Qualitative Characterization of Groundwater Sources around Nigeria National Petroleum Cooperation Oil Depot Aba, Using Multiple Linear Regressions Modelling

**Akakuru, O.C\* and Akudinobi, B.E.B**

Department of Geological Sciences, Nnamdi Azikiwe University, Awka, Nigeria.

**\***Tel: +2348037969881 Email: [obyzmagma@yahoo.com](mailto:obyzmagma@yahoo.com)

**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, Toluen, Ethylbenzene, 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 result revealed different R2: Arsenic (0.78), Copper (0.77), Iron (0.83), Mercury (0.81), Lead (0.61), Benzene (0.74), Toluene (0.85), Ethylbenzene (0.90) and Xylene (0.95), which is an indication 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.*

***Keywords****:* NNPC, Qualitative Characterization, Multiple Linear Regression, Modelling, *MATLAB*

**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 of the world has been endangered by naturally occurring pollutants and anthropogenic pollutants (Akporido, 2008). [Mitra](http://ascidatabase.com/author.php?author=Srijata&last=Mitra) and [Roy](http://ascidatabase.com/author.php?author=Pranab&last=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, ethylbenzene, 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 helps to quantify relative concentration of various pollutants in water and provide necessary cue for the implementation of rapid water quality management programmes (Jothivenkatachalam, *et al.,* 2010). A few number 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**

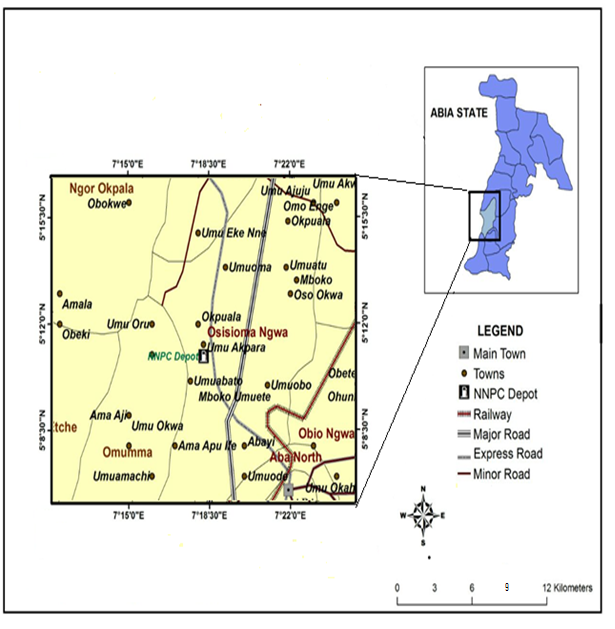
The study area comprises parts of Osisioma Ngwa, Isiala Ngwa, Obio Ngwa, Aba North, Omumma LGAs (all in Abia State), Etche LGA (in Rivers State) and Ngor Okpala LGA (in Imo State). It lies between latitudes 5o071 to 5o151N, and longitudes 7o141 to 7o221E (Fig 1) covering an area of about 169km2. It is 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](https://en.wikipedia.org/wiki/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.

**1.2 Geology**

Three major formations comprise the modern Niger Delta overlain by various types of Quaternary deposits. These are the Akata Formation, 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 in the region (Table 2.1). Its investigation is the first step towards a meaningful groundwater study of the region (Nwankwoala, 2014).

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. The sediments represent upper Deltaic Plain Deposits. The shales are few and they may represent Deltaic Plain Deposits. Onyeagocha (1980) in Nwankwoala (2014) observed that the Benin Formation is 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

**2.0 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 labelled and transported to the laboratory in 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 of 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 R2 values were studied. Among all candidate equations, the equation where the R2 was closer to 1 was selected (R2>0.5). The prediction equation for all the pollutants is presented in equation 1.

Arsenic, () =+ + + +

Copper, ()=+ + +

Iron()=+ + +

Mercury() =+ + +

Lead()=+ + + (1)

Benzene ()=+ + + +

Toluene()=+ + +

Ethylbenzene()=+ + +

Xylene() =+ + +

**Where** are Elevation data having a regression coefficient of

are Depth to water table data having a regression coefficient of

are Hydraulic Head data having a regression coefficient of

are Hydraulic Conductivity data having a regression coefficient of

are Transmissivity data having a regression coefficient of

are Aquifer thickness data having a regression coefficient of

are Specific Yield data having a regression coefficient of

are Distance data having a regression coefficient of

- = 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).

() = Pollutant

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

= (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.

1. **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**  **m2/s** | **Specific Yield**  **(%)** |
| 1 | 7.30514 | 5.181946 | 0 | 69.7 | 20 | 49.7 | 92.1 | 0.0167 | 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 | 0.78991 | 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 | 0.0171 | 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 | 0.41895 | 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 | 0.0118 | 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 | 0.96524 | 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 | 0.0181 | 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 | 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 | 0.0125 | 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 | 0.445 | 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 | 0.0171 | 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 | 0.44289 | 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 | 0.149086 | 0.344994 |
| 2 | Copper | 0 - 0. 95 | 0.032397 | 0.026117 |
| 3 | Iron | 0-0.09 | 0.025793 | 0.029739 |
| 4 | Mercury | 0-0.014 | 0.000776 | 0.00289 |
| 5 | Lead | 0-0.4 | 0.058224 | 0.129489 |
| 6 | Benzene | 0-0.5 | 0.057414 | 0.084662 |
| 7 | Toluene | 0-0.66 | 0.223207 | 0.27031 |
| 8 | Ethlybenzene | 0-1.3 | 0.11476 | 0.230942 |
| 9 | Xylene | 0-0.32 | 0.091555 | 0.246766 |

The MLR analysis was conducted to investigate the relationships between the pollutants (Y1-Y9) and other input parameters (K1-K8) as described in equation 1. An analysis of residuals was developed and R2 values were studied. Among all candidate equations, the equation where the R2 was closer to 1 was selected (R2 > 0.5). The descriptors and the regression coefficient of this model are presented in Table 3

Table 3**:** Summary of the MLR predicting pollutants

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| K-values | Arsenic  (Y1) | Copper  (Y2 ) | Iron  (Y3 ) | Mercury  (Y4 ) | Lead  (Y5 ) | Benzene  (Y6 ) | Toluene  (Y7 ) | Ethylbenzene (Y8 ) | Xylene  (Y9 ) |
| K  k1  k2  k3  k4  k5  k6  k7  k8  R-square | 3.5925  -0.6335  -0.0312  0.0410  0  -0.0111  0  0  0  0.7788 | 0.0235  0.0028  0.0000  0  0.0006  -0.0005  0  0  0  0.7715 | 0.0201  -0.0061  -0.0004  0  0.0008  0.0004  0  0  0  0.8331 | 0.0159  -0.0093  -0.0001  0.0001  0  0.0000  0  0  0  0.8081 | 0.1024  -0.0141  0.0003  -0.0014  0  0.0007  0  0  0  0.6058 | 0.3227  -0.0789  -0.0021  0.0030  0  -0.0007  0  0  0  0.7448 | -0.9475  0.0809  0.0065  0.0000  0  0.0005  0  0  0  0.8494 | 1.5693  -0.8635  -0.0080  0.0164  0  -0.0008  0  0  0  0.9001 | -0.0835  0.0029  0.0004  -0.0010  0  0.0027  0  0  0  0.9457 |

**Arsenic**

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

Y1 =3.59250.0312 0.0410 (3)



Fig. 2:Actual Vs predicted values for Arsenic

**Copper**

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

Y2=  0.000 (4)



Fig. 3:Actual Vs predicted values for Copper

**Iron**

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

Y3 =0.02010.0004 0.0008+0.000 (5)



Fig.4:Actual Vs predicted values for Iron

**Mercury**

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

Y4 =0.0159 0.0001 (6)



Fig. 5:Actual Vs predicted values for Mercury

**Lead**

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

Y5 = 0.0003 (7)



Fig. 6:Actual Vs predicted values for Lead

**Benzene**

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

Y6 = 0.0030 (8)



Fig. 7:Actual Vs predicted values for Benzene

**Toluene**

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

Y7= 0.0065 (9)



Fig. 8:Actual Vs predicted values for Toluene

**Ethlybenzene**

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

Y8 = 0.0164 (10)



Fig. 9:Actual Vs predicted values for Ethlybenzene

**Xylene**

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

Y9 = 0.0004 (11)



Fig. 10:Actual Vs predicted values for Xylene

**4.0 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 (heavy metals and BTEX) in the study area. The result from the MLR, reveals that the predicted values closely tracked the actual values as show in the positive and strong R2 values, this implies that the MLR model equation is considered a useful tool in the prediction of pollutants concentration in 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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