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AN EVALUATION OF GROUNDWATER AND SURFACE WATER RESOURCES IN ORLU AND ENVIRONS, SOUTH EASTERN NIGERIA

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Abstract
Most Nigerian rural settings suffer from non-availability of potable water. The difficulties in accessing water are great challenges which often results in water-borne diseases and other illnesses. This study evaluates the water resources in Orlu and environs with the aim of investigating the water quality in the study area. Eighteen water samples comprising nine groundwater and nine surface water were collected and analysed. The samples were then subjected to Atomic Absorption Spectroscopy for heavy metal analysis. The results show that most of the major ionic concentrations are within WHO standard. Lead, cadmium, and mercury in groundwater and cadmium, lead, and mercury in surface water are above WHO standard. Dominant water character in the study area was determined using the Piper Trilinear and Schoeller semi-logarithm diagrams. Sodium-chloride-bicarbonate waters for surface water and calcium-sulphate waters for groundwater are the principal water types. The heavy metals concentration detected in the groundwater may be attributed to the indiscriminate disposal of wastes in the study area which generated leachate that found its way into the groundwater system while the heavy metals in the surface water may be attributed to the pollution from waste, fertilizer application, fungicides and pesticides used in the farming activities in the study area. It is highly recommended that drinking water in the study area should be treated to be free from contamination.

Keywords*: Hydrochemical, gullies, heavy metals, confined aquifer, contamination*

Introduction
Nigeria is faced with increasing demands for water resources due to high population growth rate and growing prosperity. The importance of water resources in meeting a substantial percentage of this water need, and in the overall development of Nigeria's economy cannot be over-emphasized [1]. Drinking water in sufficient quantity and quality is one of the basic human needs and it is a human right [9]. The human right to water entitles everyone to sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic use [9]. The human right to water is indispensable for living a life in human dignity. It is a prerequisite for the realization of other human rights [11, 12].

The chemical composition of groundwater and the water types found in an environment are determined substantially by local geology. The types of minerals found in the environment of the groundwater, anthropogenic activities such as mining and waste disposal as well as climate and topography have a lot to say about the quality of the groundwater [2]. Chemical constituents of groundwater have been known to cause some health risks, so water supply can only be safe if accurate information on water quality is not lacking. [5].

This study was carried out on water resources in Orlu and environs, Imo State South Eastern Nigeria with the aim of assessing the water quality in the study area. Current emphasis is not only on the abundance of water but also on its quality and suitability for the sustenance of its various uses.

Description of the study area
The study area is located between latitudes 5^o 39$^'$ N and 5^o 50$^'$ N and longitudes 7^o 09$^'$ E and 8^o 20$^'$E (Fig. 1). It covers an area extent of approximately 268sq/km that comprises Amaigbo, Isiekenesi, Mgbee, Ihioma, Okwudor, Ekwe, Amandugba, and Isunjaba communities. Two types of landforms characterize the topography of the area; they include high undulating ridges and nearly flat terrain (Ibe *et al.*, 2001). The area is drained by Three (3) major rivers: Orashi river,

Njaba river and Okitankwo river (Fig. 1). Geologically, the study area is underlain by Ameki, Ogwashi-Asaba and the Benin Formations (Fig. 2) [10].

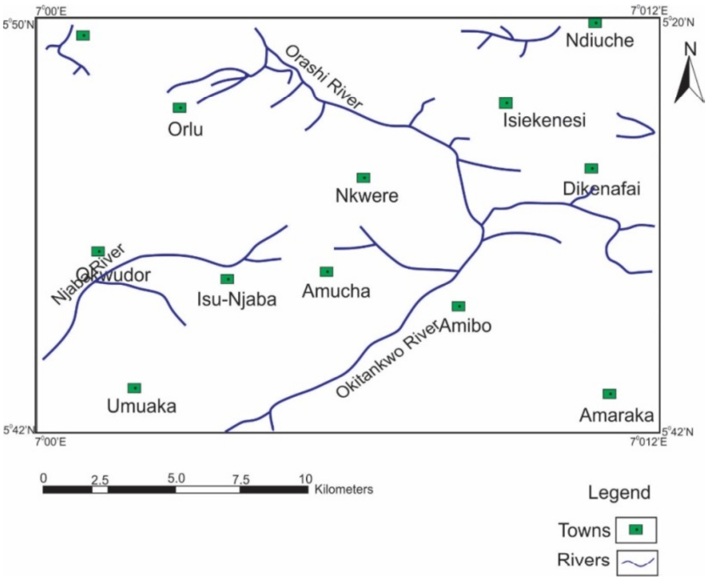


Fig.1: Map of the study area showing the drainage

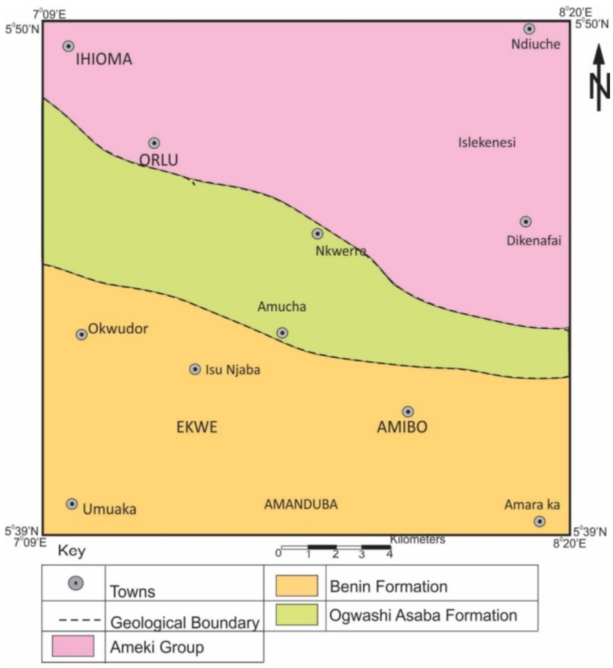


Fig.2: Geological map of the study area [2]

Materials and Methods

Water samples for geochemical analysis

A total of eighteen (18) water samples were collected comprising Nine (9) groundwater and Nine (9) surface water samples for geochemical analysis. Clean plastic containers were used to collect the water samples. They were rinsed several times with the same water sample to be analyzed, then covered with airtight cork and carefully labeled and sent to the laboratory for geochemical analysis within 24hours of the collection. All details of the analytical procedure are as reported in [6].

The analysis was carried out using atomic absorption spectroscopy for Ca^{2+}, Na^{+}, Mn^{2+}, Cl^{-}, lead (Pb^{2+}) Cadmium (Cd), Zinc (Zn) and Copper (Cu^{2+}). At each sampling point, certain physical parameters such as temperature, electrical conductivity and pH were measured in-situ using thermometer, portable electrical conductivity cell and pH meter. This is done because their values might change significantly soon after collection. Data for the parameters measured, time as well as location name and number were all recoded. Analysis of the collected water samples for their major cation and anion components was carried out in Litolab Ministry of Environment, Imo State. The major ions analyzed and the methods used in analyzing them are as follows: sodium (Na^{+}) and
potassium ($K^{+)}$ were analyzed by flame photometry, calcium (Ca^{2+}) and magnesium (Mg^{2+}) were determined by Atomic Absorption Spectrometry (AAS) and Fe was determined by Spectrophotometry. Photometric method was used to determine sulphate (SO_4^{2-}) and nitrate (NO_3^{-}) using H18200 multiparameter Benchphotometer, Cl^{-} was analysed by Argentometric method that is silver nitrate titration using potassium chromate as indicator and phenolphthalein/methyl orange titrimetric method was used to analyze bicarbonate (HCO_3^{-}) and carbonate (CO_3^{2-}).

The concentrations of Ca^{2+}, K^{+}, Mg^{2+}, Na^{+}, (SO_4^{2-}), HCO^{-}_3, and Cl^{-}, in milligram per litre were used to obtain percentage milliequivalents used in plotting Piper diagram [8]. Also, Ca^{2+}, K^{+}, Mg^{2+}, Na^{+},(SO_4^{2-}), HCO^{-}_3, and Cl^{-}, milliequivalents were used in plotting Schoeller diagram.

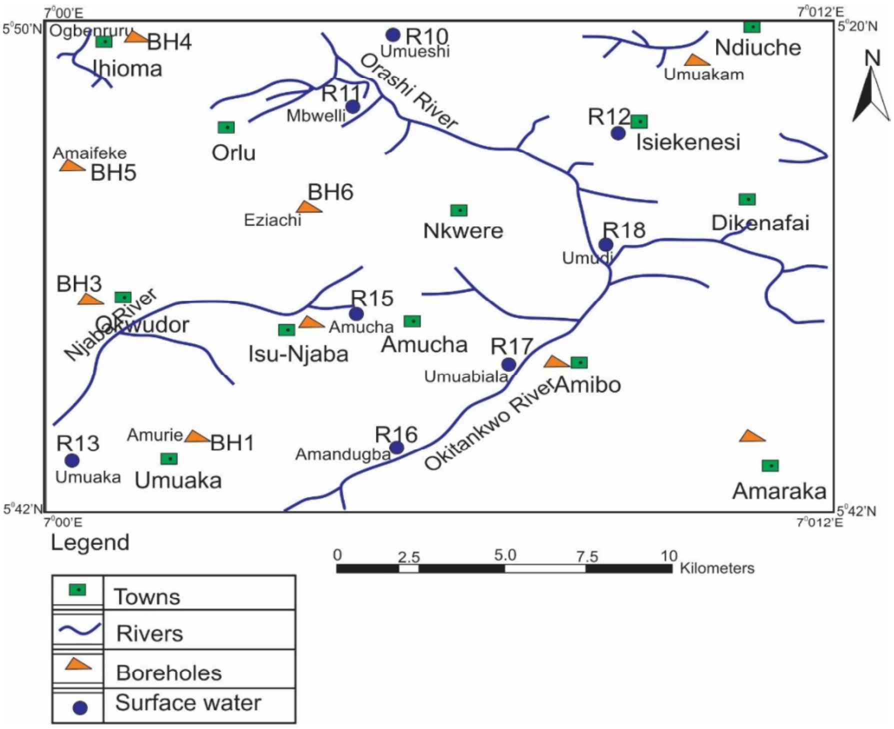


Fig. 3: Map of the study area showing water sample locations

Results and Discussion

Water Analysis

The result of water analysis are presented in Table 1. From the table, the concentration of heavy metals in the surface water samples ranges for Pb^{2+} (0.01-0.18mg/L), Hg^{2+} (0.001-0.14mg/L), Cd^{2+} (0.03-1.74mg/L), which are higher than the WHO [13] permissible guideline for these metals except for sample R11, which is within the guideline values (Fig. 4).

On the other hand, the concentration of heavy metal in the groundwater ranges for Hg^{2+} (0.02-0.07mg/L), which is above the permissible guideline except for samples BH4, BH5, BH6 and BH8, Pb^{2+} (0.02-0.62mg/L), Cd^{2+} (0.02-0.61mg/L). Some of these values are above the WHO permissible guideline values (Fig. 5).

These elevated concentrations could be due to the leachate from baterries and electrodes, fungicides and pesticides used in farming activities and paper waste dumped indiscriminately around the study area. These dumps are washed down to the nearby rivers and also found their way into the groundwater system. The concentration of Pb^{2+} is higher in the surface water samples than in the groundwater samples. The implication of the elevated level of these trace matals are such that impair safety and health. Lead, mercury and cadmium affect the body system from intracellular level to intercellular level. The brain remains the target organ for mercury, yet it can impair any organ and lead to malfunctioning of nerves, kidneys and muscles. It can cause disruption to the membrane potential and interrupt intracellular calcium homeostasis. Mercury binds to freely available thiols as the stability constants are high [7]. Mercury vapors can cause bronchitis, asthma and temporary respiratory problems. Mercury plays key role in damaging the tertiary and quaternary protein structure and alters the cellular function by attaching to the selenohydryl and sulfhydryl groups which undergo reaction with methyl mercury and hamper the cellular structure. It also intervenes with the process of transcription and translation resulting in the disappearance of ribosomes and eradication of endoplasmic reticulum and the activity of natural killer cells.

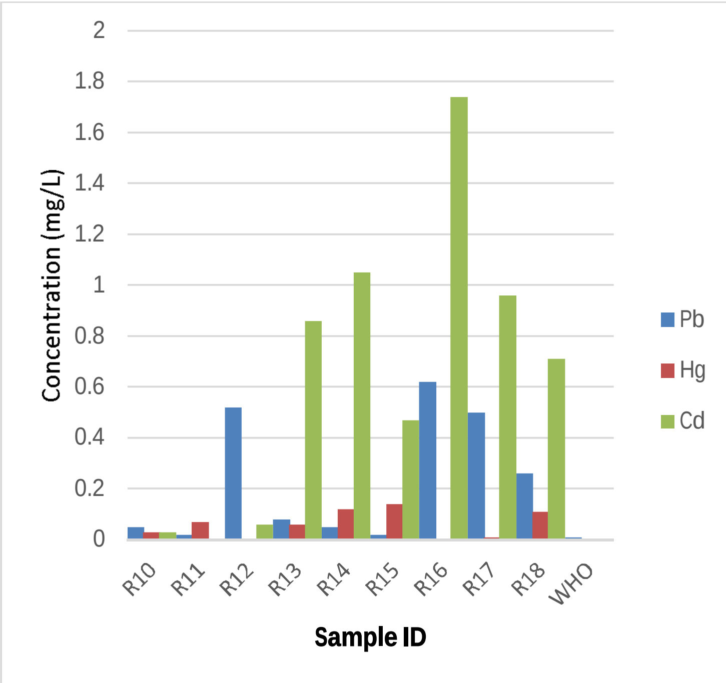


Fig. 4: Comparison of heavy metal concentrations in surface water with WHO

Table 1: Water Analysis Result

Parameters	BH1	BH2	BH3	BH4	BH5	BH6	BH7	BH8	BH9	R10	R11	R12	R13	R14	R15	R16	R17	R18	WHO, 2011
Na^{+} (mg/l)	4.49	5.36	3.85	3.23	4.63	4.72	4.12	7.06	5.43	3.91	4.23	3.4	4.2	4.36	6.2	5.6	5.39	5.49	200
Ca^{2+}(mg/l)	28.12	7.13	13.16	10.52	6.33	14.29	9.21	11.01	27.21	2.5	0.06	0.09	2	0.2	0.07	0.32	0.62	0.18	75
XMg^{2+}(mg/l)	0.19	5.9	0.18	1.02	3	0.56	0.61	0.2	7.04	0.1	0.6	0.4	0.07	0.05	0.1	0.062	0.081	1.7	0.2
K^{+}(mg/l)	0.67	0.33	0.38	0.1	0.4	0.7	0.2	0.1	0.6	1.7	3.9	8.3	1.72	0.56	3.4	2.08	1.9	1.82	
Fe^{2+}(mg/l)	0.69	0.5	0.83	0.25	0.78	0.43	0.48	0.25	0.4	0.82	0.54	1.26	0.4	0.62	0.3	1.6	0.48	0.29	1
Pb^{2+}(mg/l)	0.05	0.02	0.50	0.08	0.05	0.02	0.62	0.5	0.26	0.02	0	0.01	0.21	0.08	0.13	0.18	0.21	0.1	0.01
Hg^{2+}(mg/l)	0.03	0.01	0.07	0	0	0	0.02	0	0.01	0.03	0.07	0.001	0.06	0.12	0.14	0.001	0.01	0.11	0.001
Cd^{2+}(mg/l)	0	0.013	0.02	0.05	0.054	0.02	0.061	0.049	0.026	0.03	0	0.06	0.86	1.05	0.47	1.74	0.96	0.71	0.003
Zn^{2+}(mg/l)	0.8	0.6	0.69	1.95	2.5	2.1	0.91	1.97	2.5	2	0.04	0.68	0.8	0.4	0.5	0.75	0.33	0.007	3
Cu^{2+}(mg/l)	0.37	0.2	0.25	0.06	0.57	0.48	0.07	0.06	0.44	0.3	0.42	0.45	1.25	0.001	0.2	1.42	1.52	0.21	1
HCO_3^-(mg/l)	17.4	18.39	20.69	9.54	18.49	18.49	18.3	17.5	21	19.2	18.4	17.39	19.2	21.01	18.99	28.42	26.43	28.5	
SO_4^{2-}(mg/l)	5	1	6	5	4	5	2	5	5	5	12	55	13.1	10	2	2.3	1.03	2.36	500
Cl^-(mg/l)	20.2	14.8	19.4	16.5	22.7	18.28	18.28	15.9	19	48.7	13	30.2	16.2	12.6	9	1.82	1.47	1.4	250
NO_3^-(mg/l)	0.91	0.35	0.86	8	9	13	10	9	10	9	44	49	12	5	10	0.27	0.59	0.18	50
Colour(TCU)	11	7	18	13	14	11	12	13	12	369	119	320	89	60	17	442	276	506	15
Temperature (°C)	27	27	28.3	26	27	28	26.4	27.4	28	28.7	28.2	28.1	29	27.9	29.2	28.3	28.9	28.3	Ambient
Conductivity (us/cm)	55	37	69	72	73	95	84	72	95	164	22	19	100	84	150	160	14	21	
pH	5.5	5.7	5.2	6.1	5.7	5.9	6.3	6.2	5.9	6.5	6.7	6.7	6.6	6.8	6.2	6.7	6.5	6.8	9.2
Turbidity(NTU)	7	2	5	0	2	1	0	0	1	14	19	49	73	50	72	75	46	6.8	5
TDS(mg/l)	26	17.1	35.5	36	36.5	47.5	42	36	47	55	14.3	12.4	52	42	76	79	9.1	14.95	

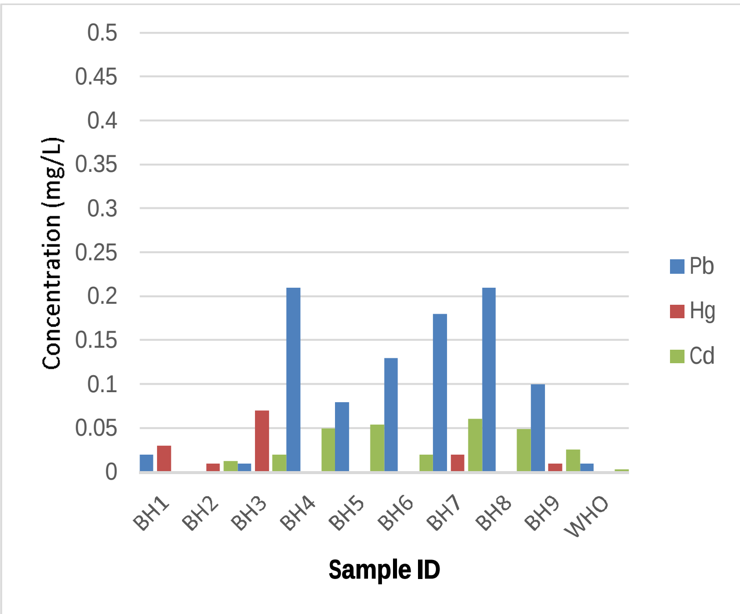
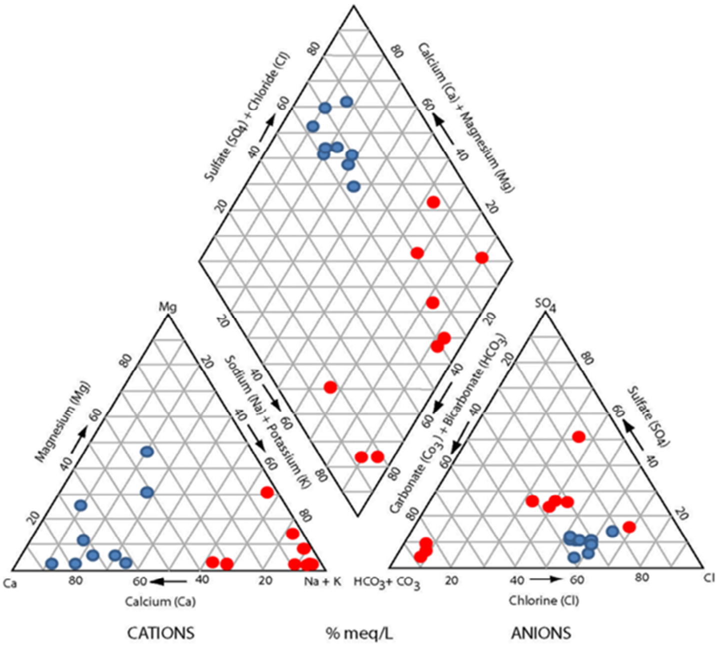


Fig. 5: Comparison of heavy metal concentrations in groundwater with WHO guideline

Piper Diagram Analysis

The major anions and cations in the water samples are Ca^{2+}, K^{+}, Mg^{2+}, Na^{+}, (SO_4^{2-}), HCO^-_3, and Cl^- which are used for Piper diagram plotting. From the Piper diagram, groundwater water samples are mainly of $Ca\text{-}SO_4$ waters which is typical of gypsum ground waters while the river water samples are Na-Cl water typical of marine and deep ancient ground waters and $Na\text{-}HCO_3$ waters typical of waters influenced by ion exchange [3]. The $Ca\text{-}SO_4$ water type has 33.33% dominance in the samples, Na-Cl water type has 16.67% while $Na\text{-}HCO_3$ has 50.00% dominance. Also it was discovered that out of the three water types present in the study area, surface water was responsible for two of the water types i.e Na-Cl and $Na\text{-}HCO_3$ while $Ca\text{-}SO_4$ water type is from groundwater (Fig. 6)



(Groundwater and Surface water)

Fig. 6: Piper trilinear diagram showing the major water types surface water and groundwater

Schoeller Diagram

Figures 7 and 8 show Schoeller Diagram for both the groundwater and surface water respectively. The close to parallel lines of the Schoeller diagram for groundwater portrays it to be composed of an equal ratio of ions, while the surface water samples have varying quantity of dissolved ions.

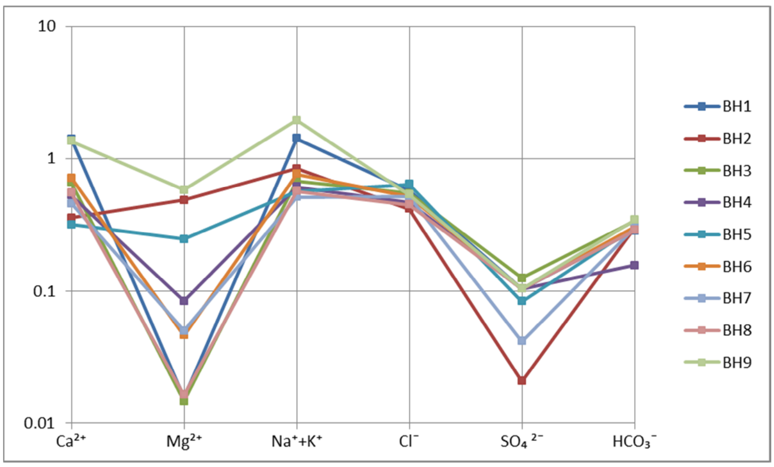


Fig. 7: Schoeller Logarithm diagram for underground water

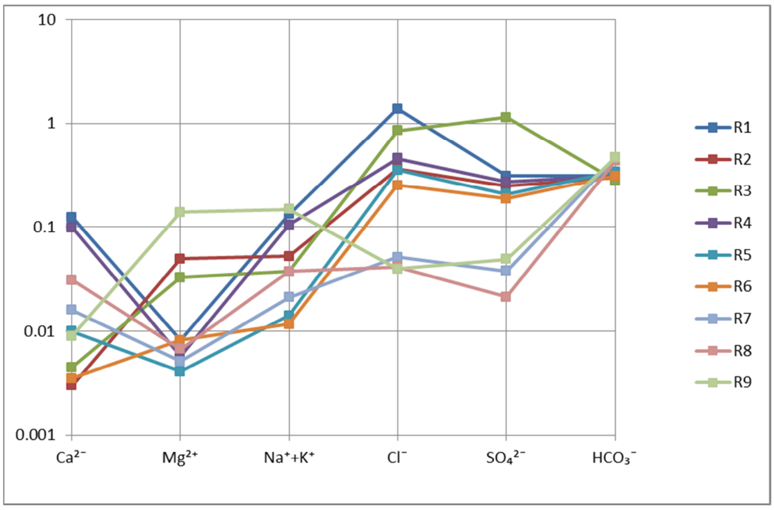


Fig. 8: Schoeller Logarithm diagram for surface water

Conclusion

The hydrochemical analysis of the water samples indicate some traces of lead, mercury, and cadmium, which are above the World Health Organisation standard for drinking water (WHO, 2011). The traces of heavy metals in the water samples are attributed to the run-off from fertilizers, fungicides, pesticides, leachate that percolated from the disposal of plastics and synthetic rubber, used batteries, electroplated metals (e.g. bolts and nuts), waste papers dumped indiscrimately at the study area.

The geochemical water facies obtained from Piper diagram for groundwater water samples is of Ca-SO_4 waters which is typical of gypsum ground waters while the river water samples are Na-Cl water typical of marine and deep ancient ground waters and Na-HCO_3 waters typical of waters influenced by ion exchange. The Ca-SO_4 water type has 33.33% dorminace in the samples, Na-Cl water type has 16.67% while Na-HCO_3 has 50.00% dorminace.

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