



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 (*I*_{geo}) and ecological risk factor (*E*^r). 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-ugbohoroAmaudara, 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)

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Cr(45.01, 70.00 and 71.00 mg/kg) Ni(32.10, 50.50 and 51.00 mg/kg) Cd(2.16, 6.25 and 6.15 mg/kg) Co(19.68, 57.06 and 56.00 mg/kg) Se(1.06, 0.50, and 1.00 mg/kg) Mn(0.001, 0.01 and 0.01 mg/kg) Hg(2.01, 2.00 and 2.50 mg/kg) As(1.07, 1.10 and 1.05 mg/kg) and Cu(33.01, 60.00 and 57.5 mg/kg). Results from single pollution indices used for the selected heavy metals from kaolin mined soil, samples (A,B and C) showed that Mn, As, Cr, Ni and Cu indicated low to moderate contamination factor while Cd, Se, Co and Hg indicated high to very high contamination factor in all the samples. The distribution trend of heavy metals concentrations in the upper and down streams of the river body during wet season, showed that there were significant difference between upper and down streams while dry season showed variations in significant differences between the upper and down streams of some of the heavy metals. The study therefore concludes that kaolin soils are contaminated with heavy metals as a result of kaolin deposit and its mining activities. The single pollution indices used for the study pointed out that Cd, Se, Co and Hg are very high in the kaolin soils. The surface waters of Iyi-ugbohoruAmaudara River at the study area are polluted with heavy metals as a result of kaolin mining activities in the area; more especially during wet season of the study. Consequently, these outcomes would pose a toxic effect to both fauna and flora and possibly threatens the aquatic lives and the local populace.

Keywords: *Kaolin mined soil; heavy metals; iyi- Ugbohoru Amaudara River; Umuahia South; Nigeria and pollution indices.*

1. 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 kaolinite 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 used to assess the environmental quality like single pollution [7]. Pollution indices is a powerful tool

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 order 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.

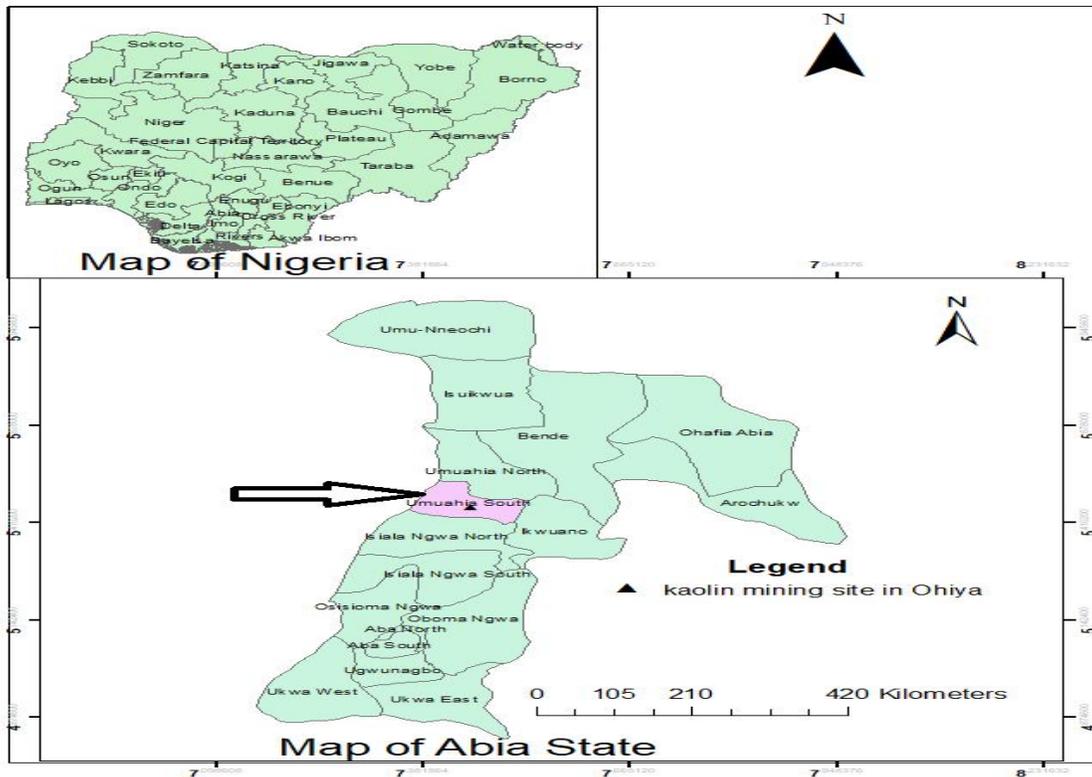


Fig. 1. Showing map of the study area

Table 1. A map showing the different soil and water sampling points in study area

Table 1: GPS coordinates of sampling points			
	Latitude	Longitude	Elevation
Kaolin mined site point A sample	N5°517104	E7°454114	9.0m
Kaolin mined site point B sample	N5°506545	E7°444698	6.0m
Kaolin mined site point C sample	N5° 513219	E7° 447935	12.0m
Un mined site point D sample	N5°536677	E7°476643	7.0m
Iyi ugbohoru Amaudara River sample	N5°513480	E7°448876	4.0m

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 (50m³ 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 Ugbohoru 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 Håkanson, 1980 [12].

$$CF = (C.\text{metal} / C.\text{background})$$

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; $1 \leq CF < 3$, moderate contamination factors; $3 \leq CF < 6$, considerable contamination factors; and $CF \geq 6$, 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:

$$I_{geo} = \log_2 (C_n / 1.5B_n)$$

Where, C_n is the measured concentration of a heavy metal in sediments/soil, B_n 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 $I_{geo} \leq 0$, class 0, unpolluted; $0 < I_{geo} \leq 1$, class 1, from unpolluted to moderately polluted;

$1 < I_{geo} \leq 2$, class 2, moderately polluted; $2 < I_{geo} \leq 3$, class 3, from moderately to strongly polluted; $3 < I_{geo} \leq 4$, class 4, strongly polluted; $4 < I_{geo} \leq 5$, class 5, from strongly to extremely polluted; and $I_{geo} > 5$, 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; $40 \leq Er < 80$, moderate potential ecological risk; $80 \leq Er < 160$, considerable potential ecological risk; $160 \leq Er < 320$, high potential ecological risk; and $Er \geq 320$, 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)	40.00 ^a	45.01 ^a	32.10 ^a	2.16 ^a	19.68 ^a	1.06 ^a	0.001 ^a	2.01 ^a	1.07 ^a	33.01 ^a
Soil (B)	52.00 ^b	70.00 ^b	50.50 ^b	6.25 ^b	57.00 ^b	0.50 ^b	0.01 ^a	2.00 ^a	1.10 ^a	60.00 ^b
Soil (C)	55.09 ^c	71.00 ^b	51.00 ^b	6.15 ^b	56.00 ^b	1.00 ^a	0.01 ^a	2.50 ^b	1.05 ^a	57.5 ^c
Control D LSD0.05%)	1.53 ^d 3.06	0.25 ^c 5.010	0.49 ^c 2.30	0.10 ^c 2.70	8.14 ^c 4.010	0.99 ^a 0.26	0.020 ^a 1.07	1.01 ^c 1.02	0.01 ^b 0.46	2.30 ^d 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 (ER¹) for kaolin mined soil sample a

Heavy metal	CF	Level	IGEO-ACCU.	Level	Er ¹	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 (er¹) for kaolin mined soil sample b

Heavy metal	CF	Level	IGEO-ACC.	Level	Er ¹	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 (er¹) for kaolin mined soil sample c

Heavy metals	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	-3.795	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, HR= high 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 (ER¹) 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	-1.795	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

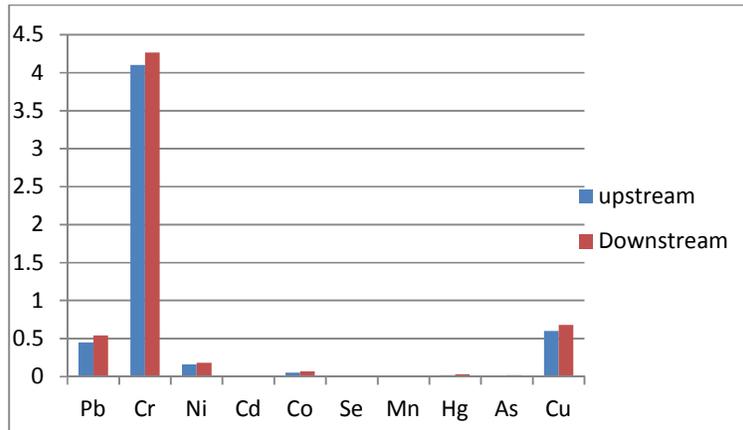


Fig. 2. Heavy Metals Concentration in IYI Ugbohoro Amaudra River Water Samples During WET Season (June-July, 2019)

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 1 ≤ CF < 3= Moderate Contamination Factor 3 ≤ CF < 6 = High Contamination Factor CF ≥ 6 = Very High Contamination Factor
Cr	100.2	107.24	
Ni	14.28	14.57	
Cd	107	137.33	
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	

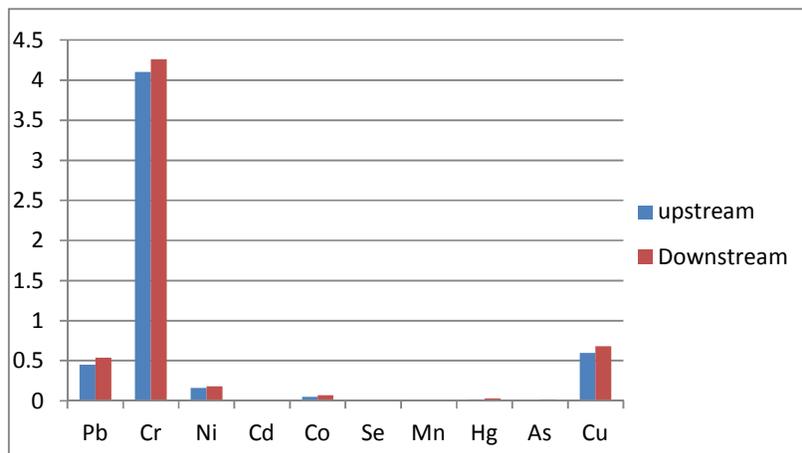


Fig. 3. Heavy Metals Concentration in IYI Ugbohoro Amaudra River Water Samples During DRY Season (January-February, 2020)

Table 8. Contamination factor (CF) of the Selected heavy metals in both upstream and downstream of IYI Ugbohor 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	3.333	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-ugbohor Amaudara 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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