 and 8(S_5 and S_8) to 27.1^{0}C in sampling station 7(S_7) and at post monsoon season it from 27.6^{0}C in sampling station 6(S_6) to 27.5^{0}C in sampling station 2(S_2).Highest water temperature was observed at pre monsoon season in sampling stations 1 and 7 (S_1 and

S_7), while the lowest temperature was at monsoon season in sampling stations 5 and 8(S_5 and S_8).

3.2.6 TOTAL SOLIDS

The seasonal variations of total solids of the lake water are shown in Table 2, 3, 4and figure 7. At pre monsoon season TS values ranged from a minimum of 38 mg/L in sampling station 8(S_8) to a maximum of 44.2 mg/L in sampling station 5(S_5) and at monsoon season a minimum of 42 mg/L in sampling stations 2 and 8(S_2 and S_8) to a maximum of 60 mg/L in sampling station7 (S_7).At post monsoon season it ranged from 40 mg/L in sampling station 8(S_8) to 62 mg/L in sampling station3(S_3).Total solid values at pre monsoon are slightly lower than monsoon and post monsoon seasons. The highest value was recorded during post monsoon season at S_3 and the lowest was at S_8 during pre monsoon season.

3.2.7 pH

The seasonal variations of pH of the lake water are shown in Table 2, 3, 4 and figure 8.The desirable limit is 6.5 to 8.5(IS 10500:2004).All the seasons pH is within the range. At pre monsoon season pH ranges from 6.71 to 6.9, at monsoon it from 6.9 to 7.4 and at post monsoon it from 6.9 to 7.6. In pre monsoon season pH is slightly acidic, i.e., below 7.

3.2.8 IRON

Seasonal variations of iron of the lake water are shown in Table 2, 3, 4and figure 9.The desirable limit is 0.3 mg/l (as per IS 10500:2004).At pre monsoon iron ranged from 0.03 mg/L in sampling station 8(S_8) to 0.46 mg/L in sampling station 1 (S_1),at monsoon it ranged from 0.1 mg/L in sampling station 8(S_8) to 0.47 mg/L in sampling station 4(S_4) and at post monsoon it ranged between 0.1 mg/L in sampling station 8(S_8) to 0.46 mg/L in sampling station 4(S_4) . All the seasons presence of iron is beyond the range except sampling station 8, which is the centre portion of the lake.

3.2.9 FLUORIDE

Seasonal variations of fluoride of the lake water are shown in Table 2, 3, 4 and figure 10.Fluoride ranged between 0.2 mg/L in sampling station 8(S_8) to 0.47 mg/L in sampling station 4(S_4) at pre monsoon season, at monsoon it ranged from 0.2 mg/L in sampling station 8(S_8) to 0.44 mg/L in sampling station 4 (S_4) and at post monsoon it ranged from 0.2 mg/L in sampling station 8(S_8) to 0.42 mg/L in sampling stations 3 and 7(S_3 and S_7). All seasons presence of fluoride are within the range.

3.2.10 POTASSIUM

Seasonal variations of potassium of the lake water are shown in Table 2, 3, 4 and figure 11. The desirable limit is 1 mg/L (as per IS 10500:2004).At pre monsoon season potassium ranged from a minimum of 1 mg/L in sampling stations 1,3 and 8(S_1,S_3 and S_8) to a maximum of 1.3 mg/L in sampling stations 4,5and 7(S_4,S_5 and S_7),at monsoon it ranged from 1.1 mg/L in sampling station 6(S_6) to 1.4 mg/L in sampling stations 2 and 7(S_2 and S_7) and monsoon season it ranged from 1 mg/L in sampling stations 5 and 8(S_5 and S_8) to 1.3 mg/L in sampling stations 2,6 and 7(S_2,S_6 and S_7). In all seasons presence of potassium are slightly above the desirable limit.

3.2.11 TOTAL COLIFORMS

Seasonal variations of number of coliforms in the lake water are shown in Table 2, 3, 4 and figure 12.The desirable limit is zero, i.e., absence of coliform (as per IS 10500:2004).At pre monsoon season number of colifrms ranged between 467 / 100 ml in sampling stations 6 and 8(S_6 and S_8) to 1100 / 100 ml in sampling stations 1,4,5 and 7(S_1,S_4,S_5 and S_7) and at monsoon and post monsoon seasons number of coliforms in all stations were 1100 / 100ml. All seasons presence of coliforms are beyond the limit. At monsoon and post monsoon season numbers of coliforms are higher than pre monsoon season.

3.2.12 E COLI

Seasonal variations of number of E coli in the lake water are shown in Table 2, 3, 4 and figure 13.The desirable limit is zero, i.e., absence of E coli (as per IS 10500:2004).At pre monsoon season the number of E coli ranged between 30 / 100 ml in sampling station 8(S_8) to 120 / 100 ml in sampling stations 1,2,3,5,6 and 7(S_1,S_2,S_3,S_5,S_6 and S_7),at monsoon season it ranged from 140 / 100ml in sampling stations 1,5 and 8(S_1,S_5 and S_8) to 260 / 100 ml in sampling stations 3,4,6 and 7(S_3,S_4,S_6 and S_7) and at post monsoon season it from120 /100 ml in sampling stations 2 and 8(S_2 and S_8) to 260 / 100 ml in sampling stations 3,4,6 and 7(S_3,S_4 and S_6).In all seasons presence of E coli are beyond the limit. At monsoon and post monsoon season number of E coli are higher than pre monsoon season because of the direct discharge of waste water from Sasthamkotta, Bharanikkavu and nearby areas.

3.5 WATER QUALITY ANALYSIS BY USING GIS INTERPOLATION

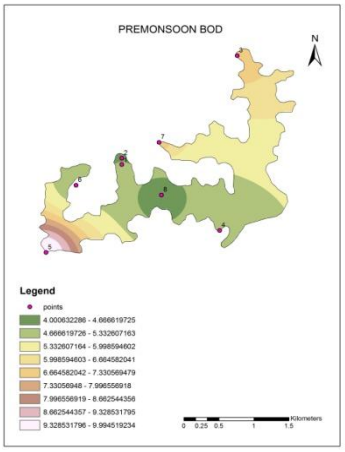

Fig.2 GIS Interpolation of BOD in premonsoon season

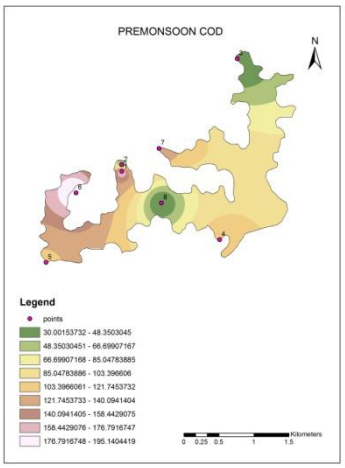

Fig.5 GIS Interpolation of COD in premonsoon season

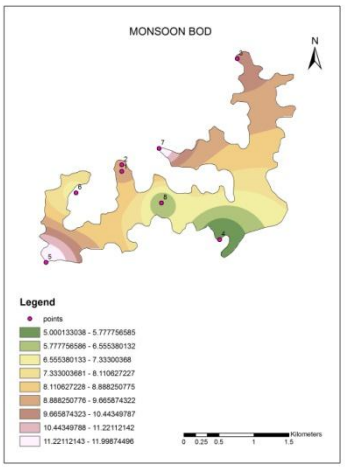

Fig.3 GIS Interpolation of BOD in monsoon season

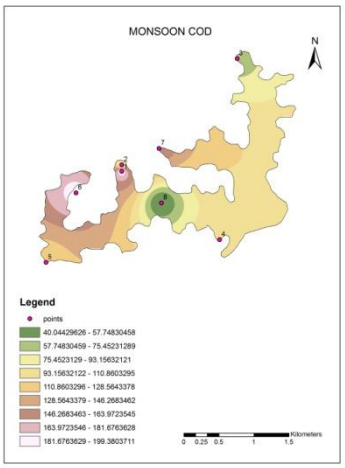

Fig.6 GIS Interpolation of COD in monsoon season

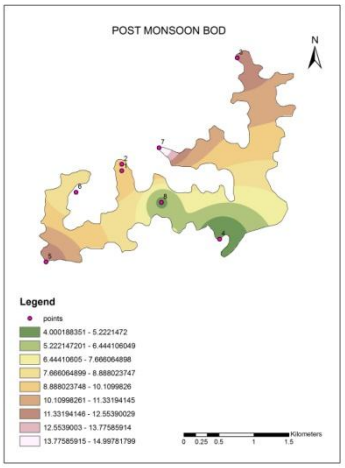

Fig.4 GIS Interpolation of BOD in post monsoon season

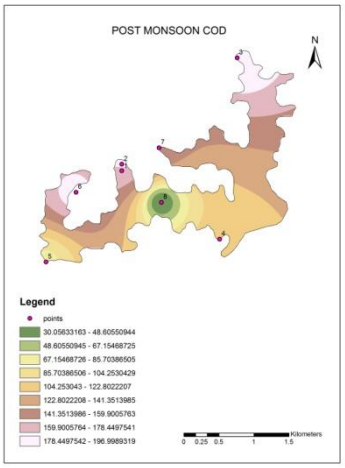

Fig.7 GIS Interpolation of COD in post monsoon season

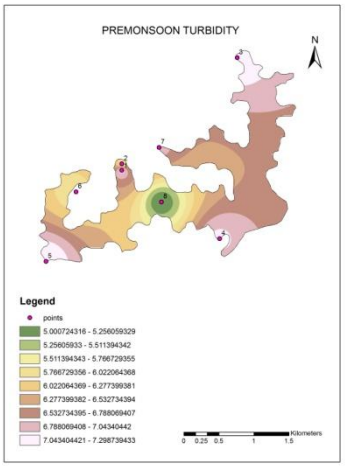

Fig.8 GIS Interpolation of Turbidity in pre monsoon season

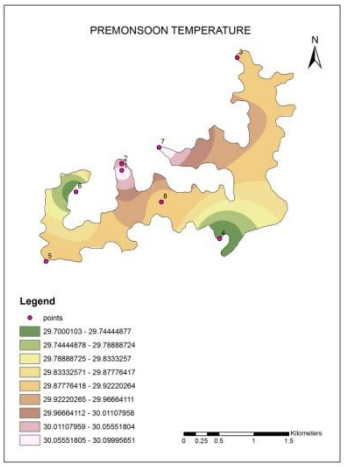

Fig.11 GIS Interpolation of Temp. in pre monsoon season

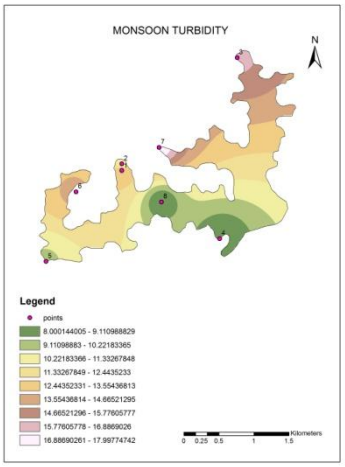

Fig.9 GIS Interpolation of Turbidity in monsoon season

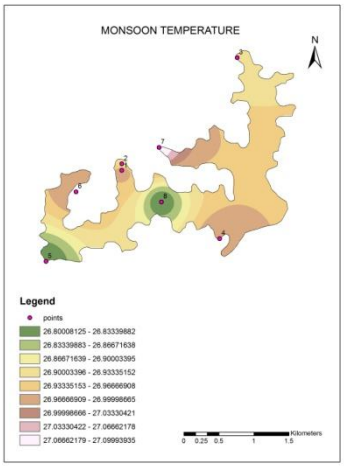

Fig.12 GIS Interpolation of Temp. in monsoon season

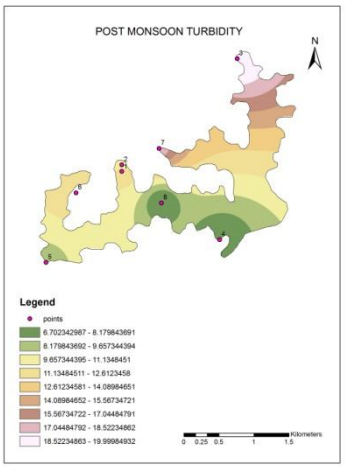

Fig.10 GIS Interpolation of Turbidity in post monsoon season

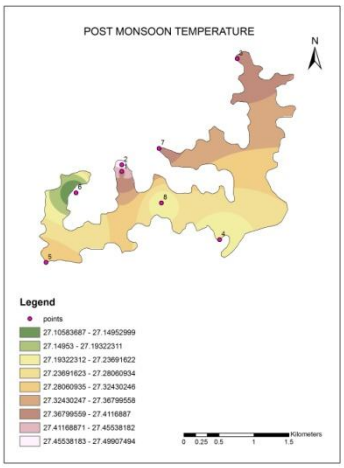

Fig.13 GIS Interpolation of Temp. in post monsoon season

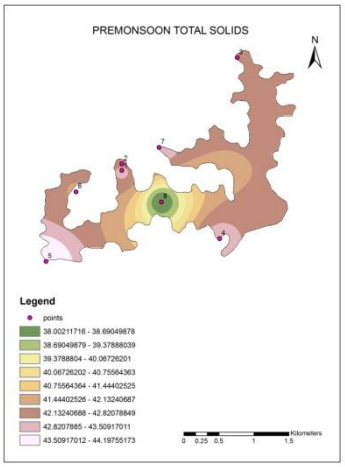

Fig.14 GIS Interpolation of TS in pre monsoon season

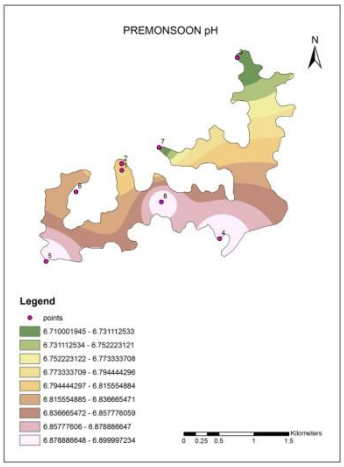

Fig.17 GIS Interpolation of pH in pre monsoon season

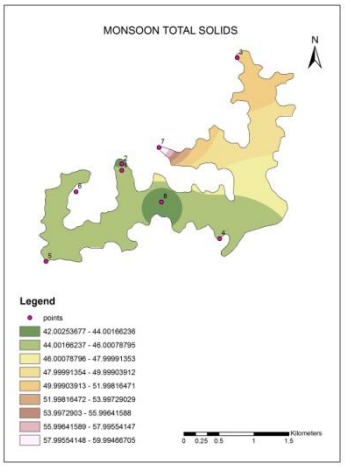

Fig.15 GIS Interpolation of TS in monsoon season

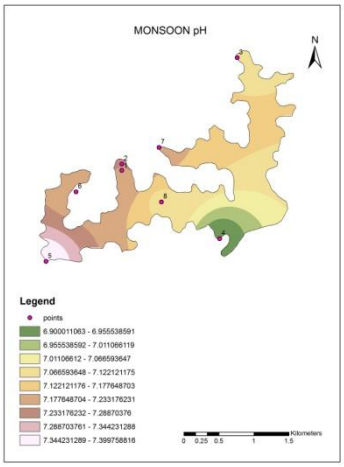

Fig.18 GIS Interpolation of pH in monsoon season

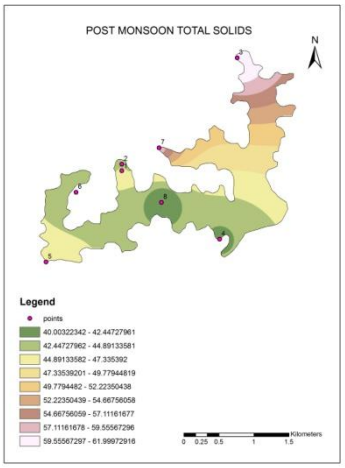

Fig.16 GIS Interpolation of TS in post monsoon season

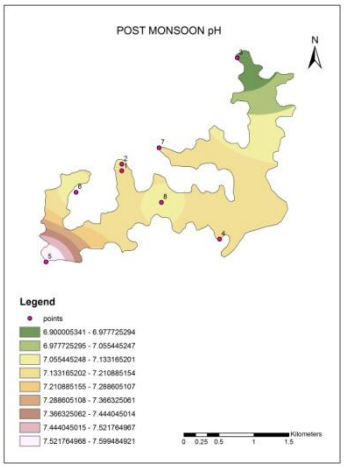

Fig.19 GIS Interpolation of pH in post monsoon season

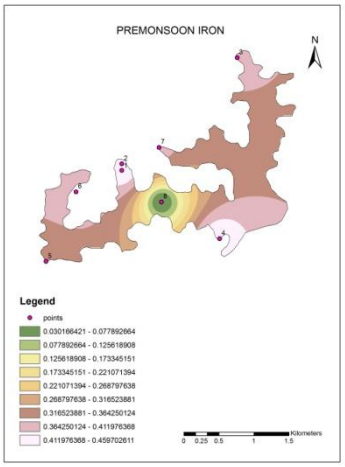

Fig.20 GIS Interpolation of iron in pre monsoon season

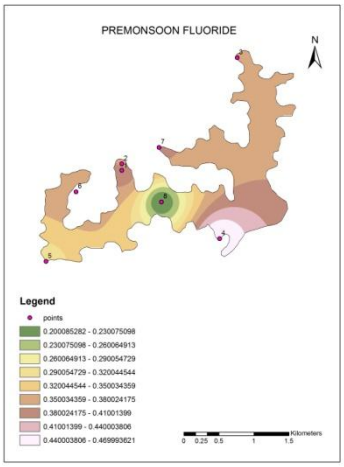

Fig.23 GIS Interpolation of F in pre monsoon season

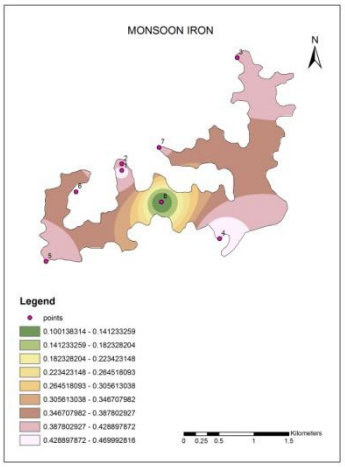

Fig.21 GIS Interpolation of iron in monsoon season

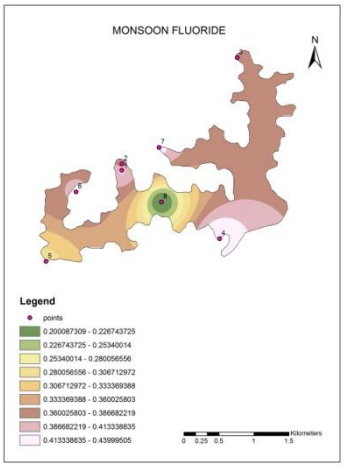

Fig.24 GIS Interpolation of F in monsoon season

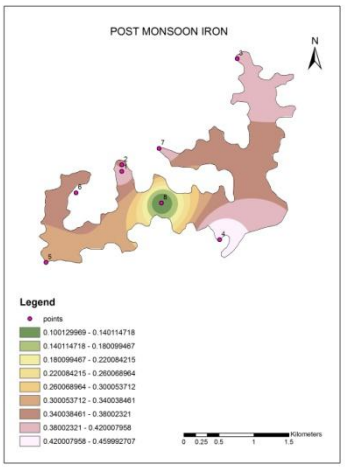

Fig.22 GIS Interpolation of iron in post monsoon season

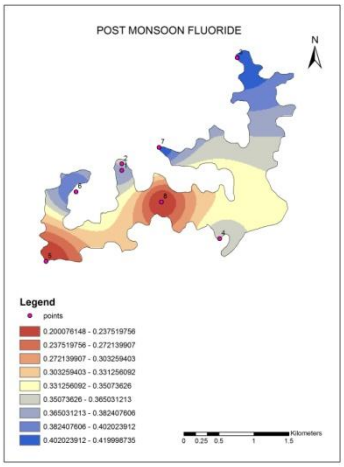

Fig.25 GIS Interpolation of F in post monsoon season

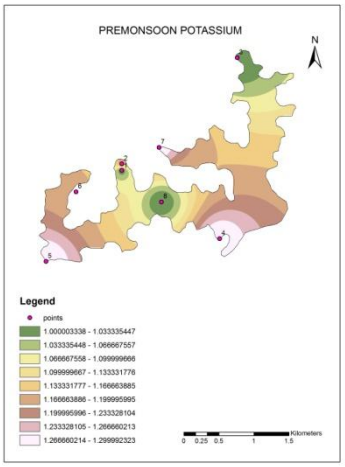

Fig.26 GIS Interpolation of potassium in pre monsoon season

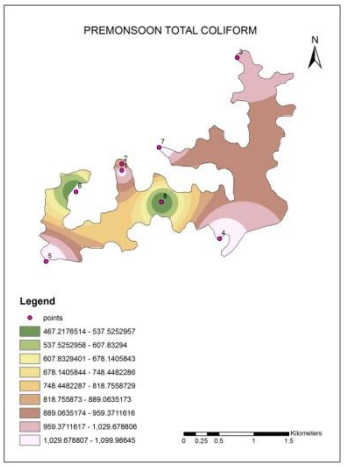

Fig.29 GIS Interpolation of total coliform in pre monsoon season

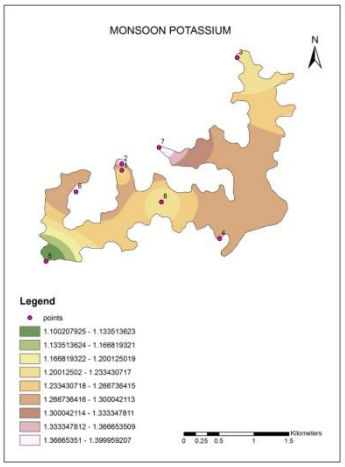

Fig.27 GIS Interpolation of potassium in monsoon season

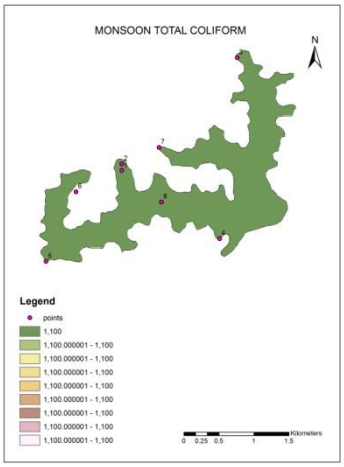

Fig.30 GIS Interpolation of total coliform in monsoon season

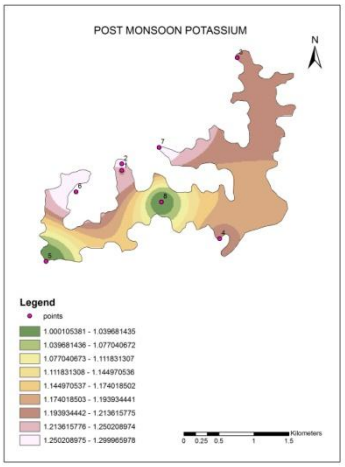

Fig.28 GIS Interpolation of potassium in post monsoon season

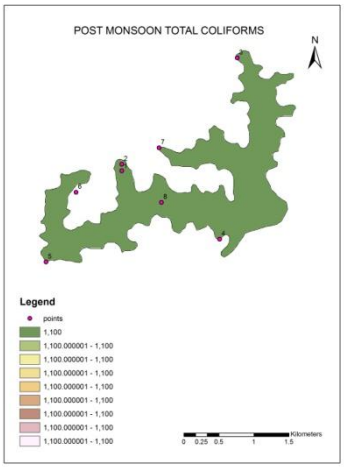

Fig.31 GIS Interpolation of total coliform in post monsoon season

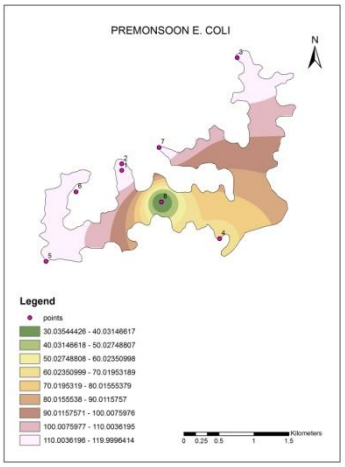

Fig.32 GIS Interpolation of E coli in pre monsoon season

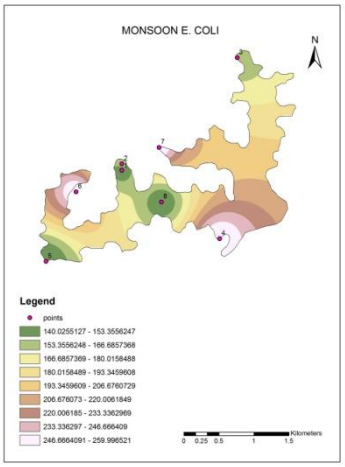

Fig.33 GIS Interpolation of E coli in monsoon season

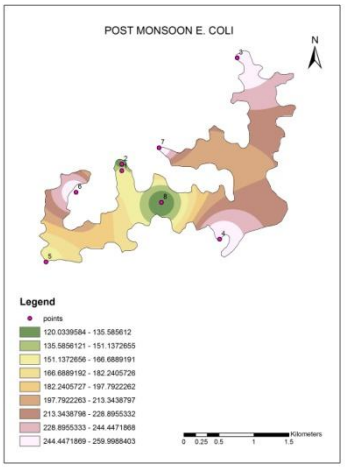

Fig.34 GIS Interpolation of E coli in post monsoon season

GIS interpolation of BOD at pre monsoon, monsoon and post monsoon season are shown in Fig.2, 3and4 respectively. From this interpolation it is clear that BOD is high in and around sampling station 5 (S_5) which is the Karali area at pre monsoon season, at monsoon it is high in and around sampling station 5 and 7(S_5 and S_7) and at post monsoon it is high in sampling station7, which is the direct discharges of waste water from Sasthamkotta and nearby areas.

GIS interpolation of COD at pre monsoon, monsoon and post monsoon season are shown in Fig.5, 6and7 respectively. After analyzing the interpolation map it is found that COD concentration is high in and around sampling stations 1 and 6(S_1 and S_6) at pre monsoon and monsoon season. Post monsoon season it is high around sampling stations 2, 3 and 6 (S_2, S_3 and S_6).

GIS interpolation of Turbidity at pre monsoon, monsoon and post monsoon season are shown in Fig.8, 9and10 respectively. Turbidity is mainly concentrated on shore side of the lake.

GIS interpolation of temperature at pre monsoon, monsoon and post monsoon season are shown in Fig.11, 12 and13respectively. The variations in temperature in all sampling stations were less at pre monsoon, monsoon and post monsoon seasons.

GIS interpolation of total solids at pre monsoon, monsoon and post monsoon season are shown in Fig.14, 15 and 16 respectively. From this interpolation map it is clear that total solid is high in and around the sampling stations 1, 4, 5 and 7 at pre monsoon season and at monsoon and post monsoon season it is high in sampling stations 3 and 7; the direct discharge of waste water from Sasthamkotta, Bharanikkavu and nearby areas.

GIS interpolation of pH at pre monsoon, monsoon and post monsoon season are shown in Fig.17, 18and19 respectively. From the interpolation map it is found that the variations in pH at all seasons are within the range.

GIS interpolation of iron at pre monsoon, monsoon and post monsoon season are shown in Fig.20, 21 and 22 respectively. From the interpolation, it is found that concentration of iron was beyond the limit at all seasons except centre of the lake.

GIS interpolation of fluoride at pre monsoon, monsoon and post monsoon season are shown in Fig. 23, 24 and 25 respectively. Fluoride concentrations are within the range.

GIS interpolation of potassium at pre monsoon, monsoon and post monsoon season are shown in Fig. 26, 27 and 28 respectively. From the interpolation it is found that concentration of potassium is almost same in all sampling stations except sampling number 1, 3 and 8 at pre monsoon season. At monsoon season it is almost same in all

sampling station and at post monsoon season it is almost same except sampling stations 5 and 8.

GIS interpolation of total coliform at pre monsoon, monsoon and post monsoon season are shown in Fig.29, 30 and 31 respectively. From the analysis of interpolation map it is found that number of coliforms were high in almost all the points at pre monsoon season. At monsoon and post monsoon it is found that concentration of total coliforms are same in all points.

GIS interpolation of E coli at pre monsoon, monsoon and post monsoon season are shown in Fig. 32, 33 and34 respectively. From interpolation map it is found that at pre monsoon, monsoon and post monsoon season concentration of E coli is high at almost all points except the centre of the lake.

IV. CONCLUSIONS

The present paper analyzes the water quality data collected from the Sasthamkotta Lake. Important issues include decreasing water quality, alternations in biological productivity (tropic state), increase in nutrient concentrations, contaminant migration into the lake etc.

- The DO values were found to range from 6.6 to 8.54 mg/L in all seasons. In comparison with the previous data, the DO of the lake is decreasing dangerously due to anthropogenic activities.
- The BOD range from 4 to 15 mg/L in all seasons. BOD is slightly increasing compared with the previous values.
- The COD ranges from 30 to 197 mg/L. Compared to the previous data, COD is increasing rapidly. This may be due to the waste agricultural chemicals discharged into the lake from the adjoining rubber plantations.
- The turbidity ranges from 5 to 18 NTU. This is high in monsoon and post monsoon seasons compared with pre monsoon season because of the direct discharge of drainage water from Sasthamkotta, Bharanikkavu and nearby areas.
- In pre monsoon season pH is slightly acidic, i.e., below 7.In all season pH is within the limit.
- In all the season presence of iron is beyond the limit (as per IS 10500).Concentration of iron is increasing compared with previous values.
- In all seasons presence of fluoride and potassium are within the range.
- Coliforms ranges from 400 to 1100/100ml.Number of coliforms is increasing very rapidly compared with the previous values.
- Ecoli ranges from 30 to 260/100ml.This is also found to be increasing very rapidly compared with the previous values.
- The quantities of phosphate and nitrate are increasing and higher than the prescribed limits.
- DO values of the lake are decreasing. They indicate that the lake is in hypereutrophic condition.
- In all the season water quality index remains in the category"fair".
- Future contamination rate were modelled using visual modflow. From the output it was clear that the contamination after 5 years will be two times the present value.

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