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Geoenvironemtal Assessment of Abandoned Barite Mines in Parts of Benue State

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Abstract:
An assessment of the impacts of abandoned barite mines on the environment was environment was carried out in this work. A total of 40 soil samples collected at varying depths of 0cm-15cm and 15cm-30cmwere collected to analysed for their heavy metal contents. The results were assessed using the following pollution indices: Index of geoaccumulation, Contamination Factor, Enrichment Factor, Nemerow Pollution Index, Pollution Load Index, Single Pollution Index, Probability of toxicity, Contamination Index and modified degree of contamination. The results show that the soils in the study area are polluted. The pollution sources were assessed using Hierarchical cluster analysis (HCA) method and the obtained results confirmed that the sources of the heavy metals are anthropogenic in origin.

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I. INTRODUCTION

Since prehistoric times, mining has been an important part of social development. Minerals have long been used to meet certain human requirements, such as securing food and shelter, providing defense, improving hunting capabilities, providing jewelry and monetary exchange, and so forth (Hartman, 1987). As a result, the majority of epochs of cultural evolution are associated with minerals or their derivatives: the Stone Age, Bronze Age, Iron Age, Steel Age, and today's Nuclear Age. Many countries' economic and industrial development is dependent on mining. Every item of modern commerce must be made from either mined or grown materials. The change and sometimes full destruction of the natural landscape at the mine site is the most obvious environmental consequence of mining. The most visible environmental impact of mining is the alteration, sometimes near-total destruction, of the mine site's natural landscape as seen in fig 1 and 2.

Fig 1: An overview of land degradation caused by barite mining

Fig 2: Settlement near an abandoned barite mining site

Natural landscape changes and rock deposits put a strain on the hydrosphere, especially in areas where there is a scarcity of water, as is the case in many developing countries. The first global traces of mining's environmental impacts, reconstructed from environmental archives such as ice cores, peatbogs, lake, and marine sediments, date back to around 6500BC. The first recorded global impact of mining was assigned to the Roman period due to Pb- smelting (Marx *et al.,* 2016). Mineral exploration has left an indelible mark on the ailing environment across the country, the most significant of which is the alteration of ecological settings. With large deposits of mineral resources spread across Nigeria, from Jos (tin and columbite) in the North to Edo (lead) in the South, and Enugu (coal) in the East to Ogun (limestone) in the West, there are bound to be stories of mining's negative impact on the environment. According to records, after crude oil, the solid mineral sector is the second largest source of pollution (Adekoya, 2003). Nigeria holds a rich abundance of solid mineral deposits. Various kinds, such as barites, gold, bentonite, gypsum, etc., are mined by artisanal miners. The growing concern about rising pollution and degradation of the environment has been emphasized. Following the exploitation of land for its abundant resources, various forms of pollution contribute to the degradation of the environment (Udiba et al., 2014). Recently attention has been drawn to barite mining in Nigeria as the federal government policy of using locally sourced materials has been enforced. This has resulted in the growth of many legal and illegal barite mining sites that generates vast quantities of mine rocks and tailings (Adamu *et al.*, 2014). Before the establishment of the Ministry of solid mineral development (MSMD) in 1995, not much attention was given to the exploration of solid minerals in Nigeria asuch during the period preceding the establishment of MSMD, exploration of solid minerals was done by artisanal miners. As a result of this directive, exploitation and exploration of raw materials took a new face especially with barite mining which is in high demand from the local and oil and gas industries (Adamu *et al.,* 2009). In Nigeria however Benue State, Cross River State, and Nasarawa State, etc are all home to barite deposits and they supply the oil industries barite needs (Oden, 2012; Obi *et al.,* 2014) the exposed rocks and waste minerals resulting from these mining activities can be mobilized to contaminate the soils, waters, sediments and biota (Lee *et al.*, 2005) and this can pose a health risk for the populace within the vicinity where mining operations is been carried out(Cox,1995). Although numerous studies on trace metal pollution and its effects have been published (Adamu and Nganje, 2010; Bhattacharya et al., 2006; Edet et al., 2014; Hwang et al., 2009; Jung, 2008; Lee et al., 2005), only a small number of publications have looked into trace metal contamination around abandoned barite mine sites (Franciskovic-Bilinski, 2006; Nagaraju et al., 2006).

Statement of problem:

Abandoned mines are a very important global concern as they pose real or potential threats to human safety and health, as well as environmental damages. Abandoned or inactive mines are generally sites where exploration, mining, or mine production ceased without remediation as remediation programs usually require huge fund amounts. Therefore, several issues such as who is responsible to provide the funds and to do the rehabilitation work, what mechanisms exist in various jurisdictions to raise the funds when no owners are identified or when they do not have enough money to pay, governments are forced to take care of it. Abandoned mines can cause several health problems and environmental hazards threats such as unsafe structures that can cause unstable conditions in that area resulting in severalaccidents. Soils and water contaminated with heavy metals or chemicals may pose great risk to life as they can become increasingly concentrated higher up the food chain, which can cause their death, or inability to reproduce.The impact of mining activities on the community health occurs at various levels. Adverse health effects that result from environmental exposure to contaminated air, water, soil, and noise pollution; and non-environmental effects such as pit closure can affect the community directly and indirectly. Heavy metal pollution of the environment remains a primary concern because of the negative effects that exposure to these metals can pose on various ecosystems and human receptors. Heavy metals are released to the environment through weathering and anthropogenic processes like mining activities which is typical of the study area located in Benue State where Mining in these areas have created a severe degradation in land and this is likely to contribute to the pollution of soils and water in the vicinity. Many of these metals released from this mining activity are toxic to plants and have the capacity to bioaccummulate, presenting health risks to humans. The study is aimed at assessing these abandoned mining sites for ecological and human risks posed to environment and the people around the vicinity of the mining operations.

Location and accessibility of study area

The study was carried out in Four (4) local government areas in the southern part of Benue State where abandoned barite mining sites abound as shown in the figure below (Fig 3). The boundary Local government areas to the study location are Buruku, Vandeikya, Ushongo and Logo LGA. The major road in the area runs from Makurdi through to Gboko through Lessel to Konshisha. This road together with a network of footpaths make the area generally accessible.

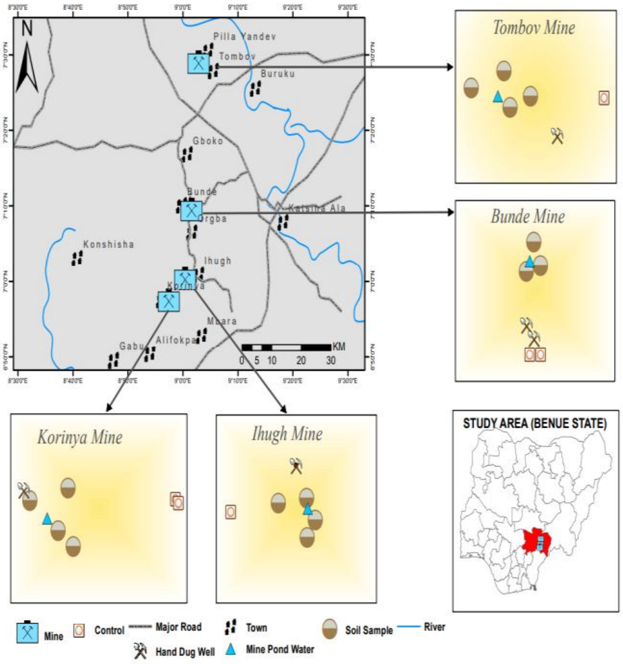

Fig 3: Map of Study Area

Aim and Objectives of study

The aim of this work is to perform a geo environmental survey of abandoned barite mining sites in some parts of benue state.

To achieve the aim, the following objectives shall be considered:

i) Analysis of soil and water samples to determine their heavy metal contents.

ii) Application of the indices of pollution for soils and water to assess the study area.

iii) Evaluation of carcinogenic and non-carcinogenic risk in the study area.

iv) Identify the pollution source using the HCA

II. METHODOLOGY

Insitu Tests: These were carried out on the field using handheld device and include Temperature, pH, salinity and electrical conductivity for the water. The devices were immersed in water and then the calibration was read off and recorded.

Sample collection and Analysis:

Soil samples for analysis were gathered from the different mine ponds and different points in the abandoned barite mining area. In all, 40 soil samples were collected comprising during two sampling campaign periods. All the samples were collected in aluminium foils. The soil samples were subjected to oven drying and sieving then Samples were crushed and sieved through 2mm sieve; 1g of the sieved samples were weighed accurately and transferred to a 250ml conical flask.10mls of the digestion mixture in the ratio (1:2:2) Perchloric, Nitric and Sulphuric acid was added into the sample and heated on a hot plate in a fume hood.The mixture was heated until a white fume is observed which signifies that digestion is complete. The sample was allowed to cool and 20mls of distilled water was added to bring the metals into solution. Sample was allowed to cool to room temperature and filtered using ashless whatman filter into a 20ml volumetric flask and made to mark with distilled water, then transferred to 100ml plastic can for analysis. soil samples for analysis were obtained from the vicinity of these four (4) abandoned barite mine sites.

STATISTICAL ANALYSIS

Ward's Hierarchical cluster analysis (HCA) method was applied using SPSS Version 23 software. Hierarchical cluster analysis is recognized as an efficient technique for fusing several data sets and this clustering is based on the agglomeration method that estimates linkage distance. In this study, the data are presented as dendrograms (tree diagrams) and this method results in the collation of an increasing number of indices on the basis of their characteristics (Murtagh and Legendre 2014).

Result and Interpretation

Pollution Indicies are frequently regarded as an effective tool for the thorough assessment of the level of contaminants. Additionally, in the case of farm fields, they can show a noteworthy part in the evaluation of soil and water quality as well as function as a foretelling of future ecological viability. Nine (9) Pollution indices previously described by several authors were used for these studies and these indices include: Index of geoaccumulation (Igeo), Single pollution Index (PI), Enrichment Factor (EF), Contamination Factor(Cf), Nemerow Pollution Index (PINemerow), Pollution Load Index (PLI), Probability of Toxicity (MERMQ), Degree of Contamination (Cdeg) and Modified Degree of Contamination (mCd).

Geoaccumulation Index (Igeo):

The geoaccumulation index (Igeo) was calculated using the formular below:

Index of Geo accumulation $I\text{geo} = \text{Log}_2 \frac{c_n}{1.5B_n}$ - - - - - (1)

where Cn—the content of heavy metal in soil and Bn—values of the geochemical background.

The results of the *Igeo* in the study area as presented in Table 1shows that the soils in the study locations falls within the uncontaminated to moderate contaminated class with the heavy metals Cd, Ba, Cu. Ni, As, Co, Pb, Cr, and Al as the contributors; while the heavy metals;Fe, Mn, Zn show an extreme soil contaminationsee Table 1b below for interpretation. The high values of Fe, Mn, and Zn across all the sampled locations suggests a high degree of anthropogenic activities prevalent in the study area.

Table 1: Geo-accumulation Index in Study Area

	HEAVY METAL											
	Zn	Cd	Ba	Cu	Ni	As	Co	Pb	Mn	Cr	Fe	Al
IHUGH	2.22	2.9×10^{-5}	2.5×10^{-3}	0.51	0.58	0.046	0.076	2.2×10^{-3}	375.2	0.47	34.19	0.77
KORINYA	4.29	4.6×10^{-4}	1.6×10^{-3}	0.85	0.92	0.045	0.26	6.8×10^{-4}	153.8	1.41	169.3	0.39
TOMBO	6.79	2.26×10^{-5}	1.4×10^{-5}	0.43	0.47	0.015	0.3	5.6×10^{-4}	1064	0.08	251	0.54
BUNDE	1.68	1.3×10^{-5}	3.5×10^{-3}	0.65	1.56	0.061	0.25	4.8 x10-4	405.7	0.02	208.9	0.31

Table1b. Classification of Soil quality according to Geoaccumulation Index I_{geo} values(Muller 1969)

Class	Values of I_{geo}	Soil quality
0	Igeo ≤ 0	unpolluted
1	0 < Igeo < 1	unpolluted to moderately polluted
2	1 < Igeo < 2	moderately polluted
3	2 < Igeo < 3	moderately to highly polluted
4	3 < Igeo < 4	highly polluted
5	4 < Igeo < 5	highly to extremely high polluted
6	5 < Igeo	extremely high polluted

Enrichment Factor

Enrichment factor is a metric that distinguishes between anthropogenic and natural sources of pollution (Dung et al. 2013; Kowalska et al. 2016; Reimann and De Caritat 2005). The Enrichment Factor is the only indices that has been studied that has a low occurrence of variability elements (Abrahim and Parker 2008; Bourennane et al., 2010; Karim et al., 2015).

The equation below was used for this study.

Enrichment Factor (EF) = $\frac{\left[\frac{C_n}{Fe}\right] sample}{\left[\frac{B_n}{Fe}\right] Background}$ - - - - - (2)

Table 2shows the results of the Enrichment Factor of heavy metals in the study area. The contamination level of the soils in the study area shows moderately to extremely severe enrichment of soil with heavy metals. However there is no Enrichment for As in the study area and a moderate Cr enrichment for the soils at Bunde.See Table 2b for interpretation.

Table 2 : Enrichment factor in the Study Area

Location	HEAVY METAL											
	Zn	Cd	Ba	Cu	Ni	As	Co	Pb	Mn	Cr	Fe	Al
IHUGH	130.01	9.06	19.52	418.43	839.32	0.64	298.26	12.93	69.81	20.92	26.72	2738.33
KORINYA	86.35	7.05	13.1	554	530.98	0.54	744.05	3.5	36.2	65.28	123.42	16102.27
TOMBO	27.64	7.03	14.43	287.57	1227.3	2.69	357.69	3.13	34.79	9.62	54.24	2814.11
BUNDE	108.8	10.45	8.58	1637.64	574.57	0.77	697.06	2.49	105.4	1.043	50.45	1334.19

Table 2b. Categories of Enrichment Factor (adopted from Elias and Gbadegesin 2011)

EF Value	Enrichment of soil
<2	deficiency to minimal enrichment
2-5	moderate enrichment
5-20	significant enrichment
20-40	very high enrichment
>40	extremely high enrichment

Contamination Factor (C*f*)

Using Tomlinson et al. (1980) model, the contamination factor (C*f*) was determined as the ratio of the metal concentration in the analyzed soil, to the target concentration.

Contamination Factor (C*f*) was calculated by the following formula

$$\text{Contamination factor } (C_F) = \frac{C_n}{C_{p-i}} \qquad (3)$$

Where Cn—mean content of heavy metal from at least five samples of individual metals and Cp-I preindustrial reference value for the substances.

From the CF values, the Degree of Contamination and Modified Degree of Contamination values for the soils in the sampled locations was derived to assess the metal pollution status of the soil. The results presented in table 3a shows a moderate to very high contamination of heavy metals in the soils across the study area for Arsenic (As) which has a Low contamination factor in the soils across the study area. (See Table 3b for interpretation)

Degree of contamination (Cdeg) and modified degree of contamination (MCd)

The overall heavy metal soil contamination can be assessed using the degree of contamination and the modified degree of contamination (mCd). The Degree of contamination was calculated using the formular below:

$$C_{deg} = \sum_{i=1}^{n} Cf \qquad (4)$$

where Cf—contamination factor and n—the number of analyzed heavy metals.

while the Modified Degree of contamination (mCd) was calculated using the following formula:

$$\text{Modified Degree of Contamination (mCd)} = \frac{\sum_{i=1}^{n} C_n}{n} \qquad (5)$$

where n—the number of analyzed heavy metals and Cn—content of individual heavy metal.

As shown in Tables 3athe overall heavy metal soil accumulation across the four locations shows a very high degree of contamination for all the analyzed metals in the study area. The modified degree of soil contamination shows an ultra-highmodified degree of soil contamination by heavy metals across the entire study area. See table 3b, and 3c for interpretation.

Table 3a: Contamination Factor, Degree of Contamination & modified degree of contamination instudy area.

Location	HEAVY METAL												contamination Degree	Modified degree of contamination
	Zn	Cd	Ba	Cu	Ni	As	Co	Pb	Mn	Cr	Fe	Al		
IHUGH	130.01	9.06	19.52	418.43	839.32	0.64	298.26	12.93	69.81	20.92	26.72	2738.33	4583.96	382
KORINYA	86.35	7.05	13.1	554	530.98	0.54	744.05	3.5	36.2	65.28	123.42	16102.27	18266.74	1522.23
TOMBO	27.64	7.03	14.43	287.57	1227.3	2.69	357.69	3.13	34.79	9.62	54.24	2814.11	4840.25	403.35
BUNDE	108.8	10.45	8.58	1637.64	574.57	0.77	697.06	2.49	105.4	1.04	50.45	1334.19	4531.45	377.62

Table3b:Contamination Factor (C_f) and Degree of Contamination (C_{deg}) interpretation (adopted from Tomlinson et al., (1980) and Ha˚kanson (1980))

C_f value	Contamination	C_{deg} value	Contamination
<1	low contamination	< 8	low degree of contamination
1-3	moderate contamination	8-16	moderate degree of contamination
3-6	considerable contamination	16-32	considerable degree of contamination
>6	very high contamination	> 32	very high degree of contamination

Table3c: Classification of Modified Degrees of Contamination (*mCd*) (adopted from Abrahin and Parker (2008)).

Values of *mCd*	Degree of contamination
<1.5	very low
1.5-2	low
2-4	moderate
4-8	high
8-16	very high
16-32	extremely high
>32	ultra-high

Pollution Load Index (PLI)

PLI is calculated as a geometric average of PI based on the following formula:

Pollution load index (PLI) = $\sqrt[n]{\mathrm{PI}_1 \text{ X } \mathrm{PI}_2 \text{ X } \mathrm{PI}_3 \text{ X} \ldots \mathrm{PI}_n}$ - - - - - (6)

where n—the number of analyzed heavy metals and PI—calculated values for the Single pollution index. The Results of the Pollution Load Index (PLI) as presented in Table 4 shows that the values range from 46.05 at Bunde to 70.69 at Korinya. Other values are 59.92 at Ihugh, and 48.07 at Tombo. The results for all the study areas show that the soils in the study area are polluted as the PLI rating for quality of soil is > 1 at all study locations. (See Table 4b for interpretation)

Nemerow Pollution Index

The Nemerow Pollution Index (PINemerow) allows the assessment of the overall degree of pollution of the soil and it was calculated based on the following formula:

Nemerow Pollution Index (NPI) = $\sqrt{\frac{\left(\frac{1}{n}\sum_{i-1}^{n} PI\right)^2 + PI_{Max}^2}{n}}$ - - - - (7)

where PI—calculated values for the Single Pollution Index, PI max—maximum value for the Single Pollution Index of all heavy metals and n—the number of heavy metals.

The results of the Nemerow Pollution Index (NPI) in the study area as presented in Table 4abelow. The NPI value for the study area at Ihugh is 798.14, At Korinya the value of the NPI is 4649.63, at Tombo the value for NPI 819.81 and finally at Bunde, the NPI value is 400.62. The results shows that the soils in all the study area are heavily polluted with heavy metals as all the indices values are >3 (See table 4d for interpretation)

Table 4a: Single Pollution Index (PI), Pollution Load Index, (PLI) & Nemerow Pollution Index(NPI) in study area.

Location	HEAVY METAL												Pollution Load Index (PLI)	Nemerow Pollution Index (NPI)
	Zn	Cd	Ba	Cu	Ni	As	Co	Pb	Mn	Cr	Fe	Al		
IHUGH	130.01	9.063	19.52	418.43	839.32	0.64	298.26	12.93	69.81	20.92	26.72	2738.33	59.92	798.14
KORINYA	86.35	7.05	13.1	554	531	0.54	744.1	3.5	36.2	65.28	123.4	16102	70.69	4650
TOMBO	27.64	7.03	14.43	287.57	1227.3	2.69	357.69	3.13	34.79	9.62	54.24	2814.1	48.07	819.81
BUNDE	108.8	10.45	8.58	1637.6	574.57	0.77	697.06	2.49	105.4	1.04	50.45	1334.2	46.05	400.62

Table 4b: Contamination classes of Single Pollution Index (*PI*)

Class	Value of *PI*	Soil pollution
1	PI<1	absent
2	1<PI<2	low
3	2<PI<3	Moderate
4	3<PI<5	Strong
5	PI>5	very strong

Table 4c:Contamination categories of Pollution Load Index (*PLI*)(Varol 2011)

Value of *PLI*	Pollution status
<1	denote perfection
1	only baseline levels of pollution
>1	deterioration of soil quality

Table 4d: Nemerow Pollution Index ($PI_{Nemerow}$) soil pollution classes(Guan et al. 2014)

Class	I	II	III	IV	V
	≤ 0.7	0.7-1	1-2	2-3	≥3
Quality of soil	Clean	Warning limit	Slight pollution	Moderate pollution	Heavy pollution

Probability of Toxicity (MERMQ)

This index is used as an instrument to recognize the harmful impact on the soil environment of heavy metals (Gao and Chen 2012; Pejman et al. 2015). MERMQ is calculated based on the following formula:

Probability of Toxicity (MERMQ) = $\frac{\sum_{i=1}^{n}\frac{Cn}{ERM}}{n}$ - - - - - - (12)

where Cn—concentration of each analyzed heavy metal, ERM—values given by Long et al. (1995) and n—the number of analyzed heavy metals.Table 5ashows the probability of toxicity (MERMQ) for select heavy metals: Zn, Cd, Cu, Ni, As, Pb, Cr in all of the sampled locations. The MERMQ value obtained at Ihugh is 0.17, Korinya is 0.19, Tombo is 0.17, this corresponds to the medium probability of toxicity level of 21% having a medium risk toxicity level ranking. while at Bunde the MERMQ is 0.034 whichcorresponds to a 9% probability of toxicity having a low risk level ranking. See Table 5b for interpretation.

Table5a: Probability of Toxicity in Study Area

Location	HEAVY METAL							MERMQ VALUE
	Zn	Cd	Cu	Ni	As	Pb	Cr	
IHUGH	0.093	0.004	0.121	0.95	0.0055	0.0017	0.019	0.17
KORINYA	0.1	0.013	0.18	0.95	0.005	0.0005	0.058	0.19
TOMBO	0.075	0.003	0.092	1.03	0.0064	0.00043	0.0053	0.17
BUNDE	0.011	0.00039	0.039	0.19	0.00099	0.0000506	0.00012	0.034

Table 5b:The Probability of Toxicity Index interpretation (*MERMQ*)

MERMQ value	Risk level	Probability of toxicity (%)
<0.1	low	9
0.1-0.5	medium	21
0.5-1.5	high	49
>1.5	very high	76

Identification of Pollution Sources using Hierarchical Cluster Analysis (HCA)

The dendrograms of heavy metals concentration are presented below Figures 5 – 8 wereconstructed using the HCA method. A number of connections amongst metals and the area were revealed using the hierarchical cluster analysis and each set of connections were includes metals from the same sources of pollution. Hierarchical cluster analysis (HCA) identified several groups of association among metals in relation with the area, and the metals associated in a group originated from the same pollution sources. Three (3) clusters were apparently detected in the study area at Ihugh. Cluster 1: As, Pb, Ba, Cd, Co; Cluster 2: Cr, Zn, Cu, Ni, Fe; Cluster 3: Al,Mn and this can be seen in Figure 5 below.

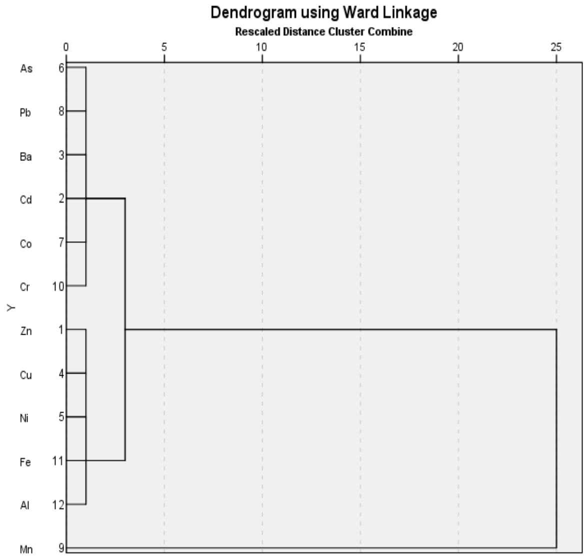

Figure 5: The dendogram for Ihugh location.

The HCA analysis showedtwo clusters (2) of associated metals in the Korinya where Cd, Pb, Ba, As, Cu, Ni, Zn, Co, and Cr formed one cluster, while Mn, Al, and Fe formed the second cluster. This is as shown in figure 6 below.

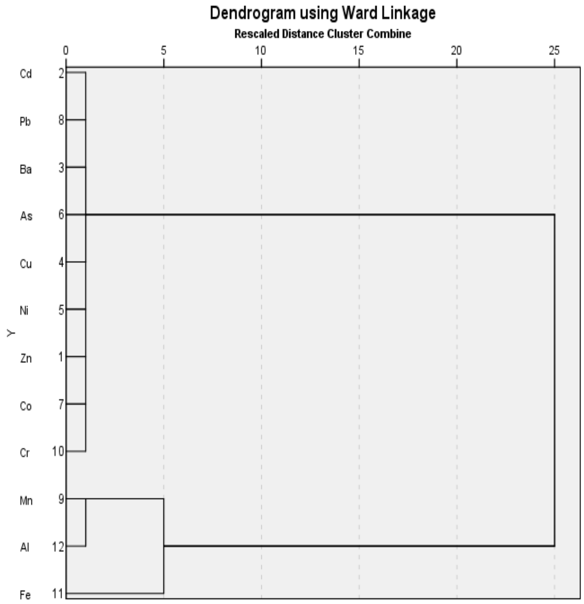

Figure 6: The dendogram for Korinya location.

At the study area in Tombo HCA identified two clusters: Cd, Pb, Ba, As, Cu, Ni, Zn, Co, and Cr formed one cluster, while Mn, Al, and Fe formed the second cluster. See figure 7

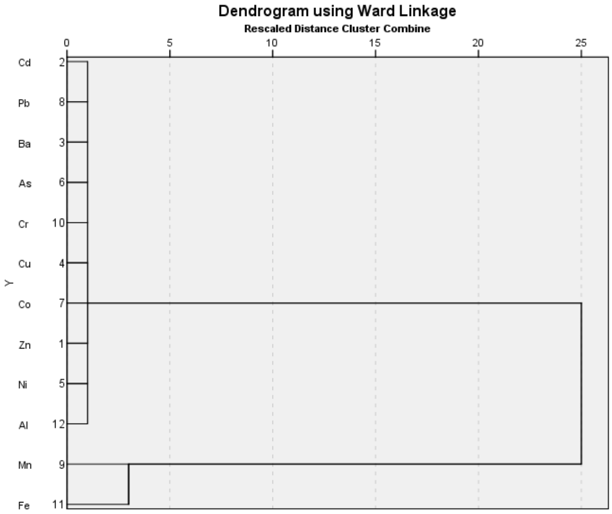

Figure 7: The dendogram for Tombo location.

Lastly the HCA analysis at the study area in Bunde confirmed two clusters; where Cd, Pb, Ba, As, Cu, Ni, Zn, Co, and Cr formed one cluster, while Mn, Al, and Fe formed the second cluster.This is as shown in Fig 8 below.

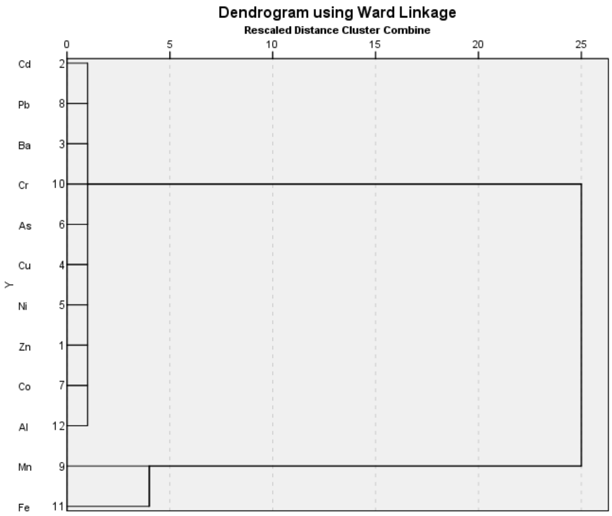

Figure 8: The dendogram for Bunde location.

The results from HCA studyshowed that grouped metals originated from the same pollution source. The presence of Mn and Fe could originate from weathering of parent materials. The presence of Fe and Mn could be indirect indicators of the Fe/Mn oxides in soils that influence heavy metals behavior in soils. The presence of the metals Cd, Pb, Ba, As, Cu, Ni, Zn, Co, showed an anthropogenic source, such as mining which is characteristic of the study area.

III. Summary And Conclusion

This study was carried out to evaluate the degree of soil contamination and human risk assessment resulting from the proliferation of abandoned barite mining sites in the study area. Two categories of pollution indices were used for this study, the single pollution indices and the complex pollution indices and the result from the study is summarized as follows.

The index of geo-accumulation of the analysed heavy metals in the study area show that the soils and uncontaminated – moderately contaminated except for Fe, Mn, and Zn which all show an extreme contamination level for all soils across the study location. The Enrichment factor for the soils in the location of study show that the soils are moderately to extremely severely enriched with heavy metals except for Arsenic (As) which shows no enrichment across the study areas and Chromium (Cr) which shows a moderate enrichment for the soils at Bunde. The contamination factor for the soils in the study area show a moderate to very high contamination level of heavy metals in the soils except for As which has a low contamination across the study area. The overall heavy metal soil accumulation show a very high degree of contamination for all the analysed heavy metals while the modified degree of contamination shows ultra high degree of contamination.

The Pollution Load Index of soils in the study location shows that the soils are polluted with heavy metals as the quality of the soil is >1 in all the study locations. The same applies to the Nemerow pollution index with values >3 in all locations it shows that the study area are heavily polluted with heavy metals and the probability of toxicity results for the analysed metals in the study locations shows a medium toxicity risk level for the soils at Ihugh, Korinya, and Tombo while the toxicity risk level at Bunde is Low.

Hierarchical cluster analysis (HCA) identified several groups of association among metals in relation with the area, and the metals associated in a group originated from the same pollution sources.

it can therefore be concluded that barite mining has caused pollution by Cd, Ba, Cu. Ni, As, Co, Pb, Cr, Al,Fe, Mn, and Zn in soils of abandoned mineareas of the study area. This pollution has notbeen given adequate attention when compared to other pollutions such as those from crude oil impact. This study is expected to serve as a basis for the formulations of policies on sustainable environmental management of abandoned mining sites in Nigeria and the world at large.

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