Assessment of Heavy Metal Concentration in Groundwater of UVWIE Local Government Area and Environs, Delta State, Nigeria

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Abstract: - Heavy Metal contamination of water is an issue of deep concern worldwide and as such the degree to which these metals may have contaminated the most valuable fresh water resource, "Ground water" must be summarily understood. Seventeen(17) Borehole and Uncased Well water samples were collected from various parts of Uvwie, Warri South and Sapelle Local Government Areas and analysed using atomic absorption spectrophotometry for six(6) heavy metals namely Manganese(Mn), Copper(Cu), Lead(Pb), Chromum(Cr), Arsenic(As) and Zinc(Zn). Upon comparison with NIS and WHO standards for drinking water, the results showed that though there were measurable concentrations of heavy metals in the ground water samples they were not high enough to pose a threat to human health. Nonetheless, the results were subjected to Statistical analysis using Descriptive methods; Principal component Analysis (PCA) and Cluster Analysis (CA); a dendogram was also plotted to describe the degree of relationship between the heavy metal concentrations. Heavy metal concentration in the ground water within the study area was found to follow two major trends: Zn>Cu>Mn>Cr>Pb>As and Cu>Mn>Zn>Cr>Pb>As in Boreholes and Uncased Well water Samples respectively. Based on the concentration trends, PCA and CA, an anthropogenic source was inferred for Zn presumably from piping works not associated with the ground water system itself while Pb, Cu and Mn displayed a relationship in terms of origin in the groundwater.

I. INTRODUCTION

Water is an essential resource and as such it forms the primary need of man in his environment. It is a vital component of life for both plants and animals available in forms of rain and snow thereby making rivers, oceans, streams, lakes, springs etc.(IBENEME, et al., 2013). The most relied upon as a readily utilisable hygienic source of this important resource for human consumption in Nigeria is groundwater. It is an important natural water resource which serves as a source of potable drinking water for several millions of people in most parts of Nigeria but whose quality however depends not only on natural factors such as aquifer lithology, groundwater velocity, quality of recharge waters and interaction with other types of water or aquifers; but also on human activities, which can alter these fragile systems, either by polluting them or by modifying the hydrological cycle, to such an extent that the use of groundwater becomes (HELENA, et al., 2000).

In recent times various regions in Delta state such as Uvwie, Warri South and Sapele LGA, have experienced massive expansion due to their proximity to the hydrocarbon industry in western Niger Delta. Sapele for example is home to several oil installations and the proximity of both Warri south and Uvwie to similar areas has led to huge population growth and rapid urbanisation of previously rural areas. This has thus resulted in the release of harmful contaminants of various sources both industrially and domestically into the environment including heavy metals.

Aim and Objectives of Study

The aim of this study is to assess the presence of heavy metals in groundwater of Uvwie, Sapele and Warri South Local Government Areas of Delta state and attempt to determine their origin.

Location and Accessibility

The study area lied within Delta state which exists as a part of the Niger Delta Region of Nigeria. The study area was accessible by both major Federal Government roads and also by smaller state roads. Footpaths were rarely used except in the fringes of the study areas where urbanisation was yet to begin. Public transportation was however readily available throughout the study areas.

II. METHODOLOGY

Sampling and Location

Samples were collected from Boreholes in the study area and where boreholes could not be obtained, hand dug wells were used. Some samples were taken from both hand dug wells and Boreholes in the same area in an attempt to establish a relationship between the two water sources in terms of heavy metal concentration. 1Ltr opaque screw cap Plastic bottles were used, washed thoroughly as a precaution prior to usage using mild detergent and then rewashed with the sample water before sample collection filled to the brim, tightly covered to retain the water parameters that was present in the water when the sample was taken and to avoid contamination.

Samples were then appropriately labelled with their GPS coordinates of the location from which they were collected, elevation, time of sample collection, ground elevation, water

level (in hand dug wells) and location or land mark present in the area. BH was added as a suffix for samples collected from boreholes and UW for samples collected from wells, thus BH 1 – 10 was used for the borehole samples and UW 1-7 for the Uncased wells making a total of 17 water samples. Collected

samples were then stored in coolers and transported to the lab within the specified retention time of 4hrs for further analysis. Sampling was done in good weather condition to avoid rainwater contamination, as this could affect the quality of the samples collected.
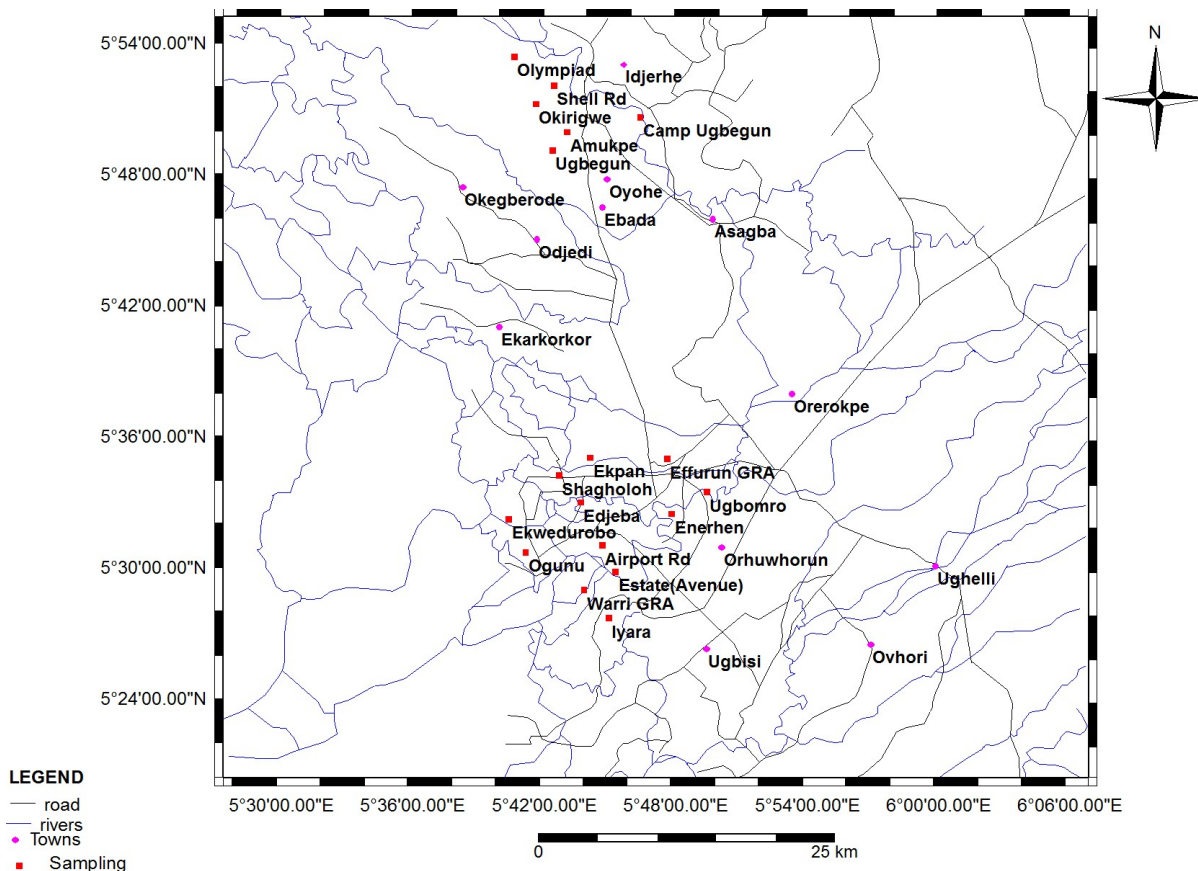

Figure 1: Map showing Sample Points and Prominent Towns in the Study Area

The sampling was done using a Global positioning System (GPS) Garmin 76 for taking coordinates and elevation readings at locations where samples were collected and a digital map for reference. Random sampling technique was employed in the selection of sampling points. The table below is a summary of sample location and their coordinates.

Table 1: Sample Points and their Coordinates

S/N	Sample Location	Coordinates		Elevation (m)	Sample Code
		LATITUDE	LONGITUDE		
1	Shagolo	5.5691	5.7276	21	BH -1
2	Ekpan	5.5706	5.7456	23	BH – 2
3	Okirighwe	5.5706	5.7114	23	BH – 3
4	Shell Rd	5.8713	5.6993	20	BH - 4
5	Ugbegun	5.8436	5.7214	6	BH - 5
6	Camp	5.8278	5.7283	9	BH - 6
7	EffurunGRA	5.5712	5.7929	16	BH - 7
8	Ogbomro	5.5646	5.8269	13	BH - 8
9	Enerhen	5.5279	5.7737	15	BH - 9
10	Warri GRA	5.5224	5.7391	23	BH - 10
11	Shagolo	5.5691	5.7276	21	UW - 1
12	Edjeba	5.5432	5.7372	19	UW -2
13	Ogunu	5.5309	5.713	10	UW - 3
14	Amukpe	5.8271	5.7286	12	UW - 4
15	Olympia	5.8907	5.6783	10	UW - 5
16	Camp	5.8278	5.7283	9	UW - 6
17	Airport Rd	5.5385	5.7544	21	UW - 7

Descriptive analysis and correlation coefficient

Descriptive data analysis carried out, including mean, standard deviation (SD), minimum and maximum concentrations, skewness, variation coefficient etc., was carried out. Together with SD, variation coefficient (VC) which is SD/mean was used to reflect the degree of discrete

distribution of different metal element concentrations, and to indicate indirectly the activeness of the selected element in the examined environment. Skewness was also utilized to reflect different distributions of the metals. In addition, correlation coefficients were calculated to determine relationships among different metals.

Multivariate analysis

Principal component analysis (PCA) and cluster analysis (CA) are the most common multivariate statistical methods used in environmental studies ((MIRANDA, et al., 1996); (DIAZ ., et al., 2002)). For our study, STATA for Windows, version 13.0 (STATACORP, 2013), was utilized for the multivariate statistical analysis, and for descriptive and correlation analyses. PCA is widely used to reduce data (LOSKA & WIECHUYA , 2003)and to extract a small number of latent factors (principal components, PCs) for analysing relationships among the observed variables. If large differences exist in the standard deviations of variables, PCA results will vary considerably depending on whether the covariance or correlation matrix is used (FARNHAM, et al., 2003). The concentrations of the heavy metals evaluated in this study vary by different orders of magnitude. PCA was therefore applied to the correlation matrix for this study, and each variable was normalized to unit variance and therefore contributes equally.

To make the results more easily interpretable, the PCA with VARIMAX normalized rotation was also applied, which can maximize the variances of the factor loadings across variables for each factor. Factor loadings >0.71 are typically regarded as excellent and <0.32 very poor (NOWAK, 1998); (GARCI´A, et al., 2004)). In this study, all principal factors extracted from the variables were retained with eigenvalues >1.0, as suggested by the Kaiser criterion (KAISER, 1960). When PCA with VARIMAX normalized rotation was performed, each PC score contains information on all of the metal elements combined into a single number, while the loadings indicate the relative contribution each element makes to that score. The PC loadings were plotted and the plot was inspected for similarities observed as clusters in the PC loading plot.

Cluster analysis (CA) was performed to further classify elements of different origin on the basis of the similarities of their chemical properties. Hierarchical cluster analysis, used in this study, assisted in identifying relatively homogeneous groups of variables, using an algorithm that starts with each variable in a separate cluster and combines clusters until only one is left. As the variables have large differences in scaling, standardization was performed before computing proximities, which can be done automatically by the hierarchical cluster analysis procedure. A dendrogram was constructed to assess the cohesiveness of the clusters formed, in which correlations among elements can readily be seen. The CA is complementary to PCA.

Field Measurement

Due to the sensitivity of groundwater chemistry to environmental changes, three crucial parameters namely: pH, Conductivity and Temperature were measured and recorded in the field using standard method

pH

The samples collected were measured for pH value in the field, using a pH meter (Model Ecosense). Each sample was placed in a plastic beaker, the electrode end of the meter was then rinsed with distilled water followed by the sample and inserted into the sample in the beaker. The READ button on the pH meter was pressed and the pH value at a stable pH reading was recorded. The process was then repeated and the average of the two reading obtained was recorded

Conductivity

Electrical conductivity (EC) for the water samples were measured using an Electrical Conductivity Meter (HANNA HI 991301). The EC meter electrode was rinse with distilled water and the sample, the sample was poured into a plastic beaker. The electrode end of the meter was then inserted in the sample. The READ button on the meter was pressed and the EC value at stable meter reading was recorded.

Temperature

The temperature of samples was measure with the aid of Mercury-in-glass thermometer calibrated in degrees centigrade. The thermometer was rinsed with distilled water and then sample after which it was immersed in a plastic beaker filled with the water sample.

The thermometer was then left in the beaker for a few seconds after which the stable temperature value on the thermometer was recorded.

Table 2: Methods of field measurement

S/N	Parameters Measured	Equipment Used	Method Standard
1	pH	pH meter (model Ecosense)	ASTM D 1293B
2	Electrical Conductivity	EC meter (HANNA HI 991301)	ASTM D 1125
3	Temperature	Mercury-in-glass	Degree Centigrade

Laboratory Analysis

The analytical methods used in the determination of the Heavy Metals Concentration in water are in accordance with the American Standard for Testing Materials(ASTM, 1962)and American Public Health Association (APHA, 1992) Standard procedures. The collected water samples were preserved with Conc. HNO3 upon arrival at the lab and refrigerated to 4.0^0C pending analysis. Prior to this the Total Dissolved Solid measurement was performed on the water samples as prescribed by the American Public Health Association Standard Procedures.

Heavy Metals

For assessment of contamination, the method of Arnold (6) was used in which heavy metals extracted by molar nitric acid is assumed to represent the amount that has been acquired through contamination.

Sample Preparation

5 mL of Conc. HNO3 was added to 100 mL of well-mixed water sample in 125mL conical flask. The solution was then evaporated to near dryness of about 20ml on hot plate while ensuring that the sample did not boil by using low to medium heat. The content of the beaker was then allowed to cool. Another 5.0ml of conc. HNO3 was added to the content of the beaker and the beaker was immediately covered with a watch glass.

The beaker was then returned to the hot plate and a gentle flux action of the solution was set by increasing the temperature of the hot plate (medium to high). This heating was continued with regular addition of HNO3 as necessitated until a light colour residue was obtained which indicated that digestion was complete. Additional 10mL Conc. HNO3 was added to the residue and washed with distilled water and filtered into a volumetric flask to remove silica and other insoluble residue. The mark was then made up to 100 mL with distilled water and the solution was stored in a 125ml polypropylene bottle.

Analysis

The heavy metals of interest: Chromium, Copper, Lead, Zinc, Arsenic and Manganese were determined in water samples and blanks with a Computerized Varian 220 Flame Atomic Absorption Spectrophotometer according to predetermined specifications as seen in Table .3 at TUDAKA Laboratories, Jakpa Road, Warri Delta State, Nigeria Single elemental

working standard solutions were prepared by dilution of 1000mg/l stock solutions of the individual elements Cr, As, Zn, Cu, Pb &Mn. The solutions ranged between 0.1mg/l to 10.0mg/l

External calibration was used by running deionised water and a suite of calibration standards for each metal. The extracted solutions and blanks were then run on the Atomic Absorption Spectrometer to obtain the absorbance values. Concentrations of the metals in the water sample were then calculated from the equations of the calibration curve.

Calculation:

Conc. of element X (mg/l) = A − B

Where A = Conc. of element X (mg/l) B = Conc. of blank (mg/l)

Table 3: Working Condition of Varian 220 fs Atomic Absorption Spectrometer

Metals	Wave-length (nm)	Slit width (nm)	Lamp current (mA)	Fuel	Support	Flame Stoichiometry
Manganese	279.5	0.2	5.0	Acetylene	Air	Oxidizing
Copper	324.7	0.5	4.0	Acetylene	Air	Oxidizing
Lead	217.0	1.0	5.0	Acetylene	Air	Oxidizing
Chromium	357.9	0.2	7.0	Acetylene	Nitrous oxide	Reducing
Arsenic	193.7	0.5	10.0	Acetylene	Nitrous oxide	Reducing
Zinc	213.9	1.0	5.0	Acetylene	Air	Oxidizing

III. PRESENTATION OF RESULTS

Table 4 below shows the results obtained from the 17 sample points analysed.

Table 4 : Result for Ground Water Analysis

Sample ID	pH	Temp ℃	Cond	TDS	Mn (mg/l)	Cu (mg/l)	Pb (mg/l)	Cr (mg/l)	As (mg/l)	Zn (mg/l)
BH - 1	5.51	26.5	470	250	0.004	0.019	BDL	0.002	BDL	0.024
BH – 2	4.48	26	98	51	0.006	0.017	0.002	BDL	BDL	0.029
BH – 3	4.01	27.5	450	330	0.003	0.011	BDL	0.002	BDL	0.042
BH - 4	4.24	26	110	80	0.004	0.021	0.003	0.007	BDL	0.02
BH - 5	4.02	26	80	60	BDL	0.009	BDL	0.005	BDL	0.019
BH - 6	4.42	27	60	40	0.002	0.013	BDL	BDL	BDL	0.025
BH - 7	3.89	27	210	150	0.005	0.013	BDL	BDL	BDL	0.108
BH - 8	6.45	27.5	40	31	0.008	0.019	BDL	BDL	BDL	0.027
BH - 9	4.31	28	160	110	0.002	0.045	BDL	0.003	BDL	0.063
BH - 10	4.23	27	200	140	0.004	0.021	BDL	BDL	BDL	0.033
UW - 1	6.01	26.5	275	140	0.019	0.057	BDL	BDL	BDL	0.015
UW - 2	4.08	27	340	170	0.013	0.085	BDL	BDL	BDL	0.012
UW - 3	6.51	28	530	280	0.009	0.151	BDL	BDL	BDL	0.009
UW - 4	5.9	28	880	650	0.025	0.102	0.005	BDL	0.004	0.013
Uw - 5	6.38	28	250	190	BDL	0.007	BDL	BDL	BDL	0.027
UW - 6	6.53	28	370	280	0.017	0.005	BDL	BDL	BDL	0.095
UW - 7	7.01	27	630	470	0.013	0.134	0.002	BDL	BDL	0.011
WHO Standard	6.5-8.4	>40	500	500	0.4	2	0.01	0.05	0.01	3
NIS Standard	6.5-8.5	Ambient	1000	500	0.2	1	0.01	0.05	0.01	3

Below detection level (BDL): this refers to values below equipment detection limit (i.e.<0.001)

Interpretation and Discussion

Hydrogen Potential (Ph)

The groundwater quality data for the study area is presented in Table 4. The hydrogen-ion concentration (pH) of the groundwater in the study area ranges from 3.89 – 7.01. The ground water in most parts of the Niger Delta Region has been found to be generally Acidic (UDOM, et al., 1999); this acidity in the groundwater has been attributed partly to gas flaring in the area. (WHO, 2006)and (NIS, 2007) stipulate the ground water with pH in the range of 6.5 –

8.5 is good for domestic use. All samples except UW-3, UW-6 and UW-7 fell below the stipulated limit of 6.5.

Electrical Conductivity (EC)

Electrical conductivity (EC) of the groundwater samples ranged from 40 µS/cm to 880µS/cm, with a mean of 303.11 µS/cm. EC is a measure of salinity, which greatly affects the taste and hence user's acceptance of the water for drinking. Table 4. shows that 100% of groundwater samples taken from boreholes were within the maximum permissible limits of 1000µS/cm for (NIS, 2007); however three out of the Seven well samples taken (UW–3, UW–4 and UW-7) had conductivity values greater than the WHO permissible limits with UW-4 having the highest conductivity value. No sample collected had conductivity value above the NIS Standard for drinking water of 1000 µS/cm.

Total Dissolved Solids (TDS)

This is a quantitative measure of the sum of organic and inorganic solutes in water. The samples collected had TDS concentrations ranging of from 31 – 650mg/l and a mean concentration of 201.29. This implies that groundwater in the area is quite fresh in all locations and is below the (WHO, 2006) and (NIS, 2007), stipulated value of 500mg/l except in the UW – 4 sample where the maximum TDS of 560mg/L was recorded. However by the classification of TDS by (NADAGOUDA, et al., 2012) all samples are permissible for drinking as seen from table 5 below.

Table 5: Classification Based on Total Dissolved Solids (NADAGOUDA, et al., 2012)

TDS	WATER CATEGORY	NO OF SAMPLES
UPTO 500	DESIRABLE FOR DRINKING	16
500 - 1000	PERMISSIBLE FO DRINKING	1
UPTO 3000	USEFUL FOR IRRIGATION	0
ABOVE 3000	UNFIT FOR DRINKING AND IRRIGATION	0

Graphical Representation of Analysis

Manganese (Mn):

The minimum and maximum Manganese concentrations varied between >0.001 and 0.025 Mg/L. All selected sample concentrations were less than the maximum (0.2 Mg/L) WHO quality. Measurable concentrations values are shows in Table 4 & 5, the comparison levels of Manganese in study area is shown in Fig 2.
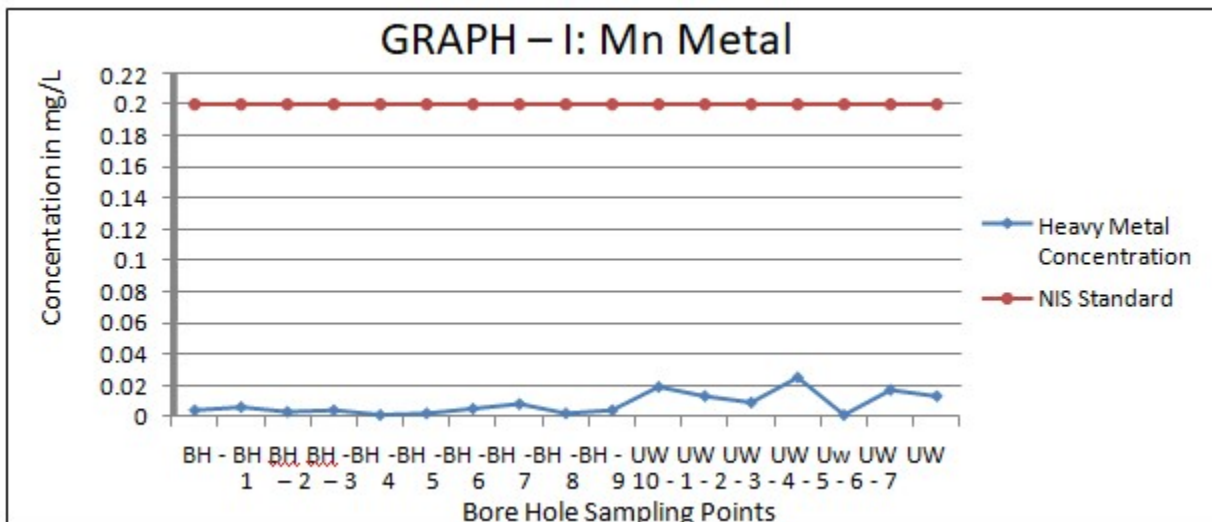

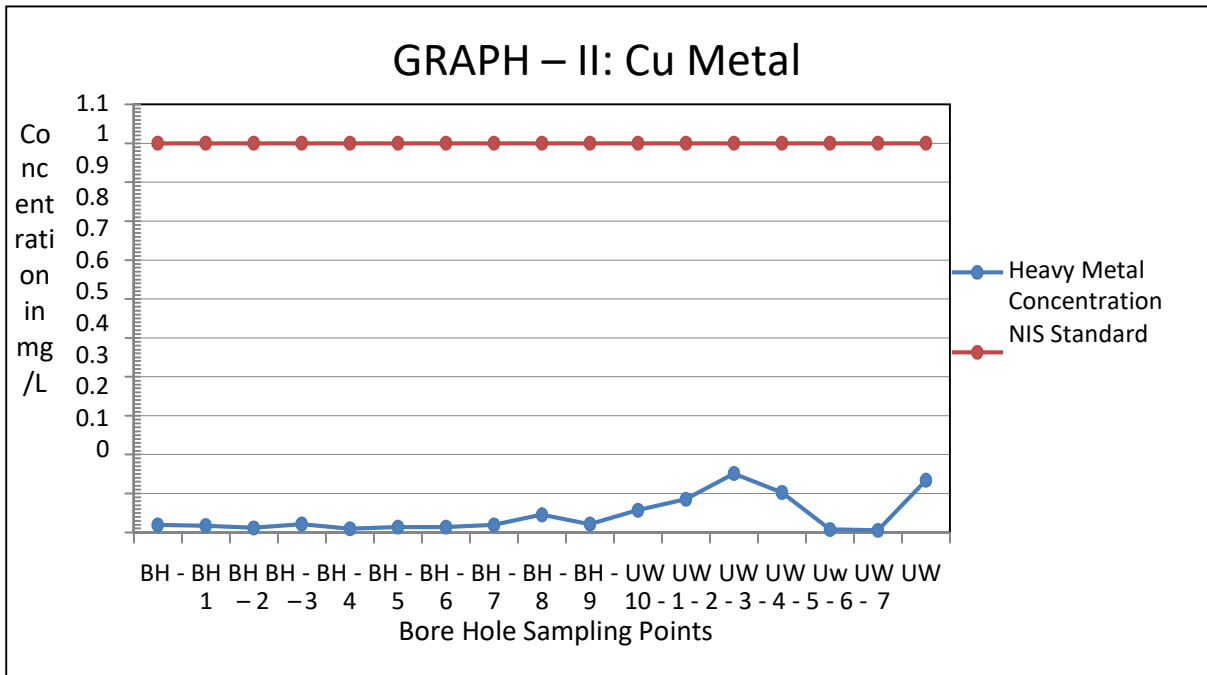Figure 2: Mn concentration plotted against NIS (2007) Standard

Figure 3: Cu concentration plotted against NIS (2007) Standard

Lead (Pb):

The minimum and maximum Lead concentrations varied between 0.019 and 0.083 Mg/L. All selected sample concentration is higher of the maximum (0.01 Mg/L) WHO quality. Measurable concentrations values are shows in Table 4 & 5 the comparison levels of Lead in study area is shown in Fig 4.
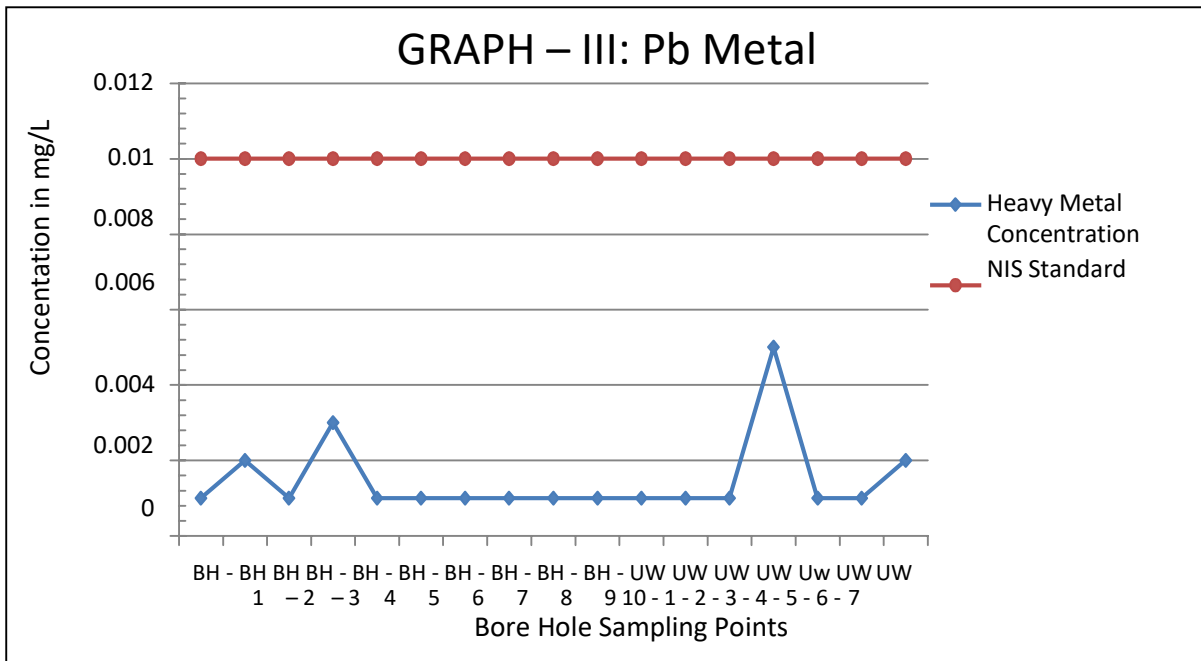

Figure 4: Pb Concentration Plotted Against NIS (2007) Standard Chromium (Cr):

The minimum and maximum concentrations of Chromium were 0.001 to 0.007 mg/L respectively. Chromium concentration levels in all studied samples were allowable in comparison to the NIS Standards. The concentration levels of chromium in all the samples are shown in Tables 4 & 5 and the comparison levels of chromium in study area is shown in Fig 5
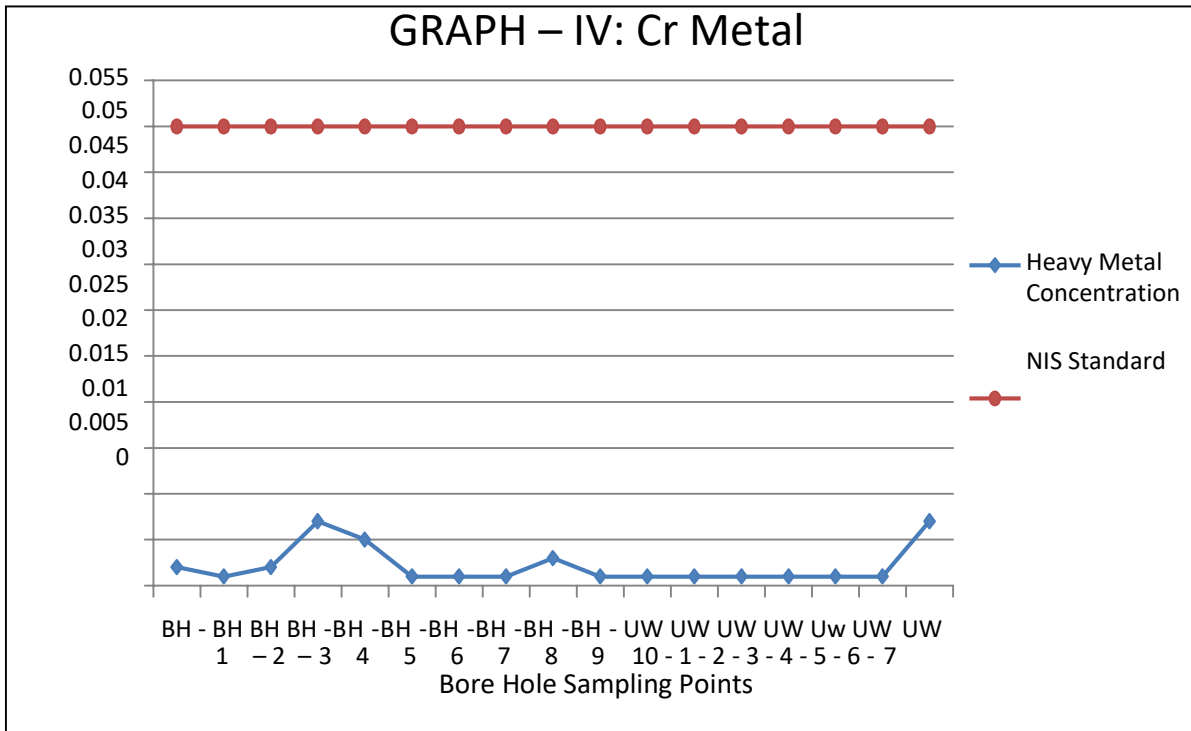
Figure 5: Cr Concentration Plotted Against NIS (2007) Standard

Histogram for Heavy Metal Concentrations

Two distinct trends were observed in the concentrations of heavy metals in the borehole samples collected. For samples collected from boreholes heavy metal concentration followed the general trend of Zn>Cu>Mn>Cr>Pb>As although some local variation was observed with Cr>Mn in BH – 4 and BH – 9 and Cu> Zn in BH – 4.
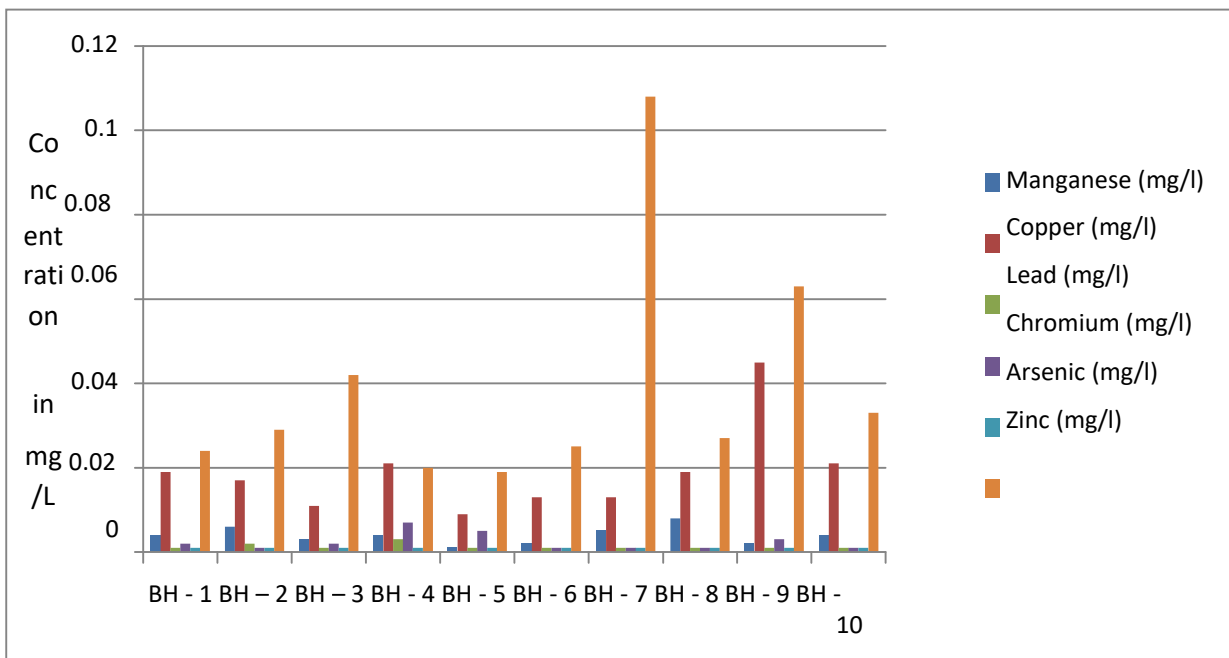

Figure 6: Histogram of Heavy Metal Concentrations in Borehole Samples

For samples collected from Uncased Wells, heavy metal concentration followed the general trend of Cu>Mn>Zn>Cr>Pb>As.
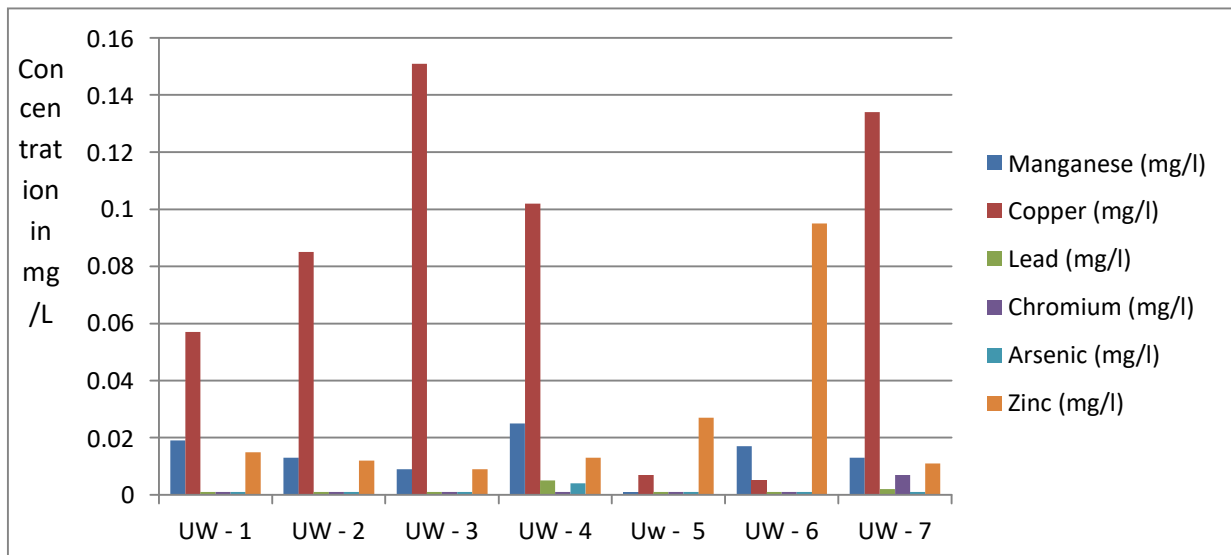
Figure 7: Histogram of Heavy Metal Concentration in Uncased Well Samples

Descriptive and Multivariate Analysis

Descriptive Analysis

Skewness values indicate that metal elements were positively skewed towards the lower concentrations, as can also be confirmed by the fact that the median concentrations of these metals are much lower than their mean concentration. It seems that, based on their variation coefficients (VCs), the examined elements primarily fell between 0.6 and 1.0 with Copper being the only metal with a VC greater than 1.0. One would expect those elements dominated by a natural source to have low VCs, while the VCs of elements affected by anthropogenic sources to be quite high.

Table 6: Heavy metal concentrations of water samples in the study areas (mg/L)

Heavy Metals	Range	Mean	Median	SD	VC	Skewness
Mn	0.01 - 0.025	0.008	0.005	0.0070622	0.882775	1.052422
Cu	0.009- 0.108	0.042882	0.019	0.0467077	1.089204	1.273133
Pb	0.001-0.005	0.001471	0.001	0.0010676	0.725962	2.46129
Cr	0.001-0.007	0.002177	0.001	0.0020987	0.964255	1.600228
As	0.001-0.004	0.001177	0.001	0.0007276	0.618445	3.75
Zn	0.009-0.108	0.033647	0.025	0.0287944	0.855777	1.640499

Correlation Coefficient Analysis (CCA)

Pearson's correlation coefficients of heavy metal elements in ground water in the study area are summarized in Table 4. From Table 4.Mn, Cu, Pb and As are significantly positively correlated which may suggest a relationship; though Pb and As seem to have a stronger correlation thus they can be presumed to be more related however the significance value is >0.01. Cu and Mn are also correlated with Pb and As while Cr is only positively correlated with Pb. Zn however is negatively correlated to with all the other heavy metals studied for this analysis reflecting a lack of relationship with the other heavy metals.

Table 7: Pearson's correlation matrix for the metal concentrations

	Mn	Cu	Pb	Cr	As	Zn
Mn		0.0186	0.1373	0.2822	0.1071	0.3097
Cu	0.5631*		0.1591	0.7392	0.1796	0.0021
Pb	0.3756	0.3573		0.2858	0.001	0.1813
Cr	-0.2768	0.0872	0.2748		0.526	0.528
As	0.4047	0.3416	0.7264**	-0.1653		0.3399
Zn	-0.262	-0.6921**	-0.3403	-0.1645	-0.2467	

The left lower part is correlation coefficient; the right upper part is significant level.

*P <0.05 (2-tailed).

** P <0.01 (2-tailed).

Multivariate Analysis

Principal Component Analysis (PCA)

Principal component analysis PCA was applied to assist in the identification of sources of pollutants. Table 8 displays the factor loadings with a VARIMAX rotation, as well as the eigenvalues. Three factors were obtained, accounting for 90.05% of the total variance. It was however observed that loadings in all Variables were relatively low falling within intermediate values between 0.32 and 0.71 with the second component being dominated by Cr at 0.8098 accounting for 10.53% of the variance and the lowest- 0.3111. Mn, Cu, Pb, and as loaded positively on component 1 confirming the result of the correlation matrix with Zn loading negatively as expected from its negative correlation with the other heavy metals. Cr is found to load heavily on the Component 2 which is also loaded negatively by Mn and Zn. This can be related to its negative correlation with all other variables except Pb. A source for the given variables could however not be delineated due to the intermediate loading of most of the factors observed. A plot of the different components against one another supports the results of the dendogram, with Zn and Cr showing low association with the other metals

Table 8: Rotated component matrix for data from ground water samples in study area

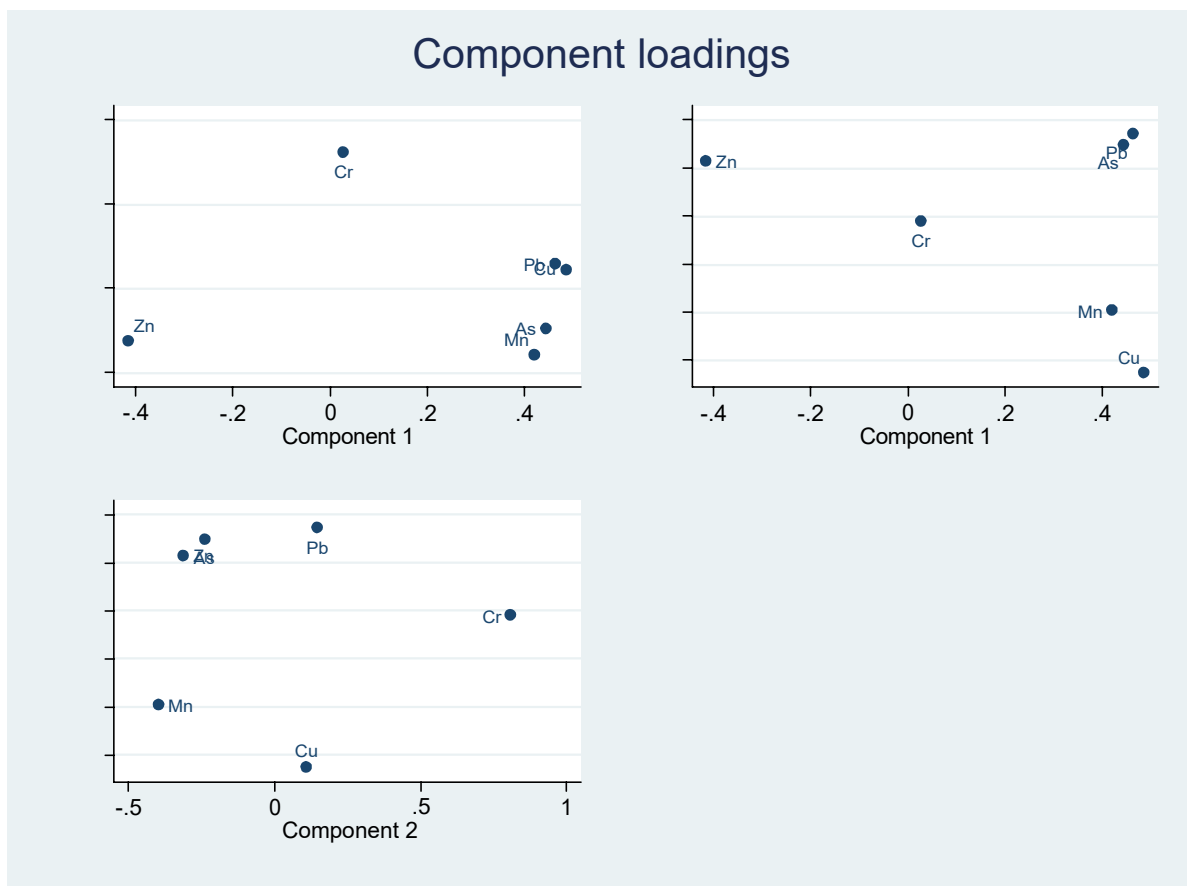| Variable	Comp1	Comp2	Comp3	Eigenvalue %of Variance	Cumulative %
Mn	0.4207	-0.3964		27.18	27.18
Cu	0.4869		-0.4505	12.17	39.35
Pb	0.4637		0.5443	7.074	46.24
Cr		0.8098		10.53	56.95
As	0.4448		0.4966	12.41	69.36
Zn	-0.4149	-0.3111	0.4304	20.69	90.05

Figure 8: Cross plot of the Factor Loading on Components 1, 2 and 3 Cluster Analysis (CA)

A Cluster Analysis was applied to the standardized bulk concentration data using Ward's method, with Euclidian distances as the criterion for forming clusters of elements. In general, this form of CA is regarded as very efficient, although it tends to create small clusters. Fig 9 displays two main clusters: (1) As–Cr;
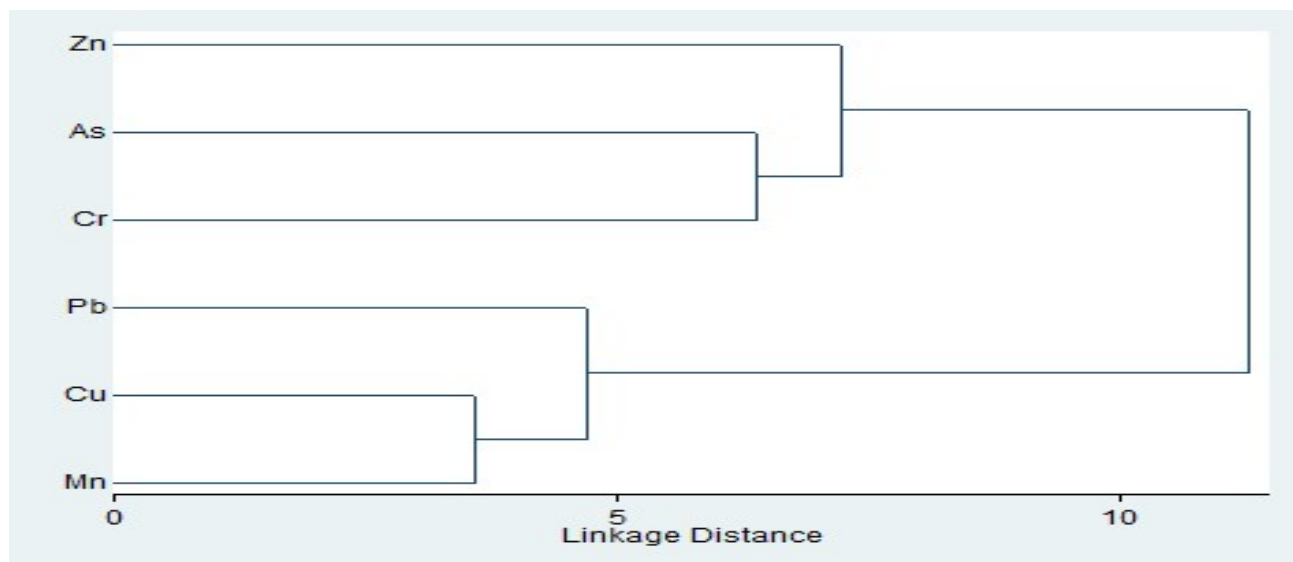

Figure 9: Hierarchical dendogram for 6 elements obtained by Ward's hierarchical clustering method (The distances reflect the degree of correlation)

IV. DISCUSSION

Heavy metal concentration in the study area is on the low side occurring in concentrations significantly lower than the WHO and NIS Standards as can be observed in plots of heavy metal concentrations against NIS Standard. A general trend of Zn>Cu>Mn>Cr>Pb>As was observed in bore hole samples and Cu>Mn>Zn>Cr>Pb>As in Uncased wells. The high Zinc concentration in Borehole samples and Copper in Uncased well water samples was distinct. While it is not clear the reason for the Cu concentration in Uncased Wells the elevated concentrations of Zn can be explained as being a result of piping and bore hole casing. A comparison of the Borehole and Well samples obtained from the same location in Shagolo (BH – 1 and UW – 1), showed that though Zn concentrations in the Borehole and well sample obtained were similar both having concentrations close to 0.2, the Cu concentration in the Uncased well sample was significantly higher inferring an anthropogenic source for Cu in the Uncased wells. A statistical analysis of the heavy metal concentrations also revealed that there was little or no anthropogenic contribution to the concentrations observed even as much as the Variance coefficient inferred that there was little or no contribution from human activity in all Heavy metals observed except Cu which had a variance coefficient slightly greater than 1.0. Mn, Cu, Pb and As positively correlated which may suggest a common origin; though Pb and As seem to have a stronger correlation thus a presumably more related origin however the significance value is very low falling below 0.01. Cu and Mn are also correlated with As while Cr is only positively correlated with Pb. Zn however is negatively correlated to with all the other studied heavy metals for this analysis reflecting a different source from the other heavy metals.

When the Correlation matrix is analysed alongside the PCA and the Hierarchical dendogram, the independence of the source of Zn is confirmed by its negative correlation with the other variables in the correlation matrix and its relatively high linkage distance. Cu and Mn are found to be associated with respect to source if the dendogram is assumed to confirm the positive relationship with the correlation matrix which assigns a low significance level to the relationship.

V. CONCLUSION

In conclusion, the ground water in the Uvwie LGA and environs appears to be relatively free from contamination with respect to the heavy metals of study. There does not appear to be a serious source of enrichment of the heavy metals Mn, Cu, Pb, Cr, As, and Zn within the study area though very localised sources may exist; evidence of this phenomenon is however not provided in this work

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