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Regression Analysis of Ground Water Quality Data of Sunamganj District, Bangladesh

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ABSTRACT: Ground water samples from different Upazilas of Sunamganj District have been analyzed for drinking and irrigation purposes. Correlation coefficients among different parameters were determined. An attempt has been made to develop linear regression equations to predict the concentration of water quality constituents having significant correlation coefficients with electrical conductivity (EC). Calcium and EC; Bicarbonate and EC are highly correlated but not perfect. Our findings show that calcium, nitrate, and bicarbonate are significantly related with electrical conductivity at 1% level of significance. Except for the total dissolved solid, all other variables are significant at a conventional level (i.e. 5 %) with expected sign. The usefulness of these linear regression equations in predicting the ground water quality is an approach, which can be applied in any other locations.

Key words: Sunamganj, Drinking water, GIS, Nitrate, Total dissolved solid

INTRODUCTION

Ground water quality has become an important water resources issue due to rapid increase of population, rapid industrialization, unplanned urbanization, flow of pollution from upland to lowland, and too much use of fertilizers, pesticides in agriculture. The problems of ground water quality are more acute in low lying area like Sunamganj, as the water level is within 200ft to 400ft. More alarming news is that most of the population uses ground water as the major source of drinking water. A few ground water studies in this region show that included pollution of ground water due to extensive extraction of ground water through tube wells which create suction of impure surface water into aquifer (Siddeque, 2005). The most common contaminant in the ground water is dissolved nitrogen in the form of nitrate (NO_3^-), owing to its high water solubility (Ersoy *et al.*, 2007). High nitrate concentrations in drinking water sources present a potential risk to health particularly to infants less than six months of age. Groundwater is the major source of irrigation in developing country like Bangladesh, and there has been a tremendous increase in suction mode irrigation. Between 30 and 40 percent of the net cultivable area of the country is under irrigation (Huq and Naidu, 2002). According to, Mridha *et al.* (1996) about 70 percent irrigation water and 90 percent of total potable water in Bangladesh are supplied from ground water source. The contribution of groundwater in relation to total irrigated area increased from 41 percent in 1982/83 to 71 percent in 1996/97 and to over 75 percent in 2001 (Ali, 2003). Shahidullah et al. (2000) attempt to assess the ground water quality in a selected area of Bangladesh (Phulpur Upazila of Mymensingh district). Water samples from 14 deep tube wells were analyzed in their paper for pH, TDS, Na^+, K^+, Ca^{++}, Mg^{++}, Fe, P, B, $NO_3 – N$, SO_4^-, Cl^-, CO_3^- and HCO_3^-. In addition, SAR, SSP and RSC were calculated following standard

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equations. Their results suggest that there was neither salinity nor toxicity problem of irrigation water, so that ground water can safely be used for long-term irrigation. In another study, Quddus and Zaman (1996) showed that the irrigation water quality in some selected villages of Meherpur district of Bangladesh. They argued that the major ions present in irrigation water are calcium, magnesium, sodium, bicarbonate, sulphate and chloride.

The environment, economic growth and development of Bangladesh are all highly influenced by water - its regional and seasonal availability, and the quality of surface and ground water. Groundwater quality is analyzed by its physical, chemical and microbiological parameters. These parameters are closely interlinked. All the research so far completed on the groundwater quality of different areas of Bangladesh is based on physicochemical analyses. No attempt has yet been made to predict the groundwater quality of Bangladesh with precision using any econometric analysis except depicting the correlation coefficient of different water quality parameters. A few numbers of literatures are available regarding the analysis of groundwater quality data using regression techniques for prediction purposes in different areas of India (Jain and Sharma, 2000; Kumar *et al.*, 1994; Jain and Sharma, 1997; Rao and Rao, 1994).

As the routine chemical analysis requires lengthy and time consuming phenomena, it would be an attractive solution to establish relationships between other different parameters with a common and easily determinable parameter. The developed regression equations for the parameters having significant correlation coefficients can be successfully used to estimate the concentration of others constituents. In this present study, an attempt has been made to study correlation between electrical conductivity and other water quality constituents and to find out the influencing constituents for water quality. Whether electrical conductivity can be used to estimate the concentration of other parameters of water quality from drinking point of view within a desirable precision level is discussed.

The location of our study area is the district which lies in the "North-Eastern Depression" of Bangladesh; the depression is characterized by flat terrain with low land elevation(Fig.1). Sunamganj District (Sylhet division) with an area of 3669.58 sq km, is surrounded by Khasia and Jaintia hills (India) on the north, Habiganj and Kishoreganj districts on the south, Sylhet district on the east, Netrokona and greater Mymensingh districts on the west. Annual average temperature is 33.2°C and minimum 13.6°C; while annual rainfall is 3334 mm. There are many *haors* and *beels* in Sunamganj.

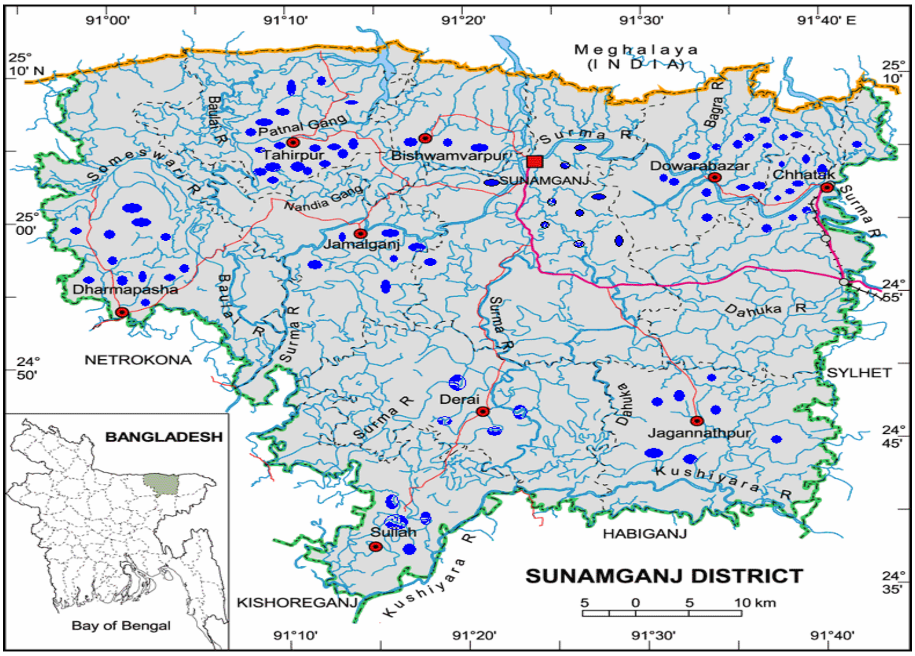

Fig. 1. Location map of the study area

Within its area, Sunamganj district has the followingUpazilas: Bishwamvarpur, Chhatak, Dowara bazaar, Derai, Jagannathpur, Jamalganj, Tahirpur, Sullah, and Sunamganj Sadar. River Surma encircled the entire district (Bangla Pedia, 2002). People of this district are pioneer in using shallow and deep tube wells for drinking and irrigation purpose. Most of the arable lands are usually irrigated by ground water to grow crops, mainly HYV rice and different types of vegetables during winter season in the area. According to BGS and DPHE (2001), private ownership of tube wells are the common features of the district, which penetrate shallow alluvial aquifers to depth 10-60 m for drinking purpose. Irrigation boreholes typically tap deeper aquifers in the region at 70-100 m depth. In some areas of the district, deep tube wells pump out ground water from a depth of 150m or more. The deep tube wells have been installed to avoid high salinity at shallower levels. Shallow hand-dug wells are found in some areas, though they are much less common than tube well.

MATERIALS & MERHODS

We have collected ninety six (96) samples of ground water from the different areas of Sunamganj district since June 2006 until May 2007. Table 1 shows the distribution pattern of the collected samples. Figure 2. Ichthyofauna of investigated area under different orders clearly indicating the loss of fish species. In this study, we have applied the linear regression approach to develop a relationship between electrical conductivity for different water quality variables. For this purpose, regression equations were computed taking different water quality constituents as dependent variable and electrical conductivity as independent variable.

Table 1. Distribution pattern of the collected samples

Name of the Location	Number of Samples Collected
Sunamganj Sadar	9
Chhatak	24
Tahirpur	21
Jamalganj	6
Jagannathpur	7
Dowarabazar	6
Derai	4
Sullah	4
Bishwamvarpur	3
Dharmapasa	12
Total	96

In fact, we have used the Ordinary Least Squares (OLS) regression with one regressor (independent variable) in the form of $y_i = \hat{a}_0 + \hat{a}_1 x + e$. There are both practical and theoretical reasons to use OLS estimators of $\mathbf{\hat{a}_0}$ **and** $\mathbf{\hat{a}_1}$. Because OLS is the dominant method used in practice, it has become the common language for regression analysis. The regression R^2 and adjusted R^2 tell us whether the regressors are good at predicting or explaining the values of the dependent variable in the sample of the data at hand (Pindyck and Rubinfeld, 1997). Adjusted R^2 is always preferred to R^2 as it considers the degrees of freedom in estimating the parameters. But R^2 or adjusted R^2 do not tell us whether: (i) an included variable is statistically significant; (ii) the regressors are a true cause of the movements in the dependent variable; (iii) there is omitted variable bias; or (iv) we have chosen the most appropriate set of regressors (Stock and Watson, 2003).

RESULTS & DISCUSSION

The minimum and maximum concentration i.e. the range of the different physicochemical parameters of water quality constituents such as- pH, Electrical Conductivity (EC), Total Dissolved Solid (TDS), Total Hardness, Iron (Fe^{total}), Calcium (Ca^{++}), Magnesium (Mg^{++}), Potassium (K^+), Sodium (Na^+), Bi-Carbonate (HCO_3^-), Chloride (Cl^-), Nitrate (NO_3^-), and different water quality indices i.e. Sodium Adsorption Ratio (SAR), Soluble Sodium Percentage (SSP), Residual Sodium Bi-Carbonate (RSBC), Permeability Index (PI), Total Hardness (TH), Magnesium Adsorption Ratio (MAR) and Kelly's Ratio (KR) in Sunamganj district for irrigation purpose are given in Table 2 and 3 along with mean and standard deviations for each parameter. The p^H value in the study area lies in the range 4.3 to 9.2 indicating alkaline nature of ground water. The conductivity varies from 12 to 1318 µS/cm with approximately 5.20% samples (5 out of 96) having conductivity values greater than 750 µS/cm, indicating high mineralization in the region for both drinking and irrigation purposes. The estimated amounts of TDS ranged from 80 mg L^{-1} in Dowarabazar to 6000 in Dharmapasa mg/L. About 15% of the water samples show TDS value beyond the desirable limit of 500 mg/L. The systematic calculation of correlation coefficient between water quality variables and regression

Table 2. Total Sample's Summary Statistics

Parameter	Concentration Min. (mg/L)	Max. (mg/L)	Mean (mg/L)	Std. Dev. (mg/L)
pH	4.3	9.2	7.18	8375
EC	12	1318	329.92	245.38
TDS	80	6000	404.10	772.74
Na	0.357	2405.20	76.53	254.73
K	0.153	1030.8	29.10	109.50
Mg	1.7	95.35	24.67	20.57
Ca	0.56	947	33.98	97.46
Fe^{Total}	0.125	15.1	2.08	3.09
NO_3	0.003	35.5	5.19	6.36
Cl	0.66	295	25.06	45.82
HCO_3	25	480	146.51	96.60

Table 3. Summary Statistics of Different Indices

Parameter	Min (mg/L)	Max (mg/L)	Concentration Mean (mg/L)	Std. Dev. (mg/L)
SAR	0.1014426	425.1833	15.29665	46.06878
SSP	0.1254486	98.17142	38.01237	27.03063
MAR	1.865285	98.57507	1.74277	25.75847
KR	0.0144126	37.58125	1.74277	4.538934
PI	2.403184	366938.8	9271.161	44603.72
TH	215	48250	3018.481	5003.516
RSBC	-712	353	111.1434	114.9313

analysis providesan indirect means for rapid monitoring of water quality. The correlation matrix for different ground water quality variables for Sunamganj district is depicted in Tables 4 and 5. It is evident that distribution of alkalinity, hardness, calcium, magnesium, sodium, chloride, bi-carbonate, nitrate, and sulphate were significantly correlated ($r > 0.5$) with electrical conductivity in most of the study areas. The level of significance is taken at 5%. Highly positive correlation coefficient is observed between Na and K (0.99), KR and SAR (0.95), Ca and Cl (0.82); Ca and EC (0.81), HCO_3 and EC (0.75); Na and TDS (0.74); TDS and K (0.73); while highly negative correlation coefficient is seen among NO_3 and TDS (-0.0053); Ca and Mg (-0.0023). Positive correlation is obtained between 79 unions (i.e. 84.04 % of the total number) and rest of the unions (15 unions i.e. 15.96 % of total number) demonstrates negative correlations. Hence, it is concluded that the correlation studies of the water quality parameters have a great significance in the study of water resources.A positive high correlation between potassium and sodium indicates that the ground water of our study area is suitable for irrigation. But, a good relation between calcium and chloride gives us an idea about the total hardness of water.

As we have previously mentioned that adjusted R^2 has a number of properties which makes it a more desirable goodness-of-fit measure than R^2, the difficulty with R^2 as a measure of goodness of fit is that R^2 pertains only to explained and unexplained variation of Y (dependent variable) and therefore, does not account for the number of degrees of freedom. On the contrary, adjusted R^2 uses variances, not variations, thus eliminating the dependence of the goodness of fit on the number of independent variables in the model (variance equals variation divided by the degrees of freedom). The adjusted R^2 values of different water quality parameters with conductivity are given in Tables 4 to 6 It is evident that electrical conductivity is the most appropriate variable predicting or explaining more than 91, 88, 86, 78, 64 and 47 % values of the dependent variable in the sample of the data at hand and explaining the fact that the variance of the residual is small compared to the variance of the dependent variable. Correlation techniques do not involve an implicit assumption of causality, while regression techniques do. The choice of dependent and independent variables in a regression model is crucial. The dependent variable is a variable to be explained, while the independent variable is a moving force (Pindyck and Rubinfeld, 1997). Two variable least squares approach is used to develop a relationship between electrical conductivity as an independent variable and different water quality variables such as Ca, Mg, Cl, NO_3, TDS, HCO_3, TH, Fe^{Total} as dependent variable. We have only considered parameters having correlation coefficient values greater than 0.5 based on the information given in Tables 4 and 5. Table 7 presents the cross section results. We report in the first column the results for ordinary least squares (OLS) regressions, with only the EC control variable and a constant. In the second column we show the values of adjusted R^2. Regression results for Ca, NO_3, HCO_3, and TH equations show that the conductivity is significant at 1% level, while the equations of Mg, Cl and Fe ^{Total} are significant at 5 % level of confidence. Only the regression coefficients obtained for TDS are significant at 10 % level of confidence. All the regression equations are obtained for 96-2=

94 degree of freedom. The significance of the relationship is also highly supported by F test (Table 7). White's test for heteroskedasticity in the residuals of the basic specification rejects the null of no heteroskedasticity; thus all standard errors of coefficients are calculated using White test. We have checked the robustness of our resultby computing the concentration of selected water quality variables, which also showed a satisfactory outcome between the observed, and the computed values.

Table 4. Correlation coefficients among different water quality parameters

	pH	EC	TDS	Na	K	Mg	Ca	Fe^{total}	NO_3	Cl	HCO_3
pH	1.0000										
EC	0.0865	1.0000									
TDS	0.1258	0.6668	1.0000								
Na	0.1894	0.7267	0.7440	1.0000							
K	0.2117	0.1200	0.7328	0.9930	1.0000						
Mg	0.1182	0.6719	0.1629	0.3053	0.2693	1.0000					
Ca	0.0404	0.8106	0.5292	-0.0254	-0.0560	-0.0023	1.0000				
Fe^{total}	0.0389	0.2171	0.2842	0.2569	0.2574	0.1476	0.0439	1.0000			
NO_3	-0.2208	0.7316	-0.0053	-0.1742	-0.1870	-0.3034	0.1886	0.1769	1.0000		
Cl	0.4989	0.5391	0.1868	0.2038	0.1948	0.3132	0.8161	0.0400	-0.0882	1.0000	
HCO_3	0.1112	0.7561	0.1408	0.0316	0.0047	0.1443	0.2437	0.2617	0.2596	0.2495	1.0000

Table 5. Correlation coefficients among different indices

	SAR	SSP	MAR	KR	PI	TH	RSBC
SAR	1.0000						
SSP	0.4802	1.0000					
MAR	0.3151	0.4726	1.0000				
KR	0.9540	0.5619	0.3809	1.0000			
PI	0.5034	0.0774	0.1463	0.4436	1.0000		
TH	0.0139	-0.1224	-0.2602	-0.0634	-0.0089	1.0000	
RSBC	0.0661	0.0770	-0.0203	0.0580	0.0188	-0.5643	1.0000

Table 6. Adjusted R^2 values of Water Quality Variables with Conductivity

Water Quality Variables	Adjusted R^2 - value
Calcium	0.869
Magnesium	0.393
Chloride	0.644
Nitrate	0.881
Total Dissolved Solid	0.780
Iron	0.471
Bi-carbonate	0.911
Total hardness	0.510

Table 7. Regression Equations for different Water Quality Variables

Regression Equation	Adjusted R^2 value	t value	p value	F- value
Ca = -6.7 + 0.12336 EC	0.869	3.17	0.002^{*}	100.06
Mg = 19.26 + 0.01640 EC	0.393	2.05	0.043^{**}	40.21
Cl = 9.415 + 0.04740 EC	0.644	2.54	0.013^{**}	60.48
NO_3 = 4.014 + 0.00356 EC	0.881	3.64	0.001^{*}	104.10
TDS = 230.81 + 0.5252 EC	0.780	1.71	0.090^{***}	29.3
Fe^{Total} = 1.173 + 0.00274 EC	0.471	2.15	0.034^{**}	46.10
HCO_3 = 48.304 + 0.2976 EC	0.911	11.20	0.000^{*}	125.47
TH = 28.67 + 0 .4568 EC	0.510	3.32	0.001^{*}	22.05

Note: * indicates significance at the 1% level, ** indicates significance at 5% level and ***indicates significance at the 10% level

CONCLUSION

It is concluded that the linear regression equations developed for predicting the concentration of different parameters based on electrical conductivity can successfully be used within reasonable precision. In most of the belts of our study area, the problems of iron, and bicarbonate were found. It is evident that electrical conductivity is the most appropriate variable predicting or explaining more than 91, 88, 86, 78, 64 and 47 % values of the dependent variable in the sample of the data at hand and explaining the fact that the variance of the residual is small compared to the variance of the dependent variable. Similar linear regression technique can be applied for other regions of the country to predict the level of significance.

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