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Prediction of groundwater quality in Selected Locations in Imo State

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Abstract: *The prediction of groundwater quality in selected locations was carried out in Owerri-West L.G.A. of Imo State. The Physical, chemical and biological parameters of groundwater samples from Nekede (Ward A), Ihiagwa (Ward B), Eziobodo (Ward C), Obinze (Ward D) and Avu (Ward E) were analysed using the Atomic Absorption Spectrophotometer (AAS). A total of three replicates of fifteen different borehole water samples were collected based on distances from closest potential sources of contamination. All parameters were detected up to 61m from pollution source and most of them increased in concentration during the periods, pointing to infiltrations from storm water. The results for Iron, pH and TVC decreased as distance increases while for nitrate and BOD increased as distance increases. Results also showed that most of the boreholes were polluted and not suitable for human consumption without adequate treatment, Regular monitoring of groundwater quality, abolishment of unhealthy waste disposal practices and introduction of modern techniques are recommended.*
Keywords: *Groundwater, Pollution, distance, Physical, Chemical, Biological.*

I. Introduction

Water is required by man in various activities such as washing, general cleaning, laundry and in agricultural activities. Water is a necessity, a resource and at the same time a major contributory factor in the contamination/pollution problems (Sabo *et al*.,2013). Water has been an indispensable commodity to man, hence there has been extensive research and effort for its proper conservation and distribution for use. Safe drinking water remains inaccessible for about 1.1 billion people in the world (Mintz *et al*., 2001). About 52% of Nigerians do not have access to improved drinking water supply (Orebiyi *et al.*, 2010). The use of water is limited by its quality and this attribute of water also defines its general purpose.

For most communities the most secure source of safe drinking water is pipe-borne water from municipal water treatment plants. Often, most of water treatment facilities do not deliver or fail to meet the water requirements of the community due to corruption, lack of maintenance or increased population. The scarcity of pipe borne water has made communities to find alternative sources of water - ground water sources being a ready source.

Wells are a common ground water source readily explored to meet community water requirement or make up the short fall (Adekunle, 2008). The source of water also contributes to its quality and the chief source of water for various domestic and agricultural uses is groundwater.

Groundwater is increasingly gaining significance as the main solution to the water supply problems in Nigeria, especially in the sub-urban and rural areas (Akoteyon,2013**).** Groundwater quality comprises of physical, chemical and biological properties. Temperature, turbidity, colour, taste and odour make up the list of physical water quality parameters. The mineral ions which are divided into major, minor and trace constituent's make up the chemical properties. These parameters mentioned determine the extent of contamination of groundwater whether or not the water is fit and of what purpose it can find use.

The rate of urbanization in Nigeria is alarming and the major cities areas are growing at rates between 10-15% per annum (Yusuf, 2007) and thus, human activities including soil fertility remediation, indiscriminate refuse and waste disposal, and the use of septic tanks, soak-away pits and pit latrines are on the increase.

Most inhabitants of Owerri West rely on borehole water as their chief supply of portable water supply, therefore it becomes imperative that not only the quality of these water sources be studied but also, their vulnerability to contamination be assessed and recommendation on efficient and effective protection strategy be given to the appropriate regulatory bodies to forestall the negative consequences of negligence to this obvious fact. In Nigeria, there is the challenge of lack of supply of pipe borne water hence many homes have borehole wells sited around the house at a distance from the septic tank.

1.1 Description of Study Area

Owerri is a rapidly growing urban centre. It became the capital of Imo State in 1976. The Imo state capital has three Local Government Areas - Owerri Municipal, Owerri North and Owerri West. The study area is Owerri West L.G.A in Imo State is in the South Eastern part of Nigeria. It is bounded by latitudes $5^{o}34$ and $5\ ^{o}34$' N and longitude $6\ ^{o}52$' and $7^{o}05$'E.

II. Materials And Methods

Five wards namely Nekede, Ihiagwa, Eziobodo, Obinze and Avu in Owerri Metropolis were chosen for the purpose of this investigation. The locations from which the samples were taken are given in Table 1. Distance from the borehole to a potential source of contamination which includes landfills, septic tank (sewers) and pit toilet (latrines) was measured with a standard meter rule and recorded. The distance is also included in Table 1. For convenience, the water samples from the 15 different boreholes were labeled W_1 – $W_{15.}$ Replicate of three samples in each of the areas were collected but from different boreholes.

The water samples were collected in the early morning hours when freshly pumped from the ground in compliance with the Nigerian Standard for Drinking Water Quality (NSDQW) best practices for Water Quality Analysis in October, 2011. Prior to collection as part of quality control measures all the bottles used for the sample collection were washed and rinsed with distilled water. The bottles were rinsed three times with the sample water at the point of collection before the final water sampling was done. The bottles were held at the bottom while filling, to avoid contamination of water from the hands or fingers (Oparaocha, *et al.*, 2011). All the sample containers were kept in ice boxes and brought to the laboratory for analysis. The bottles were labeled with masking tapes and the identification details were written on them according to sampling location as shown in Table 1.

The closest sources of pollution to these boreholes sampled were noted as shown in Table1. The qualitative analysis was carried out at the Central Laboratories of National Root Crops Research Institute Umudike (NRCRI), Umuahia, Abia State.

Table 1. Selected location areas within Owerri West L.G.A and their distances from sources of contamination

Ward	Area	Sample	Depth to static water level (m)	Distance From closest potential Sources contamination (meters)	NAFDAC	Closest contamination source
					30m	Septic tank
A	Nekede	W_1 W_2 W_3	47	3.0 12.6 14.9		Septic tank Septic tank Septic tank
B	Eziobodo	W_4 W_5 W_6	46	11.0 30.2 20.5		Septic tank Landfill Open site
C	Ihiagwa	W_7 W_8 W_9	47	26.4 13.6 13.9		Pit latrine Septic tank Septic tank
D	Obinze	W_{10} W_{11} W_{12}	46	48.6 13.3 60.4		Septic tank Septic Septic tank
E	Avu	W_{13} W_{14} W_{15}	46	50.4 61.3 13.4		Septic tank Pit latrine Pit latrine

2.1. Test for Biological Parameters

The samples collected from the various boreholes were analyzed for the following biological parameters; Biochemical Oxygen Demand (BOD), Total Viable Count (TVC) and coliform test. The membrane filter (MF) technique was used for the analysis.

2.2 Test for Chemical Parameters

The samples were analyzed for the following chemical parameters: Nitrate (NO_3^-), Zinc (Zn), Manganese (Mn), Lead (Pb), and Iron (Fe), according to the procedures described by APHA (2005).

2.3 Test for Physical Parameters

The samples were examined physically to determine the taste, colour, odour and temperature. Other physical parameters examined included the P_H ,concentration of suspended and dissolved solids.

2.4 Quadratic Regression Model

The quadratic regression model was used to predict the biochemical parameters with respect to the distances from the source of contamination.

Considering a polynomial of the form

$$Y = a_o - a_1 x + a_2 + x^2 \qquad (1)$$

where x= distance from the borehole to a potential source of contamination

Y= experimental value obtained from the laboratory

The sum of squared deviations of the observed values of y from the predicted values is given by

$$S = \Sigma(y - a_o - a_1 x - a_2x^2)^2 \qquad (2)$$

Minimizing Eq 3.2 by setting its partial derivatives with respect to a_o, a_1, a_2 equal to zero, we have

$$\left.\begin{aligned} \Sigma y &= a_o n + a_1 \Sigma x + a_2 \Sigma x^2 \\ \Sigma Xy &= a_o \Sigma x + a_1 \Sigma x^2 + a_2 \Sigma x^3 \\ \Sigma x^2 y &= a_o \Sigma x^2 + a_1 \Sigma x^3 + a_2 \Sigma x^4 \end{aligned}\right\} \qquad (3)$$

Solving the above equations give solutions to the values of a_o, a_1, a_2

For instance, considering a 3 x 3 matrix

$$\begin{bmatrix} X & Y & Z \\ C & D & E \\ F & G & H \end{bmatrix} \begin{bmatrix} a_o \\ a_1 \\ a_2 \end{bmatrix} \begin{bmatrix} I \\ J \\ k \end{bmatrix}$$

Solving for the unknown coefficient of a_o, a_1, a_2, we have

$$a_2 = \frac{K}{H} \qquad (4)$$

$$a_1 = EK - J \qquad (5)$$

$$a_o = I - y(a_1) - Z(a_2) \qquad (6)$$

The Quadratic Regression Model equations 3, 4, 5, and 6 respectively were used to predict the biological, chemical and physical parameters against distances from the sources of contamination.

III. Results And Discussion

The predicted equations and values of physico-chemical and biological parameters of the water samples obtained from boreholes in selected locations Owerri West are presented in Table 3 to Table 9. Also the graphs of predicted parameters are shown from Fig. 1 to Fig.5.

Figure 1.0 showed the graph of TVC against measured distances. The TVC values starts to decrease from at 6.4 Cfu/ml at a distance of 3 meters. At a distance of 40m, the TVC value recorded the minimum value of 3.6 Cfu/ml. After this distance, the TVC values increased with distances from the source of contamination. This implies that siting a borehole at about 40m from any source of contamination would be most appropriate for location of water supply system. Fig. 1.0 further showed that at distances greater than 40meters, the TVC values increased.

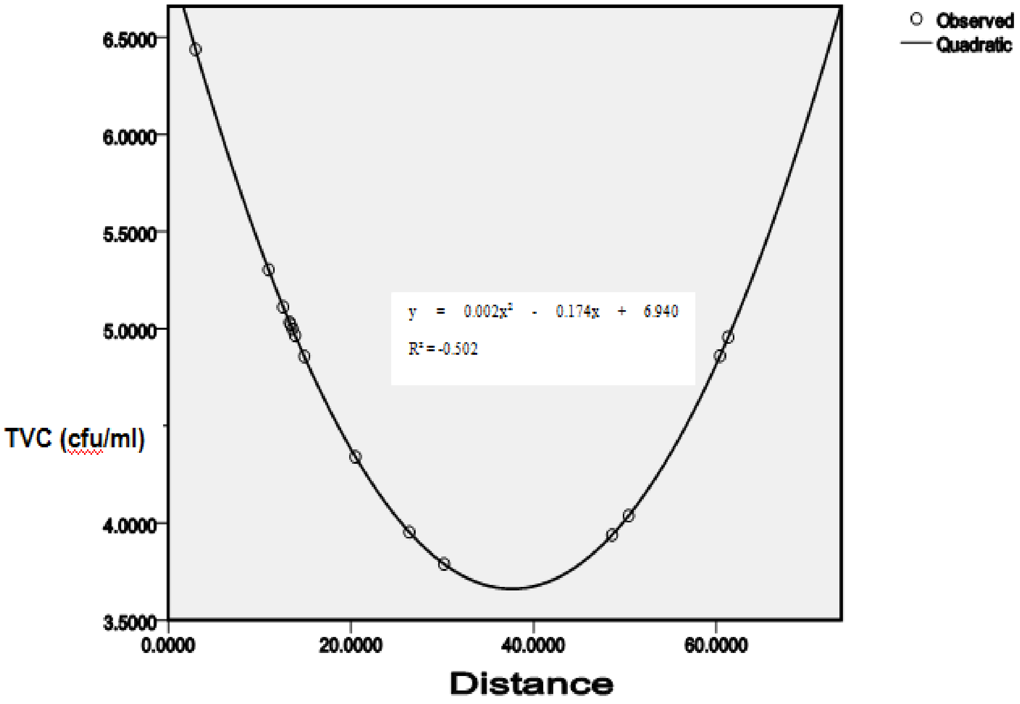

Figure 1: Distances from sources of contamination (m)

Figure 2.0 is a graph of iron (Fe) against measured distances from sources of contamination. The quadratic regression curve shows presence of iron (Fe) of a minimum value of 1.42mg/L at a distance of 30.2m. Besides, the graph further showed that Fe increases after a distance of 30.2m. This indicates that siting a borehole at a distance of about 30.2m could be advantageous to having low concentrations of Fe.

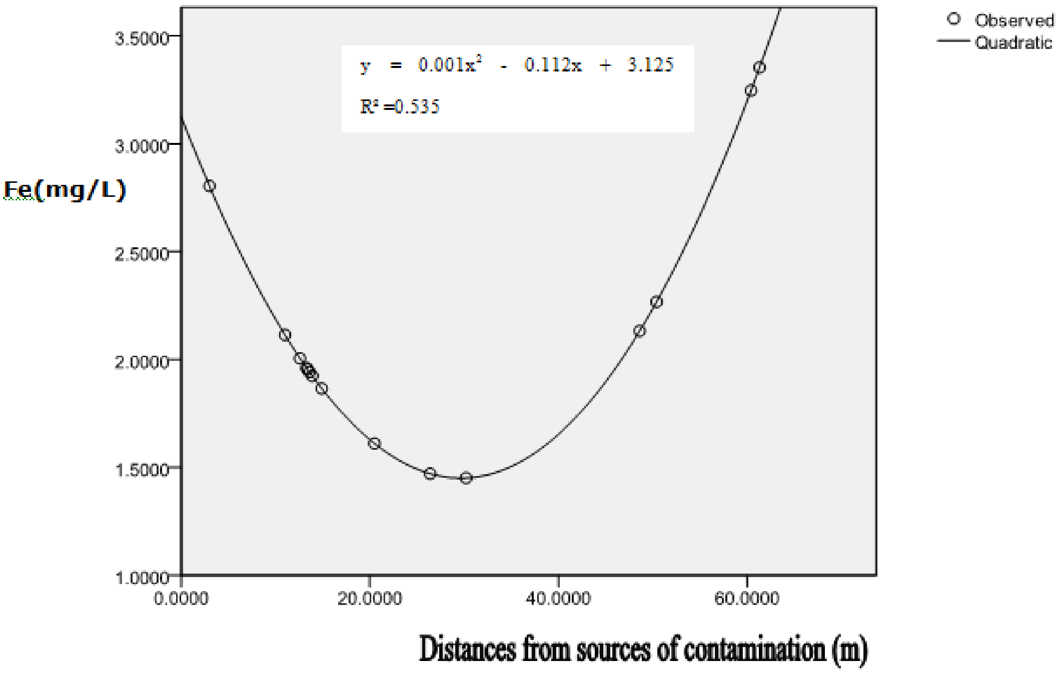

Figure 2: Graph of Iron against measured distances

Fig. 3.0 shows the graph of nitrate (NO_3) against measured distances from sources of contamination. The graph is also parabolic which has an observed NO_3 value of 0.115mg/L at a distance of 3m, and a NO_3 maximum value of 10.20mg/L at further distance of 44m which gradually decreased to 9.60mg/L at a distance of 60.4m. Further away distances (40m and above) from sources of contamination show a decrease in nitrate values. This is indicative that as distance increases, nitrate concentrations in water source decreased.Therefore,water supply systems should be sited at distances above 44m away from any sources of NO3 contamination.

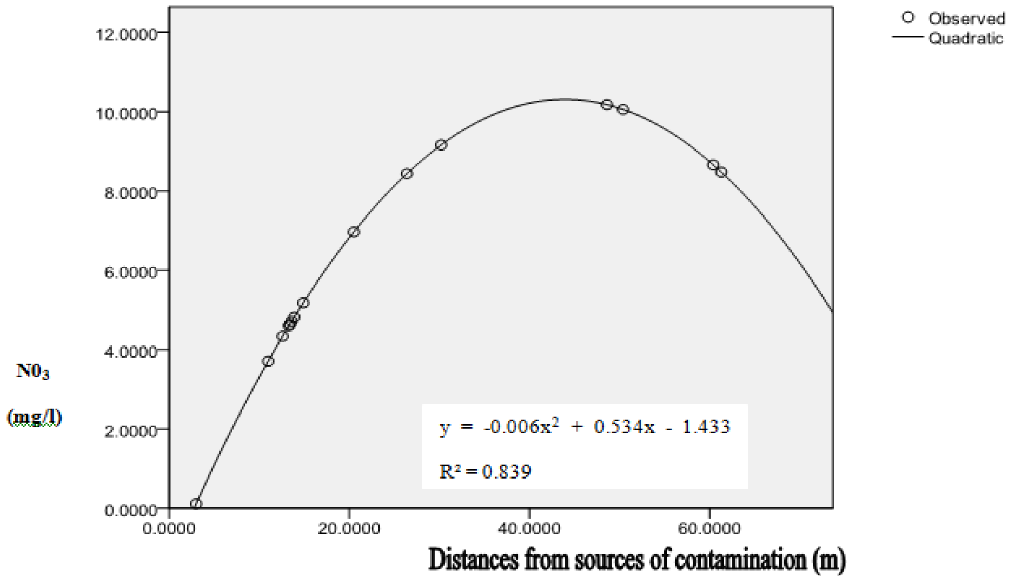

Figure 3. Graph of Nitrate against measured distances

Fig.4.0 showed the graph of pH against measured distances from sources of contamination. The pH values start to decrease from 6.36 at a distance of 3m.The pH value recorded a minimum value of 5.88 at a distance of 36m. After this distance of 36m, the pH values increased with distance from the source of contamination. This implies that at about a distance of 36m from any source of contamination, it would be appropriate for the location of water supply systems.

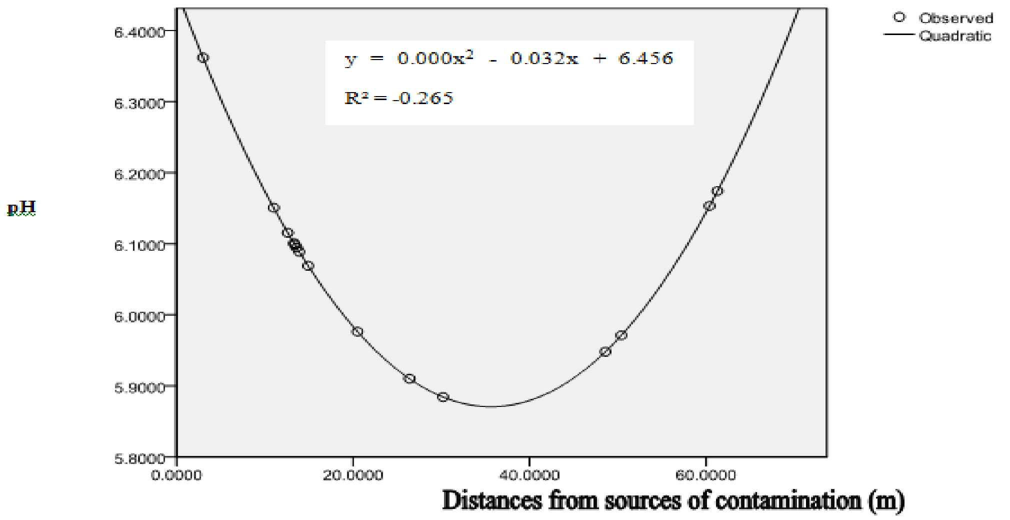

Figure 4. Graph of pH against measured distances

Fig. 5.0 shows the values of BOD against measured distances. BOD values starts to increase from 1.39mg/L at a distance of 3m. After distances of 20m, the BOD values sharply increases as the distances from source of contamination. This implies that the further away you are from BOD source contamination it would be appropriate in drilling a borehole water source

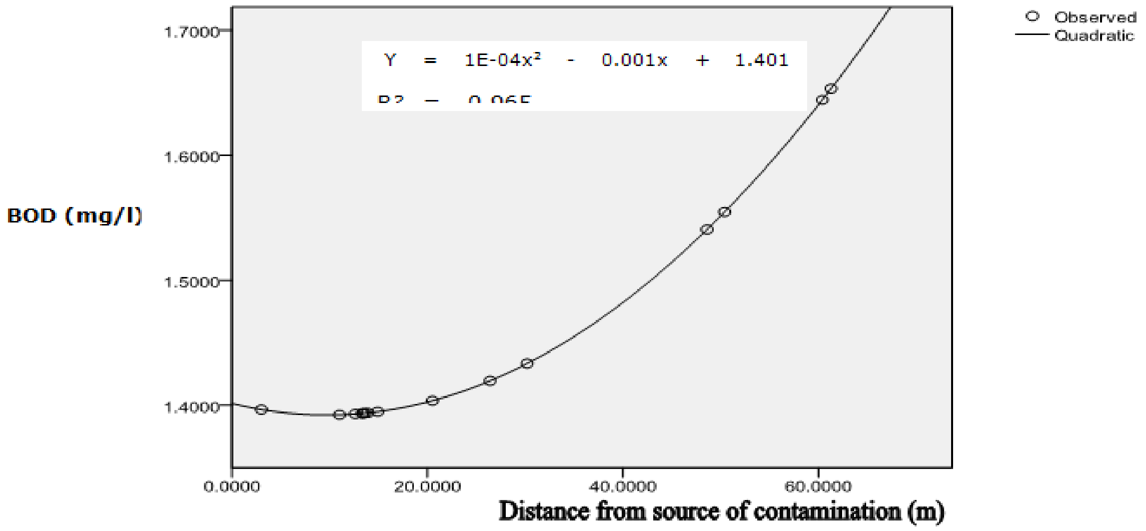

Figure 5. Graph of BOD against measured distances

Table 3: The various Physical ,Bio-chemical Parameters, Equation of Curves and Regression Parameters

Parameters	Model Equation curves for Determination of distances	Regression parameters
TVC (cfu/mL)	$Y_{Tvc} = 0.002x^2 – 0.174\ x + 6.940$	GF = -0.502 CC = -0.708
Fe^{3+}(mg/L)	$Y_{Fe}{}^{3+} = 0.001X^2 – 0.112X + 3.125$	GF = 0.535 CC = 0.731
NO_3^- (mg/L)	$Y_{NO3}{}^- = -0.006x^2 + 0.534x – 1.433$	GF = 0.839 CC =0.916
Ph	$Y_{pH} = 0.00x^2 – 0.032x + 6.456$	GF = -0.265 CC = -0.515
BOD(mg/L)	$Y_{BOD} = e - 04x^2 – 0.001x + 1.401$	GF = 0.965 CC = 0.982

Regression parameters:
GF = Goodness of fit CC = correlation coefficient, e = starndard error.

Table 4: Total viable Count (TVC) values with measured distances from all sources of contamination

Distance X (m)	$(TVC_e)y$	X^2	X^3	X^4	Xy	X^2y	$TVC_p = a_0 + a_1x + a_2x^2$
3	7.3	9	27	81	21.9	65.7	6.438234
12.6	3.0	158.76	2000.376	25204.74	37.8	476.28	5.11184
14.9	5.0	222.01	3307.949	49288.44	74.5	1110.05	4.85742
11	4.7	121	1331	14641	51.7	568.7	5.303274
30.2	3.3	912.04	27543.61	831817	99.66	3009.732	3.788356
20.5	5.3	420.25	8615.125	176610.1	108.65	2227.325	4.340378
26.4	5.0	696.96	18399.74	485753.2	132	3484.8	3.952709
13.6	3.7	184.96	2515.456	34210.2	50.32	684.352	4.998213
13.9	4.7	193.21	2685.619	37330.1	65.33	908.087	4.965028
48.6	4.3	2361.96	114791.3	5578855	208.98	10156.43	3.938168
13.3	6.0	176.89	2352.637	31290.07	79.8	1061.34	5.031815
60.4	5.3	3648.16	220348.9	13309071	320.12	19335.25	4.859217
50.4	3.3	2540.16	128024.1	6452413	166.32	8382.528	4.036997
61.3	4.7	3757.69	230346.4	14120234	288.11	17661.14	4.955927
13.4	6.0	179.56	2406.104	32241.79	80.4	1077.36	5.020568
Σ393.5	Σ71.6	Σ15582.61	Σ764695.2	Σ41179041	Σ1785.59	Σ70209.07	

TVC_e=Experimented TVC, TVC_P = Predicted TVC.
TVC_e= experimented values.
TVC_p = predicted values.

Table 5: Values of Iron with measured distances from all sources of contamination

Distance (X)	$(Fe_e)y$	X^2	X^3	X^4	Xy	X^2y	$Fe_p = a_0 + a_1x + a_2x^2$
3	3.6	9	27	81	10.8	32.4	2.804137
12.6	1.2	158.76	2000.376	25204.74	15.12	190.512	2.005333
14.9	0.4	222.01	3307.949	49288.44	5.96	88.804	1.86601
11	0.8	121	1331	14641	8.8	96.8	2.114121
30.2	2.2	912.04	27543.61	831817	66.44	2006.488	1.451383
20.5	2	420.25	8615.125	176610.1	41	840.5	1.610935
26.4	1.6	696.96	18399.74	485753.2	42.24	1115.136	1.471245
13.6	1.4	184.96	2515.456	34210.2	19.04	258.944	1.942285
13.9	1	193.21	2685.619	37330.1	13.9	193.21	1.924112
48.6	0.6	2361.96	114791.3	5578855	29.16	1417.176	2.132139
13.3	3.8	176.89	2352.637	31290.07	50.54	672.182	1.9608
60.4	3.6	3648.16	220348.9	13309071	217.44	13133.38	3.246507
50.4	3.6	2540.16	128024.1	6452413	181.44	9144.576	2.267891
61.3	2.9	3757.69	230346.4	14120234	177.77	10897.3	3.353241
13.4	3.4	179.56	2406.104	32241.79	45.56	610.504	1.95459
Σ393.5	Σ32.1	Σ15582.	Σ764695.2	Σ41179041	Σ925.21	Σ40697.91	

Table 6: Values of Lead with measured distances from all sources of contamination

Distance (X)	$(Pb_e)y$	X^2	X^3	X^4	Xy	X^2y	$Pb_p = a_0 + a_1x + a_2x^2$
3	0	9	27	81	0	0	0.014901
12.6	0	158.76	2000.376	25204.74	0	0	0.017708
14.9	0.02	222.01	3307.949	49288.44	0.298	4.4402	0.018284
11	0	121	1331	14641	0	0	0.017285
30.2	0.01	912.04	27543.61	831817	0.302	9.1204	0.021178
20.5	0	420.25	8615.125	176610.1	0	0	0.019534
26.4	0.04	696.96	18399.74	485753.2	1.056	27.8784	0.020612
13.6	0.04	184.96	2515.456	34210.2	0.544	7.3984	0.017963
13.9	0.02	193.21	2685.619	37330.1	0.278	3.8642	0.018038
48.6	0	2361.96	114791.3	5578855	0	0	0.022488
13.3	0.04	176.89	2352.637	31290.07	0.532	7.0756	0.017887
60.4	0.06	3648.16	220348.9	13309071	3.624	218.8896	0.022081
50.4	0.02	2540.16	128024.1	6452413	1.008	50.8032	0.022489
61.3	0	3757.69	230346.4	14120234	0	0	0.02201
13.4	0.04	179.56	2406.104	32241.79	0.536	7.1824	0.017912
Σ393.5	Σ0.29	Σ15582.61	Σ764695.2	Σ41179041	Σ8.178	Σ336.6524	

Table 7: Values of Nitrate with measured distances from all sources of contamination

Distance (X)	$(NO_{3e})y$	X^2	X^3	X^4	Xy	X^2y	$NO_{3p} = a_0 + a_1x + a_2x^2$
3	0	9	27	81	0	0	0.114964
12.6	0	158.76	2000.376	25204.74	0	0	4.334452
14.9	12.4	222.01	3307.949	49288.44	184.76	2752.924	5.178961
11	0	121	1331	14641	0	0	3.709028
30.2	5.4	912.04	27543.61	831817	163.08	4925.016	9.159562
20.5	0	420.25	8615.125	176610.1	0	0	6.966179
26.4	16.2	696.96	18399.74	485753.2	427.68	11290.75	8.436612
13.6	7.1	184.96	2515.456	34210.2	96.56	1313.216	4.709534

13.9	0	193.21	2685.619	37330.1	0	0	4.819687
48.6	6.3	2361.96	114791.3	5578855	306.18	14880.35	10.1766
13.3	0	176.89	2352.637	31290.07	0	0	4.598286
60.4	5.8	3648.16	220348.9	13309071	350.32	21159.33	8.662168
50.4	13	2540.16	128024.1	6452413	655.2	33022.08	10.05503
61.3	11.6	3757.69	230346.4	14120234	711.08	43589.2	8.477166
13.4	16.2	179.56	2406.104	32241.79	217.08	2908.872	4.63549
Σ393.5	Σ94	Σ15582.61	Σ764695.2	Σ41179041	Σ3111.94	Σ135841.7	

Table 8: Values of pH with measured distances from all sources of contamination

Distance (X)	$(pH_e)y$	X^2	X^3	X^4	XY	X^2Y	$pH_p = a_0 + a_1x + a_2x^2$
3	6.4	9	27	81	19.2	57.6	6.361927
12.6	6.2	158.76	2000.376	25204.74	78.12	984.312	6.11551
14.9	5.9	222.01	3307.949	49288.44	87.91	1309.859	6.069091
11	6.1	121	1331	14641	67.1	738.1	6.150679
30.2	5.8	912.04	27543.61	831817	175.16	5289.832	5.884436
20.5	6.3	420.25	8615.125	176610.1	129.15	2647.575	5.976463
26.4	5.6	696.96	18399.74	485753.2	147.84	3902.976	5.910153
13.6	6	184.96	2515.456	34210.2	81.6	1109.76	6.094729
13.9	6.1	193.21	2685.619	37330.1	84.79	1178.581	6.088674
48.6	6.1	2361.96	114791.3	5578855	296.46	14407.96	5.948226
13.3	6.5	176.89	2352.637	31290.07	86.45	1149.785	6.100866
60.4	6.3	3648.16	220348.9	13309071	380.52	22983.41	6.153416
50.4	6.1	2540.16	128024.1	6452413	307.44	15494.98	5.971228
61.3	5.9	3757.69	230346.4	14120234	361.67	22170.37	6.174335
13.4	5.8	179.56	2406.104	32241.79	77.72	1041.448	6.098811
Σ393.5	Σ91.1	Σ15582.61	Σ764695.2	Σ41179041	Σ2381.13	Σ94466.54	

Table 9. Values of BOD with measured distances from all sources of contamination

Distance (X)	(BOD_e) y	X^2	X^3	X^4	XY	X^2y	$BOD_p = a_0 + a_1x + a_2x^2$
3	1.3	9	27	81	3.9	11.7	1.39658
12.6	1.4	158.76	2000.376	25204.74	17.64	222.264	1.393016
14.9	1.4	222.01	3307.949	49288.44	20.86	310.814	1.394845
11	1.2	121	1331	14641	13.2	145.2	1.392356
30.2	1.6	912.04	2754.61	831817	48.32	1459.264	1.433398
20.5	1.6	420.25	8615.125	176610.1	32.8	672.4	1.403633
26.4	1.5	696.96	18399.74	485753.2	39.6	1045.44	1.41954
13.6	1.4	184.96	2515.456	34210.2	19.04	258.944	1.393684
13.9	1.3	193.21	2685.619	37330.1	18.07	251.173	1.393923
48.6	1.1	2361.96	114791.3	5578855	53.46	2598.156	1.54053
13.3	1.2	176.89	2352.637	31290.07	15.96	212.268	1.393463
60.4	1.6	3648.16	220348.9	13309071	96.64	5837.056	1.644158
50.4	1.4	2540.16	128024.1	6452413	70.56	3556.224	1.554574
61.3	2	3757.69	230346.4	14120234	122.6	7515.38	1.653182
13.4	1.8	179.56	2406.104	32241.79	24.12	323.208	1.393535
Σ393.5	Σ21.8	Σ15582.61	Σ764695.2	Σ41179041	Σ596.77	Σ24419.49	

IV. Conclusion And Recommendations

The prediction of groundwater quality in selected locations evaluated using standard analytical methods for testing physico-chemical and biological parameters was moderately high. The land-use activities in these locations which include poorly constructed pit latrines, septic tanks, landfills and open dump sites all aid in the vulnerability of the region to groundwater pollution.

Based on the result obtained from the quadratic regression in the selected locations, the following conclusion can be made. The quadratic regression model gives a goodness of fit and correlation coefficient in most of the predicted parameters. The predicted parameters give best fit curves to regretted data this is evident from the very high positive values of goodness of fit of the curve as stated in Table 3.Most of the graph of Predicted parameters increased with increase in distance from the borehole well source. As a preventive measure to reduce the health threat associated with consumption of the nitrate, Magnesium and iron contaminated water as contained in the ground water in the selected locations, There is need for proper treatment of water before consumption. Government through the various water resource management bodies should create massive public awareness programmes on the television and other mass media agencies to educate the populace of the health implications of groundwater pollution.

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