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Water Quality Indexing (WQI) for Predicting The Variation of Water Quality Over Time

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Abstract: This study deals with the assessment of Water Quality Index (WQI) of River Ulhas based on water quality parameters of pH, hardness, turbidity, chlorides and TDS. Constant monitoring of all the mentioned parameters was carried out on a daily basis from the year 2012 upto 2015. This study includes determining the Water Quality Index (WQI) using weighted average method and developing a corresponding regression equation considering the above mentioned parameters using IBM SPSS Modeler software. WQI is a dimensionless scale, which aggregates several water quality parameters into a single value. It can be successfully tooled to transform the complex water quality data into information that is easily understandable and useable by the general public and decision makers. WQI is one of the most effective tools to communicate information on the quality of water to the concerned citizens and policy makers or water resource managers.

Keywords: Water Quality Index, IBM SPSS Modeler software, regression, analysis.

1. INTRODUCTION

Water is the prime requirement for the existence of life. The uncontrolled exploitation of water has caused an abrupt decline in the quality and availability of water. The never ending growth of population and ill-planned exploitation of the water resource created a situation, where the very survival of man has become endangered. The global awareness and concern for the environment have paved way for the installation of various policies to control and prevent environmental pollution. Implementation of these policies has resulted in development of various technologies, which will allow for the sustainable utilization of earth's resources, thus preventing and controlling the overall degradation of the quantity and quality of these resources. Interpretation of complex water quality data is difficult to understand and to communicate during decision making process. Assembling the various parameters of the water quality data into one single number leads to an easy interpretation of data, thus providing an important tool for management and decision making purposes. The purpose of an index is to transform the large quantity of data into information that is easily understandable by the general public. Water quality index exhibits the overall water quality at a specific location and specific time based on several water quality parameters. The WQI was first developed by Horton in the early 1970s, is basically a mathematical means of calculating a single value from multiple test results. The index result represents the level of water quality in a given water basin, such as lake, river or stream. After Horton a number of workers all over the world developed WQI based on rating of different water quality parameters. Basically a WQI attempts to provide a mechanism for presenting a cumulatively derived, numerical expression defining a certain level of water quality.

1.1 Aim

Assessment of Water Quality Index (WQI) using weighted average method and development of a corresponding regression equation using IBM SPSS Modeler software.

1.2 Objective

The objectives of the project are:
- Assessment of Water Quality Index (WQI) using weighted average method.
- To develop a regression equation considering the above mentioned five parameters using IBM SPSS Modeler software.

1.3 Scope

- Resource allocation : Scientifically sound method which conveys complex water quality data in a simplified form to decision makers.
- Ranking of allocation: Indices may be applied to assist in comparing water quality at different locations or geographic areas, or even along the reach of a river.

- Enforcement of standards : To some locations, indices help to determine the extent to which legislative standards and existing criteria are being satisfied or whether they have exceeded acceptable limits.
- Trend analysis : The WQI method is widely used in the rehabilitation of river reaches, as this method helps in studying change in water quality over time.
- Public information : Indices are normally easy to make people aware of the water quality and the potential risks.

2. METHOLOGY

2.1 Data Collection

Constant monitoring of the above mentioned five parameters of River Ulhas was carried out on a daily basis from 1st January, 2012 upto 29th March, 2015.

2.2 Calculation of Weight Factor

Factors which have higher permissible limits are less harmful because they can harm quality of river water when they are present in very high quantity. So weightage of factor has an inverse relationship with its permissible limits.

Therefore, $Wi \propto 1/Xi$

Or

$$Wi = k/Xi$$

where, k = constant of proportionality,
Wi = unit weight/weightage of parameter,
Xi = permissible limit of the parameter as recommended by IS10500:2012 standards.
Values of k were calculated as:
$k = 1/\sum(1/Xi)$
where, $\sum(1/Xi) = 1/Xi(pH) + 1/Xi(Hardness) + 1/Xi(Turbidity) + 1/Xi(Chlorides) + 1/Xi(TDS)$

The weightage of all the factors/parameters were calculated on the basis of the above equation and are shown in table no. 1.

2.3 Calculation of Rating Factor

Rating scale (Table 3) was prepared for range of values of each parameter. The rating varies from 0 to 100 and is divided into five intervals. The rating Xr = 0 implies that the parameter present in water exceeds the standard maximum permissible limits and water is severely polluted. On the other hand Xr = 100 implies that the parameter present in water has the most desirable value. The other ratings fall between these two extremes and are Xr = 40, Xr = 60 and Xr = 80 standing for excessively polluted, moderately polluted and slightly less polluted respectively. This scale is modified version of rating scale given by Tiwari and Mishra [8] (1985).

Table 1 : Weight Factors Of Water Quality Parameters

Water Quality Parameters	**IS 10500:2012 Standards**	**Unit Weight (Wi)**
pH	8.5	0.1042
Hardness	200	0.0044
Turbidity	1	0.8660
Chlorides	250	0.0035
TDS	500	0.0018

TABLE 2 : Rating Scale For Calculating WQI

Value Of WQI	**Quality Of Water**
90 – 100	Excellent
70 – 90	Good
50 – 70	Medium
25 – 50	Bad
0 – 25	Very Bad

2.4 Calculation of Water Quality index

Essentially, WQI is a compilation of a number of parameters that can be used to determine the overall quality of a river.

WQI is calculated for each SAMPLE and is given in Table 4. The parameters involved in the WQI are PH, Hardness, Turbidity, Chlorides, TDS. The numerical value is then multiplied by a weighting factor that is relative to the significance of the test to water quality. The sum of the resulting values is added together to arrive at an overall water quality index.

$$\mathbf{WQI = Wi \times Xr}$$

i.e. Water Quality Index is equal to the product of rating (Xr) and unit weight (Wi) of all the factors.

Wi * Xr = Wi(pH) * Xr(pH) + Wi(Hardness) * Xr(Hardness) + Wi(Turbidity) * Xr (Turbidity) + Wi(Chlorides) * Xr(Chlorides) + Wi(TDS) * Xr(TDS)

The values of Xi, Wi and Xr are given in Tables 3 and 4. Hence by multiplying Wi and Xr we can get the value of WQI. The WQI result represent the level of water quality in a given water basin such as lake, river or stream. Similar WQI was given by Mariappan et al., [9], (1998) by using nine important water quality parameters.

2.5 Multiple linear regression analysis

It is one of the very important statistical tools which are used in almost all fields of sciences. In regression analysis there are two types of variables. The variable whose value is influenced is called dependent variable and the variables which influence the dependent variable are called explanatory (regressors) variables. And the model equation is :

$$Y= \beta0 +\beta1X1 + \beta2 X2 +\beta3X3 + \beta4 X4 +\beta5X5 + \beta6 X6 +\beta7X7 + \beta8X8 + e \ldots\ldots\ldots\ldots$$

In this study WQI is considered as dependent variable and parameters are considered as explanatory variables. Chenini I. et al**29** have successfully applied multiple linear regression for Evaluation of ground water quality. Rene E. et. al.**30,31** has also applied regression equation for prediction of water quality indices.

Water Quality Parameters	**RANGE 1**	**RANGE 2**	**RANGE 3**	**RANGE 4**	**RANGE 5**
Ph	6.5 – 8.5	8.6 - 8.7 6.8 – 6.9	8.8 – 8.9 6.7 – 6.8	9.0 – 9.2 6.5 – 6.7	> 9.2 < 6.5
Hardness	0-200	200-225	225-250	250-275	>275
Turbidity	<1	1-5	5-10	10-15	>15
Chlorides	0-250	250-275	275-300	300-325	>325
TDS	0-500	500-525	525-550	550-575	>575
Xr	100	80	60	40	0
Extent of Pollution	Clean	Slight Pollution	Moderate Pollution	Excess Pollution	Severe Pollution

3. RESULTS AND DISCUSSION

To study the Water Quality Index (WQI) total five parameters were studied. Then with the help of Pearson Correlation (summarized in Table) statistically significantly correlated variables were identified. Now as our main motive is to check the WQI is correctly drawn or not, we go for regression. From Table , we can easily find unstandardized coefficients for the equation constant, pH, hardness, turbidity, chlorides and Total Dissolved Solids are -126.440, 6.527, -0.121, -0.145, 0.949 and 0.142 respectively. Table shows that the model fits with 89% accuracy.

$$Y = -126.440 + 6.527*(pH) - 0.121* (hardness) - 0.145 * (turbidity) + 0.949 * (chloride) +0.142 * (TDS).$$

From analysis, WQI by Weighted average method and regression equations was observed as follows:

Table No. 3:Rating Scale for Quality of Water

Value Of WQI	**Quality Of Water**
90 – 100	Excellent
70 – 90	Good
50 – 70	Medium
25 – 50	Bad
0 – 25	Very Bad

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4. CONCLUSION

The results of the study indicated that the water quality of River Ulhas exhibited significant seasonal trend pattern.

Table No. 4: Pearson Correlation

Parameters	pH	Hardness	Turbidity	Chloride	TDS
pH	1.000	-	-	-	-
Hardness	.496	1.000	-	-	-
Turbidity	.063	-.340	1.000	-	-
Chloride	.391	.796	-.548	1.000	-
TDS	.118	.722	-.333	.545	1.000
Total WQI	.341	.523	-.641	.810	.222

The predicted values of WQI reveals that the water quality of River Ulhas varies significantly. The variations of WQI are attributed to the fluctuations in chloride and turbidity levels.The SPSS Modeler model developed was found to exhibit 89% accuracy.

Table No. 5: Modal Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics		
					R Square Change	F Change	df1
1.	.892	.796	.794	13.06850	.796	637.977	5

Change Statistic		Durbin-Watson
df2	Sig. F Change	
820	0.000	.674

Table No. 6: ANOVA

	Sum of Squares	Df	Mean Square	F	Sig.
Regression	544786.725	5	108957.345	637.977	0.00
Residual	140044.259	820	170.786		
Total	684830.984	825			

Table No. 7: Coefficients

Parameters	Unstandardized Coefficients		Standardised Coefficients	t
	B	Std. Error		
(Constant)	-126.440	9.675		-13.069
pH	6.527	1.050	.128	6.215
Hardness	-.121	.047	-.094	-2.559
Turbidity	-.145	.009	-.333	-16.382
Chloride	.949	.036	.800	26.301
TDS	.142	.013	-.273	-10.888

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Table No. 8: Residuals Statistics

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-12.31643	93.21481	49.13781	25.697228	826
Residual	-33.101501	40.205116	0.000	13.028838	826
Std. Predicted Value	-2.391	1.715	0.000	1.000	826
Std. Residual	-2.533	3.076	0.000	.997	826

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