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An Assessment of Water Quality in River Periyar, Kerala, South India Using Water Quality Index.

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Abstract: *River periyar of Eloor-Edayar industrial stretch has been a subject of pollution study for many years but so far, indexing of water quality has never been attempted. Indexing of water quality variables was carried out using water quality index method developed by Canadian Council of Ministry of Environment (CCME). Statistical techniques like correlation and regression using SPSS software was used to understand the relation between parameters and water quality index. Overall water quality index showed "Poor" quality index in the river, with each sampling site coming under the "poor" quality index range. Correlation analysis showed that water quality index decreases with increase in parameter concentration and vice versa for parameters like calcium, sulphate, chloride, nitrate-nitrogen, total hardness, fluoride, and conductivity. From the analysis, it was found that the water quality index range increases with increase in pH and dissolved oxygen. Regression analysis was used to identify the extend to which each factor; scope, frequency and amplitude, used in the calculation, influenced the water quality index. From the analysis, it was observed that the number of parameters that exceeds the guideline (Scope, F_1) and the number of times each parameter exceeding the guideline (Frequency, F_2) affects the water quality index of the river. While the extend to which each parameter exceeding the standard limit (amplitude, F3) does not affect the water quality index.*
Keywords: *Amplitude, Correlation, Frequency, Regression, Scope, Water quality Index.*

I. Introduction

Water, the most precious of all resources is the lifeline of all living organisms on Earth. Rivers are an important part of earth's water cycle. They play an efficient and prominent role in sculpting earth's topography by carrying huge quantities of water from land to the sea. Most of the world's great cities have developed on the banks of rivers. Anthropogenic activities such as discharge of domestic, industrial and other major activities has caused major pollution problems to these rivers. Traditional approaches to assessing river water quality are based on comparison of experimentally determined parameter values with the existing local normative. Usual method of analysis does not give a global vision on spatial and temporal trends in the overall water quality. Water Quality Index is an effective tool in conveying information regarding the pollution status of the river. The use of Water quality index was initially proposed by Horton (1965) and Brown *et al* (1970)[1]. Since then, many different methods for the calculation of WQI's have been developed. Several authors have proposed the use of a WQI as a means to derive numerical expression for the general quality of the surface water (Brown et al., 1970; Otto, 1978; Miller et al., 1986; Bordalo et al., 2001; Cude, 2001; Hallock, 2002)[2,3,4,5 and 6]. WQI is considered better for transformation of information to general audiences (Stambuck-Giljanovic, 1999)[7] when their specific characteristic limitations are taken into consideration (Otto, 1978; Flores, 2002; Hallock, 2002; Pesce and Wunderlin, 2002)[2,8,6and 9]. WQI's can be very useful tool for management in decision and policy-making.

II. Aim And Objective

1. To convey the pollution status of the river through water quality index.
2. To analyze the relation between parameters and water quality index using statistical software SPSS.

III. Methodology

The paper presents the water quality index of river Periyar in terms of parameters such as pH, conductivity, Total dissolved solids, Total hardness, Dissolved Oxygen, Chemical Oxygen Demand, Calcium, Magnesium, Sulphates, Chlorides, Nitrate-N, Iron, Fluoride, and Phenol. Sampling points were fixed and selected after thorough field survey. Samples were collected from near both banks and from middle of the river.

Samples were collected during April '07 to May '08 during morning hours. Care has been taken to collect samples during low tide. River bisects the industrial belt at Eloor before discharging into the back waters adjoining the Arabian Sea Jayapalan, et al., (1976)[11]. One flows between Edayar & Eloor Island and the other flows between Eloor Island and kalamassery, to join back at the Eloor ferry. 16 sampling points have been selected, starting from Edamula. Edamula, the first sampling point is in the upstream of river and the last sampling point is Eloor ferry which is the confluence point of the river which further flows to join the estuary.

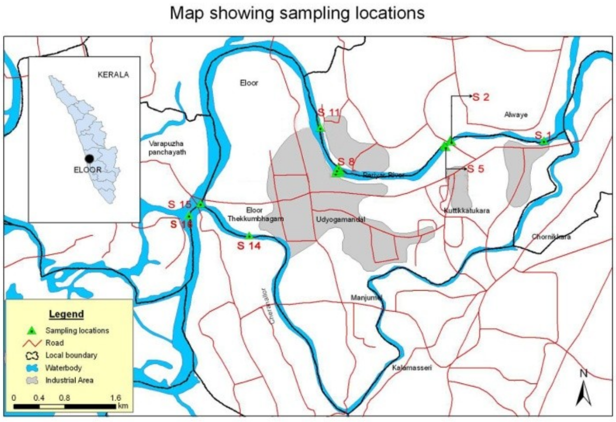

Fig 1: Map showing sampling locations

TABLE 1: Brief description of sampling sites

Sample No	Sampling Points
S1	Edamula, upstream of the river
S2	Pathalam Bund North (Edayar) , before reaching the bund
S5	Pathalam Bund South (Edayar), after the bund
S8	Sudchemi (Edayar), close to the sudchemi factory in the edayar region
S11	Pallikadavu (Edayar), near the bank of edayar region with few small-scale industries
S14	Kuzhikandam, discharge point of industries like HIL, Merchem
S15	Eloor Ferry Right, confluence point of the two branches to main river.
S16	Eloor Ferry Left, confluence point of two branches to the main river.

3.1 Analytical methods and instruments used

One litre of each sample was collected in pre-cleaned polythene bottles following standard methods and preserved till all analysis was completed. PH, Conductivity, Total Dissolved Solids were measured using digital meters soon after the collection of samples. Ethylene Di-amine tetra acetic acid (EDTA) titration method was used for analyzing Total hardness and calcium (APHA, 1992) [12]. For chloride estimation, Argentometric method and for Bio-chemical oxygen demand and dissolved oxygen modified Winkler methods were used (APHA, 1992) [12]. Iron is estimated spectrophotometrically with O – phenanthroline reagent. Turbidimetric method with barium chloride reagent is used for sulphate estimation. Sodium and potassium was analyzed using flame photometer. Nitrate-N was analyzed colorimetrically using Brucine- sulphanilic acid, Gravimetric method for magnesium estimation and SPADNS method for fluoride estimation whereas Phenol was analyzed using amino-antipyrene and chloroform extraction method. All the parameters were analysed following recommended analytical methods (APHA, 1992) [12].

3.2 Water Quality Index

The results obtained from the analysis of parameters were used for calculating the water quality index of the river. From different methods of water quality index available, here we use the one developed by Canadian council of Ministry of Environment [13] to analyse the water quality index of river Periyar, India. This index is based on combination of three factors

1. The number of variables whose objectives are not met (Scope)
2. The frequency with which the objectives are not met (frequency)
3. The amount by which objectives are not met (amplitude).

These are combined to produce a single value (between 0 and 100) that describes water quality.

Scope, F_1 represents the percentage of variables that do not meet the objectives at least once during the time period under consideration (failed variables), relative to the total number of variables measure.

$$\mathbf{F1} = \frac{\textbf{Number of failed variables}}{\textbf{Total number of variables}} \mathbf{x100} \qquad \text{---- (1)}$$

Frequency, F2 represents the percentage of individual tests that do not meet objectives (failed test)

$$\mathbf{F2} = \frac{\textbf{Number of failed test}}{\textbf{Total number of test}} \mathbf{x100} \qquad \text{----- (2)}$$

Amplitude, F_3 represents the amount by which the failed test values, do not meet the objective. F_3 is calculated in 3 steps.

The number of times the individual concentrations is greater than the objective (or less than when the objective is minimum) the objective is termed excursion and is expressed as follows.

When the test value does not exceed the objective

$$\mathbf{Excursion} = \frac{\textbf{Failed test value}}{\textbf{objective}} - \mathbf{1} \qquad \text{------- (3)}$$

For the cases in which test value does not fall below the objective

$$\mathbf{Excursion} = \frac{\textbf{objective}}{\textbf{Failed test value}} - \mathbf{1} \qquad \text{-------- (4)}$$

The collective amount by which individual tests are out of compliance is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both those meeting the objectives and not meeting the objectives). This variable always referred to as the normalized sum of excursions or NSE, is calculated as

$$\mathbf{NSE} = \sum_{i=1}^{n} \frac{\textbf{Excursions}}{\textbf{Total of the test}} \qquad \text{-------- (5)}$$

F_3 is calculated by an asymptotic function that scales the normalized sum of the excursions from the objectives to yield a range between 0 and 100.

$$\mathbf{F3} = \frac{\textbf{NSE}}{\textbf{NSEx0.01+0.01}} \qquad \text{--------- (6)}$$

Once the factors have been obtained, index can be calculated by summing the three factors. The sum of squares of each factor is therefore equal to the square of the index. This approach treats the index as a three dimensional space defined by each factor along one axis. With this model, the index changes in direct proportion to changes in all three factors.

The CCME water quality index: CCMEWQI = 100 $(\sqrt{F1^2 + F2^2 + F3^2})/1.732$ --- (7)

Once the CCMEWQI has been determined, water quality is ranked by relating it to one of the following categories:

EXCELLENT: 95-100 water quality is protected with virtual absence of threat or impairment; conditions very close to natural or pristine levels.

GOOD: 80-94 water quality is protected with a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.

FAIR: 65-79 water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.

MARGINAL: 45-64 water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.

POOR: 0-44 water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels

Failed test values or variables are taken for calculation based on the standards given by the Bureau of Indian standards. Following table 2 give the list of variables and the permissible limit of these variables in water.

Table 2: List of Parameters and their standards (BIS: 10500-1991)

Serial No.	Parameters	Standard
1	Ph	6.5-8.5
2	Dissolved Oxygen	5.0-6.0mg/l
3	Chemical Oxygen Demand	250mg/l
4	Total dissolved solids	500mg/l
5	Chlorides	250mg/l
6	Sulphate	200mg/l
7	Nitrate-nitrogen	45mg/l
8	Fluoride	0.6-1.2mg/l
9	Phenol	0.001mg/l
10	Iron	0.3mg/l
11	Conductivity	0.5-1.5mS/cm
12	Magnesium	30mg/l
13	Calcium	75mg/l

Correlation - regression of water quality index and parameter was done using SPSS statistical software.

IV. Result And Discussion

Water samples were analyzed for parameters such as pH, conductivity, Total dissolved solids, Total hardness, Dissolved Oxygen, Chemical Oxygen Demand, Calcium, Magnesium, Phenol, fluoride, Iron, Nitrate-Nitrogen, Sulphate and Chloride .Water quality index were calculated for these parameters using the index method developed by Canadian Council of ministers of Environment [13] . Annual average of the parameter was used for calculating the water quality index.

Table 3: Annual mean Water Quality Parameters of river Periyar 2007-08

Parameters	Ph	DO mg/l	Cond mS/cm	NO_3-N mg/l	COD mg/l	SO_4 mg/l	Cl mg/l	F mg/l	Phe mg/l	TDS mg/l	Fe mg/l	Ca mg/l	Mg mg/l	TH mg/l
Sample No														
S1	6.2	6.97	4.34	0.33	289.1	3.2	27.08	0.21	0.57	3674.8	0.4	3.2	2.9	17.64
S2	6.0	5.82	10.30	0.56	844.0	39.26	128.0	0.26	0.10	4694.5	0.4	6.4	7.0	46.07
S5	5.8	5.89	0.35	0.67	249.8	10.11	74.33	0.25	0.12	10135.7	1.5	7.0	8.30	76.47
S8	5.9	5.98	122.48	0.46	447.4	47.50	195.3	0.21	0.08	410.6	0.43	10.22	16.5	93.96
S11	5.9	6.35	125.23	0.41	345.6	39.54	232.8	0.28	0.17	368.12	1.51	10.15	14.34	84.71
S14	5.1	3.2	129.3	1.43	380.0	292.98	445.37	0.36	1.07	805.57	2.06	40.88	61.107	3244.5
S15	5.9	4.12	139.73	0.61	321.2	68.84	246.90	0.29	0.53	509.74	1.07	18.16	17.18	110.67
S16	5.9	5.31	142.98	0.763	379.4	184.48	404.43	0.36	0.75	582.23	1.54	10.94	36.50	217.64

DO-Dissolved Oxygen, Cond- conductivity, NO_3-N-Nitrate-nitrogen,COD-Chemical Oxygen Demand, SO_4 – Sulphate, Cl- Chloride, F-fluoride, Phe-Phenol, TDS- Total Dissolved Solids, Fe-Iron, Ca- Calcium, Mg-Magnesium, TH- Total Hardness.

River water showed slightly acidic nature throughout the sampling points. Dissolved oxygen in river is in the permissible limit (BIS 10500-1991: 5-6 mg/l) except for S14, S15 and S16 sampling sites. Water has high conductivity which may be due to the presence of high concentration of ions in the river. Nitrate-n concentration is well within the permissible limit (BIS 10500-1991: 45mg/l). COD, fluoride, phenol, total dissolved solids, and iron are well above the permissible limit (BIS 10500-1991: 250mg/l,0.6-1.2mg/l, 0.001mg/l, 500mg/l, and 0.3mg/l respectively) for all the sampling sites. Magnesium, Sulphate, chloride, and Total hardness have concentrations within the allowable limit except for S14 sampling site.

Table 3: Table showing Water Quality Index different sites

Serial No	Sampling Points	Water Quality Index
S1	Edamula	33.88
S2	Pathalam Bund 1 North	25.72
S5	Pathalam Bund 2 South	27.52
S8	Sudchemi	24.81
S11	Pallikadavu	24.38
S14	Kuzhikandam	19.25
S15	Eloor Ferry (R)	25.75
S16	Eloor Ferry (L)	22.0
Overall water Quality Index		**24.76**

The overall water quality index was calculated as 24.76 which fell under the 'poor' water class (index value between 0-45). The water quality index reduced towards the downstream of the river. Site S1 has the highest index value compared to other sampling sites. Pollution level on the upstream and downstream of the pathalam bund is found to be almost similar. Variations occur between pathalam bund 1 and pathalam bund 2 (S2 and S5) with the construction of the temporary earthen bund to prevent salt water intrusion during summer. Comparatively water quality index at the pathalam bund 2 (S5) south is slightly better than the pathalam bund 1 (S2) north. Close proximity sampling sites S8 and S11 shows similar water quality index range (24.81, 24.38). S14 showed the least quality index range (19.25) whereas Site S16 is found to be in the lower index range than S15, since polluted water from the sampling site S14 flows through S16 [14].

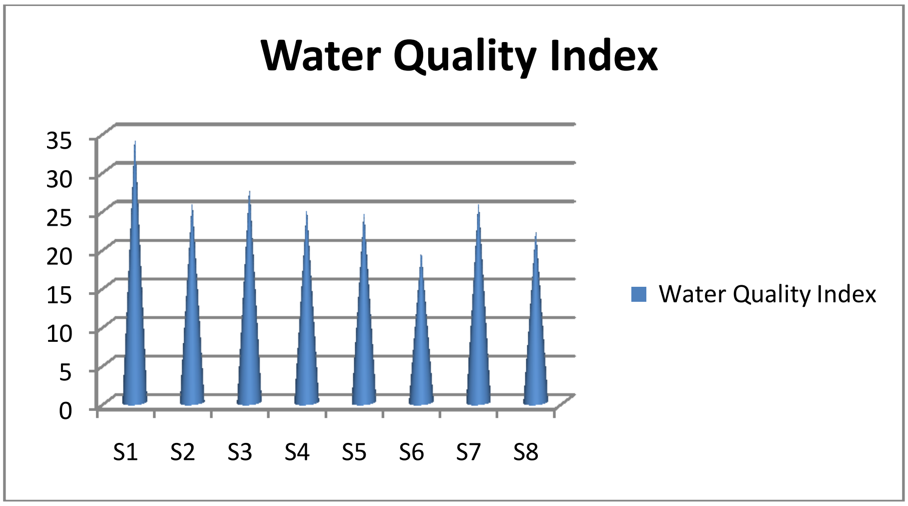

Fig 2: Graph showing Water Quality Index Variation for sampling points

By correlating the water quality index with parameters, it was found that total hardness and chloride are correlated at 1% level of significance and pH, DO, Calcium, Sulphate, Nitrate-N, Fluoride, and Conductivity are correlated at 5% level of significance. Dissolved oxygen is positively correlated to ph (0.801). Discharge from industries reduces the ph of the river water and decomposition of this effluent use the oxygen dissolved in water, thus resulting in reduced DO. This accounted for the positive correlation of DO to ph. Calcium is negatively correlated to ph and DO. Calcium present in water on reaction reduces the ph and decomposition of calcium compounds present, reduces dissolved oxygen in water. Sulphate is negatively correlated to ph and DO whereas positively correlated to calcium. This may be due to the presence of calcium sulphate in water sample of river. Chloride shows negative correlation to ph & DO and Calcium, magnesium and sulphate shows positive correlation with chloride indicating the presence of calcium chloride and magnesium chloride in water samples. Positive significant correlation was shown by nitrate with calcium, sulphate and chloride. Ph and DO shows negative correlation with nitrate. Total hardness shows negative significant correlation with ph and DO and Positive significant correlation with calcium, sulphate, chloride and nitrate-nitrogen. Iron bears negative correlation to ph and shows positive correlation with nitrate-nitrogen and total hardness. Fluoride is positively related to sulphate, chloride, nitrate-nitrogen, and total hardness. Positive correlation was shown by phenol with calcium, sulphate, nitrate-nitrogen, total hardness and fluoride. Conductivity is negatively correlated to total dissolved solids and bears positive correlation to magnesium and chloride. From the correlation analysis it was found that water quality index decreases with increase in calcium, sulphate, chloride, nitrate-nitrogen, total hardness, fluoride and conductivity and vice versa. Whereas ph and dissolved oxygen decreases with decrease in water quality index or increase with increase in water quality index.

The r-square measure is about 0.998, indicating that with these three predictor variables F_1 (Scope), F_2 (frequency) and F_3 (amplitude) we can account for about 99% of the variation in water quality index. The F-statistic test shows that the three independent variables have significant linear relationship with water quality index. The regression study of factors Scope, frequency and amplitude with the water quality index shows that the factors, scope (F_1) and frequency (F_2) are significantly correlated to water quality index, while amplitude (F_3) is not linearly related to water quality. So the analysis shows that number of parameters that exceeds the guideline (scope) and the number of times it exceeds (frequency) affects the water quality index whereas the value by which, each parameter exceeding the guideline (amplitude) does not affect the water quality index. The factors; scope and frequency show significance less than 0.05 but the factor; amplitude shows significance of 0.582 and is not found to affect water quality index.

V. Conclusion

Overall water quality index showed poor quality index in the river. All sampling sites under investigation fell under the poor quality index range, with kuzhikandam site exhibiting the lowest. Water quality deteriorated, as river flows downstream especially towards the Eloor Ferry. Correlating the factors of CCME water quality Index with parameters has never been attempted before. Statistical correlation reveals that water quality index decreases with increase in calcium, sulphate, chloride, nitrate-n, total hardness, fluoride, conductivity and vice versa while water quality index increases with increase in ph and DO. Regression analysis of the water quality index with factors (F_1, F_2, and F_3) shows that the number of parameters that exceeds the guideline (Scope, F_1) and the number of times the parameter exceeding the guideline (Frequency,

F_2) affects the water quality index of the river while the extend to which each parameter exceeding the guideline (Amplitude, F_3) does not affect the water quality index.

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