Journal of Scientific Research & Reports
3(6): 884-893, 2014; Article no. JSRR.2014.010

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Quality Assessment of Soil and Groundwater near Kaduna Refinery and Petrochemical Company, Northwest Nigeria

A. N. Amadi[1*], N. O. Okoye[1], A. D. Alabi[1], Aminu Tukur[2] and E. M. Angwa[1]

[1]Department of Geology, Federal University of Technology, P.M.B 65, Minna, Nigeria.
[2]Katsina State Rural Water Supply and Sanitation Agency, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Authors ANA designed the study. Author NOO wrote the protocol. Author ADA wrote the first draft of the manuscript. Author AT pay the literature searches, analyses of the study were performed the spectroscopy analysis. Author EMA managed the experimental process. All authors read and approved the final manuscript.

Original Research Article

Received 27th August 2013
Accepted 27th October 2013
Published 17th February 2014

ABSTRACT

Soil and water are precious natural resources on which rely the sustainability of agriculture, industrialization and the civilization of mankind. Unfortunately, they have been subjected to contamination due to anthropogenic activities leading to the release of heavy metals into the environment. The history of petroleum exploration, exploitation, refining and marketing in Nigeria is a long, complex and painful one in terms of soil and groundwater pollution, which has resulted to multiple environmental and health problems. The study reveals that in some locations near the refinery, the soil and the groundwater are slightly polluted with heavy metals in the order of Fe > As > Zn > Cu > Pb > Cr > Cd > Mn, which may be attributed to the natural enrichment of groundwater through weathering of bedrock in the course of groundwater migration and anthropogenic via dumping of untreated effluents from the refinery and petrochemical into the nearby soil and surface water. The use of groundwater from the shallow hand-dug wells by host communities should be discouraged and alternative source of water should be provided by the company or government. Deep sited boreholes should be sunk to replace the existing

**Corresponding author: E-mail: geoama76@gmail.com;*

shallow hand-dug wells in the area. Effluents and waste-water from the refinery and petrochemical should be treated before disposing into the nearby farmlands or surface water.

Keywords: Quality assessment; soil and groundwater analysis; kaduna refinery and petrochemical company; Northwest Nigeria.

1. INTRODUCTION

An understanding of our fragile environment can begin with the recognition of how human activities can be regulated a better and healthy environment. Industrial activities have led to the release of heavy metals into the environment [1,2]. Unlike the organic pollutants that are biodegradable, heavy metal ions are not easily degradable [3] thus making them a source of great concern. Through food chain, the heavy metal bio-accumulates in living organism and reduced level that causes toxicological effects [4]. It is in view of the impact of heavy metals on man that the present work was embarked upon. It is targeted at evaluating the concentration of some heavy metals (Cu, Cr, As, Fe, Pb, Mn and Zn) in soils and groundwater surrounding the Kaduna Refinery and Petrochemical Company, northwest Nigeria [5]. Ascertained that the following heavy metals with their mean concentration are: Cu (0.10mg/l), Pb (0.49mg/l), Fe (0.97mg/l) and Zn (2.40mg/l) related to the lithology of the reservoir rocks are usually present in crude oil from the Niger Delta and these values are more in the residual fraction during distillation [6] documented that Cd, Cr, Cu, Fe, Ni and Zn are utilized in the refining of crude oil.

Kaduna refinery and petrochemical company refines crude oil by distillation process, which involves the separation of crude oil into different hydrocarbon groups. The crude oil is subjected to various treatment and separation processes in order to remove undesirable constituents and improve on the product quality. According to [7], to the following heavy metals: Cd, Cr, Cu, Fe, Pb, Ni, Mo and Zn are utilized for blending of petroleum. Some of these heavy metals are lost and constitute components of effluents disposed off into surrounding streams, river and soils. The effluents leach into the subsurface and may contaminate the shallow aquifers.

2. MATERIALS AND METHODS

2.1 Study Area Location

The study area comprises of some communities surrounding Kaduna Refinery and Petrochemical Companies (KRPC). It lies between latitude $10^{o}23^{1}\ 42^{11}$N to $10^{o}27^{1}\ 18^{11}$N and longitude $7^{o}27^{1}\ 30^{11}$E to $7^{o}31^{1}\ 12^{11}$E, covering a total of about 64km^2 Fig. 1. The area is accessible through major roads, minor roads and railway.

2.2 Physiography of the Area

Kaduna state lies within the Sudan savannah and consists of two seasons: dry and rainy seasons, typical of a tropical continental climate. The average temperature and rainfall in the area are 38.2ºC and 1530mm respectively [8]. The vegetation is characterised by grassland with scattered trees and woody shrubs. The soils are reddish-brown typical of ferruginous soils. The area is underlain by crystalline basement complex composed mainly of

metamorphic rocks [9]. Rivers Kaduna and Romi and their tributaries are the major drainage features in the area [10]. Generally, the tributaries are seasonal and dry up completely during the dry season Fig. 1. The drainage pattern is mostly dendritic which indicates absence of structural control over drainage lines [11].

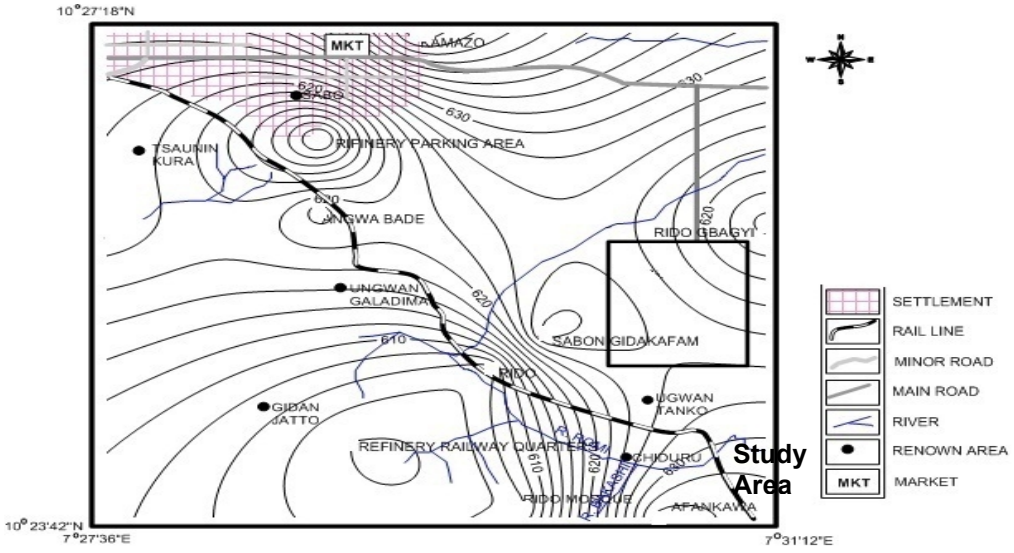

Fig. 1. Topographic map of the study area

2.3 Geology of the Study Area

The study area consists mainly of the Migmatite-Gneiss Complex which consists of migmatites, biotites and granitic gneisses Fig. 2. The magnetite gneiss complex represents reactivated metasediment which are characterized by a variety of structures and textures. In the southeastern corner, younger granites and batholiths are evident. Deep chemical weathering and fluvial erosion, influenced by the bioclimatic nature of the environment have developed the characteristics high undulating plains with subdued interfluves. The crystalline basement complex composes mainly of metamorphic rocks. According to [9,11], the major rock type in the area comprises of migmatite-gneiss complex had underlain most of Kaduna-Zaria area. Grant [12], the metasedimentary series consist of undifferentiated schist, including gneiss, fine grained flaggy quartzite and pegmatites. These are metamorphosed sedimentary and metavolcanic rocks. The basement rocks crop out at the surface by spectacular exposures of well-defined migmatites west of Kaduna and NE-SW trending batholiths in the south of Kaduna city Fig. 2. These batholiths comprise of porphyritic to leucocratic granites, granodiorites, diorites charnockites and monzonites [13]. The study area is capped by laterites. The laterites are sometimes highly consolidated especially at the surface and weathered into lateritic nodules mixed with silty and sandy clays.

2.4 Sampling and Analysis

The village heads in the area were interviewed and vital information on the negative effect of the refinery was revealed. Soil and groundwater samples were collected within the vicinity of the refinery. All the water samples were collected in clean plastic bottles. The soil samples were obtain between 10-30 cm depth and sampling tools were washed and dried before the

next sample was collected. The collected samples were stored in polythene plastic containers and air dried in the laboratory at room temperature. It was grounded using mortar and pestle before sieved under 2 mm mesh ready for digestion and analysis. Standard procedures for sample collection, digestion and analysis were followed [13]. In the course of the fieldwork, the coordinates of the sampled location were obtained using the Global Positioning System (GPS). They values were imputed into Surfer-9.0 software and used to generate the digital terrain model Fig. 3 and groundwater flow direction Fig. 4 of the area.

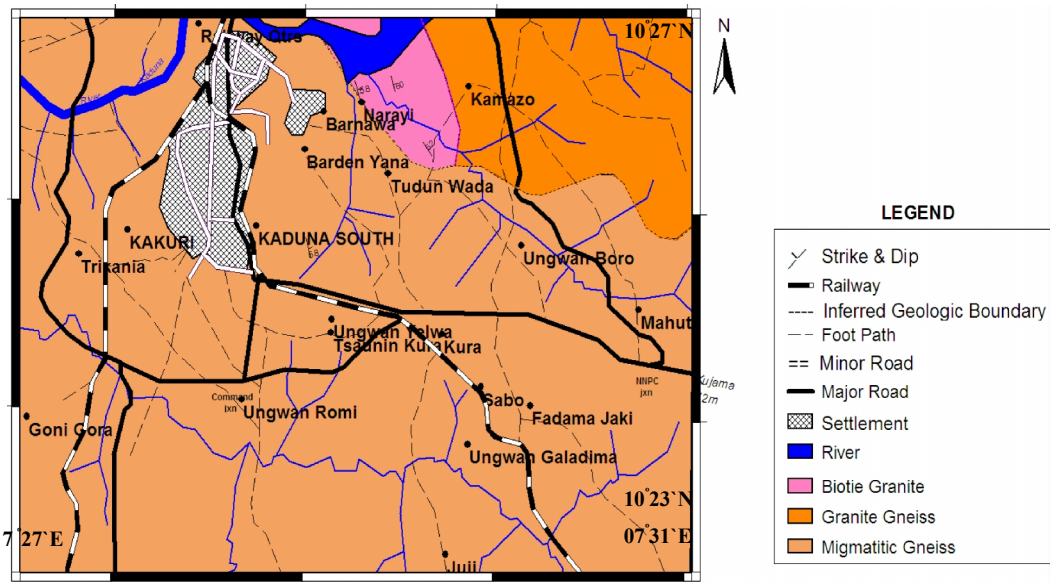

Fig. 2. Geological map of the study area

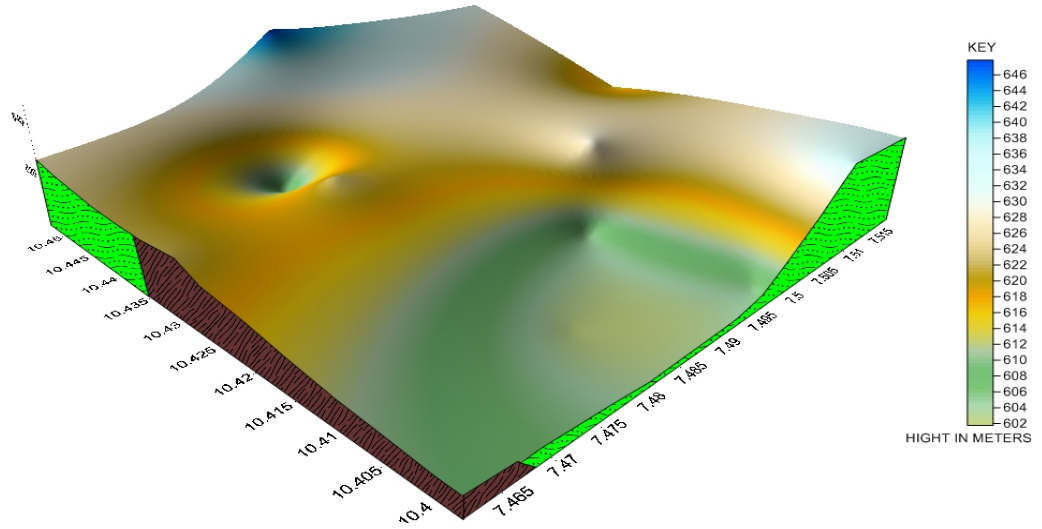

Fig. 3. Digital Terrain Model of the Study Area

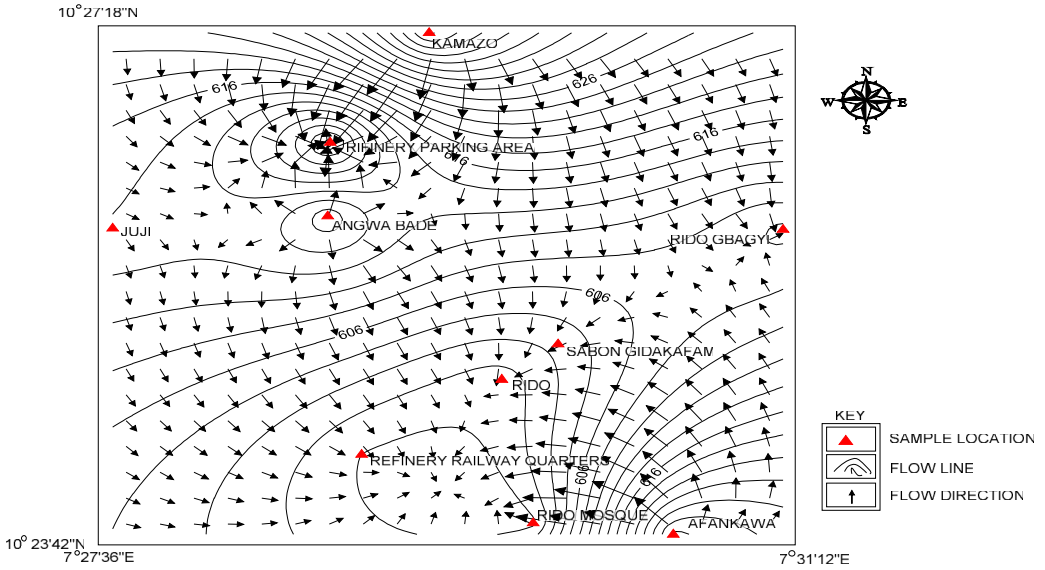

Fig. 4. Groundwater flow direction of the Study Area

3. RESULTS AND DISCUSSION

The statistical summary of the geochemical analysis are shown in Table 1 while the correlation analysis between heavy metals in soil and groundwater are illustrated in Figs. 5 and 6 respectively. The pH range 5.63-7.50 indicates slight acidity which may be attributed to the impact of the effluent on the soil and groundwater system in the area. The remaining physical parameters had their concentration within the permissible limits of [15]. The result of the microbial analysis revealed the presence of total coliform bacteria in the hand-dug well water from the area. Their presence is an indication of the groundwater is contaminated with animal/human excreta. During the sampling, it was observed that some un-ringed and un-covered hand-dug wells were sited very close to soakaways/latrine in the area and this proximity may have led to the bacteriological contamination. Studies have also revealed bacteriological contamination of groundwater from shallow hand-dug well in Zaria, Kaduna State [16,17,18].

Similarly, the concentration of the major cations and anions falls within the threshold values for a portable drinking water recommended by [15,19] for all the groundwater samples analysed. But in some locations, the concentrations of the heavy metal were found to exceed the recommended maximum permissible limit. Their enrichment were similar in both soil and groundwater Figs. 5 and 6 and in the order of Fe > As > Cu > Zn > Pb > Cr > Cd > Mn. These heavy metals enrichment the geomaterials (soil and groundwater) may be attributed to release of untreated effluent from the refinery into the nearby soils. Studies have shown that these metals form components of the crude oil [20,2,22,23]. Also in the course of bedrock dissolution, heavy metals are released into the groundwater system by natural processes. The possible sources of groundwater contamination in the area is partly geogenic (bedrock dilution) and anthropogenic (human activities) domiciled in the area. The fieldwork and laboratory analysis confirmed that the impact of the anthropogenic factor is more compared to the geogenic. This fact was established from the results of control samples collected far away from the refinery. The concentrations of the control samples in each parameter were much lower. Presently the effect of Kaduna refinery effluent on the soil

and groundwater is still within the permissible limit of Nigerian standard for safe Drinking Water Quality [19] except some heavy metal. Evaluation of the crustal abundance of the metals also indicates a slight contamination. The discharge of untreated effluents into the environment should discontinue immediately due to the bioaccumulation effect of the heavy metals [24]. The south-western part of the area has more loading in terms of contamination the other part. This is partly due to the fact that the groundwater in the area flows in a NE-SW direction and contaminants migrates towards the southern portion in line with the groundwater flow direction. The geological mapping carried out also revealed a NE-SW principal joint direction, which serves as conduits through which water migrates. Any contaminants carried by the groundwater are discharged in this area.

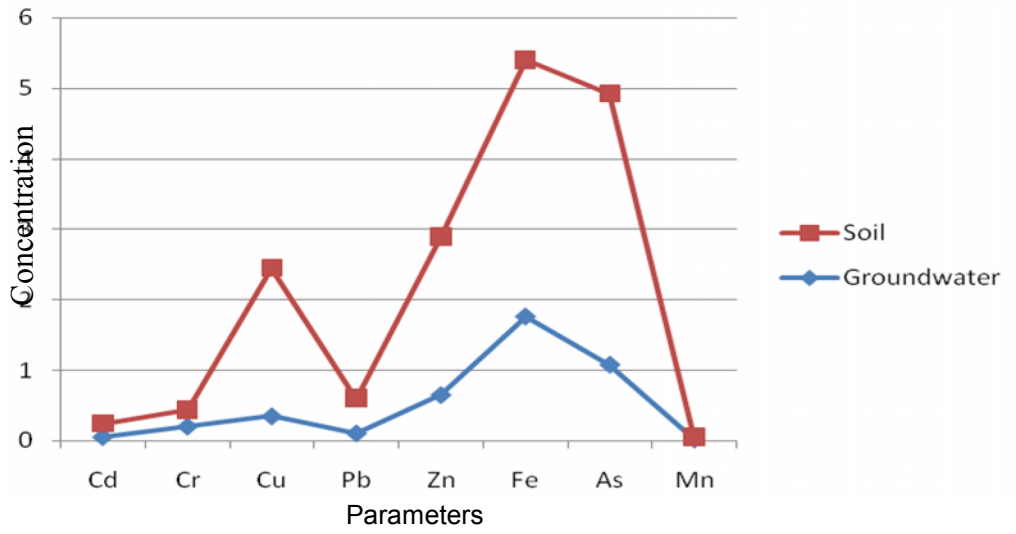

Fig. 5. Correlation analysis of heavy metals in soil and groundwater from the area

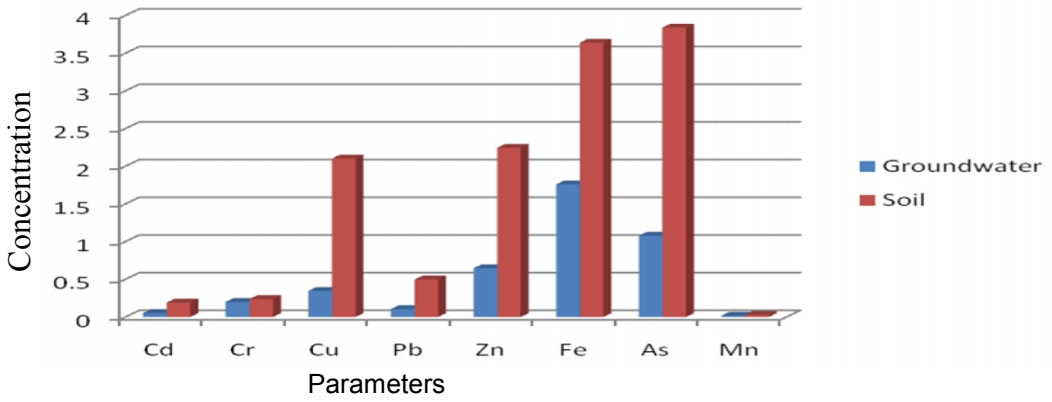

Fig. 6. Comparism of heavy metal enrich=ment in soil and groundwater in the area

Table 1. Statistical Summary of Groundwater Samples from the Study Area

Parameter	Min.	Max.	Mean	Median	Std.Deviatn	Variance	Skewness	Kurtosis
pH	5.53	7.50	6.20	6.57	0.527	0.28	0.0246	0.36
Tem(ºC)	21.00	27.00	25.00	20.40	6.204	38.48	-3.31	10.96
TDS(mg/l)	112.80	986.50	234.25	122.64	275.14	75704.53	2.40	5.75
Cond(s/cm)	40.50	301.00	140.80	123.30	80.26	6441.16	0.64	-0.40
Hardness	10.00	120.00	42.84	28.00	24.95	622.62	2.20	5.79
Sodium(mg/l)	15.00	230.00	44.30	11.85	72.11	5200.09	3.21	10.44
Potassium(mg/l)	0.30	175.00	32.46	0.97	60.03	3603.93	3.32	10.99
Calcium(mg/l)	2.00	210.00	52.18	14.00	52.26	3165.16	3.19	10.38
Magnesium(mg/l)	3.00	260.00	62.60	10.00	72.36	5236.66	3.29	10.85
Chloride(mg/l)	25.80	240.00	56.25	36.80	64.47	4156.48	3.25	10.65
Bicarbonate(mg/l)	16.00	220.00	58.00	38.00	52.00	2704.00	2.96	9.29
Carbonate(mg/l)	0.00	180.00	27.45	0.00	60.30	3636.36	3.32	11.00
Sulphate(mg/l)	3.00	195.00	35.40	9.00	57.78	3338.89	3.30	10.89
Nitrate(mg/l)	0.00	53.00	16.20	0.10	14.99	224.88	3.31	10.97
Copper(ppm)	0.01	1.01	0.20	0.024	0.596	0.355	3.32	10.99
Iron(ppm)	0.02	1.27	0.53	0.621	1.230	1.512	2.10	4.68
Zinc(ppm)	0.06	0.35	0.12	0.084	0.084	0.007	2.42	5.92
Lead(ppm)	0.00	0.08	0.29	0.019	0.914	0.836	3.32	10.99
Total coliform	0.00	14.00	5.00	1.00	1.58	2.49	1.87	3.33

The concentration of 8 major ions (Na^+ ,K^+, Mg^{2+}, Ca^{2+}, Cl^-, $CO3^{2-}$, HCO^-3 and $SO4^{2-}$) are represented on a Piper trilinear diagram Fig. 7 by grouping the K^+ with Na^+ and the $CO3^{2-}$ with HCO^-_3 thus reducing the number of parameters for plotting to 6. On the Piper diagram, the relative concentration of the cations and anions are plotted in the lower triangles and the resulting two points are extended into the central field to represent the total ion concentrations. The Piper diagram Fig. 7 is used to classify the hydrochemical facies of the groundwater samples according to their dominant ions. The water in the area is Ca/Mg-SO_4^{2-} /HCO_3^- type which indicates normal alkaline earth water [25].

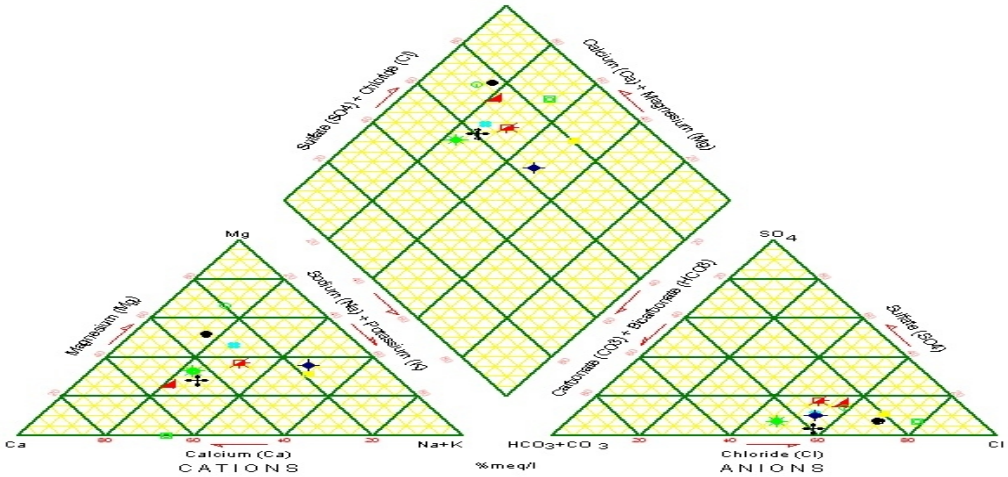

Fig. 7. Piper diagram showing the water type in the area

4. CONCLUSION AND RECOMMENDATION

The results of laboratory analysis and fieldwork revealed that the soil and groundwater quality in the area has been affected by oil spillage and improper disposal of untreated effluents from petroleum product leading to their enrichment with heavy metals in the order of Fe > As > Zn > Cu > Pb > Cr > Cd > Mn. Part of the heavy metal enriched the groundwater through bedrock dissolution processes. The use by the host communities of groundwater from shallow hand-dug wells should be discouraged and alternative source of groundwater should be provided for the inhabitants. Deep sited boreholes should be sunk to replace the existing shallow hand-dug wells in the area. Effluents and waste-water from the refinery and petrochemical should be treated before disposing into the nearby farmlands or surface water. Bioremediations and phytoremediation should be employed in the cleaning up of contaminated sites.

ACKNOWLEDGEMENT

The research team is very grateful to Prof. P. I. Olasehinde, Department of Geology, Federal University of Technology, Minna, Nigeria for his mentorship.

COMPETING INTERESTS

Authors have declared that no competing interest exists.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=417&id=22&aid=3749