Application of Statistical Techniques for Modeling of Groundwater Quality Parameters

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Abstract-**Statistical techniques such as correlation and regression analysis are widely used in geochemistry for interpreting commonly collected groundwater quality data and relating them to specific hydro-geological processes. The basic purpose of such an analysis to the study of the hydro-geochemistry of an aquifer is to find a set of factors, few in number, which can explain a large amount of the variance of the analytical data. Correlation and regression models have been developed for the groundwaters of entire Bangalore city, categorized under three major zones. In the present study, an attempt has been made to predict one variable (parameter) for a given value of another parameter by regression model equation. Nitrate and TDS parameters have been chosen for modeling by virtue of their characteristics and effect caused on human beings and livestock. The total hardness representing major cations and anions has also been chosen for modeling and using these, the concentration of other parameters have been predicted with a fair degree of accuracy.**

Keywords—Contamination, Correlation, Groundwater, Regression, Variable.

I. Introduction

Fresh groundwater systems are important sources of potable water throughout the world. Mostly, fresh water aquifers are in contact with pollutants sources that are added by the surrounding sources and which if drawn into water aquifer system can diminish the water potability as well as its usefulness for other purposes. Thus, a quantitative understanding of the patterns of movement and mixing between fresh and contaminated water and of the factors that influence these processes is necessary to manage and protect these resources for future use.

Statistical techniques such as correlation and regression analysis are widely used in geochemistry for interpreting commonly collected groundwater quality data and relating them to specific hydro-geological processes. The basic purpose of such an analysis to the study of the hydro-geochemistry of an aquifer is to find a set of factors, few in number, which can explain a large amount of the variance of the analytical data [1].

The correlation is the statistical technique to analyze the nature and behavior of two variables (parameters) of some system in order to measure the nature and degree of correlation coefficient. The regression coefficient (b) determines the amount of change expected in the dependent variable for a given change in independent variable. Interrelationship studies between different variables are very helpful tools in promoting research and opening new frontiers of knowledge [2]. The study of correlation reduces the range of uncertainty associated with decision making [3].A typical regression equation (line) model graph has been shown in Fig 2.

II. Details of Study Area

Bangalore city is situated at the watershed boundary between the east flowing Cauvery and Ponnaiyar rivers. The city has meager water resource in its neighborhood, being part of semi-arid peninsular India. The undulating topography of the city has been meticulously managed in the past, to build a chain of water storage lakes (called tanks locally) in the valley areas. The southern and western areas of Bangalore possess a rugged topography of granitic and gneissic masses covered by small shrubs and bushes. The eastern edge of the city is a featureless plain with minor undulations.

The study area of Bangalore city has been divided into three industrial zones, namely,

Zone I: Bangalore North

Zone II: Bangalore East

Zone III: Bangalore South

The industrial areas selected in each zone are listed below.

Zone I: Bangalore North

1. Peenya industrial area
2. Tannery industrial area

Zone II: Bangalore East

1. K.R.Puram industrial area
2. Whitefield industrial area
3. Bellandur industrial area

Zone III: Bangalore South

1. Bommasandra industrial area
2. Bommanahalli industrial area
3. Kengeri industrial area

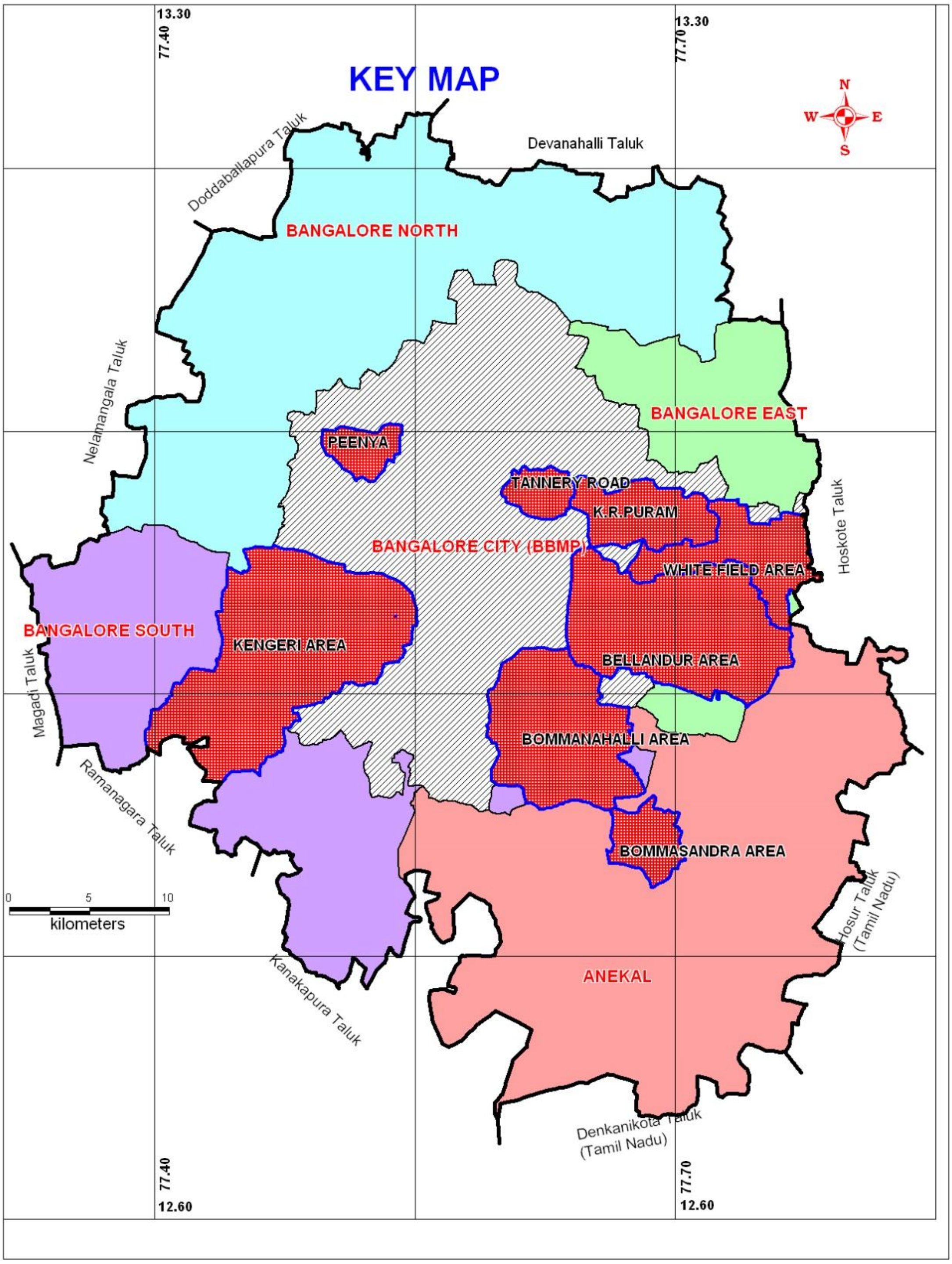

Figure 1: Key map of Study area (Bangalore) showing the individual study areas.

III. MATERIALS AND METHODS

From the total study area comprising of three zones and eight sampling locations, 30 samples each were collected from these 8 areas, during April 2014. Thus, a total of 240 samples were collected from both the borewells and open wells in the area and the samples were subjected to an elaborate physico-chemical analysis as per the Standard methods for the examination of water and waste water according to APHA, 2002 [4].The guidelines for the permissible limits of these parameters are as per the Bureau of Indian Standards, BIS 10,500 (2003) [5]. From the 20 parameters that were analyzed, Nitrate and TDS parameters have been chosen for modeling by virtue of their characteristics and effect caused on human beings and livestock. The total hardness representing major cations like Ca^{2+}, Mg^{2+} and anions such as Cl^-, SO_4^- and HCO_3^- and CO_3^{2-} has also been chosen for modeling. Further, because of the environmental significance of these parameters and also because of their excessive concentrations in the study areas, they have been chosen for modeling[6].

According to the present study, there is a significant correlation between most of the physico-chemical parameters analyzed. As a result, an attempt has been made to predict one variable (parameter) for a given value of another parameter by regression model equation as indicated in Fig 2:

$y=a+bx$

Where, y: dependent variable

x: independent variable

a: constant (intercept of regression line at y axis)

b: regression coefficient

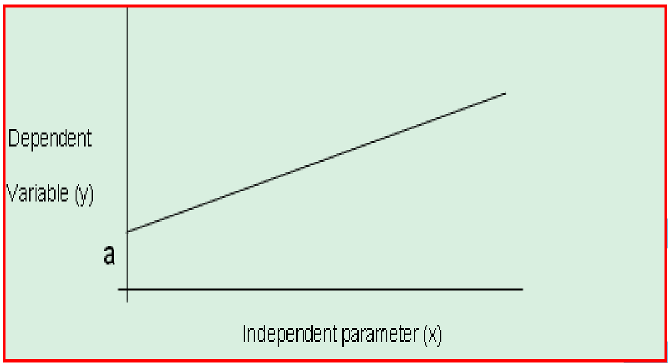

Figure 2: Typical Regression equation line

IV. RESULTS AND DISCUSSIONS

Based on the values of dependent variables such as hardness, nitrate and TDS, the concentrations of several independent variables have been predictedas shown in tables 1 to 9 for the three study zones.

Correlation and prediction using total hardness model

Using this model Ca, Mg, Cl, NO_3, TDS and EC can be determined. For instance the total hardness value of sample P5 of Peenya industrial area was found to be 676 mg/L. Therefore its EC value obtained from the model is found to be 2254 micro-mhos, which is very close to the actual EC value of 2245 micro-mhos. Thus, this modeling is used to predict the other parameter concentrations by knowing one parameter.

Correlation and prediction using nitrate model

With the help of Nitrate model, total hardness, Ca, Mg, Cl, TDS and EC can be determined. For instance the nitrate concentration in sample BE 24 of Bellandur industrial area was found to be 271 mg/L. Therefore its TDS value obtained from the model is found to be 2029 mg/L, which is very close to the actual TDS value of 2035 mg/L. Similarly, Ca, Mg, Cl, TH, and EC values can be predicted using the same model.

Correlation and prediction using TDS model

With the help of TDS model, total hardness, Ca, Mg, Cl, NO_3, and EC can be determined. For instance the TDS concentration in sample BH 8 of Bellandur industrial area was found to be 585 mg/L. Therefore its Cl value obtained from the model is found to be 135 mg/L, which is very close to the actual Cl value of 138 mg/L. Similarly, Ca, Mg, NO_3, TH, and EC values can be predicted using the same model.

Table 1: Correlation and prediction using total hardness model for Bangalore North

Relationship	Correlation coefficient	Regression coefficient	Prediction Equation
TH v/s Ca	0.946	0.21	Ca = 18.875 + 0.21 TH
TH v/s Mg	0.935	0.116	Mg = -11.226 + 0.116 TH
TH v/s Cl	0.841	0.908	Cl = - 64.458 + 0.908 TH
TH v/s NO_3	0.320	0.044	NO_3 = 50.025+ .044 TH
TH v/s TDS	0.900	1.655	TDS = 281.046 + 1.655 TH
TH v/s EC	0.901	2.689	EC = 446.377 + 2.689 TH

Table 2: Correlation and prediction using nitrate model for Bangalore North

Relationship	Correlation coefficient	Regression coefficient	Prediction Equation
NO_3 v/s TH	0.32	2.35	TH = 651.434 + 2.35 NO_3
NO_3 v/s Ca	0.30	0.43	Ca = 161. 09 + 0.43 NO_3
NO_3 v/s Mg	0.34	0.31	Mg = 60.887 + 0.31 NO_3
NO_3 v/s Cl	0.36	2.828	Cl = 466.62 + 2.828 NO_3
NO_3 v/s TDS	0.44	5.945	TDS = 1179.412 + 5.945 NO_3
NO_3 v/s EC	0.43	9.347	EC = 1933.607 + 9.347 NO_3

Table 3: Correlation and prediction using TDS model for Bangalore North

Relationship	Correlation coefficient	Regression coefficient	Prediction Equation
TDS v/s TH	0.900	0.488	TH = 28.211 + 0.488 TDS
TDS v/s Ca	0.896	0.108	Ca = 15.221 + 0.108 TDS
TDS v/s Mg	0.800	0.053	Mg = - 2.115 + 0.053 TDS
TDS v/s Cl	0.958	0.562	Cl = - 240.780 + 0.562 TDS
TDS v/s NO_3	0.440	0.032	NO_3 = 32.174 + 0.032 TDS
TDS v/s EC	0.997	1.618	EC = 0.829 + 1.618 TDS

Table 4: Correlation and prediction using Total hardness model for Bangalore East

Relationship	Correlation coefficient	Regression coefficient	Prediction Equation
TH v/s Ca	0.963	0.278	Ca = -0.299 + 0.278 TH
TH v/s Mg	0.85	0.75	Mg = 0.204 + .075 TH
TH v/s Cl	0.887	0.782	Cl = - 40.97 + .782 TH
TH v/s NO_3	0.604	0.172	$N0_3$ = - 2.568 + 0.172 TH
TH v/s TDS	0.884	1.77	TDS = 119.83 + 1.77 TH
TH v/s EC	0.855	2.88	EC = 191.73 + 2.88 TH

Table 5: Correlation and prediction using Nitrate model for Bangalore East

Relationship	Correlation coefficient	Regression coefficient	Prediction Equation
NO_3 v/s TH	0.604	0.172	TH = 325.253 + 2.12326 $N0_3$
NO_3 v/s Ca	0.62	0.624	Ca = 87.03 + .624 $N0_3$
NO_3 v/s Mg	0.5	0.14	Mg= 26.45 + .14 $N0_3$
NO_3 v/s Cl	0.55	1.71	Cl = 210.36 + 1.71 $N0_3$
NO_3 v/s TDS	0.76	5.34	TDS = 562.14 + 5.34 $N0_3$
NO_3 v/s EC	0.73	8.57	EC = 921.43 + 8.57 $N0_3$

Table 6: Correlation and prediction using TDS model for Bangalore East

Relationship	Correlation coefficient	Regression coefficient	Prediction Equation
TDS v/s TH	0.884	0.442	TH = 56.8 + .442 TDS
TDS v/s Ca	0.871	0.125	Ca = 12.73 + 0.125 TDS
TDS v/s Mg	0.715	0.32	Mg = 6.15 + .032 TDS
TDS v/s Cl	0.931	0.41	Cl = - 61.03 + .41 TDS
TDSv/s NO_3	0.759	0.108	$N0_3$ = -25.15 + .108 TDS
TDS v/s EC	0.986	1.66	EC = -34.71 + 1.66 TDS

Table 7: Correlation and prediction using Total hardness model for Bangalore South

Relationship	Correlation coefficient	Regression coefficient	Prediction Equation
TH v/s Ca	0.949	0.22	Ca = 13.28 + 0.22 TH
TH v/s Mg	0.924	0.109	Mg = -8.013 + 0.109 TH
TH v/s Cl	0.946	0.845	Cl = - 153.47 + 0.845 TH
TH v/s NO_3	0.270	0.047	NO_3 = 42.798 + 0.047 TH
TH v/s TDS	0.954	1.438	TDS = 117.04 + 1.438 TH
TH v/s EC	0.951	2.256	EC = 266.99 + 2.256 TH

Table 8: Correlation and prediction using Nitrate model for Bangalore South

Relationship	Correlation coefficient	Regression coefficient	Prediction Equation
NO_3 v/s TH	0.27	1.567	TH = 577.663 + 1.567 NO_3
NO_3 v/s Ca	0.328	0.446	Ca = 134.18 + 0.446 NO_3
NO_3 v/s Mg	0.20	0.11	Mg = 59.19 + 0.11 NO_3
NO_3 v/s Cl	0.253	1.312	Cl = 335.276 + 1.312 NO_3
NO_3 v/s TDS	0.403	3.52	TDS = 852.734 + 3.52 NO_3
NO_3 v/s EC	0.40	5.26	EC = 1440.54 + 5.26 NO_3

Table 9: Correlation and prediction using TDS model for Bangalore South

Relationship	Correlation coefficient	Regression coefficient	Prediction Equation
TDS v/s TH	0.954	0.633	TH = - 11.665 + 0.633 TDS
TDS v/s Ca	0.925	0.144	Ca = 7.294 + 0.144 TDS
TDS v/s Mg	0.858	0.067	Mg = - 7.207 + 0.067 TDS
TDS v/s Cl	0.949	0.562	Cl = -194.119 + 0.562 TDS
TDSv/s NO_3	0.403	0.046	NO_3 = 23.728 + 0.046 TDS
TDS v/s EC	0.992	1.56	EC = 92.857 + 1.56 TDS

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