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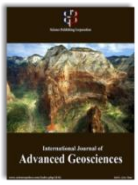

Qualitative characterization of groundwater sources around Nigeria National Petroleum Cooperation Oil Depot Aba, using multiple linear regressions modelling

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Abstract

Qualitative characterization of groundwater sources around NNPC oil depot Aba, using Multiple Linear Regression Modelling has been done to predict the concentration of pollutants (heavy metals and Benzene, Toluene, Ethlybenzene, Xylene (BTEX)) in the study area. This was achieved through water level measurements, grain size, and water sample analyses. Fifty eight (58) water samples were collected within the study area and were subjected to chemical analyses. Eight (8) input parameters for the modelling comprised of the elevation data, depth to water table data, hydraulic head data, hydraulic conductivity data, transmissivity data, aquifer thickness data, and specific yield. The heavy metals and the BTEX were the depended variables, while the input parameters were the independent variables. Multiple Linear Regression (MLR) equations were modeled using MATLAB. The investigation revealed that ionic species of some important water quality concern include Arsenic, Copper, Mercury, Lead (heavy metals); Benzene, Ethlybenzene, and Xylene (organic pollutant). Pre-use treatment becomes a priority in all domestic and industrial application of these water sources. The MLR result revealed different R^2: Arsenic (0.77), Copper (0.77), Iron (0.83), Mercury (0.80), Lead (0.61), Benzene (0.74), Toluene (0.84), Ethylbenzene (0.90) and Xylene (0.94), indicating that the predicted values closely tracked the actual values. A total of nine (9) MLR model equations were developed for the prediction of the concentration of pollutants in the study area. the study therefore recommends that it is fundamentally important that standard environmental management and appropriate environmental regulations should be established and enforced within the vicinity of the depot.

Keywords: *NNPC; Qualitative Characterization; Multiple Linear Regression; Modelling; MATLAB.*

1. Introduction

Water quality is of vital concern to mankind, since it is directly linked with human welfare (Balkrishnan et al., 2011). It is regrettable that rapid urbanization, improper waste disposal and landfill, excessive application of fertilizers and unsanitary conditions have threatened groundwater quality. Consequently, human health in many parts around the world has been endangered by naturally-occurring pollutants and anthropogenic pollutants (Akporido, 2008). Mitra and Roy (2011) noted that pollution of groundwater by heavy metals (including; zinc, copper, chromium, nickel, cadmium, lead and mercury) could come from several sources, such as industrial discharges from chemical and metallurgic factories, or leakage from landfills.

A group of organic pollutants comprising benzene, toluene, ethyl benzene, and xylene (BTEX) contains volatile organic compounds (VOCs) which can contaminate or pollute soils through spills involving the release of petroleum products such as gasoline, diesel fuel, lubricating oil and heating oil from leaking oil tanks (Salanitro et al., 1997; Nwankwoala, 2014). BTEX have in recent years, attracted much attention, since they constitute one of the most common major threats to groundwater reservoirs and indoor climate-deriving from contaminated sites (Uzoekwe and Oghosanine, 2011). This is mainly due to the potential effects of benzene, which is considered a strong carcinogen and is highly mobile in the soil and groundwater environments. Activities involving the use of petrol, heating fuel, and kerosene containing significant percentages of BTEX can produce pollutants and contaminants. BTEX are prime pollutants/contaminants that have attracted wide attention because of their high-water solubility and toxicity. BTEX can cause cancers, mucosal pain, blood diseases, damage to the central nervous and respiratory systems, and liver and kidney functional impairment (Li and Zhou, 2011; Nourmoradi et al., 2012). Six benzene series, including BTEX were placed on the top blacklist of pollutants for priority control in China (Cheng, 2016).

A systematic study of Multiple Linear Regression coefficients of the water-quality parameters help to quantify relative concentration of various pollutants in water and provide the necessary cues for the implementation of rapid water quality management programmes (Jothivenkatachalam, et al., 2010). A few numbers of studies are available regarding the analysis of groundwater quality data using regression techniques in different parts of India and Bangladesh (Kumar and Sinha, 2010).

1.1. Location of the study area

The study area comprises parts of Osisioma Ngwa, Isiala Ngwa, Obio Ngwa, Aba North, Omumma LGAs (all in Abia State), Etche LGA (in Rivers State) and Ngor Okpala LGA (in Imo State). It lies between latitudes 5^o07^1 to 5^o15^1N, and longitudes 7^o14^1 to 7^o22^1E (Fig 1) covering an area of about $169km^2$. It is densely populated, with an average population density of five thousand, five hundred (5,500) inhabitants (Adindu et al., 2012). The area became a collecting point for agricultural products following the British made railway running through it to Port Harcourt. The area is a major settlement and commercial centre in a region that is surrounded by small villages and towns. The indigenous people of the area are well known for its craftsmen (Akakuru et al., 2017).

1.2. Geology

Three major formations comprise the modern Niger Delta overlain by various types of Quaternary deposits. These are the Akata Formations, which is predominantly shale and clay; the Agbada Formation which is generally fluviatile and fluviomarine, and the Benin Formation, constituting a continental deposit of sand and gravel (Nwankwoala, 2014). The depositional pattern which accompanied the accumulation of sediments during the formation of the delta, gave rise to structural traps (growth faults and roll-over anticlines) in the Agbada Formation.

The extremely sandy nature of the upper Benin Formation and the abundant growth faults in the underlying Akata Formation have permitted meteoric water to penetrate very deep into the subsurface. The controlling effect of geology on groundwater occurrence in the Niger Delta is no longer in doubt. The sedimentation pattern as well as stratification determines both the quality and quantity of water to the region. Its investigation is the first step towards a meaningful groundwater study of the region.
The study area is underlain by the Benin Formation (the Coastal Plain-Sands). The major rock types include sands, sandstone, and gravel with clay occurring as lenses. The sand and sandstone are coarse to fine grained partly unconsolidated, with thickness ranging from 0-2100m (Akakuru and Akudinobi, 2018). The sediments represent upper Deltaic Plain Deposits. The shales are few, and they may represent Deltaic Plain Deposits. Nwankwoala (2014) observed that the Benin Formation was composed mainly of high resistant fresh water bearing continental sands and gravels, with clay and shale intercalations.

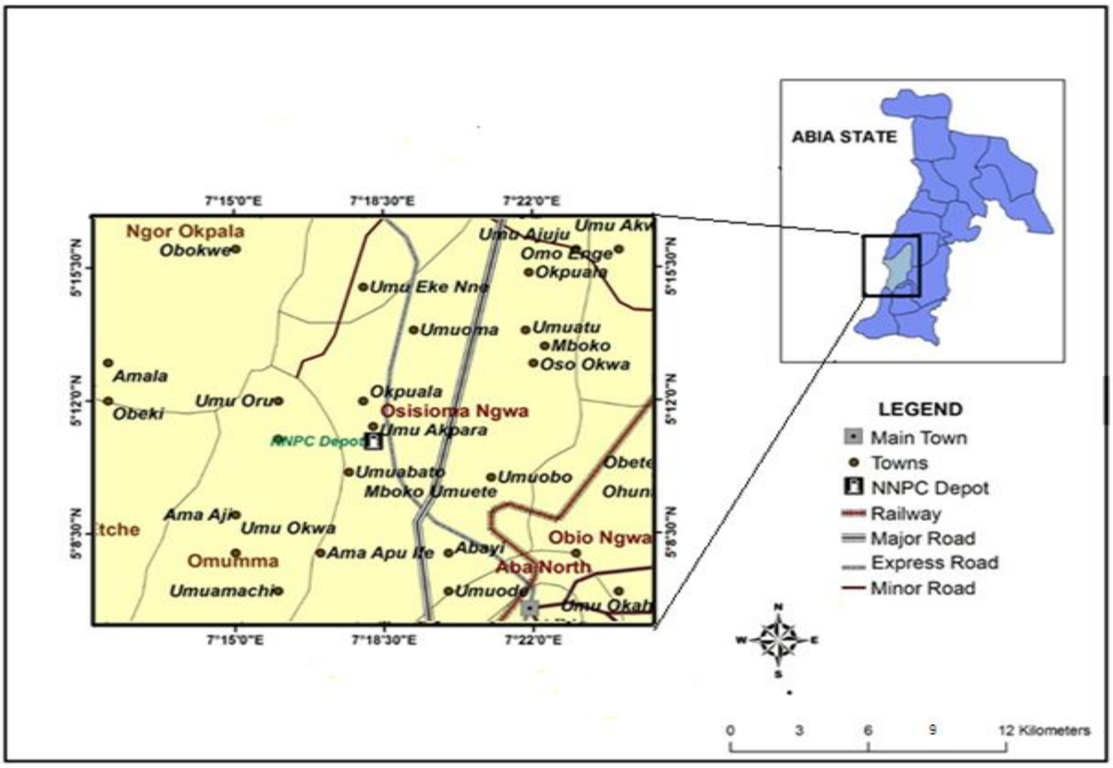

Fig. 1: Location Map of the Study Area.

2. Methodology

Water sample collections were done in line with the guidelines of American Public Health Association (1995). To reduce the risk of sample contamination, all water samples were collected in fresh sample containers (polyethylene plastic cans), which were acid – washed to reduce the effect of interferences between containers and sample. This was done by washing each container with a detergent and rinsing with tap water; re-rinsing with 1:1 nitric acid solution; rinsing with deionized water and air-dried. Before collection, each container was rinsed with the sample to be collected. Samples were labeled and transported to the laboratory in an ice-pack cooler kit; samples collected were analyzed within 24 hours of collection. Fifty eight (58) groundwater samples within the study area were collected. Water samples collected were subjected to chemical and Gas Chromatography (GC) analyses. Heavy metals analysed included: Arsenic, Copper, Iron, Mercury, and Lead. Organic pollutants analysed were: Benzene, Ethylbenzene, Toluene and Xylene (BTEX).
Hydraulic head values were obtained through the measurements of two parameters namely: water levels in wells and surface elevation above mean sea level at each well site. Elevation measurements were done using a portable Global Positioning System (GPS) device (model GARMIN GPS 76 CSX). Fifty eight (58) hydraulic head measurements were collected. In measuring the water level, plopper was used. It involved the use of a concave metal attached to the graduated tape, plopping noise is heard when it hits the groundwater surface. Measurements in the wells were carried out during the early hours during the day to avoid the acceleration of drawdown in wells which generally, begin at about 8am (Walton, 1970). Fifty eight (58) water level measurements were made. The soil samples were collected from different locations. Soil samples for grain size analysis were collected and the depth at which they were retrieved recorded. The fine soil particles were drained off leaving the coarser particles which were dried and subjected to mechanical sieving. Electric sieve shaker (Endecotts EFL 2000/1) was used for all sieve tests.

2.1. Multiple linear regressions (MLR)

The MLR analysis is a statistical approach for modelling the linear relationship between two or more variables. Multiple linear regression involves a variable to be explained (the dependent variable) and additional explanatory variables (the independent variables) that are thought to produce or be associated with changes in the dependent variable. The Modelling of each pollutant was carried out using MATLAB 7.9. An analysis of residuals was developed, and R^2 values were studied. Among all candidate equations, the equation where the R^2 was closer to 1 was selected (R^2>0.5). The prediction equation for all the pollutants is presented in equation 1.

Arsenic, $(Y_1) = K + x_1k_1 + x_2k_2 + x_3k_3 + x_4k_4 + x_5k_5 + x_6k_6 + x_7k_7 + x_8k_8$

Copper, $(Y_2) = K + x_9k_1 + x_{10}k_2 + x_{11}k_3 + x_{12}k_4 + x_{13}k_5 + x_{14}k_6 + x_{15}k_7 + x_{16}k_8$

Iron $(Y_3) = K + x_{17}k_1 + x_{18}k_2 + x_{19}k_3 + x_{20}k_4 + x_{21}k_5 + x_{22}k_6 + x_{23}k_7 + x_{24}k_8$

Mercury $(Y_4) = K + x_{25}k_1 + x_{26}k_2 + x_{27}k_3 + x_{28}k_4 + x_{29}k_5 + x_{30}k_6 + x_{31}k_7 + x_{32}k_8$

Lead $(Y_5) = K + x_{33}k_1 + x_{34}k_2 + x_{35}k_3 + x_{36}k_4 + x_{37}k_5 + x_{38}k_6 + x_{39}k_7 + x_{40}k_8$ (1)

Benzene $(Y_6) = K + x_{41}k_1 + x_{42}k_2 + x_{43}k_3 + x_{44}k_4 + x_{45}k_5 + x_{46}k_6 + x_{47}k_7 + x_{48}k_8$

Toluene $(Y_7) = K + x_{49}k_1 + x_{50}k_2 + x_{51}k_3 + x_{52}k_4 + x_{53}k_5 + x_{54}k_6 + x_{55}k_7 + x_{56}k_8$

Ethylbenzene $(Y_8) = K + x_{57}k_1 + x_{58}k_2 + x_{59}k_3 + x_{60}k_4 + x_{61}k_5 + x_{62}k_6 + x_{63}k_7 + x_{64}k_8$

Xylene $(Y_9) = K + x_{65}k_1 + x_{66}k_2 + x_{67}k_3 + x_{68}k_4 + x_{69}k_5 + x_{70}k_6 + x_{71}k_7 + x_{72}k_8$

Where : $x_1, x_9, x_{17}, x_{25}, x_{33}, x_{41}, x_{49}, x_{57}$, and x_{65} are Elevation data having a regression coefficient of k_1.

$x_2, x_{10}, x_{18}, x_{26}, x_{34}, x_{42}, x_{50}, x_{58}$, and x_{66} are Depth to water table data having a regression coefficient of k_2.

$x_3, x_{11}, x_{19}, x_{27}, x_{35}, x_{43}, x_{51}, x_{59}$, and x_{67} are Hydraulic Head data having a regression coefficient of k_3.

$x_4, x_{12}, x_{20}, x_{28}, x_{36}, x_{44}, x_{52}, x_{60}$, and x_{68} are Hydraulic Conductivity data having a regression coefficient of k_4.

$x_5, x_{13}, x_{21}, x_{29}, x_{37}, x_{45}, x_{53}, x_{61}$, and x_{69} are Transmissivity data having a regression coefficient of k_5.

$x_6, x_{14}, x_{22}, x_{30}, x_{38}, x_{46}, x_{54}, x_{62}$, and x_{70} are Aquifer thickness data having a regression coefficient of k_6.

$x_7, x_{15}, x_{23}, x_{31}, x_{39}, x_{47}, x_{55}, x_{63}$, and x_{71} are Specific Yield data having a regression coefficient of k_7.

$x_8, x_{16}, x_{24}, x_{32}, x_{40}, x_{48}, x_{56}, x_{64}$, and x_{72} are Distance data having a regression coefficient of k_8.

k_1- k_8= Regression Coefficient of the input parameters (elevation, depth to water table, hydraulic head, hydraulic conductivity, transmissivity, aquifer thickness, specific yield, and distance).

K = Constant (it adjusts the input parameters inputted and accounts for the input parameters that were not accounted for that also affect the pollutant of interest).

$(Y_1 - Y_9)$ = Pollutant

The multi-linear regression equation in equation 1 was further deduced into matrix notation (equ. 2).

$$\begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \\ Y_4 \\ Y_5 \\ Y_6 \\ Y_7 \\ Y_8 \\ Y_9 \end{bmatrix} = \begin{bmatrix} 1 & x_1 & x_2 & x_3 & x_4 & x_5 & x_6 & x_7 & x_8 \\ 1 & x_9 & x_{10} & x_{11} & x_{12} & x_{13} & x_{14} & x_{15} & x_{16} \\ 1 & x_{17} & x_{18} & x_{19} & x_{20} & x_{21} & x_{22} & x_{23} & x_{24} \\ 1 & x_{25} & x_{26} & x_{27} & x_{28} & x_{29} & x_{30} & x_{31} & x_{32} \\ 1 & x_{33} & x_{34} & x_{35} & x_{36} & x_{37} & x_{38} & x_{39} & x_{40} \\ 1 & x_{41} & x_{42} & x_{43} & x_{44} & x_{45} & x_{46} & x_{47} & x_{48} \\ 1 & x_{49} & x_{50} & x_{51} & x_{52} & x_{53} & x_{54} & x_{55} & x_{56} \\ 1 & x_{57} & x_{58} & x_{59} & x_{60} & x_{61} & x_{62} & x_{63} & x_{64} \\ 1 & x_{65} & x_{66} & x_{67} & x_{68} & x_{69} & x_{70} & x_{71} & x_{72} \end{bmatrix} \begin{bmatrix} K \\ K_1 \\ K_2 \\ K_3 \\ K_4 \\ K_5 \\ K_6 \\ K_7 \\ K_8 \end{bmatrix} \quad (2)$$

The expected values of the regression coefficients was calculated by inverting the system using the stepwise regression algorithm in MATLAB with the aim of predicting the impact of the aquifer systems and/or input parameters on the quality of groundwater in the study area.

3. Results and discussions

The result of some key aquifer parameters (input parameter for the modelling) is presented in Table 1 while the summary of the chemical analyses of the heavy metals and BTEX is presented in Table 2.

Table 1: Aquifer parameters in the study area

s/n	Longitude (E)	Latitude (N)	Distance from the loading bay(Km)	Elevation	Depth to water table(m)	Hydraulic head (m)	Aquifer Thickness (b) (m)	Hydraulic Conductivity (m/s)	Transmissivity m^2/s	Specific Yield (%)
1	7.30514	5.181946	0	69.7	20	49.7	92.1		1.53807	27.63
2	7.305482	5.190969	1.03297	91.4	38.7	52.7	65.3		1.09051	19.59
3	7.29606	5.190798	1.425531	65.2	29.4	35.8	35.6		0.59452	10.68
4	7.295831	5.182974	1.056046	66.7	10.6	56.1	111.3		1.85871	33.39
5	7.296973	5.173837	1.277124	104.7	33.6	71.1	47.3	0.0167	0.78991	14.19
6	7.304968	5.174693	0.790377	93	13.3	79.7	27.7		0.46259	8.31
7	7.312792	5.172638	1.301945	64.55	11.8	52.75	35.2		0.58784	10.56
8	7.315133	5.181546	1.095759	66.45	17.1	49.35	113.6		1.89712	34.08
9	7.317132	5.190512	1.517095	88.3	21.1	67.2	57.1		0.95357	17.13
10	7.318674	5.198336	2.335573	62.05	32.4	29.65	45.7		0.78147	13.71
11	7.306396	5.196965	1.681641	101.45	49.2	52.25	80.8		1.38168	24.24
12	7.294061	5.196623	2.054323	78.9	26.4	52.5	125.6		2.14776	37.68
13	7.286523	5.194453	2.505798	73.9	26.8	47.1	24.5		0.41895	7.35
14	7.286808	5.18286	2.053781	61.7	43.3	18.4	25.4		0.43434	7.62
15	7.285152	5.166299	2.808501	62.8	17.9	44.9	15.6		0.26676	4.68
16	7.297373	5.163957	2.16175	70.5	26.8	43.7	24.5	0.0171	0.41895	7.35
17	7.314105	5.164072	2.198747	69.7	13.3	56.4	27.7		0.47367	8.31
18	7.323014	5.169154	2.395318	88.3	26.8	61.5	60.3		1.03113	18.09
19	7.323071	5.182117	1.965622	62.05	22.4	39.65	69.6		1.19016	20.88
20	7.331466	5.206731	4.006718	60.45	17.1	43.35	110.6		1.30508	33.18
21	7.314277	5.2105	3.334002	78.9	21.1	57.8	53.1		0.62658	15.93
22	7.295032	5.208901	3.19468	73.9	32.4	41.5	46.7		0.55106	14.01
23	7.2775	5.211699	4.5297	94.55	49.2	45.35	81.8	0.0118	0.96524	24.54

24	7.276472	5.197479	3.651236	71.7	26.4	45.3	131.6		1.55288	39.48
25	7.275427	5.177925	3.350509	66.45	26.8	39.65	24.5		0.2891	7.35
26	7.276141	5.151727	4.644343	93	10.6	82.4	111.4		1.31452	33.42
27	7.312476	5.152298	3.372008	64.55	33.6	30.95	49		0.5782	14.7
28	7.333962	5.151727	4.584304	71.7	13.3	58.4	23.7		0.27966	7.11
29	7.335961	5.168217	3.711615	75.06	11.8	63.26	35.2		0.41536	10.56
30	7.335889	5.183207	3.38729	143.8	60.9	82.9	38.1		0.44958	11.43
31	7.343884	5.209262	6.207626	131	91.4	39.6	92		1.6652	27.6
32	7.324682	5.222326	8.100968	126	43.3	82.7	25.4		0.45974	7.62
33	7.298913	5.220684	6.426804	95	17.9	77.1	15.6		0.28236	4.68
34	7.266219	5.222611	6.269738	66.3	26.8	39.5	24.5		0.44345	7.35
35	7.265362	5.174998	4.51016	68.1	13.3	54.8	27.7		0.50137	8.31
36	7.266219	5.146944	5.781024	90.2	26.8	63.4	63.2	0.0181	1.14392	18.96
37	7.303553	5.143732	4.240393	104.5	64.9	39.6	32.1		0.58101	9.63
38	7.327038	5.141733	5.050871	75.5	15.7	59.8	25.4		0.45974	7.62
39	7.346169	5.148229	5.840867	80.2	63.9	16.3	38.1		0.68961	11.43
40	7.345383	5.176783	4.465447	75.6	43.8	31.8	35.2		0.63712	10.56
41	7.357019	5.203409	6.207626	62.05	60.9	1.15	38.1		0.47625	11.43
42	7.355734	5.234746	8.100968	131.45	91.4	40.05	122.5		1.53125	36.75
43	7.327466	5.235389	6.426804	78.9	52.6	26.3	71.5		0.89375	21.45
44	7.271715	5.237102	7.156286	73.9	43.3	30.6	25.4		0.3175	7.62
45	7.250871	5.216115	7.136527	61.7	38.7	23	65.3		0.81625	19.59
46	7.251371	5.176854	6.008496	122.05	29.4	92.65	35.6	0.0125	0.445	10.68
47	7.253798	5.16015	6.178389	136.85	10.6	126.25	105.4		1.3175	31.62
48	7.281638	5.135594	5.751949	69.7	33.6	36.1	49.6		0.62	14.88
49	7.304766	5.133238	5.381237	88.3	13.3	75	27.7		0.34625	8.31
50	7.371653	5.198697	5.381237	62.05	11.8	50.25	35.2		0.60192	10.56
51	7.369368	5.234461	9.182768	126.4	60.9	65.5	38.1		0.65151	11.43
52	7.26165	5.243669	8.376849	128.8	91.4	37.4	120.6		2.06226	36.18
53	7.241377	5.227893	8.742946	93.9	26.8	67.1	24.5		0.41895	7.35
54	7.242448	5.1725	7.046227	64.55	43.3	21.25	25.4		0.43434	7.62
55	7.295486	5.119319	6.986859	71.7	17.9	53.8	25.9	0.0171	0.44289	7.77
56	7.340886	5.12096	7.820493	66.45	5.3	61.15	25.4		0.43434	7.62
57	7.369654	5.141233	8.429232	81.4	26.8	54.6	24.5		0.41895	7.35
58	7.369226	5.17457	7.121973	94.2	43.3	50.9	25.4		0.43434	7.62

Table 2: Summary of Chemical Analyses

s/n	Parameter	Range	Average	Standard deviation
1	Arsenic	0-1.35	0.149	0.344
2	Copper	0 - 0. 95	0.032	0.026
3	Iron	0-0.09	0.025	0.029
4	Mercury	0-0.014	0.000	0.00
5	Lead	0-0.4	0.058	0.129
6	Benzene	0-0.5	0.057	0.084
7	Toluene	0-0.66	0.223	0.27
8	Ethlybenzene	0-1.3	0.11	0.230
9	Xylene	0-0.32	0.091	0.246

Table 3: Summary of the MLR Predicting Pollutants

K-values	Arsenic (Y_1)	Copper (Y_2)	Iron (Y_3)	Mercury (Y_4)	Lead (Y_5)	Benzene (Y_6)	Toluene (Y_7)	Ethylbenzene (Y_8)	Xylene (Y_9)
K	3.5925	0.0235	0.0201	0.0159	0.1024	0.3227	-0.9475	1.5693	-0.0835
k_1	-0.6335	0.0028	-0.0061	-0.0093	-0.0141	-0.0789	0.0809	-0.8635	0.0029
k_2	-0.0312	0.0000	-0.0004	-0.0001	0.0003	-0.0021	0.0065	-0.0080	0.0004
k_3	0.0410	0	0	0.0001	-0.0014	0.0030	0.0000	0.0164	-0.0010
k_4	0	0.0006	0.0008	0	0	0	0	0	0
k_5	-0.0111	-0.0005	0.0004	0.0000	0.0007	-0.0007	0.0005	-0.0008	0.0027
k_6	0	0	0	0	0	0	0	0	0
k_7	0	0	0	0	0	0	0	0	0
k_8	0	0	0	0	0	0	0	0	0
R-square	0.7788	0.7715	0.8331	0.8081	0.6058	0.7448	0.8494	0.9001	0.9457

The MLR analysis was conducted to investigate the relationships between the pollutants (Y_1-Y_9) and other input parameters (K_1-K_8) as described in equation 1. Analyses of residuals were developed and R^2 values were studied. Among all candidate equations, the equation where the R^2 was closer to 1 was selected ($R^2 > 0.5$). The descriptors and the regression coefficient of this model are presented in Table 3.

Arsenic

The multi-linear regression equation for Arsenic in the study area is given by:

$$Y_1 = 3.5925 - 0.6335x_1 - 0.0312x_2 + 0.0410x_3 - 0.0111x_5 \quad (3)$$

Copper

The multi-linear regression equation for Copper in the study area is given by:

$$Y_2 = 0.0235 + 0.0028x_1 + 0.0006x_4 - 0.0005x_5 \quad (4)$$

Iron

The multi-linear regression equation for Iron in the study area is given by:

$$Y_3 = 0.0201 - 0.0061x_1 - 0.0004x_2 + 0.0008x_4 + 0.0004x_5 \quad (5)$$

Mercury

The multi-linear regression equation for Mercury in the study area with is given by:

$$Y_4 = 0.0159 - 0.0093x_1 - 0.0001x_2 + 0.0001x_3 \quad (6)$$

Lead

The multi-linear regression equation for Lead in the study area is given by:

$$Y_5 = 0.1024 - 0.0141x_1 + 0.0003x_2 - 0.0014x_3 + 0.0007x_5 \quad (7)$$

Benzene

The multi-linear regression equation for Benzene in the study area is given by:

$$Y_6 = 0.3227 - 0.0789x_1 - 0.0021x_2 + 0.0030x_3 - 0.0007x_5 \quad (8)$$

Toluene

The multi-linear regression equation for Toluene in the study area is given by:

$$Y_7 = -0.9475 + 0.0809x_1 + 0.0065x_2 + 0.0005x_5 \quad (9)$$

Ethlybenzene

The multi-linear regression equation for Ethlybenzene in the study area is given by:

$$Y_8 = 1.5693 - 0.8635x_1 - 0.0080x_2 + 0.0164x_3 - 0.0008x_5 \quad (10)$$

Xylene

The multi-linear regression equation for Xylene in the study area is given by:

$$Y_9 = -0.0835 + 0.0029x_1 + 0.0004x_2 - 0.0010x_3 + 0.0027x_5 \quad (11)$$

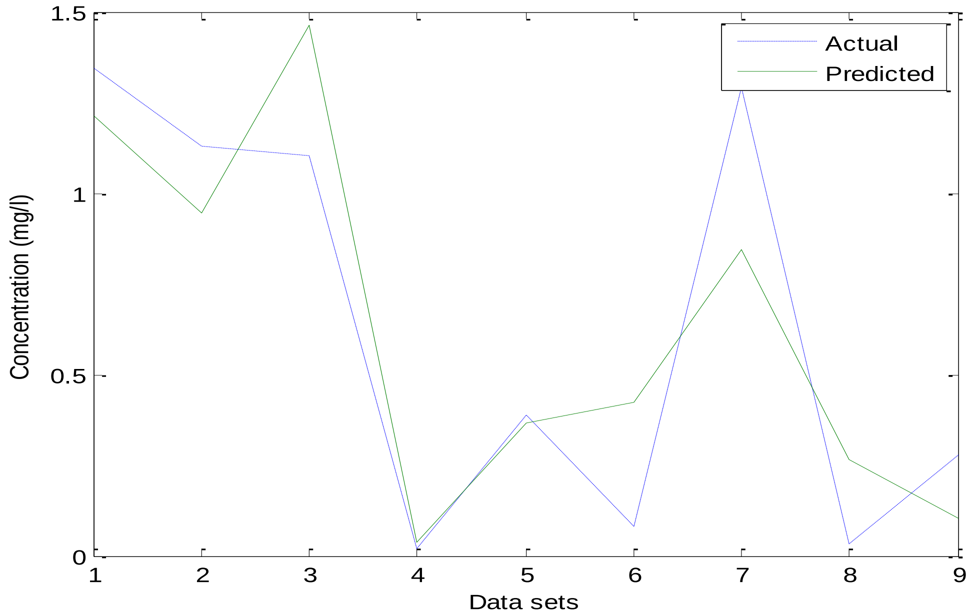

Fig. 2: Arsenic value showing a very close relationship between the actual vs predicted values (R^2=77%).

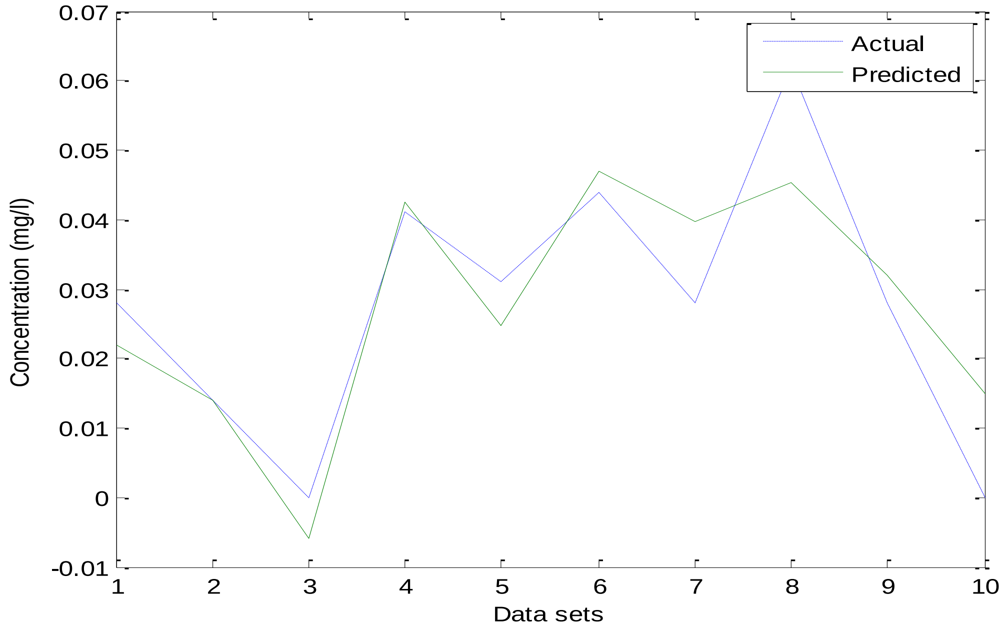

Fig. 3: Copper value showing a very close relationship between the actual vs predicted values (R^2=77%).

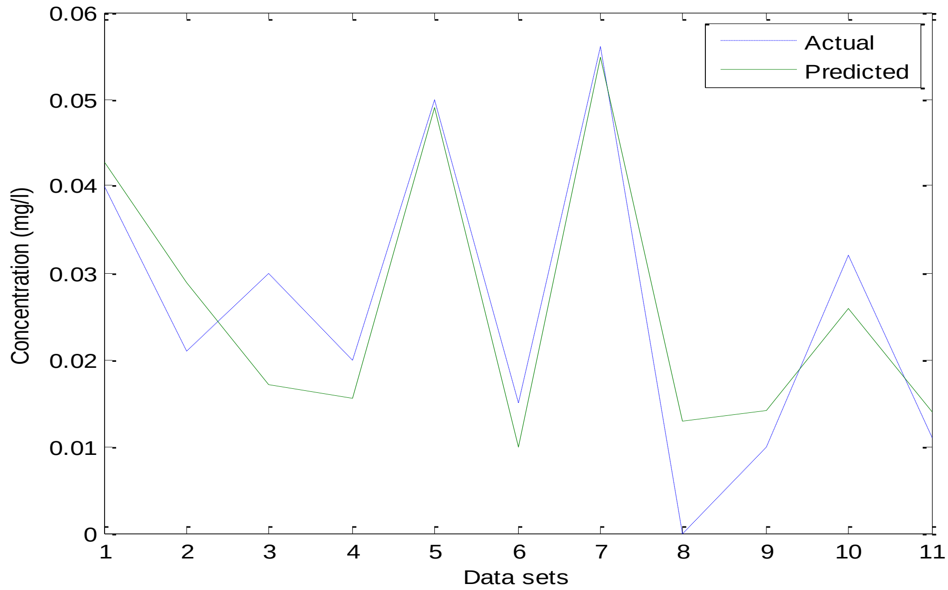

Fig. 4: Iron value showing a very close relationship between the actual vs predicted values (R^2=83%).

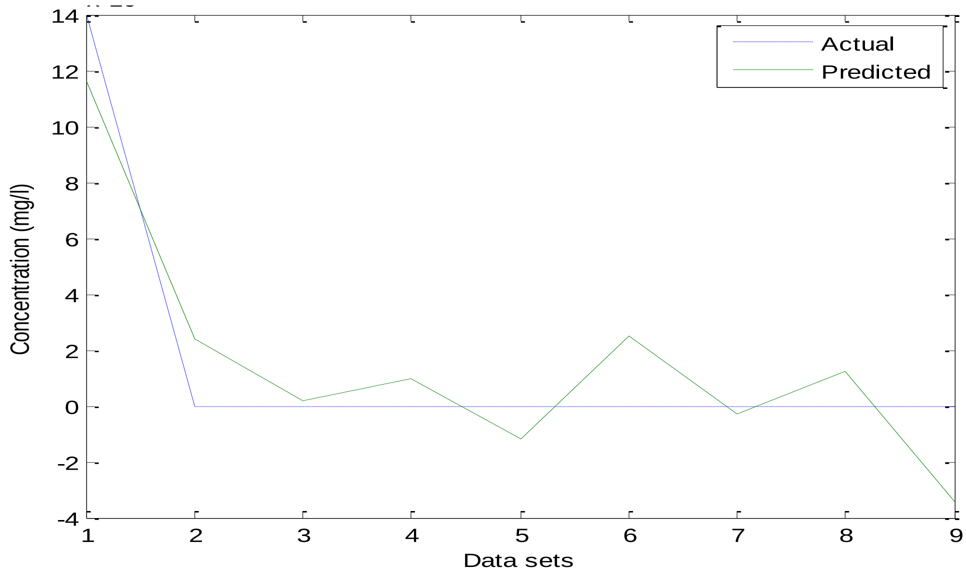

Fig. 5: Mercury value showing a very close relationship between the actual vs predicted values (R^2=80%).

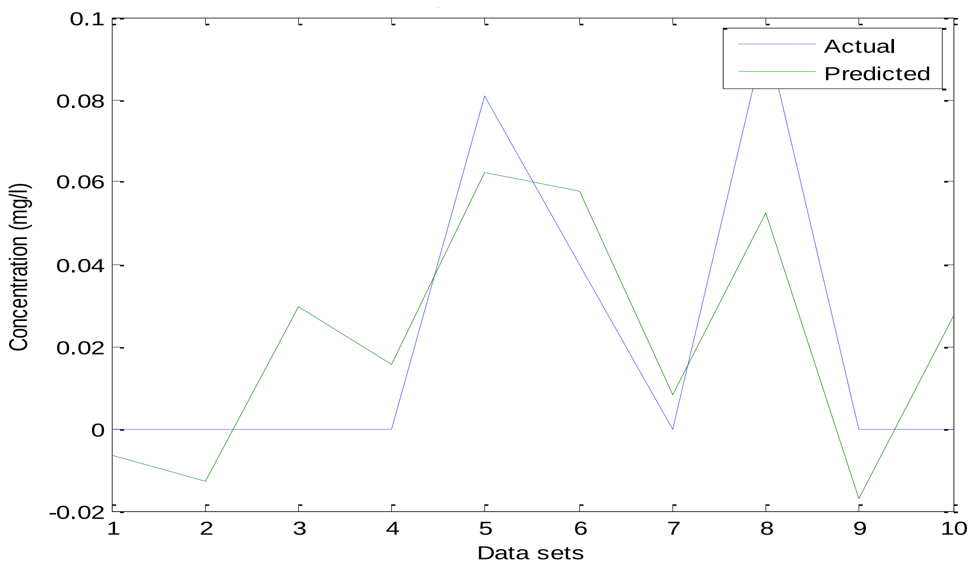

Fig. 6: Lead value showing the relationship between the actual vs predicted values (R^2=60%).

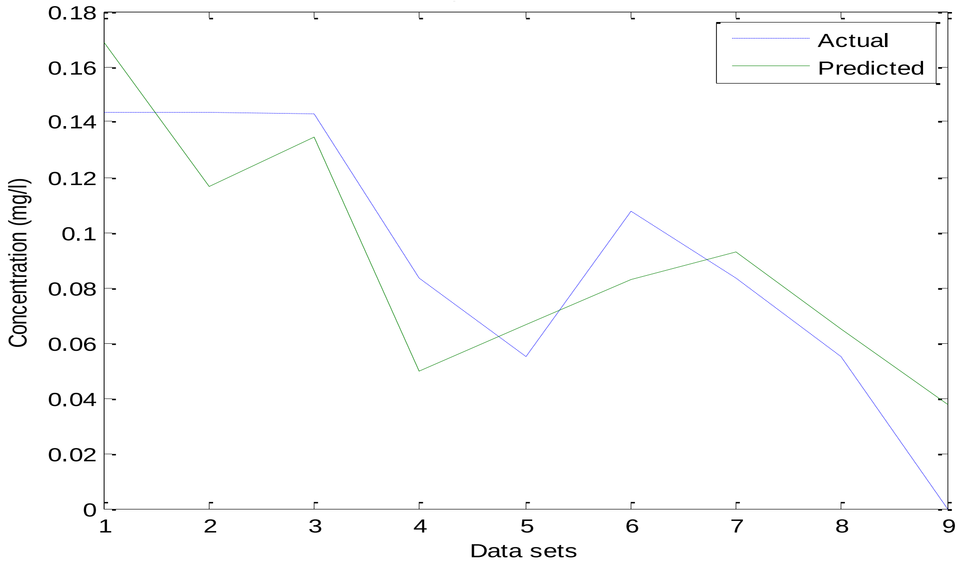

Fig. 7: Benzene value showing a very close relationship between the actual vs predicted values (R^2=74%).

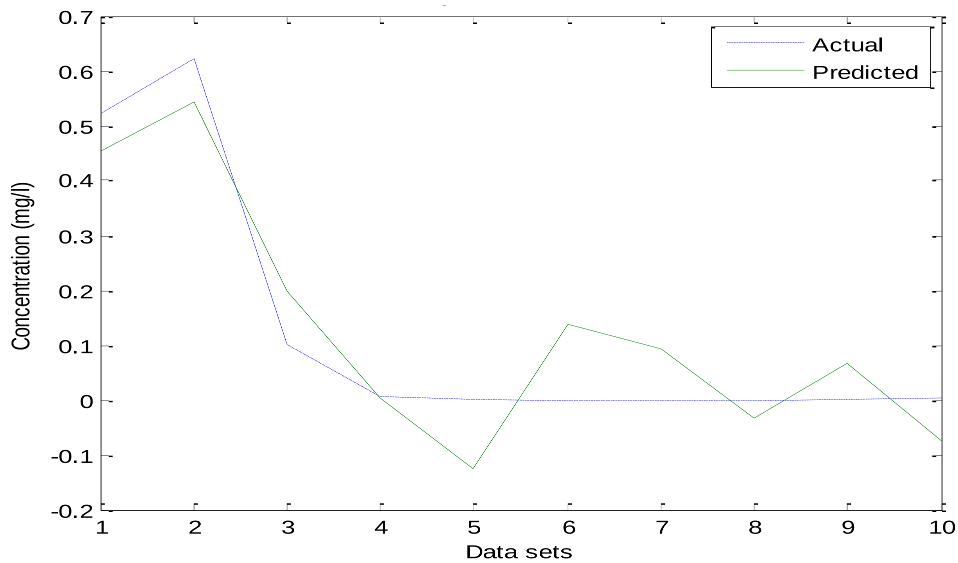

Fig. 8: Toluene Value showing a very close relationship between the actual vs predicted values (R^2=84%).

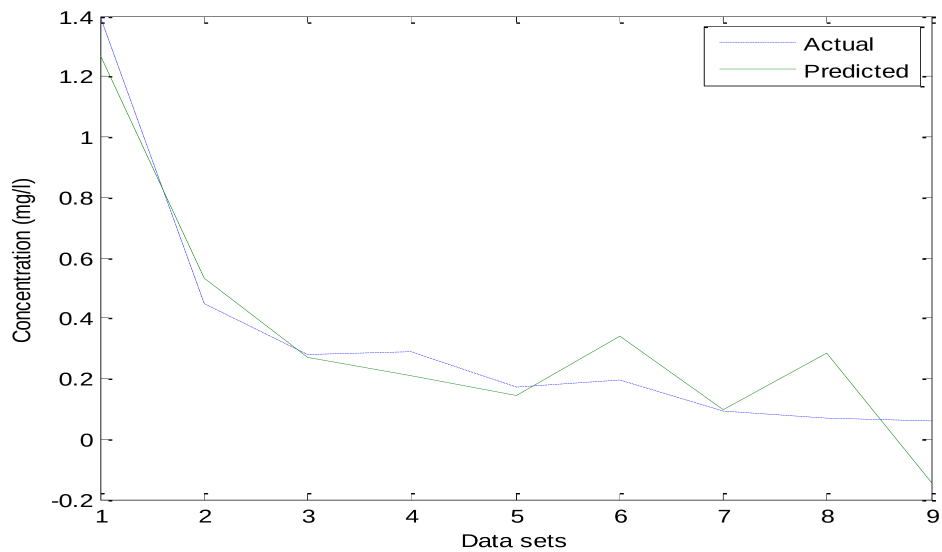

Fig. 9: Ethlybenzene value showing a very close relationship between the actual vs predicted values (R^2=90%).

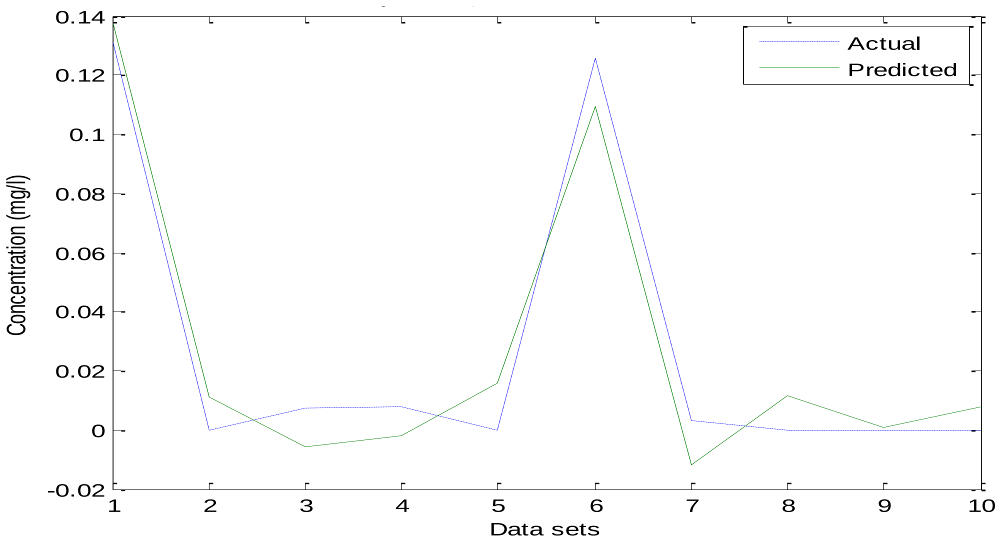

Fig. 10: Xylene value showing a very close relationship between the actual vs predicted values (R^2=94%).

4. Conclusion

Qualitative characterization of groundwater sources around NNPC oil depot Aba, using multiple linear regression modelling has been done to predict the concentration of pollutants in the study area. The results of the investigation revealed that ionic species of some important water quality concern include Arsenic, Copper, Mercury, Lead (heavy metals); Benzene, Ethlybenzene, and Xylene (organic pollutant). Pre-use treatment becomes a priority in all domestic and industrial application of these water sources.

The result from the MLR reveals that the predicted values closely tracked the actual values as the show in the positive and strong R^2 values, this implies that the MLR model equation is considered a useful tool in the prediction of pollutants concentration for the area. A total of nine (9) MLR model equations were developed for the prediction of the concentration of pollutants in the study area. The activities in NNPC depot and other oil-based projects should be of environmental concern, as adverse effects arising from the heavy metals and BTEX cannot be over-emphasized. Hence, it is fundamentally important that standard environmental management and appropriate environmental regulations should be established and enforced within the vicinity of the depot.

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