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## RESEARCH ARTICLE

# PROGNOSIS OF WATER QUALITY USING STATISTICAL MODELLING: SULURTANK, COIMBATORE, INDIA

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**ABSTRACT**

Pollution of surface water has been growing incessantly in India particularly due to the indiscriminate discharge of waste water from various sources without using any water treatment techniques. Global Water Supply and Sanitation Assessment (GWSSA), 2000 reported that the water related diseases kill a child every eight seconds and are responsible for all illness and death in the world. The scarcity for good quality drinking is increasingly becoming a rising issue and has invited attention. Hence, in this paper an attempt has been made to study about water quality of the Sulur tank which is located at $11.03^0$N and $77.13^0$E of Coimbatore district, India. The tank is heavily polluted due to domestic waste water discharge. The water quality of the tank was analyzed by collecting samples from a point on weekly basis from December 2010 to March 2011. The various physio – chemical and biological parameters such as pH, Electrical Conductivity, Total Dissolved Solids, Total Suspended Solids, Total Hardness, Turbidity, Alkalinity, Nitrate, Calcium Hardness, Magnesium Hardness, Biological Oxygen Demand, Chemical Oxygen Demand, Dissolved Oxygen are analyzed experimentally as per the Indian Standards. The range of the test results obtained are as follows pH (7.2-9.1) , Electrical Conductivity (1330 – 1946.9 µohm/cm) , Turbidity (0.4 – 0.7 NTU) , Total Dissolved Solids ( 770 – 4801.20 mg/l) ,Total Suspended Solids ( 0.3 – 4.5 mg/l) ,Total Hardness ( 48.2 – 237.15 mg/l) , Alkalinity (360 – 900 mg/l) , Nitrate ( 0.56 – 5.17 mg/l) , Calcium Hardness (100 – 156mg/l) , Magnesium Hardness (48 – 105.6 mg/l) , Biological Oxygen Demand ( 18 -29 mg/L) , Chemical Oxygen Demand (98 – 220 mg/l ) , Dissolved Oxygen (17 – 25 mg/l). These parameters are important factors for accessing quality of water. The variation in the test result is due to domestic discharge to the tank and seasonal condition. Using the results, the regression equations are established using SPSS 16. The parameters were correlated using Principal Component Analysis method by which, the highly correlated parameters (r>0.5) were formulated into regression equations. The results useful for the rapid and reliable monitoring measures are essential for keeping a close watch on water quality and healthy environment. The obtained equations are programmed using .NET. Thus the framework helps to predict the future state of water quality easily.



## INTRODUCTION

The quality of drinking-water is a powerful environmental determinant of health. Assurance of drinking water safety is a foundation for the prevention and control of waterborne diseases (WHO, 2009). Moreover, Global Water Supply and Sanitation Assessment (GWSSA), 2000 reported that the water related diseases kill a child every eight seconds and are responsible for all illness and death in the world. The scarcity is increasingly becoming a rising issue and has invited attention. Perhaps the US Geological Survey observed that 97% of the water on the earth is salt water, and only 3% is fresh water of which slightly over two thirds is frozen in glaciers and polar ice caps. The remaining unfrozen freshwater is mainly found as groundwater, with only a small fraction present above ground or in the air (GreenFacts Website, 2008). The Fresh water is a renewable resource, yet the world's supply of clean, fresh water is steadily decreasing. The dumping of industrial and domestic waste into the water bodies promotes algal growth there by making the surrounding unpleasant and harmful to living organisms. As a result of all this it is believed that India will be on the list of water – stressed countries by the year 2025 when nearly half the world population will experience water shortage. So hence water conservation is gaining importance (A.K. Dikshit and Sunil K. Choukiker, 2005). Therefore, mathematical models have been used extensively over the past fifty years to address water quality problems and are currently used to investigate and assess virtually every type of water resource problem

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(Friedman et al, 1984). Today water quality model development is taking a new shape especially in the field of river basin management, river dynamics and river water quality (K.L. Prakash et al, 2009).

**Back ground information**

Water quality modeling involves the prediction of water pollution using mathematical simulation techniques. The model can become an important tool to aid in local planning and environmental analysis. Consequently, many number of surface water quality models have been developed all over the world. For eg. Iqbal Hossain *et al.* (2010) developed a model that continuously simulates the accumulation and wash- off of water quality pollutants in the Gold Coast , Australia. The model allows estimation of pollutants build –up during dry periods and pollutants wash-off during storm events which include TSS, TP, TN. Kincaid and Campbell (2005) Studied water quality within the Rio Chone estuary, a seasonally inverse, tropical estuary, in Ecuador was characterized by modelling the distribution of BOD and DIN (Dissolved Inorganic Nitrogen) within the water column. Mohan (2003) applied pollutant transport model at Palar river basin, India. It is found that the developed model and the solution methods proved to be a variable tool for planning and management of ground water contamination problem. Ekercin (2007) focussed mainly on the water quality modelling through remotely sensed imagery and ground data around Istanbul Turkey. Then the water quality models are developed by using fuzzy logic for the assessment of water quality parameters together with the spectral reflectance. Shyamala et al. (2008) characterized the parameters of ground water in Telungupalayam area, India. In which the quality of ground water each parameter was compared with the standard desirable limit of that parameter in drinking water as prescribed by different agencies. A systematic correlation and regression study showed a significant linear relationship among the different pairs of water quality by Jothivenkatachalam and Nithya (2010).

**Research area**

Coimbatore, "MANCHESTER OF THE SOUTH" situated in the basin of the river Noyyal, Tamilnadu. The River Noyyal is a seasonal river emerges in the Vellingri hills. Surplus water from the Noyyal River spilled into the canals and was channelled to the tanks, preventing unwanted flooding. Many lakes and ponds were constructed near the river in ancient times. The tanks were a major factor in replenishing the ground water through percolation of the subsoil water. This basin has 23 anicuts and 30 tanks. Out of which Coimbatore has 18 tanks. The study is carried out in Sulur tank which is situated in the east of the Coimbatore city. It is located at $11.03^0$N and $77.13^0$E. Sulur consists of two tanks which are located nearby. People utilize the water for domestic and industrial purposes. The tank is also heavily polluted due to domestic waste (PWD, Coimbatore, 2008). The location of study area is shown in the fig.1. The status of tank from the study reveals that the periodical monitoring is necessary for the tank. A systematic study of correlation and regression coefficients of the water quality parameters not only helps to assess the overall water quality but also to quantify relative concentration of various pollutants in water and provide necessary cue for implementation of rapid water quality management programmes10-12**.** In this present study, an attempt has been made to evaluate and improve the quality of water in the study area and thereby to analyze correlation and regression study of various physico-chemical parameters.

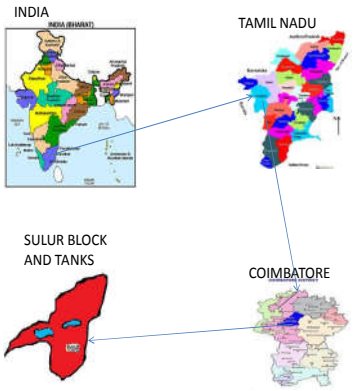


**Fig. 1. Study area location**

## METHODOLOGY

The quality of water depends on its purpose of usage and expressed by different sets of parameters (Khanna, 1989). In this study, the water quality is investigated by analyzing various phsio-chemical parameters and regression model is developed by following steps:

**Collection of water samples**

Water samples were collected from Sulur tank periodically, on weekly basis during December 2010 – March 2011. The samples were collected at a particular time and place (grab method) in a clean, washed plastic jerry can enclosed with ice box. The parameters like pH and Electrical conductivity were measured in the site itself. The samples were refrigerated in ice box at $4^0$C (Maiti S.K, 1988)**.**

**Water quality analysis**

The analysis was carried out for various water quality parameters such as pH, Electrical Conductivity (EC), Turbidity, Alkalinity, Total Hardness (TH), Calcium Hardness (CaH), Magnesium Hardness (MgH), Total Dissolved Solids (TDS), Chloride, Nitrate, BOD, COD, Total Suspended Solids (TSS) and DO as per IS procedure.

**Water quality modelling**

Statistical modelling is performed using SPSS 16. The obtained results of the water quality are entered into the data base. Factor analysis is performed using Principal Component Analysis (PCA). The parameters which are having correlation coefficient ($r>0.5$) indicates that the variables are highly correlated. From the correlated variables the dependent variables pH, EC, TH, turbidity and the independent variables TDS, TSS, nitrate, BOD, COD, DO, TH, CaH, MgH chloride,

alkalinity are identified. The equations are developed for inter – related dependent and independent variables are formulated using regressing analysis.

The obtained regression equation is in the form of

$$y = u + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 \ldots\ldots\ldots$$

Where,

y is the dependent variable

$x_1, x_2, x_3 \ldots$ are the independent variables.

u is the intercept.

$\beta_1, \beta 2, \beta 3$ are the coefficients of the independent variables.

**Programming in .net**

The equation modelled using SPSS is programmed by .NET. As a result a framework is generated which helps to predict the future water quality of the Sulur tank easily. To determine the pH, the alkalinity value is entered or vice versa similarly the four above similar cases are entered to obtain the unknown parameter. The dialog box depicting the predicted and observed variable value can also be plotted which there by helps to calculate the accuracy of the modelled equation.

## RESULTS AND DISCUSSION

As per the Pollution Control Board, to characterise any water quality by 14 parameters like pH, EC, Turbidity, TDS, TSS, TH, Alkalinity, Chloride, MgH, CaH, BOD, COD ,DO and Nitrate were analysed. The result of the analysed parameters is given in Table.1. The pH is considered as important chemical parameter as it represents geochemical equilibrium of the water. From table 1, the maximum value pH obtained through the analysis is greater than permissible limits showing alkaline trend. Alkaline pH in tank is due to the fact that disposal of domestic sewage in to the tank. The maximum value of EC is 1946.9 µohm/cm in the study. Thus the results indicate that the higher value than the permissible limit due to the affects of survival of the aquatic organisms.

Total dissolved solids are mainly due to the mixing of domestic waste, human waste and kitchen waste deposition in the tank. Total suspended solids are mainly due to its location. Sulur tank is situated on a national high way, which increases the littoral level of the tank. The dissolved oxygen level in sulur tank is higher than the permissible limits when compared to the results in the table 1. The higher dissolved oxygen is mainly due to the high surface velocity of the water. The air creates small waves which increases the level of dissolved oxygen.The presence of nitrates indicated the existence of organic matter, pesticides, disease causing organisms and other inorganic chemicals. The presence of chloride is mainly increases due to passage of water through natural rock formation and industrial sewage (dying industries) as shown in the table 1.

**Regression analysis**

The prediction helps in decision making of parameters to be treated. The use of the software makes prediction simpler. The values which are highly correlated are grouped. The dependent and the Independent variables are selected. The dependent variables are pH, Turbidity, DO, EC and independent variables are Alkalinity, TSS, TDS,. The systematic calculation of correlation coefficient between water quality variables and regression analysis provide indirect means for rapid monitoring of water quality. The correlation matrix for water quality variables is depicted in Table 2. It is evident that distribution of TDS was significantly correlated ($r > 0.5$) with Electrical conductivity and also DO is significantly correlated with BOD and COD. The linear regression analyses have been carried out for the water quality parameters which are found to have moderate, better and higher level of significance in their correlation coefficient. The regression equations obtained from the analysis are given in the Table 3. The different dependent characteristics of water quality were calculated using the regression equation and by substituting the values for the independent parameters in the equations. Hence it can be concluded that the correlation studies of the water quality parameters have a great significance in the study of water resources.

**.Net Frame work**

The frame work in .Net programming is developed form the obtained regression equations. The Fig.2, Fig.3, Fig.4 and Fig.5 shows the computed value and predicted value of pH Vs Alkalinity, TSS Vs Turbidity EC Vs TDS and DO Vs BOD & COD. By using regression equations, the alkalinity (mg/l) value is entered to obtain pH value and vice versa. From Fig.2 it is observed that there is only 11 percent deviation between the values. Due to rainy season during 6th and 7th sampling period causes high variation in turbidity value as shown in Fig.3. From Fig.4, it is observed that the much dilution of dissolved salts during rainy season results variation in the electrical conductivity at 5th to 7th sampling period. The Fig.5 evident that more or less the same observed and predicted value is obtained for DO. The descent at 8th sampling period is due the flow current in the water.

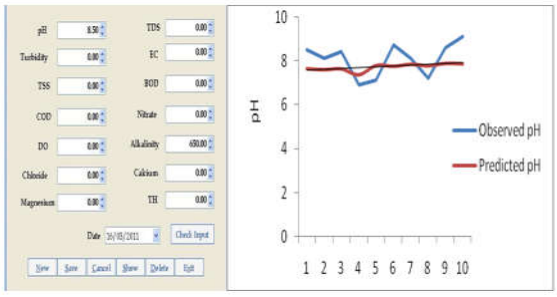


**Fig. 2 Computed pH Vs Predicted pH**

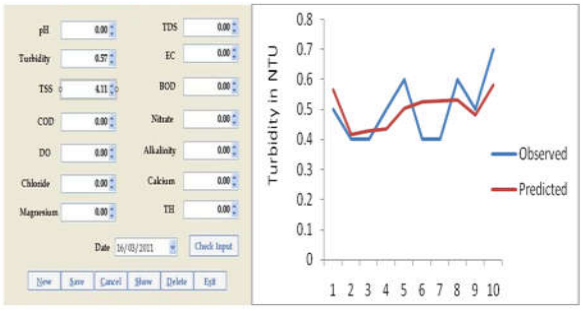


**Fig. 3 Computed turbidity Vs Predicted turbidity**

**Table 1. Water Quality Parameters**

| Samples | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Permissible limits |
|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 8.5 | 8.1 | 8.4 | 6.9 | 7.1 | 8.7 | 8.1 | 7.2 | 8.6 | 9.1 | 6.5-8.5 |
| TDS(mg/l) | 1194 | 770 | 1600 | 2918 | 4810 | 1433 | 1333 | 2535 | 2145 | 2787 | 500 |
| Turbidity(NTU) | 0.5 | 0.4 | 0.4 | 0.5 | 0.6 | 0.4 | 0.4 | 0.6 | 0.5 | 0.7 | 5 |
| EC (µohm/cm) | 1540 | 1400 | 1600 | 1910.2 | 1946.9 | 1800 | 1657.7 | 1723.8 | 1489 | 1330 | 250-750 |
| TSS(mg/l) | 4.11 | 0.3 | 0.63 | 0.8 | 2.5 | 3.11 | 3.19 | 3.2 | 2 | 4.5 | 500 |
| BOD(mg/l) | 22 | 26 | 29 | 18 | 18 | 19 | 20 | 23 | 21 | 28 | 30 |
| COD(mg/l) | 108 | 220 | 162 | 140 | 100 | 111 | 102 | 98 | 136 | 121 | 225 |
| Nitrate(mg/l) | 2.6 | 0.56 | 4.08 | 5.11 | 5.17 | 3.87 | 4.82 | 4.92 | 4.95 | 5.09 | 45 |
| DO(mg/l) | 2.0 | 2.2 | 2.5 | 1.9 | 1.7 | 1.79 | 1.7 | 1.5 | 1.9 | 1.95 | 4-5 |
| Alkalinity(mg/l) | 650 | 600 | 640 | 360 | 800 | 760 | 856 | 789 | 900 | 879 | 600 |
| Chloride(mg/l) | 765.72 | 400 | 890 | 2368 | 4679 | 34529 | 2416 | 2896 | 1879 | 3561.2 | 250 |
| CaH(mg/l) | 112 | 120 | 119 | 145 | 156 | 135 | 115 | 130 | 100 | 140 | 75 |
| MgH(mg/l) | 56 | 48 | 56 | 90 | 105.6 | 399 | 67 | 89 | 78.5 | 91.7 | 150 |
| TH(mg/l) | 48.2 | 168 | 226 | 115 | 237.2 | 135.9 | 156.7 | 191.6 | 176.2 | 209.9 | 300 |

**Table 2. Correlation Matrix**

| | pH | TDS | Turbidity | EC | TSS | BOD | COD | Nitrate | DO | Alkalinity | Cl | CaH | MgH | TH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 1.000 | | | | | | | | | | | | | |
| TDS | -0.530 | 1.000 | | | | | | | | | | | | |
| Turbidity | -0.110 | 0.696 | 1.000 | | | | | | | | | | | |
| EC | -0.743 | 0.535 | -0.064 | 1.000 | | | | | | | | | | |
| TSS | 0.363 | 0.114 | 0.537 | -0.144 | 1.000 | | | | | | | | | |
| BOD | 0.504 | -0.352 | 0.078 | -0.754 | -0.091 | 1.000 | | | | | | | | |
| COD | 0.116 | -0.434 | -0.432 | -0.445 | -0.770 | 0.499 | 1.000 | | | | | | | |
| Nitrate | -0.206 | 0.632 | 0.437 | 0.421 | 0.247 | -0.234 | -0.647 | 1.000 | | | | | | |
| DO | 0.402 | -0.419 | -0.408 | -0.452 | -0.538 | 0.663 | 0.731 | -0.372 | 1.000 | | | | | |
| Alkalinity | 0.462 | 0.114 | 0.314 | -0.311 | 0.602 | 0.087 | -0.445 | 0.291 | -0.381 | 1.000 | | | | |
| Cl | -0.240 | 0.777 | 0.577 | 0.514 | 0.450 | -0.450 | -0.663 | 0.635 | -0.681 | 0.412 | 1.000 | | | |
| CaH | -0.493 | 0.735 | 0.476 | 0.584 | 0.062 | -0.266 | -0.247 | 0.315 | -0.307 | -0.219 | 0.734 | 1.000 | | |
| MgH | -0.523 | 0.889 | 0.804 | 0.300 | 0.178 | -0.227 | -0.413 | 0.657 | -0.477 | 0.154 | 0.621 | 0.526 | 1.000 | |
| TH | -0.117 | 0.550 | 0.314 | 0.070 | -0.268 | 0.305 | 0.110 | 0.459 | 0.53 | 0.304 | 0.430 | 0.383 | 0.492 | 1.000 |

**Table 3. Regression equation for correlated parameters**

| CORRELATEDPARAMETERS | REGRESSION EQUATION |
|---|---|
| pH and Alkalinity | pH =7.013 + 0.001 Alkalinity |
| Turbidity and TSS | Turbidity = 0.406 + 0.039 TSS |
| EC and TDS | EC = 1436.853 -0.094 TDS |
| DO with BOD and COD | DO = 7.791 +0.277 BOD +0.04 COD |

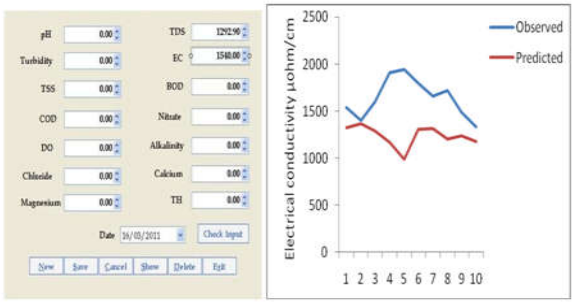


**Fig. 4 Computed EC Vs Predicted EC**

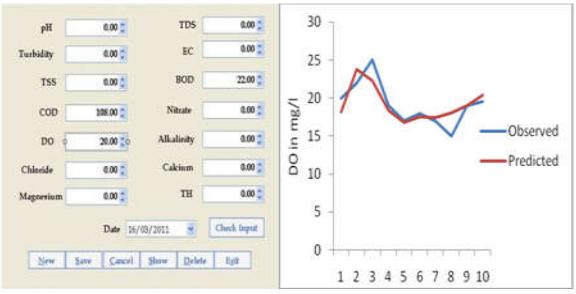


**Fig. 5. Computed DO Vs Predicted DO**

## CONCLUSION

The water sample collected for ten weeks from Sulur tank of Coimbatore district is analyzed and studied. On the basis of these analytical findings, the pH, TDS, DO of the entire water sample exceeds the permissible limits to some extent. MgH, TH, TSS, Turbidity, and Nitrate for all the samples are very much within the permissible limit. Alkalinity, Chloride and EC of all the ten samples are in higher range than permissible limits. BOD, COD are maintaining its standards. The reason for dwindling quality of water in this spot may be due to high encroachment and domestic sewage disposal. This may cause water borne disease to the people living nearby. Hence, rapid and reliable monitoring measures are essential for keeping a close watch on water quality and healthy environment. In the correlation Regression study, it is concluded that all the parameters are more or less correlated with each other. The linear correlation is very useful to get fairly accurate idea of quality of surface water by determining a few parameters experimentally.

SPSS has been found to be an effective way to introduce modelling in environmental systems. Formulating the modeled equation into a framework using .NET not only gave an easy

access to the equations but also helped to illustrate the results in unambiguous manner.

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