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MULTIVARIATE STATISTICAL ASSESSMENT OF TRACE METALS IN UNDERGROUND WATER CONSUMED IN CRUDE OIL AND NON-CRUDE OIL PRODUCING COMMUNITIES OF AKWA IBOM STATE, NIGERIA

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ABSTRACT

The study evaluated trace metals concentration and pollution of the underground water samples consumed in crude oil producing and non-producing sites of Akwa Ibom State, Nigeria. Multivariate statistical approaches were used to evaluate sources of the trace metal concentration in water samples assessed**.** Results obtained indicated three four components as a major source of trace metal load in the underground water from crude oil producing community tested with Eigen value greater than one and significant total variance of 97.11%. The first factor explained the total variance of 48.22 % with positive loading for Iron, Lead, and Cadmium. Also, the principal component analysis of the underground water from the non-producing locations revealed four factors with Eigen Value greater than one and with a significant total variance of 96.67%.The first factor explained the total variance of 45.48 % with positive loading for Zn, Cu, Cr, and Cobalt. The study revealed that anthropogenic activities contributed to trace metal load in underground water samples tested from both study locations. The study revealed that lithogenic Iron content affected the underground water sources obtained from the crude oil producing and non-producing locations of Akwa Ibom State, Nigeria. The level of trace metal such as lead, cadmium, Vanadium, and Nickel was also significantly higher in the underground water samples consumed from the crude oil producing sites. This showed that the underground water samples from the crude oil production site as well as non-crude oil producing sites are not totally free from metal pollution. It is therefore not quite safe and suitable for human consumption since the underground water obtained is not treated to prevent trace metal infiltration.

KEYWORDS: PCA-Principal Component Analysis; Cluster Analysis; Underground Water; Trace Metal; Correlation Coefficient matrix

INTRODUCTION

Udosen *et al. (*2016) revealed that water is an essential component of the ecosystem which interfaces air, land and other abiotic components such as rock. As reported by Udosen *et al*. (2016) Over the years water pollution has become a problem due to the global increase in anthropogenic activities. Trace metal loads are not only serious environmental issues but has also become a potential source of underground water contaminants. This has negatively affected the quality of the underground water quality consumed in the crude oil-bearing as well as non-crude oil communities. The indiscriminate disposal of effluent coupled with unsustainable natural resources extraction has contributed to an increase in trace metal load within the environment. As stated by Adedosu *et al*. (2014) the soil act as the matrix to the effluent generated.

Akubugwu *et al*. (2011)) also mentioned that the trace metals released from the effluent are easily transported and accumulated in the soil as well as the underground water beneath the earth surface. Trace metal pollution is very detrimental to human growth and development (Alkarkhi *et al.*2009). It is non-biodegradable and cannot be destroyed as well as such when transferred into a human it can lead to severe irreversible health conditions.

Chinenyeze *et al*. (2015)) revealed that trace metal pollution of the underground water quality in the coastal communities of Nigeria has been on increase due to the extensive extraction of natural resources within these areas. As mentioned by Fataei *et al*. (2011) the tendency to increase metal load is obvious in view of the unsustainable extraction of natural resources within these areas. Ali *et al*. (2014) in their study of the underground water samples collected in the coastal communities of Nigeria indicated a high concentration of lead and Iron. Roozhaham *et al. (*2015) further mentioned that chromium and cadmium were also found in the underground water samples collected in the coastal communities of the south-south region of Nigeria. Through crude oil production activities had over the years contributed to an increase in the concentration of trace metals released into the environment. According to Kellow (2006) Other human activities and anthropogenic activities also contributed to the enhancement of trace metals load in the soil with its attendant effect on the groundwater quality.

The indiscriminate disposal of waste coupled with leachate from the waste dumpsite according to Yisa*et al*. (2016) also contributed to the enhancement of trace metal load in the underground water samples. Metal toxicity occurs when trace metal accumulates in humans leading to severe damage to vital organs in the body (Kellow, 2006). Metal toxicity according to Kellow (2006) could be acute, chronic depending on the concentration being exposed over time. Chronic toxicity is dangerous and could take a longer period to manifest (Kellow, 2006). While acute toxicity could manifest over the certain period. It is easy to identify and manage over time. The effect though could be dangerous but if identified on time such an effect could be reversed by isolating the victim from the source of exposure (Kellow,2006). Sekabira *et al*. (2010) further mentioned that metal exposure is dangerous to both adult and children.

Chibuike *et al.* (.2014)) revealed that trace metal and other obnoxious substances inherently enters the body through inhalation, ingestion and by contact with the skin. Yisa *et al*. (2016) opined that the fastest route of entry of obnoxious substances into the body is through ingestion. Ingested substances such as trace metals are easily transported through the bloodstream to the liver and kidney (Yisa *et al.*2016). Since trace metals are non-biodegradable the often remains stable in the body organ leading to the gradual decline in health due to effect caused on the vital organs in the body. According to Yisa *et al*. (2016), trace metal can also combine with other inorganic or organic substances leading to the product that are potentially dangerous to humans as well as animals. In free–state, trace metal are more stable and can easily mobilize to soil and plants as well as surface and underground water environment

As reported by Bam *et al. (*2014) underground water sample trace metal pollution is rampant depending on the geological formation and the available metal in the area. According to Bam *et al*. (2014), the mineral deposit often gets entangled and transported underneath the earth surface thereby contaminating the underground water quality. Hence the pollutants which cause the contamination of the underground water quality can occur naturally due to mineralization and due to industrial effluents generated and dispose indiscriminately into the soil environment.

Therefore, a multivariate statistical analysis was used to evaluate the sources of pollution of trace metal in underground water (Sekabira *et al.*2010). The multivariate approaches which involve the application of principal component and cluster analysis are modern tools used to evaluate pollution (Saha and Hossain,2012). It is significantly used to identify water pollution sources and distinguish between the internal versus anthropogenic contribution (Yisa *et al*.2016).

Hence the study with the focus on trace metals load in underground water was undertaken in view of increase in industrial activities within the study area. There is that tendency of trace metal mobilization and transportation from the soil into the underground water surface in view of increase in anthropogenic activities around this area. This could enhance the trace metal load in the water within the area. Therefore, the study was focused on trace metal concentration with the view of evaluating the possible sources of trace metal pollution using multivariate approaches.

Study Area

The study was conducted in Esit Eket Crude oil-producing area. Nsit Ibom also was selected as the non-producing community for this study. Esit Eket is one of the Local Government Areas in Akwa Ibom State Nigeria where crude is abundantly processed and transported. Currently, crude oil production is done both onshore and offshore within the specific locations of Esit Eket Local Government Areas of Akwa Ibom State, Nigeria. The Non-Producing community is an area not affected by crude oil production activities. The area also had no crude oil production well and no gas being flared within the non-producing area selected for the purpose of this study.

Experimental Design

A single factor in randomized block sampling design was utilized for this study. In this case, five areas affected by crude oil-related activities were randomly selected. Three areas strongly affected by crude oil-related activities were selected in the five areas randomly selected. Water samples collected from underground water sources randomly from the three study sites in triplicate. Also, at the non-crude oil-bearing community of Nsit Ubium, three areas were selected randomly and water collected randomly from the three study sites. Water samples collected were all stored in sterile plastic sample containers and stored inside cooler with labels and taken to the laboratory for trace metal analysis.

Water Sampling and Laboratory Analysis

A sterile container originally washed with HCl was used for the collection of the water samples. The underground water from three selected borehole in crude oil and non-crude oil producing communities were flushed for three minutes. The sample containers then raised and the water sample collected directly into the container. The sample containers were properly labeled into the cooler and transported to the laboratory for analysis. The concentration of the metals present in each was assessed using HACH3900 model Spectrophotometer using ten 10mls of water samples with the relative powder pillows. Dilution factors applied to the results when the concentration was noticed high

Statistical Analysis

Regression coefficient, principal component analysis, and multivariate agglomerate hierarchal cluster analysis were employed to analyze the trace metal properties of the underground water samples collected from designated study sites. The similarities between trace metals in the water samples measured through the application of cluster analysis. The sources of trace metals determined using the principal components analysis. The level of the correlation coefficient between trace metals in water measured at $p<0,05$, $p<0.01$ to determine the relationship between the trace metals in the underground water at the studied sites according to Kellow (2006).

RESULTS AND DISCUSSIONS

UNDERGROUND WATER QUALITYFROM CRUDEOIL PRODUCING AREA

Pearson Correlation Matrix

Correlation matrix in table 1 shows that most of the trace metals correlated with one another either positively or negatively, but also insignificant at $P< 0.05$ as indicated by their r values in table 1. However, strong positive correlation existed between Fe and C0 at $P<0.01$ with r -value of 1.00. Consequently, the present of Fe in the water sample from crude oil-bearing community soil may have lead to the increase in the concentration of cobalt at the water. Fe also correlated positively and insignificantly with Mn**,** Cd, and Cr. Thus, an increase in Fe may lead to the corresponding decrease in Cd, Cr, Mn content of the underground water of the study site. Mn showed positive and significant correlated with Cd at $P\leq0.05$ with r -value 0. 886. Hence increase in Mn may cause a corresponding increase in Cd content of the underground water sample from the crude oil-bearing community of Esit-Eket, Akwa Ibom State, Nigeria. Copper correlated positively and insignificantly with Cr, Co, and CD. While Cr showed positive but insignificant correlation with Co. Therefore, increase in copper and Chromium may lead to a decrease in the concentration of Cr, Co, Cd in the studied underground water quality from crude oil producing community. However, Pb correlated negatively but significantly with V at $P\leq0,05$ with r -value of -0.812. Therefore increase in Pb may cause thecorresponding increase in the level of V in the underground water sample from the studied water sample of Esit Eket Akwa Ibom State, Nigeria. Nevertheless, the availability of other trace metals in the studied water sample may have influenced the availability of the other negatively but insignificantly and therefore their concentration may be affected by variable factors (Tijjani *et al*.2013).

Principal Component Analysis

The results of the principal component analysis of trace metals in the underground water sample from Esit Eket Akwa Ibom State, Nigeria are as shown in table 2. Results obtained indicated four main components (Table 3) with Eigenvalue greater than one and significant total variance of 97.11% (Table 2). Factor one contributed total variance of48.22% with strong positive correlation with Iron, Chromium, Cadmium, Cobalt, and Copper but with negative loading for Zinc. This represented the impact of the trace metal in the water was influenced by anthropogenic activities caused by human factors within the area. Factor two contributed total variance of 18.58 % with strong positive loading on lead and negative loading on Vanadium this represented the impact of agricultural effluent and natural process in the water sample of the Esit-Eket Crude oil producing community. Factor three accounted for total variance of 17.59 % and defined strong loading for Copper, Nickel, and Zinc. This represented the impact of other industrial effluent and natural process within the studied soil sample. Factor four accounted for total variance of 12.71% and defined strong loading for Zn this however, represented the effect of industrial effluent and waste leachate on the underground water sample from the studied locations.

Cluster Analysis

The association among the trace metals in the water sample soil is illustrated in figure 2. Figure 2 shows two main clusters. Clusters showed were based on Wards method of extraction. Cluster 1 showed the linkage between Co, V, Ni, Cr, Cd, Pb. While cluster two shows a linkage between Mn, Cu, and Zn. Both Cluster 1 and 11 formed lithogenic leakage with Iron. Indicating that these metals are regarded as contaminants which originated from mixed anthropogenic and lithogenic origin. Therefore, Co, V, Ni, Cr, Cd, Pb, Mn, Cu, Zn, and Fe could be regarded as the contaminant that originated from mixed anthropogenic and lithogenic sources in view of the similarities showed by these metals with Iron. As such may be regarded as contaminant originated from the same geological origin and formation. The relationship as shown in cluster confirms the findings obtained in the Principal component analysis.

A plot of the major principal components of PCA resulted in four different plots (figure 1). The plot 1 showed very strong positive loading for Fe, Cd, Cr, Co, Cu which is actually similar to factor 1(Figure 1). Plot two however, showed strong positive loading for Pb similar to factor two. Plot three of the cluster showed positive loading for Nickel, Zinc, and copper which is similar to factor three (Figure 1). Plot four showed positive loading for Zinc which is similar to factor four. Others showed a negative relationship with no factor loading for any other trace metals as showed in the plots. As such the relationship and similarities among other trace metals drafted towards zero as shown in figure 2.

Table 1: Correlation Matrix of trace Metal in Underground Water Crude Oil Producing Area

Correlations										
	Fe	Mn	Zn	Cu	Cd	Cr	Pb	Co	Vi	Ni
Fe	1.000			.	.	.			.	
Mn	.657	1.000								
Zn	-.543	-.657	1.000							
Cu	.543	.771	-.314	1.000						
Cd	.771	.886*	-.771	.771	1.000					
Cr	.714	.657	-.143	.486	.600	1.000				
Pb	-.200	.143	.200	-.086	.029	.486	1.000			
Co	1.000**	.657	-.543	.543	.771	.714	-.200	1.000		
Vi	.406	.058	.058	.464	.116	-.058	-.812*	.406	1.000	
Ni	-.200	.371	.200	.257	-.086	.143	.200	-.200	.000	1.000
**. Correlation is significant at the 0.01 level (2-tailed).										
*. Correlation is significant at the 0.05 level (2-tailed).										

Table 2: Principal Component Analysis Underground Water Crude Oil Producing Area

Total Variance Explained									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.823	48.232	48.232	4.823	48.232	48.232	4.342	43.417	43.417
2	1.858	18.576	66.808	1.858	18.576	66.808	1.841	18.408	61.825
3	1.759	17.587	84.394	1.759	17.587	84.394	1.768	17.676	79.501
4	1.271	12.711	97.106	1.271	12.711	97.106	1.760	17.605	97.106
5	.289	2.894	100.000						
6	3.144E-16	3.144E-15	100.000						
7	7.302E-17	7.302E-16	100.000						
8	3.044E-19	3.044E-18	100.000						
9	1.582E-16	1.582E-15	100.000						
10	2.372E-16	2.372E-15	100.000						
Extraction Method: Principal Component Analysis.									

Table 3: Extraction Method: Principal Component Analysis Underground Water Crude Oil producing Area

Component				
	1	2	3	4
Fe	.916	-.155	-.156	.335
Cd	.892		-.191	.353
Cr	.881	.393	.199	.159
Co	.876		-.254	
Mn	.837	.253	.331	-.331
Cu	.745	-.303	.571	.118

Table 3: Contd.,				
Vi	-.272	-.824	.472	.156
Pb	-.382	.810		.427
Ni		.413	.821	-.388
Zn	-.409	.111	.510	.721
a. 4 components extracted.				

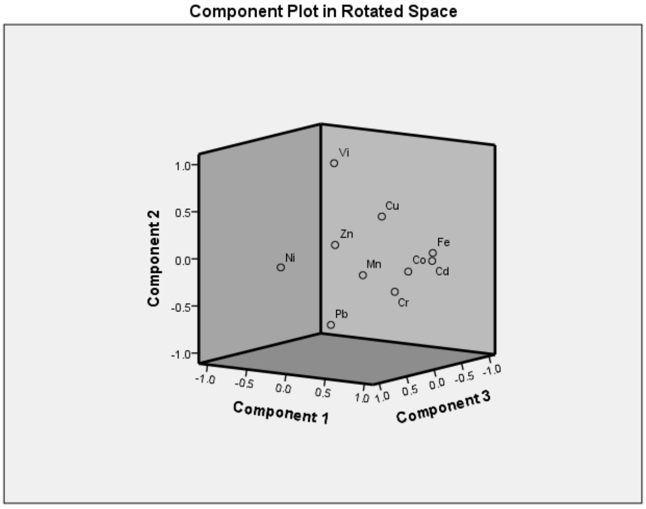

Figure 1: Principal Component Analysis Underground Water Crude oil Producing Area

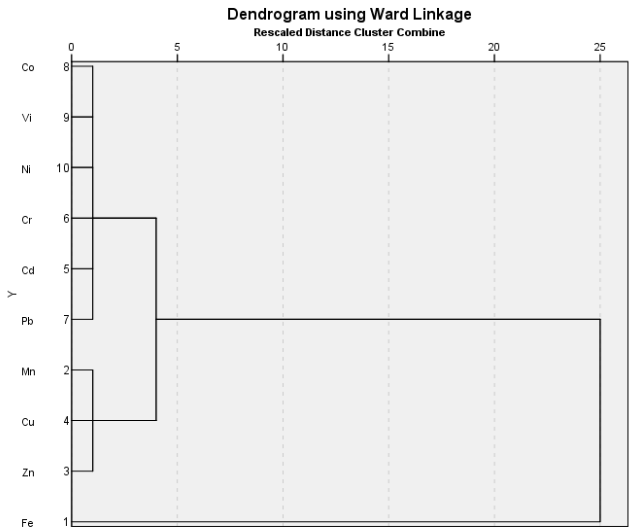

Figure 2: Hierarchical Cluster of Underground Water Crude Oil Producing Area

UNDERGROUND WATER QUALITYFROM Non-CRUDEOIL PRODUCING AREA

Pearson Correlation Coefficient Matrix

Correlation matrix in table 4 shows that most of the trace metals correlated with one another either positively or negatively, but also insignificant at P< 0.05 as indicated by their r -values in table 4. However, strong positive and insignificant **correlation existed** between Fe and Zn, Cu, Cr. Consequently, the present of Fe in the water sample from non- crude oil-bearing community selected for this study may not have any effect on Zn, Cr, Cu. Fe also correlated negatively and insignificantly with **T**hus an increase in Fe may lead to the corresponding decrease in V content of the underground water of the study site. Mn showed positive and insignificantly correlation with Cd with r-value 0657. Hence increase in Mn may not cause the corresponding increase in Cd content of the underground water sample from the non-crude oil bearing community of Nsit Ubium, Akwa Ibom State, Nigeria. Zinc correlated positively and significantly with Cr at P≤0.05 with r-value 0.829. While Zn also showed positive but insignificant correlation with Co and Therefore increase in Zn may lead to a decrease in the concentration of Co and V in the studied underground water quality from non-crude oil producing **c**ommunity. However, Cu correlated positively and significantly with Cr at P≤0,05 with r-value of 0.886. Therefore increase in Cu may cause the corresponding increase in the level of Cr in the underground water sample from the studied water sample of Nsit Ubium Akwa Ibom State, Nigeria. Chromium showed negative and significant correlation with V at P≤0.05 with r -value-0.926. Hence increase in chromium may lead to an increase in the level of vanadium in the underground water quality from Nsit Ubium Local government area study sites. Cobalt also showed negative and significant correlation with V at P≤0.05 with r-value -0.876. Nickel, however, showed no correlation with any of the trace metal in the underground water samples assessed in non-producing sites of Nsit Ubium study locations. Nevertheless, the availability of other trace metals in the studied water sample may have influenced the availability of the other negatively but insignificantly and therefore their concentration may be affected by variable factors (Tijjani *et al*.2013).

Principal Component Analysis

The results of the principal component analysis of trace metals in the underground water sample from Nsit Ubium Akwa Ibom State, Nigeria is as shown in table 5. Results obtained in table 5 indicated four main components with Eigen value greater than one and significant total variance of 96.67%. Factor one contributed total variance of 45.48% with strong positive correlation with Zinc, Copper, Chromium, Cobalt, and negative loading for cadmium(Table 6). This represented the impact of the trace metal in the water was influenced by anthropogenic activities caused by human factors within the area. Factor two (Table 6) contributed total variance of 25.67 % with strong positive loading on cadmium, Lead and negative loading on Vanadium this represented the impact of agricultural effluent and natural process in the water sample of the Nsit-Ubium non-crude oil producing community. Factor three accounted for total variance of 13.98 % and defined strong loading for Manganese (Table6). This represented the impact of other industrial effluent and natural process within the studied water sample. Factor four accounted for total variance of 11.54% and defined strong loading for Fe and negative loading on Cobalt as shown in table 6. This however, represented the effect of industrial effluent and waste leachate on the underground water sample from the studied locations.

Cluster Analysis

The association among the trace metals in the water sample soil is illustrated in figure 4. Figure 4 shows two main clusters. Clusters showed were based on Wards method of extraction. Cluster 1 showed the linkage between Co, V, Cr, Cd, Pb, Zn, Cu. While cluster two shows a linkage between Mn and Fe. Cluster 1 can be sub-divided into Co, V, Cr, Cd, Pb, Zn, Cu, and Cd, Pb, Zn, and Cu. This showed the similarities that existed between these trace metals. They are therefore regarded as contaminants that originated from anthropogenic activities. Mn in Cluster 11 as well as Cd, Pb, Zn, Cu in cluster 1 formed lithogenic leakage with Iron. Indicating that these metals are regarded as contaminates which originated from mixed anthropogenic and lithogenic origin. Therefore Mn, Cu, Zn, Pb, and Fe could be regarded as the contaminant that originated from mixed anthropogenic and lithogenic sources in view of the similarities showed by these metals with Iron. As such may be regarded as contaminant originated from the same geological origin and formation. The relationship as shown in cluster confirms the findings obtained in the Principal component analysis

A plot of the major principal components of PCA resulted in four different plots (figure 3). The plot 3 showed very strong positive loading for Zn, Cu, Cr, Co which is actually similar to factor 1(Figure 3). Plot two however, showed strong positive loading for Cd, Pb similar to factor two. Plot three of the cluster showed positive loading for Mn, which is similar to factor three (Figure 3). Plot four showed positive loading for Fe which is like factor four. Others showed a negative relationship with no factor loading for any other trace metals as showed in the plots. As such the relationship and similarities among other trace metals drafted towards zero as shown in figure 3.

Table 4: Correlation Matrix of Trace Metal from Underground Water from Non-Crude Oil Producing Area

Correlations										
	Fe	**Mn**	**Zn**	**Cu**	**Cd**	**Cr**	**Pb**	**Co**	**V**	**Ni**
Fe	1.000									
Mn	-.086	1.000								
Zn	.543	.143	1.000							
Cu	.600	-.486	.714	1.000						
Cd	-.200	.657	-.143	-.314	1.000					.
Cr	.600	-.371	.829*	.886*	-.371	1.000				.
Pb	.145	-.087	-.232	-.174	.232	.087	1.000			.
Co	.068	-.034	.778	.541	-.101	.778	.051	1.000		.
V	-.463	.185	-.802	-.648	.309	-.926**	-.266	-.876*	1.000	.
Ni	0.00.	0.00.	0.00.	0.00.	0.00.	0.00.	0.00.	0.00.	0.00.	1.000.
***. Correlation is significant at the 0.05 level (2-tailed).**										
****. Correlation is significant at the 0.01 level (2-tailed).**										

Table 5: Extraction Method: Principal Component Analysis of Trace Metal in Underground Water Sample Non-Producing Area

Total Variance Explained									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.093	45.478	45.478	4.093	45.478	45.478	3.683	40.924	40.924
2	2.311	25.679	71.157	2.311	25.679	71.157	2.328	25.870	66.793
3	1.258	13.976	85.133	1.258	13.976	85.133	1.377	15.298	82.092
4	1.038	11.537	96.670	1.038	11.537	96.670	1.312	14.579	96.670
5	.300	3.330	100.000						
6	1.721E-16	1.912E-15	100.000						
7	1.033E-16	1.148E-15	100.000						
8	-1.456E-16	-1.618E-15	100.000						
9	-2.088E-16	-2.320E-15	100.000						

Table 6: Total Component of Trace Metal Extracted

	Component			
	1	**2**	**3**	**4**
Fe	.454	-.414	-.304	.678
Mn	-.080	.398	.847	.332
Zn	.862	.182	.400	.195

Table 6: Contd.,				
Cu	.935	.016	-.234	.068
Cd	-.606	.686	-.240	.304
Cr	.970	.011	-.164	-.058
Pb	-.440	.789	-.374	.197
Co	.503	.622	-.017	-.528
V	-.713	-.684	.087	-.112

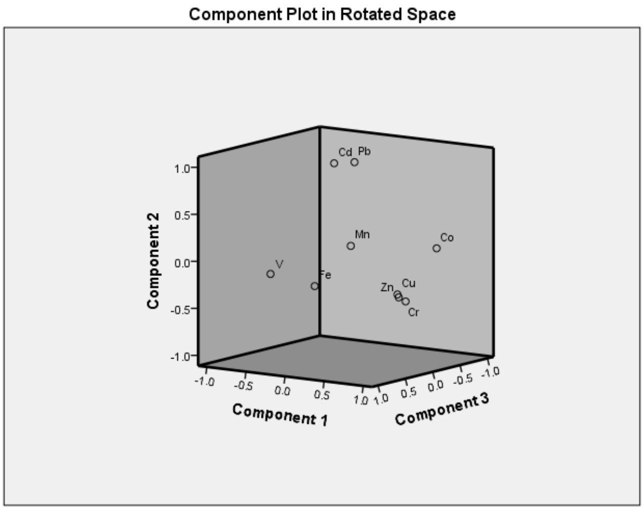

Figure 3: Principal Component Analysis Plot of Trace Metal in Non-Crude oil [Producing Area

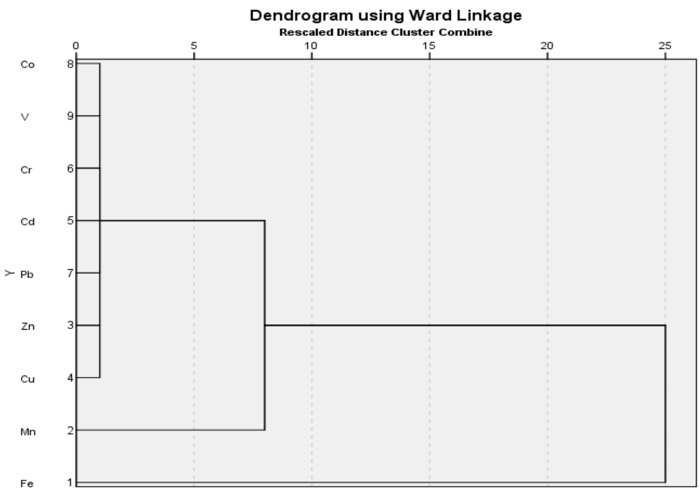

Figure 4: Cluster of Trace Metal in Underground Water from Non-Oil Producing Area

CORRELATION COEFFICIENT BETWEEN TRACE METAL IN CRUDE OIL and NON-CRUDE OIL UNDERGROUND WATER SAMPLES

The relationship between trace metal in the crude oil and non-crude producing underground water samples are as shown on Table7. Results revealed positive and negative relationships between the trace metals in crude oil and non-crude oil producing underground water samples. The results showed that Fe correlated positively and significantly with Copper at P≤0.05 with r -value 0. 886. Fe also correlated positively and insignificantly with Co and Ni with r values.600 and.794 respectively. Indicating that theincrease in Fe may cause the corresponding decrease in Co and Ni content of the underground water samples from the two study locations. Mn also correlated negatively and significantly with Zn at P≤0.05 with r -value -0. 886. The result showed that increase in Mn may cause the corresponding increase in the concentration of Zn content of the underground water samples from the two study locations. This finding is in line with () on their study on the effect of trace metal in the underground water sample from. Cu also correlated positively and significantly with Co at P≤0.05 with r -value 0.829. However, lead (Pb) showed correlated negatively and insignificantly with V and Ni with r values -706 and -600 respectively. Indicating that an increase in the lead may cause a decrease in V and Ni content of the underground water samples from the two study locations. Nevertheless, the availability of other trace metals in the studied water sample may have influenced the availability of the other negatively but insignificantly and therefore their concentration may be affected by variable factors (Tijjani*et al*.2013).

Table 7: Correlation Coefficient Between trace metal in Underground Water in Crude oil and Non-Crude oil Producing Areas

Correlations										
	Fe	**Mn**	**Zn**	**Cu**	**Cd**	**Cr**	**Pb**	**Co**	**Vi**	**Ni**
Fe	1.000									
Mn	.086	1.000								
Zn	.086	-.886*	1.000							
Cu	.829*	.371	-.200	1.000						
Cd	.429	.771	-.657	.600	1.000					
Cr	.371	.257	-.086	.771	.486	1.000				
Pb	-.657	-.029	.029	-.486	.086	.086	1.000			
Co	.600	.486	-.486	.829*	.829*	.714	-.143	1.000		
Vi	.794	-.265	.177	.441	.088	-.088	-.706	.353	1.000	
Ni	.086	.086	.029	.257	-.371	.143	-.600	-.200	-.088	1.000
*. Correlation is significant at the 0.05 level (2-tailed).										

CONCLUSIONS

The outcome of the multivariate analysis has shown that the pollution sources of the underground water samples from crude oil and non-crude oil producing locations soil are associated with anthropogenic and human-related activities within the study area. The increase in positive loading for trace metal for both the underground water samples from crude oil producing and non-producing communities could be detrimental to human being growth and development. This is because of the potential effect associated with bioaccumulation and translocation of these metals into the human body during the consumption of such water. Over time the toxicity concentration of those metals could exceed the permissible exposure limits thereby causing severe health consequences to humans. Hence since the concentration of are associated with mixed lithogenic and anthropogenic sources, there is a need for the treatment of this water to eliminate the metal contamination. Alterna- actively, multinational organization involves in crude oil exploration and processing should provide the treated source of potable water to prevent trace metal toxicity at the crude oil-bearing community of Esit Eket. At the non-producing location appropriate government agencies should repair the delipidated public water facilities and discourage people from drinking untreatable underground water sources. Also, a measure to combat underground water pollution, the following measures should be considered during drilling:

- Geological survey of the soil environment should be conducted to ensure the area is safe and suitable for underground water supply source.

- On discovering the water proper physicochemical analysis should be conducted to ascertain the free trace metal available in the water.
- Underground water should be treated to ensure such is safe and suitable for human consumption.
- A proper casing of the supply source should be done to avoid infiltration of contaminants from other sources.
- The underground water source should not be drilled close to waste dump site to prevent intermittent trace metal pollution.
- The underground water source should not be sited within the floodplain or closer to waste pit to prevent ingress of trace metal to the underground water source.
- Pipes attached to enhance the water supply from the underground source to the surface should be regularly checked for corrosion, wear, and tear.
- Proper maintenance culture should be maintained to ensure that water obtained is clear and suitable for human consumption.

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