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RESEARCH ARTICLE

Geo-statistics and heavy metal indexing of surface water around Okaba coal mines, Kogi State, Nigeria

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SUMMARY : Because of the role of surface water and indeed water in our daily lives, this research was carried out to evaluate the impact of coal mining. Consequently, ten (10) dry season water samples were collected and analysed for major ions, physiochemical and heavy metals. The data acquired were subjected to factor /cluster analysis. The heavy metals were further evaluated using anthropogenic factor (AF), heavy metal pollution index (HPI) and metal index (MI).The factor/cluster analysis suggested significant heavy metal inputs into the water due to coal mining and related activities. The relatively enhanced level of these heavy metals was also due to the acidic nature of the environment. NO_3 and SO_4 were also high for the same reason, particularly SO_4. AF result suggested higher input from mining with respect to all heavy metals, particularly Cd, Zn, Ni and Fe. The HPI though below the critical value of 100 was above the half mark while the MI implies water contamination.Geo-statistical and heavy metal indices key to data evaluation. Mining companies need to put in control measures to forestall surface water contamination. The communities and regulators also need to be sensible and responsible to what happens in their environment.

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Key **W**ords **:**
Okaba coal mines, Heavy metal indexing, Multivariate analysis, Anthropogenic factor

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Coal mining either by surface or underground methods has irreparable consequences on the environment if not properly executed (Chad, 2003). Surface and underground mining methods involve exploration for and removal of minerals from the earth. Mining ruins the land, water, forests and air. It can barren land, pollute water, denude forests, defile the air and degrade the quality of people that work and live in the area (Concas *et al.,* 2006) Associated with mining are physical, chemical and biological alterations of soil/sediment, alteration of drainage patterns, erosion and siltation of streams (Navarro *et al.,* 2008). Also associated with mining is heavy metal pollution of soil/sediment and water bodies (Eze and Chukwu, 2011). This study was carried out to evaluate the degree of contamination associated with coal mining on surface water around the coal mines.

Study area:

The coal measures found in Nigeria occur within the geological units represented by the Mamu Formation (Lower Maestrichtian) and the Nsukka Formation (Upper Maestritchtian to Danian) (Obianuju, 2005). Okaba coal mine is located in the Anambra Basin in eastern Nigeria. The area is underlain by two formations: the Mamu (Early to Late Maestritchan) and Ajali (Middle to Late Maestritchtian) Formations (Obaje *et al.,* 2000). The coal bearing sequence is found in Mamu Formation (Lower Maestrichtian). This Formation is underlain by Enugu shales (Campanian) and overlain by the false-bedded Ajali sandstones of Middle Maestrichtian age. Mamu Formation (Lower Coal Measures) consists of sandstone bands, mudstones, sandy shale/carbonaceous shale and coal measures at several horizons. The shales and mudstones often alternate with thin bands and lenses of siltstones (Offodili, 1976). Ajali Formation (False bedded sandstones) is made up of friable coarse-grained, white sandstones and sometimes iron stained. The Formation consists of gravelly

and coarse sandstone within the upper horizons and grades into medium, fine-grained at greater depths. Clay and coal units occur towards the bottom indicating transition between Ajali and Mamu formations (Offodili, 1976; Obaje *et al.*, 2000). Overlaying this formation is red earthy sands due to weathering and ferruginisation (Fig. A).

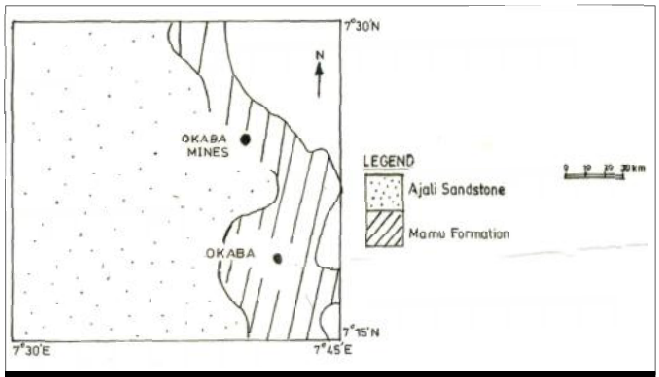

Fig. A : Geological map of study area (modified after Objanuja, 2005)

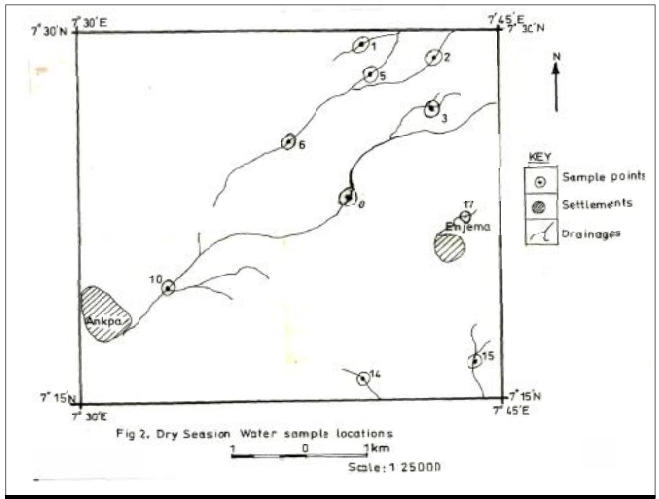

Fig. B : Sample location map of study area

EXPERIMENTAL METHODOLOGY

Grab sampling technique was used for surface water samples. Surface water was collected using stainless steel bucket sampler and Teflon lined PVC Niskin bottles (water sampler). Water samples were collected randomly, ensuring their fair distribution over the entire study area. Water samples were taken about a foot/mid depth below the surface 0- 15 cm) (APHA, 2002). Water sample bottles were acid soaked in dilute nitric acid before the analysis. New bottles and those used before were soaked and cleaned with strong metal-free acid, rinsed thoroughly first with tap water and then with distilled water. Finally, they were dried and stored in a clean place. On the field, all sample bottles were rinsed again with sample water before collection. The samples were collected by (filling a sample bottle pointing upward) rapid immersion in water and capping to minimize exposure to the atmosphere and air borne particulate matter (Sweat, 1999).

Upon collection of water samples, *in situ* measurement of conductivity, temperature, pH, and Tds were carried out using portable meters (APHA, 2002). Water samples were collected in two separate sets of sterilized polythene bottles: one for the determination of anions and the other acidified with dilute nitric acid to a pH of 1-2 and stored at 4 ^{0}C prior to analysis for cations and heavy metal determination. The samples were preserved and properly labeled polythene bottles with plastic stoppers were used. Filtration was done immediately after sample collection by vacuum at low pressure. Cellulose nitrate filter papers with pores of 0.45 micron in diameter were used. pH, temperature, conductivity and Tds were determined on unfiltered sub samples.

Analytical methods :

In situ measurements of temperature, pH, Tds and Ec were determined intrusively with their appropriate probes. Spectrophotometer (Model Genesys 20) was used to determine the concentrations of K, Na and Ca. Atomic absorption spectrophotometer (Model 210 VGP) was used to determine the concentrations of Mg, Pb, Zn, Ni, Cu, Cd, and Fe. All analyses were performed at Soil Science Deptartment, Faculty of Agriculture Lab., Kogi State University, Anyigba according to (APHA, 2002).

SPSS v 11.0 was used to perform all data analysis after performing auto-scaling for all parameters. Mathematically, PCA and PFA involve the following five major steps: code variables to have zero means and unit variance. calculate the covariance matrix find eigenvalues and corresponding eigenvectors discard any component that only account for small proportion of variation in data set and develop the factor loading matrix and perform varimax rotation on the factor loading matrix to infer the principal parameters (Pathak *et al.*, 2008; Yang *et al.*, 2009). In this study, only components or factors exhibiting an eigenvalues greater than one were retained. Component loadings were used to determine the relative importance of variables as compared to other variables in a PC and do not reflect the importance of the components (Lokhande *et al.*, 2008).

Hierarchical cluster analysis:

Cluster analysis was used to find the true groups of data. In clustering, objects were grouped such that similar objects fell into the same class. Hierarchical clustering joins the most similar observations and successively the next most similar observations. The levels of similarity at which observations are merged were used to construct dendrogram. In this study,

squared euclidean distance method was used to construct dendrogram. A low distance shows the two objects are similar or close together whereas a large distance indicating dissimilarity (Reghunath *et al.,* 2002).

Factor analysis:

The raw data were treated first with Z-scale transformation to make the data standardized. Multivariate data analysis was utilized to identify the correlations among the measured parameters. Principal component analysis was done to reduce the number of input variables. Spearman's correlation matrix was performed to illustrate the correlation coefficients among the variables (Reghunath *et al.,* 2002; Pathak *et al.,* 2008).

Heavy metal assessment of water:

Anthropogenic factor (AF) is quantification of the degree of contamination relative to either average crustal composition of the respective heavy metal or to measured background values from geologically similar and uncontaminated area. It is expressed as: AF = Cm/Bm where, Cm is the measured concentration in sediment or water and Bm is the background concentration (value) of heavy metal m, either taken from the literature (average shale/ average crustal abundance) or directly determined from a geologically similar area.

Metal index (MI) as proposed by Tamasi and Cini (2004) is: $MI = \Sigma [Ci / (MAC)i]$ where, MAC is maximum allowable concentration, C is the concentration of each element. The higher the concentration of a metal compared to its respective MAC value, the worst the quality of the water. MI value > 1 is a threshold of warning.

Heavy metal pollution index (HPI) is a method of rating that shows the composite influence of individual heavy metal on the overall quality of water. The rating is a value between zero and one, reflecting the relative importance of individual quality considerations and defined as inversely proportional to the recommended standard (Si) for each parameter (Reza and Singh, 2010). The calculation involves the following steps: first, the calculation of weightage of ith parameter; second, the calculation of the quality rating for each of the heavy metal; third, the summation of these sub-indices in the overall index.

The heavy metal pollution index (HPI) model is given by $\mathbf{HPI} = \frac{\sum_{i=1}^{n}(QiWi)}{\sum_{i=1}^{n} Wi}$

where, Qi is the sub index of the ith parameter, Wi = K/Si is the unit weightage of ith parameter taken as value inversely proportional to the recommended standard Si of the corresponding parameter and n is the number of parameters considered (i=1-6 in this study) (Reza and Singh, 2010; Bakan *et al.,* 2010). The sub index of the parameter is calculated by $Qi = \Sigma^{n}_{i=1}$ (Mi (-) Ii)/ (Si- Ii) where Mi is the monitored value of heavy metal of ith parameter, Ii, is the ideal value of ith parameter, Si is the standard value of ith parameter. The sign (-) indicates the numerical difference of the two values, ignoring the algebraic sign. The proposed index is intended for the purpose of drinking water. The critical pollution index value for drinking water is 100. The HPI value has been determined by taking the average value of heavy metals. It is used to study and compare variations of overall pollution level that include many parameters together and to assess overall pollution level with respect to heavy metals (Prasad and Kumari, 2008; Reza and Singh, 2010). Aggregation process is important in calculating any environmental index. Six functions were utilized to calculate an aggregated score (index score) for the sampled media.

EXPERIMENTAL FINDINGS AND DISCUSSION

It evident from Table 1 temperature varied from 25.40 - 27.00^{0}C with 26.15^{0}C mean. pH has a mean of 6.37 indicting acidic water. Tds varied from 1.80 - 1999.00 and has a mean of 886.38. Ec has a mean of 1.70, alkalinity 1.09, K 9.81 mg/l, Na 4.38 mg/l, Ca 6.42 mg/l and Mg 0.13 mg/l. Average order among major cations was K>Ca>Na>Mg. Cl has a mean of 0.73 mg/l, NO_3 8.27 mg/l and SO_4 3.99 mg/l. Average trend among major anions was $NO_3 > SO_4 >$ Cl. Fe ranged from 0.35 - 20.17 mg/l with a mean of 2.87 mg/l, Cu has a mean of 0.11 mg/l and ranged from 0.03 - 0.5 mg/l. Zn varied from 0.29 - 1.65 mg/l with a mean value of 0.85 mg/l. Pb has a mean of 0.54 mg/l and varied between 0.21 - 0.92 mg/l. Ni varied from 2.55 - 7.81 mg/l but has a mean of 4.13 mg/l and Cd varied from 0.40 - 0.87 mg/l with mean value of 0.57 mg/l. Ni > Fe > Zn > Cd > Pb > Cu was the average concentration trend among the heavy metals (Table 1).

pH correlated significantly with the anions, same for Tds and Pb. Ec also showed strong correlation with Cl and Pb. Among the cations, Ca correlated with K and Na. The relationship between NO_3 and SO_4; Fe and SO_4; Fe and Ni were also significant. These indicate some degree of affinity. Other parameters recorded moderate to weak correlation (Table 2).

R-mode varimax rotated factor analysis performed extracted three factors. Factor 1 has eigenvalue of 1.881 and total variance of 31.351%. Factor 1 is characterized by high factor loadings of Ni, Fe and weak loading of Pb. Factor 2 consists of Zn and Cd with eigenvalue of 1.521 and total variance of 25.345%. High, positive loadings of Cu and Pb were recorded in factor 3. This factor has eigenvalue of 1.458 and 24.304% total variance (Table 3).

The R-mode cluster analysis of the heavy metals extracted two clusters. Cluster 1 consists of Fe, Ni, Cu and Pb with Fe and Ni showing highest similarities. Cluster 2 is an association between Zn and Cd (Fig. 1).

Factor one in Q-mode factor analysis consists of pH, Tds, Ec, K, Ca, Mg and Cl with eigenvalue of 3.159 and total

Asian J. Environ. Sci., **8**(1) June, 2013: 1-8
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Table 1 : Okaba dry season water samples (mg/l) and descriptive statistics

Sample location	Temp. °C	pH	Tds	Ec	Alk	K	Na	Ca	Mg	Cl	NO_3	SO_4	Fe	Cu	Zn	Pb	Ni	Cd
OK01	26.70	3.50	1999.00	3.97	.01	3.80	5.64	8.50	.08	1.77	34.89	13.63	20.17	.06	.78	.90	7.05	.43
OK02	26.80	6.40	1999.00	3.49	.10	18.00	6.23	10.75	.06	1.77	7.05	6.62	1.05	.08	.69	.83	7.81	.62
OK03	25.50	7.70	1999.00	3.26	.10	18.90	6.58	10.73	.03	.33	9.15	1.63	1.33	.09	1.65	.71	2.60	.87
OK05	26.50	7.40	202.00	.28	1.8	9.40	6.45	9.75	.02	.04	2.68	2.81	.35	.06	.36	.29	4.90	.70
OK06	25.50	5.80	40.00	.05	.30	9.00	2.67	2.25	.12	.04	7.31	6.29	.60	.09	.29	.49	3.37	.54
OK08	26.50	5.30	1999.00	3.60	.10	11.60	2.29	5.75	.08	1.77	1.84	.98	.80	.50	.40	.92	2.55	.40
OK10	25.90	7.40	532.00	.05	6.2	3.80	.44	2.75	.07	.05	4.42	2.68	.37	.03	1.29	.56	4.10	.47
OK15	27.00	7.20	1.80	.02	.60	3.00	4.26	.50	.21	.03	4.15	.45	.45	.06	.87	.24	3.11	.56
OK14	25.70	7.50	42.00	.06	.80	8.50	4.10	5.10	.50	.04	5.15	2.82	1.29	.04	.79	.21	2.60	.45
OK17	25.40	5.50	50.00	2.18	.98	12.14	5.18	8.16	.10	1.50	6.05	2.01	2.31	.08	1.37	.25	3.25	.61
Min	25.40	3.50	1.80	.02	.01	3.00	.44	.50	.02	.03	1.84	.45	.35	.03	.29	.21	2.55	.40
Max	27.00	7.70	1999.00	3.97	6.15	18.90	6.58	10.75	.50	1.77	34.89	13.63	20.17	.50	1.65	.92	7.81	.87
Mean	26.15	6.37	886.38	1.70	1.09	9.81	4.38	6.42	.13	.73	8.27	3.99	2.87	.11	.85	.54	4.13	.57
Std Dev.	.61	1.35	969.36	1.75	1.86	5.57	2.05	3.71	.14	.84	9.61	3.95	6.11	.14	.46	.29	1.89	.14
Cp	27.00	7.30	127.00	0.84	0.48	3.12	0.34	0.22	0.07	0.03	7.13	0.17	1.02	0.06	0.02	0.22	1.42	0.01

* Cp = Control point

Table 2 : Okaba dry season water correlation coefficient

	Temp.	pH	Tds	Ec	Alk	K	Na	Ca	Mg	Cl	NO_3	SO_4	Fe	Cu	Zn	Pb	Ni	Cd
Temp.	1.000																	
pH	-.199	1.000																
Tds	.310	-.376	1.000															
Ec	.208	-.580	.903	1.000														
Alk	-.161	.380	-.329	-.493	1.000													
K	-.271	.183	.469	.514	-.418	1.000												
Na	.176	-.019	.262	.405	-.594	498	1.000											
Ca	-.001	-.117	.576	.668	-.321	705	.768	1.000										
Mg	-.152	.235	-.449	-.437	-.104	-.276	-.161	-407	1.000									
Cl	.299	-.749	.665	.866	-.405	305	.226	.488	-.324	1.000								
NO_3	.193	-.709	.432	.490	-.258	-.250	.291	.257	-.129	.410	1.000							
SO_4	.226	-.708	.370	.387	-.222	-.180	.221	.255	-.149	.416	.885	1.000						
Ff	.265	-.766	.407	.494	-.237	-.331	.250	.238	-.102	.474	.978	.849	1.000					
Cu	.169	-.308	.438	.440	-.283	208	-.236	-007	-.178	.469	-.227	-.253	-.127	1.000				
Zn	-.429	.271	.096	.160	.231	206	.113	.187	-.079	-.050	.062	-.242	-.002	-.340	1.000			
Pb	.292	-.515	.934	.807	-.205	297	-.008	.366	-.508	.652	.454	.478	.430	.495	-.071	1.000		
Ni	.547	-.402	.420	.397	-.053	034	.381	.456	-.361	.484	.547	.753	.526	-.287	-.212	.445	1.000	
Cd	-.245	.492	.074	.079	-.159	635	.649	.532	-.398	-.249	-.195	-.276	-.310	-.319	.431	-.140	-053	1.000

variance of 31.588%. Factor 2 is characterized by high factor loadings of pH, NO_3 and SO_4 with weak loading of K. It has eigenvalue of 2.862 and total variance of 28.619%. Factor 3 has eigenvalue of 2.270 and 22.703% total variance. Factor 3 consists of high positive factor loadings of Na, Ca and moderate loading of K (Table 4).

The R-mode cluster analysis extracted three clusters. Cluster 1 is an association of Tds, Ec, Cl, Na, Ca and K. Na, Ca and K are linked to this cluster at a farther Euclidean (Fig. 2). Clusters 2 and 3 are made up of NO_3, SO_4 and pH, Mg, respectively.

AF =Cm/Cp: Cm = measured concentration; Cp = control point concentration.

The anthropogenic factor (AF) calculated using average heavy metal concentrations revealed the following percentages: Cd 98.26%, Zn 97.70%, Ni 74.43%, Fe 73.79%, Pb 71.05% and Cu has the lowest AF of 64.50%. AF trend of Okaba dry season water samples was Cd > Zn > Ni > Fe > Pb > Cu (Table 5 and Fig. 3).

The HPI of Okaba dry season water samples was 56.21

Table 3 : R-mode varimax rotated factor analysis of heavy metals

Variables	Factor			Communalities
	1	2	3	
Fe	.839	-.104	.088	.723
Cu	-.313	-.335	.867	.962
Zn	-.027	.857	-.062	.739
Pb	.527	.041	.819	.950
Ni	.883	-.080	-.062	.790
Cd	-.144	.810	-.142	.696
Eigenvalue	1.881	1.521	1.458	
% total variance	31.351	25.345	24.304	
Cumulative %	31.351	56.696	81.000	

Table 4: R-mode varimax rotated factor analysis of major ions and physiochemical

Variables	Factor			Communalities
	1	2	3	
pH	-.475	-.778	.201	.872
Tds	.810	.230	.269	.782
Ec	.854	.321	.336	.944
K	.503	-.423	.653	.858
Na	.034	.178	.931	.900
Ca	.457	.086	.834	.911
Mg	-.634	.019	-.098	.412
Cl	.806	.392	.089	.811
NO_3	.135	.942	.151	.929
SO_4	.127	.916	.127	.872
Eigenvalue	3.159	2.862	2.270	
% total variance	31.588	28.619	22.703	
Cumulative %	31.588	60.206	82.910	

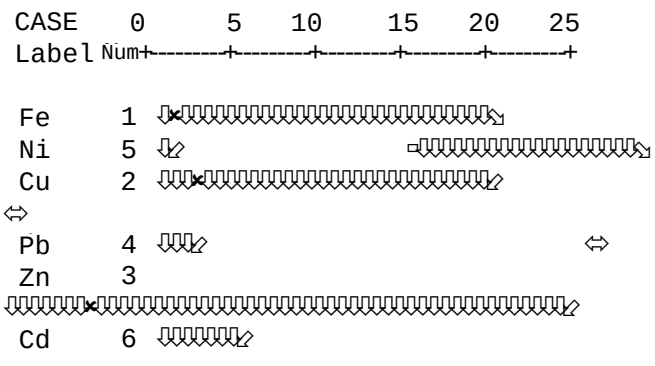

Fig. 1 : R-mode cluster analysis of heavy metals

Fig. 2 : R-mode cluster analysis of anions and physiochemical

Table 5: AF of Okaba dry season water samples.

Heavy	Mean	Cp	AF	AF %	Geogenic
Metals (mg/l)	Value	Value	Value		%
Fe	2.872	1.02	2.84	73.79	26.21
Cu	0.109	0.06	1.82	64.50	35.50
Zn	0.849	0.02	42.45	97.70	2.30
Pb	0.54	0.22	2.45	71.05	28.95
Ni	4.134	1.42	2.91	74.43	25.57
Cd	0.565	0.01	56.50	98.26	1.74

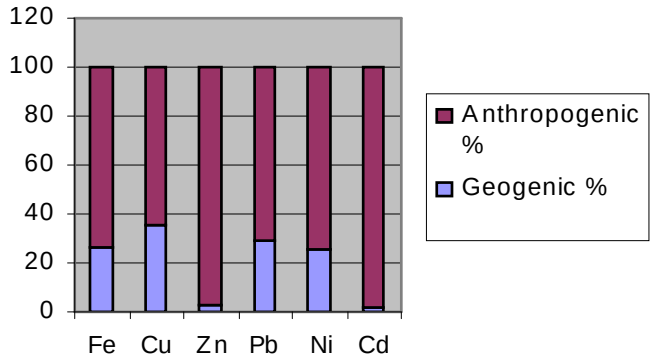

Fig. 3 : AF of Okaba dry season water samples

(Table 6). This is above the half mark of the critical pollution index value of 100 (Prasad and Kumari, 2008; Reza and Singh, 2010). Metal indexing (MI) also was 460.46 (Table 7). Values of MI>1 is a threshold of warning (Bakan *et al.*, 2010; Al-Oud *et al.*, 2011).

The major cations and heavy metal trends in Okaba dry season water were: K (9.81) > Ca (6.42) > Na (4.38) > Mg (0.13) and Ni (4.13) > Fe (2.87) > Zn (0.85) > Cd (0.57) > Pb (0.54) > Cu (0.11). The average pH of the dry season water was 6.37. This is attributable to the presence of pyrite, sulphide minerals which are reactive to atmospheric oxygen and water under humid conditions. The initial products of oxidation are ferrous and ferric sulphates, suphuric acid and hydrated ferric oxide (Nelson, 2004). Apart from the association of the major cations,

Table 6 : Heavy metal pollution indexing (HPI) of Okaba dry season water

Heavy metals (mg/l)	Mean value (m/l) (Mi)	Standard value (Si) NIS, 2007	Baseline Value (Ii)	Unit Weightage (Wi)	Subindex (Qi)	Wi *Qi
Fe	2.87	0.30	1.02	3.333	2.57	8.57
Cu	0.11	1.00	0.06	1.00	0.05	0.05
Zn	0.85	3.00	0.02	0.333	0.28	0.09
Pb	0.54	0.01	0.22	100.00	1.52	152
Ni	4.13	0.02	1.42	50.00	1.94	97.00
Cd	0.57	0.003	0.01	333.333	80.00	26666.64
				ΣWi = 487.999		ΣWi *Qi = 26924.35
Okaba dry season water HPI = 56.21						

Table 7 : Metal indexing (MI) of Okaba dry season water

Heavy metals (mg/l)	Ci	MAC	MI
Fe	2.87	0.30	9.57
Cu	0.11	1.00	0.11
Zn	0.85	3.00	0.28
Pb	0.54	0.01	54.00
Ni	4.13	0.02	206.5
Cd	0.57	0.003	190.00
		Okaba dry season water MI = 460.46	

anions and heavy metals to pyrite and sulphide minerals, their generally high concentration can also be related to their susceptible to leaching out by surface and infiltrating waters (Concas *et al.,* 2006). The low water pH also favours the residence of heavy metals in solution leading to an amplification of water contamination (Concas *et al.,* 2006).

The relationship between heavy metals and physiochemical, major ions and the relationships among the heavy metals were relatively weak except that between Fe-pH, Pb-Tds, Fe-NO_3, Fe-SO_4 and Ni-SO_4 (r = > 0.70). These pair with relatively strong correlation imply significant relation. Weak relationships were also experienced between major ions and physiochemical and among major ions, the exception being the significant relation between Cl, NO_3, SO_4 and pH; Cl-Ec, Ca-K, Ca-Na and SO_4-NO_3. This significant regression may suggest anthropogenic source (Tijani *et al.,* 2004; Abimbola *et al.,* 2005).

R-mode factor analysis of heavy metals yielded three factors. Factors 1 and 2 consist of Ni, Fe, Pb and Zn. Factor 3 consists of Cu and Pb. These three factors suggest anthropogenic source due to coal mining and related activities given the high factor loadings. The R-mode cluster extracted two clusters. Cluster 1 suggests a mixture of natural and anthropogenic sources while cluster 2 is related to anthropogenic input (Reghunath *et al.,* 2002).

In R-mode factor analysis of major ions and physiochemical, factor 1 suggests natural/anthropogenic factors. This factor could be related to salinization of water as it contains Ec and some important inorganic salts. It also could represent contamination of water by domestic sewage (Pathak *et al.,* 2008). Given the significant relationship between pH, NO_3 and SO_4, factor 2 suggests anthropogenic sources such as leaching of sulphide minerals, solubilization of previously precipitated hydrated sulphates, fertilized farmyards and probably denitrification of NH_3 which may have resulted from underground coal gasification (Nganje *et al.,* 2010). Factor three on the other hand may be due to dissolution of feldspathic minerals found in sandstones and shales in the study area - natural processes. Cluster one (R-mode) suggests also water, rock interaction and domestic contamination while cluster two suggests anthropogenic. Cluster three indicates natural processes (Lokhande *et al.,* 2008, Yang *et al.,* 2009).

The anthropogenic factor (AF) used for heavy metal evaluation of Okaba dry season water samples revealed this trend: Cd > Zn > Ni > Fe > Pb > Cu. Cu and Pb were least and dissolved Fe was lower than expected because Fe was oxidized, hydrolyzed and precipitated rapidly, which explains the yellow-red ferric precipitates observed in the channels (Concas *et al.,* 2006; Navarro *et al.,* 2008). The relatively lower concentrations of Pb may be attributable to its immobile nature and strong affinity for sediments and suspended particles and so it was strongly sorbed onto sediments (Eze and Chukwu, 2011; Navarro *et al.,* 2008). While low acidities of water allow heavy metals such as Cd, Zn, Ni, Fe, Pb and Cu to enter into solution phase and be transported, the total heavy metal content was very high with respect to Cd, Zn and Ni, high for Fe and lower for Cu and Pb as these metals appear associated to sulphides in this type of mine (Navarro *et al.,* 2008).

The potential for acid mine drainage and the release of toxic heavy metals from mine wastes exist throughout Okaba area. This poses major environmental hazard to fresh water resources. Acid mine drainage has enhanced the levels of heavy metals due to low pH as a result of sulphide minerals. The implication of this is increasing bioavailability, bioaccumulation and toxicity which may result to serious health and environmental consequences (Tijani *et al.,* 2004; Nganje *et al.,* 2010).

The HPI for Okaba dry season water samples was 56.21 and signifies that the water is not contaminated (Reza and Singh, 2010; Bakan *et al.,* 2010). Metal indexing on the other hand was 460.46, which imply low water quality (Prasad and Kumari, 2008; Tamasi and Cini, 2004; Caiero *et al.,* 2005; Al-Oud *et al.,* 2011).

Conclusion:

The potential for heavy metal contamination of surface water resource exist in Okaba coal area. The need to restore the mine area is urgent now than before. This is to reduce the effects of wide spread contamination and consequently heavy metal toxicity, given the role of surface water in our rural communities.

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