Regression Model for Predicting Water Quality Parameters: Study of Igando, Lagos-Nigeria

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Abstract. Fifteen groundwater samples were collected from hand dug well. The depths of wells were measured and the water quality analyzed for 7 heavy metals (Fe, Cu, Mn, Pb, Zn, Cr and Cd) after standard method. The study aimed at predicting groundwater quality parameters with depth with a view to ascertain its quality using both correlation and regression model. The results show that depths of hand dug wells ranged between 15.5 m-22.60 m with a mean of 19.47.Iron,Copper, Cadmium, Manganese, Lead, Zinc and Chromium ranged between (0.00-10.16, 0.02-8.71, 0.02-0.32, 0.04-30.00, 0.00-3.14, 1.40-55.18 and 0.00-0.04 mg/L) respectively. The Coefficient of variation revealed that all the examined groundwater parameters with the exception of Chromium are highly variable. All the parameters examined with the exception of Chromium were found to be above the maximum permissible limit for drinking water standard in the area. The regression coefficient of determination accounts for 75.17%.The regression model significantly explains how the depth of well affects groundwater parameters representing about 25% of the information not accounted for in the model. The functional relationship and the degree of correlation between depth of well and parameter indicates that among all the parameter examined only Iron, Copper and Zinc have a significant linear association with depth at 0.05 level of significance (0.024, 0.020 and 0.001 respectively).The study demonstrates the effectiveness of regression model in predicting water quality parameters for the present and future purposes.

Keywords: Depth, Groundwater quality, Heavy metals, Regression model, Lagos-Nigeria

1 INTRODUCTION

Groundwater constitutes an important source of water for drinking, domestic, agriculture and industrial production. The use of groundwater has increased significantly in the last decades due to its overall good quality and high reliability during drought seasons, and generally low development costs. Groundwater is the world's most extracted resource particularly in semi-urban and rural areas of developing countries. In arid and semi-arid regions and in the inlands, groundwater is the most important and safe source for drinking water (UNESCO, 2007). High rate of urbanization have contributed to increased water demand globally (WHO/UNICEF, 2006; Longe, 2011). In the last three decades, Lagos State had witnessed a phenomenal increase in population and urbanization. The rise in population has resulted to intensive abstraction of groundwater for various uses (Todd & Mays, 2005).

Similarly, contamination of groundwater from natural, human activities and the increasing use and disposal of chemicals to the land surface pose a serious threat to groundwater resource and consequently health risk to local resource users and to the natural environment (Morris, Lawrence, Chilton, Adams, Calow, & Klinck , 2003; Milovanovic, 2007). Pollutants in groundwater are virtually limitless. The sources and courses of groundwater pollution are closely related with human activities .Most groundwater pollutants stems from land uses such as municipal (i.e. leakages, liquid, waste and solid wastes from land fill), industrial (i.e. liquid wastes, tank and pipeline leakages, oil field and brines) and agricultural sources (i.e. irrigation return flow which are sometimes saline) (Todd &Mays, 2005). They may also be from spills, surface discharges in form of hydrocarbons in groundwater table or rather from stockpiles in industrial, construction or agricultural sites. It may also result from cesspools, septic tanks, saline water intrusion and interchange through wells.

The chemical composition of groundwater is regulated by various factors, which include atmospheric input (i.e., sea spray, aerosols, etc.), mineral weathering through rock-water interaction, anthropogenic activities, and biogeochemical processes. The weathering of minerals exerts an important control on groundwater chemistry (Bowser, 1992; Bullen, Krabbenhoft, & Kendall, 1996; Kim, 2002; Kim et al., 2005). This process generally dominates the concentration of the major cations (Ca, Mg, Na, K) in groundwater (Bartarya, 1993; Kim, 2002, Kim, Rajmohan, Hyun-Jung, Seok-Hwi, Gab-Soo & Seong-Taek *et al*. 2005). Furthermore, the transport of contaminants in the groundwater system is affected by different processes such as advection, dispersion, diffusion, adsorption and decay. Dispersion plays an important role in groundwater pollution because some pollutants spread out and change in volume due to molecular diffusion and mechanical dispersion beneath the ground. Dispersion of pollutants is controlled by permeability and porosity. Dispersion causes mixing with uncontaminated groundwater, hence it is a mechanism for dilution. Dispersion process is also useful in predicting transport away from point sources of contamination. It is also useful in predicting the spread of nonpoint-source contaminants. Hence, understanding the processes affecting groundwater composition is difficult, especially in areas with complex land-use characteristics (Kim, Rajmohan, Hyun-Jung, Seok-Hwi, Gab-Soo & Seong-Taek *et al.* 2005).

Knowledge of water table - depth is a crucial element in hydrological investigation, including agricultural salinity management, landfill characterization, chemical seepage movement, and water supply studies (Buchanan &Triantafilis, 2009; Goyal &Chaudhary, 2010).In this study, multivariate analysis methods of both correlation and regression model was adopted to predict groundwater quality parameters of the study area with a view to monitoring its quality for various uses.

1.1 The study area

The study area is situated at the north-western part of Lagos, Nigeria. It is located approximately between latitude 6° 28’ N to 6° 42’N and longitude 3° 13’ 30’’E to 3° 17’ 15’’E. It occupies an area of about 173.1sq. Km (MPP&UD, 2009). River Owo demarcates the area from Ado-Odo/Ota LG of Ogun state .Towards its east are Ifako- Ijaiye, Agege and Ikeja LGAs of Lagos state. Oshodi/Isolo, Amuwo-Odofin and Ojo LGAs of the state bound it in the southern part. The climate is characterized by two distinct seasons, a dry season spanning from November through March and April, and a wet or rainy season from April to October with a short break in mid-August. Annual precipitation of over 2000 mm is a major source of groundwater recharge in the area (Longe, 2011).

The area is characterized by two major climatic seasons, a dry season spanning from November through March and April, a wet or rainy season from April to October with a short break in mid-August. Annual precipitation of over 2000 mm is a major source of groundwater recharge in the area (Longe, 2011).Temperatures range from 28°C– 33°C.The soil is almost completely covered by red sandy clays (laterite) while the vegetation is composed of swamp forest and coastal plants.

The geology is underlain by inter-bedded sands, gravelly sands, silts, and clays. The hydrology is dominated by River Owo and its tributaries (River Abesan, River Oponu, and River Illo).They drain into the Ologe lagoon.

The population is about 1,277,714 people with a density of about 6,899 people per km^2 (Odumosu, Balogun & Ojo, 1999; NPC, 2006).The major source of public water supply in the area is through boreholes and hand dug wells. Major land uses includes, residential, industrial, commercial, agricultural and landfill. The new Igando Landfill operation is a major land use in the area. It started in 1996 with a projected lifespan of between 5 and 6 years. The landfill covered an area of about three hectares and is surrounded by residential, commercial and industrial land uses (Longe & Balogun, 2009).Tipping at the landfill on a daily basis is averaged at 1000 tonnes of waste. The landfill receives waste of about 469,202.50 tonnes from the entire state with varying types of wastes ranging from organic to inorganic and hazardous / non-hazardous wastes (Longe, 2010).

2 MATERIALS AND METHOD

Fifteen (15) groundwater samples were collected around landfill from the study area during the month of September, 2010 (dry season) using random sampling technique. The month of September was chosen because it is a dry season when dilution rate and depth to groundwater will be low (Todd & Mays, 2005).The samples were analyzed for heavy metals including (Iron, Lead, Manganese, Copper, Chromium, Cadmium, and Zinc after standard methods for the examination of water and wastewater quality (APHA, 1998). Also, static water level and depth of each wells were determined using graduated steel tape method. A lead weight was attached to the end of the tape to aid in plumb-ness and added feel.

Groundwater samples were collected in a 1.5lit. polyethylene bottles after rinsing with the water being sampled and were properly sealed. Samples were properly labeled and stored in cooler containing ice cubes and were transferred to the Chemistry Department, University of Lagos, Akoka for laboratory analysis within 24hours.Global Positioning System (GPS Channel 76 model) was used to take the co-ordinates of the sampling locations and were plotted using ArcGIS 9.3 (Fig. 1).

2.1 Analytical method

The heavy metals (Zinc, Lead, Cadmium, Iron, Manganese, Copper and Chromium) examined were determined using Atomic Absorption Spectrophotometer (AAS) and the concentration of each parameter was read directly at their specific wavelenght. Zn(213.9nm), Pb(217nm) , Cd (228.8nm), Fe(248.3nm), Mn(279.58nm), Cu (324.8nm) and Cr(357.9nm) .

3 RESULTS AND DISCUSSION

Table 1 present the descriptive statistics of heavy metal in groundwater of the study area. The result show that, depths of hand dug wells ranged between 15.5 m-22.60 m with a mean depths of 19.47 m. Iron, Copper, Cadmium, Manganese, Lead, Zinc and Chromium ranged between (0.00 - 10.16, 0.02 - 8.71, 0.02 - 0.32, 0.04 - 30.00, 0.00 - 3.14, 1.40 - 55.18 and 0.00 - 0.04 mg/L) mg/L respectively. The mean concentration of the examined heavy metals in groundwater of the study area show that, Zinc has the highest (18.12 mg/L with standard deviation of 17.30 mg/L) followed by Manganese (2.89 mg/L with standard deviation of 7.68 mg/L), Copper (2.08 mg/L with standard deviation of 3.08 mg/L), Iron (1.81mg/L with standard deviation of 3.12 mg/L), Lead (0.36 mg/L with standard deviation of 0.88 mg/L), Cadmium (0.13 mg/L with standard deviation of 0.08 mg/L) while Chromium remained the least (0.02mg/L with standard deviation of 0.01mg/L).

On the pattern of relative variation, the result of the Coefficient of variation (C.V %) shows that all the examined groundwater parameters, with the exception of Chromium and Cadmium, are highly variable. Further, the World Health Organization (WHO,2006) standard limit for drinking water quality adopted to adjudge the suitability of the well water for human consumption showed that all the parameters examined, with the exception of Chromium, were found to be above the maximum standard limit for drinking water quality in the study area.

Table 2 show the regression parameter estimate of each of the groundwater parameters under study. The regression model is given as: Depth (m) = 18.94 + 0.03Fe – 0.34Cu – 10.92Cd + 0.08Mn + 1.05Pb + 0.14Zn – 29.24Cr. Model description: 0.03m increase in well depth will amount to a unit increase in Iron (Fe), 0.34 m decrease in well depth will amount to a unit increase in Copper (Cu), 10.92 m decrease in well depth will amount to a unit increase in Cadmium (Cd), 0.08 m increase in well depth will amount to a unit increase in Manganese (Mn), 1.05 m increase in well depth will amount to a unit increase in Lead (Pb), 0.14 m increase in well depth will amount to a increase in Zinc (Zn) while 29.24 m decrease in well depth will amount to a unit increase in Chromium (Cr). Invariably, a relatively shallow well will situate high concentration of Copper (Cu), Cadmium (Cd) and Chromium (Cr), and the concentration of Iron (Fe), Manganese (Mn), Lead (Pb) and Zinc (Zn) will be insignificant. The regression coefficient of determination is obtained as 0.7517 (75.17%). This significantly explains the adequacy of the model and how the depths of well affects groundwater parameters. The result implies that about 25 percent of the information on the groundwater parameters is not accounted for in the model.

The functional relationship and the degree of correlation between the depths of well and each of the groundwater parameter under study is shown in Table 3. The result indicates that among all the parameter examined only Iron (Fe), Copper (Cu) and Zinc (Zn) have a significant linear association with depth, obtained as 0.576, 0.592 and 0.759 respectively. This implies that the mean concentration of each of the significant parameters is strongly affected by the depths of well. Thus, as depth of well increases their mean concentration increases. These were clearly depicted in the scatter plots and scatter matrix in figures (2a-2g) and Figure 3, respectively. In addition, based on the standardized coefficients (Table 2) (Zn = 0.955), it can be inferred that depth of well mostly affects the concentration of Zinc (Zn) in groundwater quality compared to other groundwater parameters in the study area.

The regression multiple correlations (R) of well depth (m) with all the groundwater parameters (Fe, Cu, Cd, Mn, Pb, Zn and Cr) obtained as 0.867 suggests that the groundwater parameters have a strong linear relationship with depths of well but with the exception of Cadmium (Cd) which shows an indirect relationship. This is supported in the regression equation (model) obtained for each groundwater parameter with depths of wells as dependent variable in Table 3.

Presence of Iron in drinking water in large quantity is responsible for haemochromtosis, impart objectionable taste and colour (WHO, 1980; Rowe, Quigley & Booker, 1995).This study further supports the report of high Iron concentrations in groundwater in Nigeria (WHO, 2006).Presence of Copper in excess in drinking water is responsible for nausea (Araya, Chen, Klevay, Strain, Johnson & Robsson *et al*. 2003). The presence of Manganese in excess amount presents undesirable tastes, foster growth in reservoirs, and is responsible for cardiovascular mortality (WHO, 1980). It is also responsible for behavioral change in children and results in tiredness, anaemia, irritability and abdominal discomfort. High concentration of

Zinc in drinking water could be toxic in human and can lead to abdominal pain, nausea, lack of muscular coordination (Prasad & Oberleas, 1976), acute renal failure (Todd & Mays,2005) and also impart undesirable astringent taste. Though, Chromium was found to be within the standard limit of WHO (2006) for drinking water quality, high concentration of Chromium could cause digestive tract cancer in man, or increase the risk of lung cancer in man (Todd & Mays, 2005).

Furthermore, excess Cadmium in drinking water quality can lead to severe gastro-intestinal upset (WHO, 1984b) and also renal or kidney problems (Schmoll, Howard, Chilton & Chorus,2006).The level of detected heavy metals in groundwater quality in the study area further confirm the findings of (Tengrui, Al-Harbawi, Lin, Jun, & Long, 2007; Ogundiran & Afolabi, 2008) who reported that, these metals are brought into groundwater system by human activities such as industrial, landfill among others.

In addition, within the hydrological cycle, groundwater flow patterns are influenced by geological factors such as differences in aquifer lithology, structure of the confining strata and topography of the ground surface (Todd & Mays, 2005). Topography is a major factor that influences groundwater flow both at local, intermediate and regional scales. According to Adelana, Olasehinde, Bale, Vrbka, Edet, & Goni (2008), the relative positions and difference in elevation of recharge and discharge areas determine the hydraulic gradients and length of groundwater flow paths in any given area.

4 CONCLUSIONS

The present study adopted a regression model to predict groundwater quality characteristics of open hand dug well in Igando, Lagos-Nigeria .The WHO drinking water quality standards adopted show that all the examined heavy metals were found to be above the required standard except Chromium. In all the sampled groundwater quality, Cadmium was not detected in any of the sampling locations. Result of the regression model, as applied to the chemical data set of groundwater quality in the area provides an insight into how the depth of well affects the groundwater parameters. It also provides information on the groundwater parameters that is not accounted for in the model.

Similarly, the functional relationship and the degree of correlation between the depth of well and each of the groundwater parameter indicates that among all the parameter examined only Iron Copper, and Zinc have a significant linear association with depth. This is further explained by the mean concentration of each of the significant parameters that is strongly affected by the depth of well. Thus, as depth of well increases their mean concentration increases. The study demonstrates the effectiveness of regression model in predicting water quality parameters so as to provide information on the groundwater quality of the study area which will serve as a data base for future investigations and monitoring of groundwater quality. The paper recommends the need for determining groundwater flow direction from the landfill before locating/ digging of water wells in the area and also the need to control human activities and the release of effluents onto the land surface that replenish groundwater.

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Table 1: Descriptive Statistics of Heavy Metal Characteristics in Groundwater

Parameter	Min	Max	Mean	SD	CV (%)	WHO Std(mg/L)
Depth (m)	15.50	22.60	19.47	2.48	12.74	-
Iron (mg/L)	0.00	10.16	1.81	3.12	172.38	0.3
Copper (mg/L)	0.02	8.71	2.08	3.08	148.08	2.0
Cadmium (mg/L)	0.02	0.32	0.13	0.08	61.54	NA
Manganese (mg/L)	0.04	30.00	2.89	7.68	265.74	0.05
Lead (mg/L)	0.00	3.14	0.36	0.88	244.44	0.01
Zinc (mg/L	1.40	55.18	18.12	17.30	95.47	5.0
Chromium (mg/L	0.00	0.04	0.02	0.01	50.00	0.05

Min-Minimum, Max-Maximum, SD-Standard Deviation, CV-Coefficient of Variation,
WHO- World Health Organization,NA-Not Available

Table 2: Regression Estimates of Groundwater Parameters

Term	Unstandardized Coefficients	Std Error	Standardized Coefficients	t	P-value
Intercept	18.94	1.989		9.519	.000
Fe	0.03	1.074	.041	.031	.976
Cu	-0.34	.843	-.421	-.403	.699

Term	Unstandardized Coefficients	Std Error	Standardized Coefficients	t	P-value
Cd	-10.92	9.447	-.371	-1.156	.286
Mn	0.08	.158	.234	.478	.647
Pb	1.05	1.191	.371	.879	.408
Zn	0.14	.132	.955	1.034	.336
Cr	-29.24	43.234	-.154	-.676	.521

Model Summary: Regression multiple correlation (R) = 0.867, Regression Coefficient of determination (R^2) = 0.752. Dependent Variable: Depth (m).

Table 3: Relationship and degree of correlation between the depth of well and groundwater parameters

Parameter	Regression Equation	R -Square	Correlation (r)	P-value
Fe	18.637 + 0.458 Fe	0.332	0.576	.012*
Cu	18.476 + 0.477 Cu	0.351	0.592	.010*
Cd	21.068 - 12.001 Cd	0.166	-0.408	.066
Mn	19.189 + 0.097 Mn	0.089	0.299	.140
Pb	19.348 + 0.329 Pb	0.014	0.117	.339
Zn	17.496 + 0.109 Zn	0.576	0.759	.001*
Cr	19.232 + 15.362 Cr	0.007	0.081	.388

* The parameters have a significant relationship with water depth at 5%.
Dependent Variable: Depth (m).

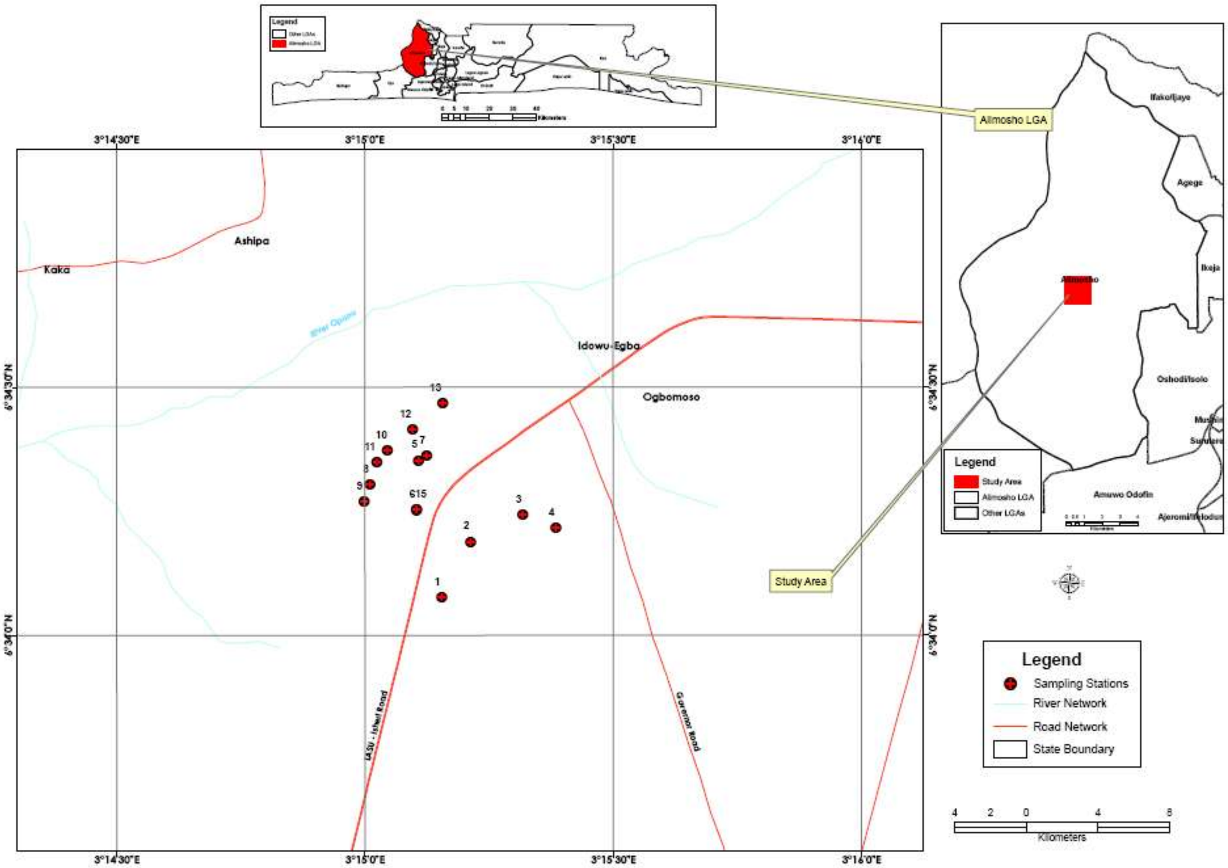

Fig.1: The sampling Locations

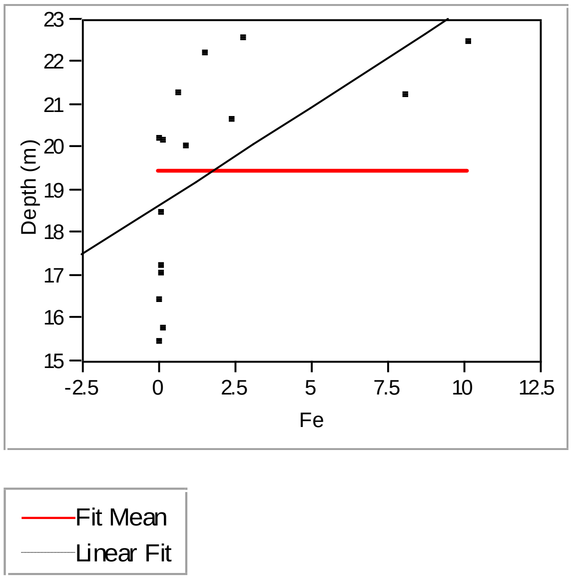

Fig.2a: Bivariate Fit of Depth Versus Fe

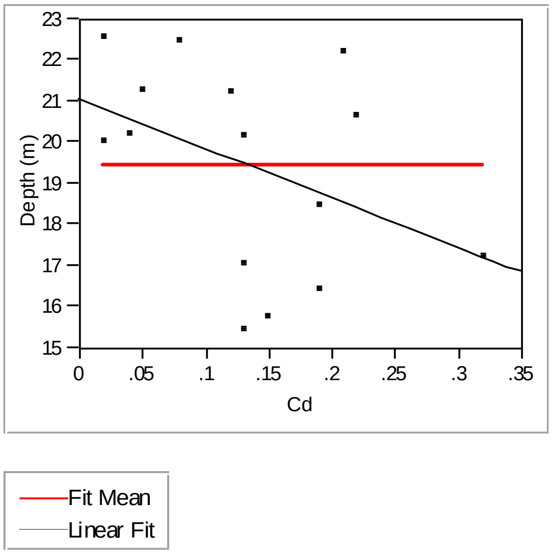

Fig.2b: Bivariate Fit of Depth versus Cd

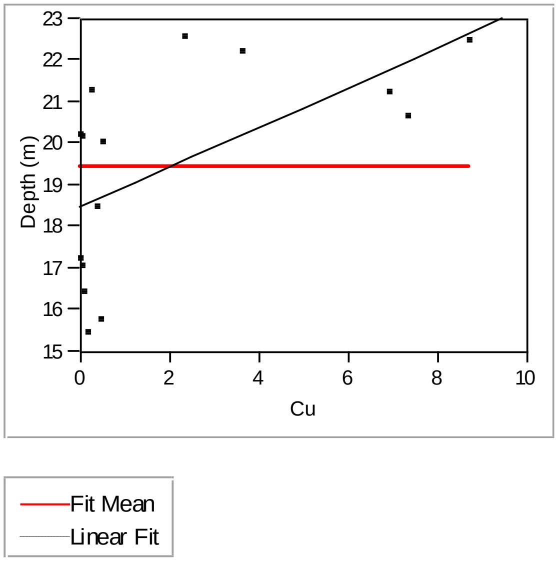

Fig. 2c:Bivariate Fit of Depth versus Cu

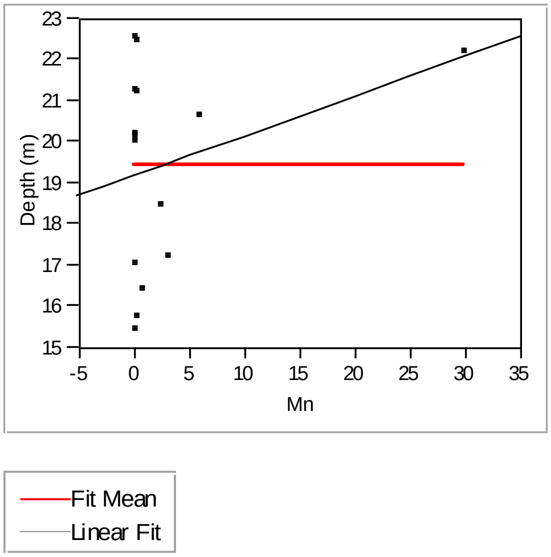

Fig. 2d:Bivariate Fit of Depth versus Mn

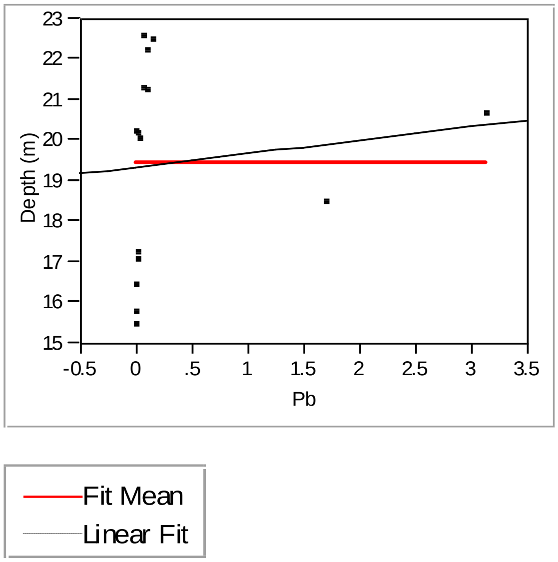

Fig.2e:Bivariate Fit of Depth versus Pb

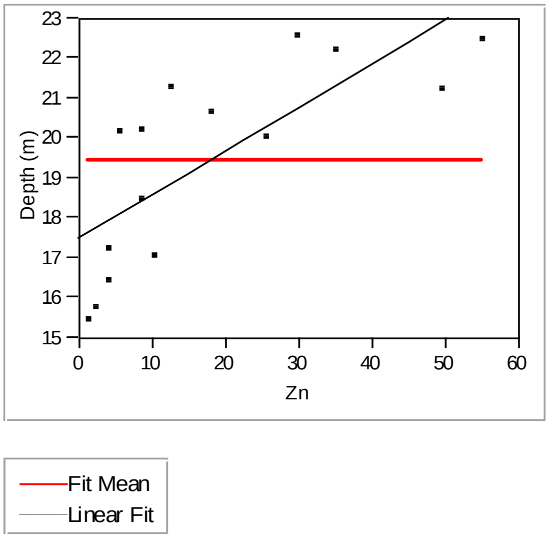

Fig.2f:Bivariate Fit of Depth versus Zn

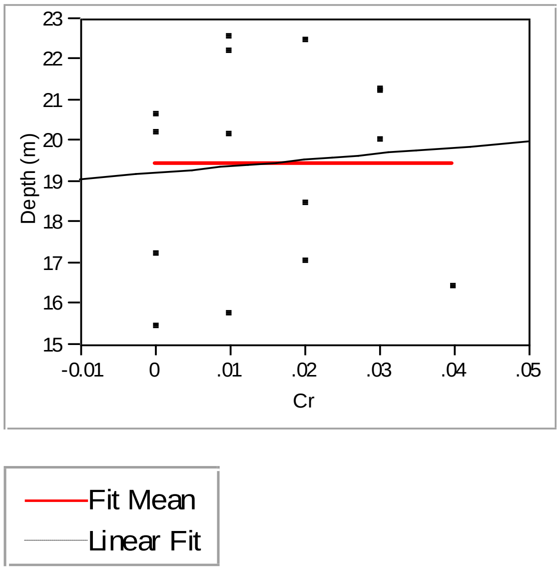

Fig. 2g: Bivariate Fit of Depth versus Cr

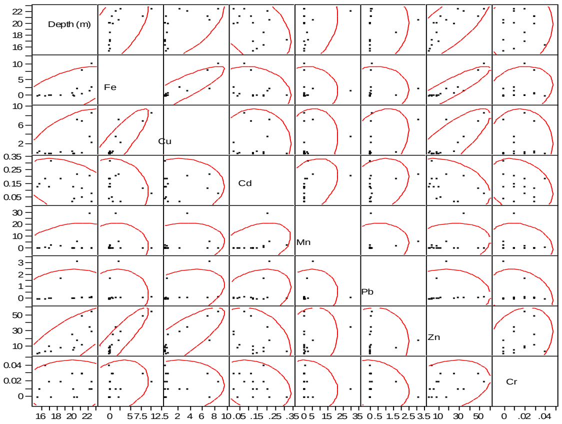

Fig. 3: Scatterplot Matrix of groundwater parameters