Heavy Metals Content in Kaolin Mined Soil and Water Body at Ohiya, Umuahia South, Abia State, Nigeria

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Authors’ contributions

This work was carried out in collaboration among all authors. Author CEL designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors CMUA and AAA managed the analyses of the study. Author PON managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Heavy metals (HM) have been a global concern for its toxic and detrimental effect on the environment especially when it exceeds the permissible limit through anthropogenic activities like kaolin mining. Kaolin mining has improved the economic wellbeing of the local people through employment and otherwise; and at the same time attached with environmental consequences that threatens the livelihood of the community members. This study was carried out to ascertain the concentrations of selected heavy metals in kaolin mined soils and water body and its pollution density using single pollution indices such as contamination factor (CF), geo-accumulation (Igeo) and ecological risk factor (E). Soil sample were collected from three different kaolin mined sites labelled (A,B and C) also surface water samples were collected from upper and down streams of Iyi-ugbohoronmaudara, both samples were digested and elemental analysis was carried out using Atomic Absorption Spectrophotometer (AAS UNICAM 919 model). The concentration of the metals in three different kaolin mined soil samples ranges from Pb(40.00, 52.00 and 55.09 mg/kg)
INTRODUCTION

Environmental pollution from heavy metals (HM) remains a global concern because of the negative effects heavy metals can pose on various ecosystem and human receptors. Heavy metals are introduced into the environment from geogenic (weathering) and anthropogenic sources including waste disposal, agricultural activities, vehicular traffic, petroleum refineries, paint industries, photography, and mining [1]. According to Kaasalainen and Yli-Halla [2], heavy metals emitted from anthropogenic source like mining activities are highly mobile in the soil environment with increased potential to cause ecological and human health complications compared to those of geogenic source. The contribution of metalliferous mining to elevated concentrations of heavy metals including arsenic (As), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), mercury (Hg), manganese (Mn), nickel (Ni), uranium (U) and zinc (Zn) in the environment is widely reported [3]. Metals contained in mine tailings overburden are spread to various ecological receptors (fauna and flora), water resources, and the atmosphere when particles of the tailings are dispersed to surrounding environments through various environmental fate pathways. These metals could be absorbed by soil particles, taken up by plants, absorbed by micro-, meso- and macro-organisms, or leached to surrounding water bodies. In addition, tailing overburdens are usually open and contains stagnant water, constituting danger to the avian community which also harbours larvae for mosquito. The openness of the tailings also facilitates erosion which contributes to extensive spatial dispersion of the tailings particles and consequently heavy metals [4]. Tailings overburden therefore does not just affect the scenic view of the landscape but may also present significant risks to biotic and abiotic environments. This study therefore, designs to explore the concentration level of heavy metals in soil and water and the possible negative effects of kaolin mining activities on the ecosystem. Kaolin mining is a kind of mining that goes with a range of clay substances made up of Kaonite and several other minerals produced by the alteration of felspathic rock, most times, Kaolin appears in different colors like white, pink, grey, yellow or red with a soft plastic nature. As a compound, the composition of kaolinitic and other minerals substances varies from sample to sample. Like all other clays it is a hydrated silicate that is very stable during natural conditions. It is ranked as one of the top seven industrial minerals in the world. [5]; (http://www.industryarc.com/Research/Kaolin-Market-Resarch-500193, 2020).

Kaolin is used as filler and raw materials in the manufacture and production of several goods such as ceramics, bricks, tiles, cement, paint, paper etc. depending on its individual chemical component and the extent to which it is processed [6]. Studies have reported different pollution calculation methods which can be use to assess the environmental quality like single pollution [7]. Pollution indices is a powerful tool

Keywords: Kaolin mined soil; heavy metals; iyi-Ugbohoro Amaudara River; Umuahia South; Nigeria and pollution indices.
for processing, analyzing, and conveying raw environmental information to decision makers, managers, technicians, and the public [8]. This study narrowed it down; by using pollution indices to measure heavy metals concentration in soil and water samples in kaolin mined area in other to determine the quality of ecological geochemistry environment.

2. MATERIALS AND METHODS

2.1 Description of study Area

The study site is located at kaolin mining site at Ohiya community in Umuahia south L.G.A of Abia State. Ohiya is located near the Abia Tower junction on the Umuahia side, along the Enugu-Port Harcourt Express way. It has an area of 140km² and a population of 198,780 [9]. The area lies at latitudes 5°26' and 5°34'N and longitudes 7°22 and 7°33'E. It has high relative humidity values over 70% and is characterized by high temperature of about 29°C-31°C. The area is part of the equatorial belt with average annual rainfall of about 2,400mm per annum. (See Fig. 1 and Table 1 below).

The vegetation of the area is typically evergreen rainforest that appears luxuriant during the rainy season. The presence of the evergreen luxuriant forest has aided the rearing of cattle and other domestic animals in the community. The area has a down sloppy river of about 5kilometers away from the kaolin mining points and most of the community members make use of the river for their domestic purposes. Due to the rural setting of the area, the main occupation of people is mostly farming though some are traders and artisans. The major crops grown include cassava, maize, yam, and cocoyam; forest trees found in the area are mostly palm trees and cashew trees.

Fig. 1. Showing map of the study area
2.2 Collection of Soil Samples for Heavy Metals Determination From Three Different Sampling Points at Ohiya Kaolin Mined Sites

Assessment of the Kaolin mine sites at Ohiya and ubakala were carried out to determine the level of different heavy metals concentrations in the area. Core soil samples were randomly collected in ten different points from the overburden excavated by the miners at 0-15cm depth each at first sampling site (Labelled A). Another core soil samples were randomly collected in ten different points from the second sampling site at a distance of about 5kilometers (Labelled B) and the same were repeated in the third soil sampling site ranging a distance of about 10kilometers (Labelled C) on the Kaolin mine sites. Also the same methods were used to collect soil samples from a distance of 20kilometers away from kaolin mining site where about a 10 years fallow existed and were absolutely noted therewereno evidence of kaolin deposit in the soil which serves as the control (Labelled D) and their coordinates were obtained using GPS. The core soil samples from each sampling sites were homogenized in a clean plastic bucket and a composite sample was drawn from each. The composite samples were air dried and allowed to pass through a 2mm sieve, then it was pour into polythene bags and labeled accordingly, all were done at the laboratory section of department of environmental management and toxicology Michael Okpara University of Agriculture, Umudike. The samples were then taken to RO_ Laboratory Research, University of Ibadan within 24hours of preparation for heavy metals analysis.

2.3 Sample Preparation for Heavy Metals Determination and Procedure Used

Three grams of air dried soil were weighed into a tube (50mL in volume) and 1ml of HNO₃ and 10ml of HCl (Aqua Regia of ratio 1:2) were added to the samples. The content was heated on a digested block in fume cupboard to dryness at 120°C [10]. The mixture was allowed to cool and then dissolved with 20% nitric acid (5 mL). After filtering the mixture with filter paper, the filtrate was made up to 20 cm3 volumes with distilled water. The various concentration standards for the various elements as well as the blank were equally prepared. Each of these preparations was then analyzed for heavy metals using elemental atomic absorption spectrophotometric method (AAS UNICAM 919 model was used). [11]

2.4 Water Samples Collection

Surface water samples were collected during wet season (June-July, 2019) from a sloppy river at Ohiya known as “Iyi Ugbohoro Amaudara” using well sterilized plastic bottles labelled Downstream and Upstream, the upper stream sample was collected 50 meters away from the downstream, 5mls of HCl acid was added in each of the samples collected for preservative measure. Coordinates of the sample points were extrapolated using GPS tracker and the samples were transported to RO-laboratory Ibadan for heavy metals analysis. The same procedure was repeated for water samples collections from the same river during dry season (January-February, 2020) for heavy metals analysis.

2.5 Heavy Metals Determination and the Procedure Used

Metal digestion was done using the Milestone Acid digestion method. Five millilitre of each water sample was pipetted into 20ml teflon tube. Concentrated acids of 6ml nitric acid (HNO₃, 65%) 3ml of hydrochloric acid (HCl, 37%) and 0.25ml hydrogen peroxide (H₂O₂) were added to each sample. A blank was also prepared. The samples were placed in an ETHOS 900 microwave digester for thirty minutes. After digestion, the samples were allowed to cool to room temperature and the solutions then diluted to 20 ml with distilled water. The liquid extract
was then analyzed for heavy metals using elemental atomic absorption spectrophotometric method.

### 2.6 Detamination of Pollution Levels Using (Single Indices Calculations)

In this study, the commonly used pollution indices were single indices. Single indices are indicators used to calculate only one metal contamination, which include: contamination factor, ecological risk factor, and index of geo-accumulation. It was used to analyze kaolin mined affected soils and water for level of heavy metals contamination. The level of contamination can be expressed by the contamination factor (CF). The CF is calculated according to Hökanson, 1980 [12].

\[
CF = \frac{C_{\text{metal}}}{C_{\text{background}}}
\]

1) The CF is the ratio obtained by dividing the concentration of each metal (C.metal) in the sediment by the baseline soil. The background value (C.background) corresponds to the baseline soil concentrations reported by Canadian Soil Quality Guidelines for Agriculture Soils (CSQGAS). The following terminologies were used to describe the level of contamination factor: CF<1, low contamination factor; 1≤ CF <3, moderate contamination factors; 3≤ CF <6, considerable contamination factors; and CF ≥6, very high contamination factor [13].

2) Index of geo-accumulation (Igeo), a common criterion to evaluate the heavy metal pollution in the sediments, it was originally proposed by Muller, 1969 [14] to determine metal contamination in sediments, by comparing current concentrations with pre-industrial levels with the following formula:

\[
I_{geo} = \log_2 \left( \frac{C_n}{1.5B_n} \right)
\]

Where, Cn is the measured concentration of a heavy metal in sediments/soil, Bn is the geochemical background value in average shale of element n and 1.5 is the background matrix correction due to Terrigenous effects. The factor 1.5 is introduced to minimize the effect of the possible variations in the background or control values which may be attributed to lithogenic variations in the sediment. The geo-accumulation index (Igeo) was categorized into seven classes: Igeo<0, class 0, unpolluted; 0<Igeo≤1, class 1, from unpolluted to moderately polluted; 1<Igeo≤2, class 2, moderately polluted; 2<Igeo≤3, class 3, from moderately to strongly polluted; 3<Igeo≤4, class 4, strongly polluted; 4<Igeo≤5, class 5, from strongly to extremely polluted; and Igeo>5, class 6, extremely polluted [15].

3) Ecological risk factor (Er) An ecological risk factor (Eri) was proposed by Håkanson [12] to quantitatively express the potential ecological risk of a given contaminant

\[Er = Tr \times CF\]

Where Tr is the toxic-response factor for a given substance, and CF is the contamination factor. The Tr values of heavy metals suggested by Håkanson [12] for Pb, Cu, Cd and Zn are 5, 5, 30 and 1, respectively. The following terminologies are used to describe the risk factor: Er<40, low potential ecological risk; 40≤Er<80, moderate potential ecological risk; 80≤Er<160, considerable potential ecological risk; 160≤Er<320, high potential ecological risk; and Er≥320, very high ecological risk. The potential ecological risk (RI) of the heavy metals is quantitatively evaluated by the potential ecological risk index (Er) [12,16], which takes into account both contamination factor (CF), and the “toxic-response” factor. The potential ecological risk values obtained were compared with categories grade of Er and RI of metal pollution risk on the environment as suggested [12,17].

### 3. RESULTS AND DISCUSSION

Results from Table 1 on comparative evaluation of level of heavy metals concentrations in three different kaolin mined sites labelled A, B and C with the control D showed high level Pb, Cr, Ni, Cd, Co, Hg, As and Cu concentrations in all the three sites studied when compared with the control site, except Se and Mn which showed low concentration levels in all the three kaolin mined sites (1.06 mg/kg, 0.50 mg/kg and 1.00 mg/kg and (0.001mg/kg, 0.01mg/kg and 0.01mg/kg) when compared with the control site. The high level concentrations of most of the present study heavy metals indicated contamination of the study sites which could be attributed to kaolin mining activities in the study area. More so, studies reviewed that kaolin develops negative charge ions between its layers and attracts positive charge ions like heavy metals such as Pb, Co, Cd, Cu, Cr etc. resulting to
contamination of soils where kaolin is deposited [18] which could be attributed as the reason why most of the metals are more concentrated in the present study media. Also, in agreement with Bonglasin et al., [19] reported that kaolin which is widely consumed in North-western Cameroon and in Nigeria, contains high amount of Pb, Cd, and Hg which known to be very toxic to humans. Implication of soil contamination with heavy metals is that, they are easily absorbed in the soil, and can accumulate along with food chain causing toxicity on plants and animals as well as adverse health effects [20,21].

3.1 Pollution Levels with Heavy Metals in Three Different Kaolin Mined Soil Points A, B and C and Control Point D

Results on the tables above reviewed the three single pollution indices factors for the selected heavy metals from kaolin mined soil, sample A. Co, Mn, As, Cr, Ni and Cu indicated low to moderate contamination factor while Cd, Se and Hg indicated high to very high contamination factor showing that source of the contamination has a significant effect on the heavy metals level which could be directed to kaolin mining activities at area and can be seen to be detrimental to the community and the exposed miners. Geo-accumulation indices showed that Cr, Ni, Co, Mn, Hg, As and Cu indicated unpolluted in the kaolin mined sample A, while Cd, Se and Pb were seen to be moderately polluted and the Ecological risk of Cr, Mn, As, Pb, Ni, Co and Cu showed low to moderately ecological risk, while Cd, Se and Hg showed very high ecological risk (Table 3). These implies that kaolin mined soil sample A happens to be more polluted with Cd, Se and Hg than the other selected heavy metals considering the three pollution indices used in this study. The same scenario applies in kaolin mined soil sample B and kaolin mined sample C, which also imply that the soils were more polluted with Cd, Se, Co and Hg than the other selected metals. (Tables 4 and 5). However, the control soil sample D reviewed that none of the selected metals were seen to be contaminated with the control site soil after using the same three pollution indices (Table 6); which in other words, shows that the contamination levels with the heavy metals in kaolin mined soils are as a result of kaolin deposit and its mining activities over the years in the study area. The ecological risk of these metals (Cd, Se, Co and Hg) being at high concentrations is that it could be toxically dangerous to the entire ecosystem [22].

3.2 Heavy Metals Concentrations in the Upper and Down Streams River Of IYI Ugbohoro Amaudara During Wet and Dry Seasons

The distribution trend of Pb, Cr, Ni, Cd, Co, Se, Mn, Hg, As and Cu concentrations in the upper and down streams of the surface water during wet season, showed that there were significant difference between the upper and down streams in most of the metals in this study, which established that the metals were present in the river body at higher concentrations when compared with W H O drinking water standard but, fluctuate from upper stream which likely to be the entry point of flow current water to downstream, the increase in flow current could be attributed to the sloppy topography of the study area especially during wet season. Heavy metals are leached out and in sloppy areas, are carried by acid water downstream or run-off to the sea. Through mining activities, water bodies are most emphatically polluted [23,24]. Environmental contamination by heavy metals is very evident in areas of mining and old mined sites and pollution increases with reduced in distance from mining sites [25]. The contamination factor of Pb, Cr, Ni, Cd, Co, Mn, Se, Hg and As indicated very high contamination factor, only Cu indicated low contamination factor (0.3-0.34) during wet season these showed that the contamination of the river body with heavy metals are from source which could be attributed to kaolin mining sites at the study area. However, during dry season there were trend of significant difference between the upper and down streams in respect to Pb, Cr, Ni, Co and Cu while there were no significant difference between the upper and down streams in respect to Cd, Se, Mn, Hg and As which indicated that some of the metals were at a minimal concentrations during dry season than the wet season while some were still high most especially, those heavy metals which recorded higher concentrations in all the three kaolin mined sites in this study which also indicated that the high concentration levels of heavy metals in the river body of the study area could be attributed to kaolin mining activities which through run-off and leaching gets into the river body [26].
Table 2. Concentrations of some heavy metals in soil samples from three kaolin mined sites

| Soil samples | Pb mg/kg | Cr mg/kg | Ni mg/kg | Cd mg/kg | Co mg/kg | Se mg/kg | Mn mg/kg | Hg mg/kg | As mg/kg | Cu mg/kg |
|--------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| Soil (A)     | 40.00a   | 45.01a   | 32.10a   | 2.16a    | 19.68a   | 1.06a    | 0.011a   | 2.01a    | 1.07a    | 33.01a   |
| Soil (B)     | 52.00b   | 70.00b   | 50.50b   | 6.25b    | 57.00b   | 0.50b    | 0.013a   | 2.00a    | 1.10a    | 60.00b   |
| Soil (C)     | 55.09c   | 71.00b   | 51.00b   | 6.15b    | 56.00b   | 1.00a    | 0.011a   | 2.50a    | 1.05a    | 57.5c    |
| Control D    | 1.53a    | 0.25c    | 0.49c    | 0.10c    | 8.14c    | 0.99a    | 0.020a   | 1.01c    | 0.01b    | 2.30c    |
| LSD 0.05%    | 3.06     | 5.010    | 2.30     | 2.70     | 4.010    | 0.26     | 1.07     | 1.02     | 0.46     | 4.06     |

Mean values down the columns with the same superscript are not significantly different (P>0.05)

Table 3. Heavy metals pollution levels using contamination factor (CF) GEO accumulation (IGEO) and ecological risk factor (ER) for kaolin mined soil sample a

| Heavy metal | CF    | Level | IGEO-ACC. | Level | Er | Level |
|-------------|-------|-------|-----------|-------|----|-------|
| Pb          | 2.00  | MCF   | 0.124     | MP    | 10 | MR    |
| Cr          | 1.05  | MCF   | -0.156    | UP    | 2.1| LR    |
| Ni          | 1.605 | MCF   | 0.029     | UP    | 8.025| MR    |
| Cd          | 7.20  | HCF   | 0.681     | MP    | 216| VHR   |
| Co          | 0.984 | LCF   | -0.81     | UP    | 9.84| MR    |
| Se          | 53    | VHCF  | 1.548     | MP    | 265| VHR   |
| Mn          | 0.0025| LCF   | 0.221     | UP    | 0.0125| LR    |
| Hg          | 34.06 | VHCF  | -0.527    | UP    | 1,362.4| VHR    |
| As          | 0.44  | LCF   | -0.527    | UP    | 4.4 | LR    |
| Cu          | 1.50  | MCF   | 0.0013    | UP    | 7.5 | MR    |

Keys: HCF= high contamination factor, LCF= low contamination factor, MCF= moderate contamination factor, VHCF= very high contamination factor, MP= moderate polluted, UP= unpolluted, LR= low ecological risk, MR = moderate ecological risk, VHR= very high ecological risk.
### Table 4. Heavy metals pollution levels using contamination factor (cf), geo-accumulation (igeo) and ecological risk factor (er') for kaolin mined soil b

| Heavy metal | CF  | Level | IGEO-ACC. | Level | Er' | Level |
|-------------|-----|-------|-----------|-------|-----|-------|
| Pb          | 2.6 | MCF   | 0.238     | MP    | 13  | CR    |
| Cr          | 1.627 | MCF   | 0.035     | MP    | 3.254 | LR    |
| Ni          | 2.525 | MCF   | 0.226     | MP    | 12.625 | CR    |
| Cd          | 20.83 | VHCF  | 1.142     | SP    | 624.9 | VHR   |
| Co          | 2.85  | MCF   | 0.278     | MP    | 28.5 | VHR   |
| Se          | 25    | VHCF  | 1.221     | SP    | 125  | VHR   |
| Mn          | 0.00025 | LCF | -2.795   | UP    | 0.00125 | LR    |
| Hg          | 33.89 | VHCF  | 1.354     | SP    | 1.3556 | VHR   |
| As          | 0.458 | LCF   | -0.515    | UP    | 4.58  | LR    |
| Cu          | 2.727 | MCF   | 0.259     | MP    | 13.635 | CR    |

**Keys:** HCF= high contamination factor, LCF= low contamination factor, MCF= moderate contamination factor, VHCF= very high contamination factor, MP= moderate polluted, UP= unpolluted, SP= strongly polluted, CR= considerable ecological risk, LR= low ecological risk, MR= moderate ecological risk, VHR= very high ecological risk

### Table 5. Heavy metals pollution levels using contamination factor (cf), geo-accumulation (igeo) and ecological risk factor (er') for kaolin mined soil sample c

| Heavy metal | CF  | Level | IGEO-ACC. | Level | Eri | Level |
|-------------|-----|-------|-----------|-------|-----|-------|
| Pb          | 2.754 | MCF   | 0.263     | MP    | 13.77 | CR    |
| Cr          | 1.651 | MCF   | 0.041     | MP    | 3.302 | LR    |
| Ni          | 2.55  | MCF   | 0.230     | MP    | 12.75 | CR    |
| Cd          | 20.5  | VHCF  | 1.135     | SP    | 615   | VHR   |
| Co          | 2.8   | MCF   | 0.270     | MP    | 28    | HR    |
| Se          | 50    | VHCF  | 1.522     | SP    | 250   | VHR   |
| Mn          | 0.00025 | LCF | -3.796   | UP    | 0.00125 | LR    |
| Hg          | 42.372 | VHCF  | 1.450     | SP    | 1.694.88 | VHR   |
| As          | 0.437 | LCF   | -0.536    | UP    | 4.37  | LR    |
| Cu          | 2.613 | MCF   | 0.241     | MP    | 13.065 | CR    |

**Keys:** HCF= high contamination factor, LCF= low contamination factor, MCF= moderate contamination factor, VHCF= very high contamination factor, MP= moderate polluted, UP= unpolluted, SP= strongly polluted, CR= considerable ecological risk, LR= low ecological risk, MR= moderate ecological risk, VHR= very high ecological risk

### Table 6. HEAVY metals pollution levels using contamination factor (CF) GEO-accumulation (IGEO) and ecological risk factor (ER') for kaolin mined soil sample D

| Heavy metal | CF  | Level | IGEO-ACC. | Level | Eri | Level |
|-------------|-----|-------|-----------|-------|-----|-------|
| Pb          | 0.0765 | LCF   | -1.292    | UP    | 0.382 | LR    |
| Cr          | 0.0058 | LCF   | -2.420    | UP    | 0.0116 | LR    |
| Ni          | 0.0245 | LCF   | -1.796    | UP    | 0.1225 | LR    |
| Cd          | 0.333  | LCF   | -0.653    | UP    | 9.99  | MR    |
| Co          | 0.407  | LCF   | -0.567    | UP    | 4.07  | LR    |
| Se          | 3.105  | MCF   | 1.118     | MP    | 7.102 | MR    |
| Mn          | 0.005  | LCF   | -3.522    | UP    | 0.0025 | LR    |
| Hg          | 2.118  | MCF   | 1.057     | UP    | 6.0172 | MR    |
| As          | 0.0416 | LCF   | -1.568    | UP    | 0.416 | LR    |
| Cu          | 0.1045 | LCF   | -1.161    | UP    | 0.522 | LR    |

**Keys:** HCF= high contamination factor, LCF= low contamination factor, MCF= moderate contamination factor, VHCF= very high contamination factor, MP= moderate polluted, UP= unpolluted, LR= low ecological risk, MR= moderate ecological risk, VHR= very high ecological risk
Fig. 2. Heavy Metals Concentration in IYI Ugbohoro Amaudra River Water Samples During WET Season (June-July, 2019)

Table 7. Contamination Factor (CF) of the selected heavy metals in both upstream and downstream of IYI Ugbohoro Amaudara River during wet season

| Heavy metals | Upstream CF | Downstream CF | Scale values |
|--------------|-------------|---------------|--------------|
| Pb           | 120.2       | 131.2         | CF < 1 = Low Contamination Factor |
| Cr           | 100.2       | 107.24        | 1 ≤ CF < 3 = Moderate Contamination Factor |
| Ni           | 14.28       | 14.57         | 3 ≤ CF < 6 = High Contamination Factor |
| Cd           | 107         | 137.33        | CF ≥ 6 = Very High Contamination Factor |
| Co           | 500         | 510.5         |              |
| Se           | 4.25        | 4.025         |              |
| Mn           | 10.5        | 160           |              |
| Hg           | 87.16       | 168.33        |              |
| As           | 101         | 131.1         |              |
| Cu           | 0.551       | 0.6           |              |

Fig. 3. Heavy Metals Concentration in IYI Ugbohoro Amaudra River Water Samples During DRY Season (January-February, 2020)
Table 8. Contamination factor (CF) of the Selected heavy metals in both upstream and downstream of Iyi Ugbohoro Amaudara River during dry season

| Heavy metals | Upstream CF | Downstream CF | Scale values |
|--------------|-------------|---------------|--------------|
| Pb           | 44.8        | 53.9          | CF < 1 = Low Contamination Factor |
| Cr           | 82          | 85.24         | 1 ≤ CF < 3 = Moderate Contamination Factor |
| Ni           | 2.285       | 2.571         | 3 ≤ CF < 6 = High Contamination Factor |
| Cd           | 0.333       | 0.666         | CF ≥ 6 = Very High Contamination Factor |
| Co           | 25          | 33.5          |             |
| Se           | 0.0025      | 0.005         |             |
| Mn           | 0.05        | 0.1           |             |
| Hg           | 5.333       | 5             |             |
| As           | 1.6         | 1.9           |             |
| Cu           | 0.3         | 0.34          |             |

4. CONCLUSION

The study conclude that kaolin soils are contaminated with heavy metals, the three single pollution indices used for this study confirmed that heavy metals in the kaolin sites soil are very high which is invariably as a result of the naturally deposited mineral in the study area called "kaolin".

Furthermore, the surface waters of “Iyi-UgbohoroAmaudara River” examined during wet and dry season proved that the surface waters are contaminated with the same heavy metals as seen in kaolin mined soils, the study therefore conclude that the contamination of the surface water was as a result of kaolin mining activities at the area. Consequently, these outcomes would pose a toxic effect to both fauna and flora and possibly threatens the aquatic lives and the local populace.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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