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Research paper

Heavy Metal Contamination in Soil around a Gold Mining Site: A Case Study of Alaagba Community, Ile-Ife, Nigeria.

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Abstract: Human activities and mining operations produce waste materials which contain trace metals that could be absorbed by soils around the mine site and its surroundings. One of the major sources of metals in the soil in Ile-Ife, Osun State is gold mining. The State is highly mineralized and the concentrations of Pb, Fe, Cu, Mg, can increase in the environment because of mining activities, leading to environmental pollution and pose toxicity risks to humans and animals. The aim of this study is to identify the concentration level and the trends of heavy metals in the soil at different points at the mining site.Soil samples were collected from the gold mining site for three months from different spots and atomic absorption spectroscopy was utilized to examine the concentrations of Pb, Fe, Cu, and Mg.The result from this research shows that the value of magnesium (Mg) and Iron (Fe) were significantly highin all the five samples collected from the site for three months, with the highest absorbance value of 0.9935 for Mg, and 0.6934 for Fe with concomitant decrease in the value of lead (Pb) and copper (Cu). This proofs that there is a trace of heavy metals such as Mg, Fe, Pb, and Cu on the mining site.

The researchers suggested that point sources of heavy metals should be closely monitored and proper treatment toremove toxic levels of heavy metals accumulation inthe environment must be put into consideration.

Keywords: Artisanal mining, Deforestation, Environmental impact, Heavy metals, Large-scale mining, Soil contamination.

Introduction:

Like most human activities, mining operations produce waste materials which contain trace metals that could be absorbed by soil around the mine site and its surroundings. One of the major sources of heavy metals in the soil in Ile-Ife, Osun State is gold mining. The State is highly mineralized, and the concentrations of Fe and Mg are abundance compared with Pb and Cu, which can increase in the environment because of mining activities, leading to environmental pollution and pose toxicity risks to humans and animals. Mining of mineral resources and related activities results in extensive deforestation, soil damage, altering microbial communities, and affecting vegetation leading to destruction of vast amount of land. Metals released to the atmosphere from mining activities travel long distances and are deposited on the soil, vegetation, and water. Gold mining operations either by underground or open-cut mining is the most recognizable and demonstrable environmental problem since it modifies or by altering the physical, chemical, and biological parameters of the environment surrounding the mining area and it has far-reaching influence on human being civilization and ecological unit. The environmental levels of heavy metals are of great interest globally particularly because these elements are potentially hazardous to the health of animals, humans, and plants especially at elevated levels (Hazrat et al., 2019).

This escalating trend of environmental contamination by heavy metals is of serious concern not only to Nigeria but the world at large. In fact, various studies have shown that heavy metals are potentially toxic to humans, animals, and crops grown on contaminated soil (Hussain and Bordoloi, 2019).Naturally, heavy metals are present in rocks and soil in different concentration ranges. However, their biogeochemical cycles have greatly accelerated due to the activities of man (Ranjeet et al., 2018).Various forms of pollution contribute to the degradation of the environmental quality following the exploitation of land and water resources (Vhahangwele and Khathutshelo, 2018). Heavy metals are naturally accumulated in the environment through dissolution of rocks and weathering while they may be introduced artificially by humans into the soil during industrial activities, artisanal mining, and agricultural activities. Anthropogenic input therefore constitutes the major source of these metals in the environment (Tirry et al., 2018). The extraction and processing of mineral deposits by artisanal small-scale and large-scale miners to generate income is widespread in the northern and western part of Nigeria. Gold is the most common out of all minerals prospected for in Nigeria. The state of the soil where gold mining and exploration are carried out has raised serious concerns and questions. In recent times, gold mining has become very popular because it is a significant source of lead (Pb), mercury (Hg), and other heavy metal contamination of the environment (Arif et al., 2015). Gold mining has negative environmental impacts ranging from digging out a huge pit to disposing of the tailings and left over chemicals in the environment (Sabah and Fouzul2012). Widespread erosion, water pollution, and destruction of landscape which drowned human beings and animals were the results of both artisanal and large-scale mining activities (Ogezi, 2005).Artisanal small-scale gold mining is known as a craze ceaselessly increasing work in several countries throughout the world. Artisanal small-scale gold miners produce all together about 10-15% of gold in the world (Telmer Kevin and Veiga Marcello, 2009). The United Nation Environment Program estimated that more than 15 million people, including three million women and children, participate in more than 70 countries in this activity (WHA67. 2014). Over 90% of solid mineral in Nigeria is mined by artisanal small-scale miners, who are frequently challenged by limited knowledge of mineral processing techniques and lack of appropriate mining methods (Idowu, 2013).Osun state is regarded as one of the major locations for both large-scale mining companies and artisanal mining activities. Artisanal small-scale mining, which is quite different from modern mining, employs very simple technologies and make use of simple tools both in the mining and processing of the metal ore unlike the large-scale mining companies that make use of heavy-duty machine and apply high technology in their operation. In addition, usually, there is no planning for rehabilitation after the closure of the mining activities. The most visible outcome of both large-scale mining companies and artisanal miners is environmental destruction. Artisanalsmall-scale gold mining activities are mainly manual, low-technology, subsistence activities which employ large numbers of people (Van Straaten, 2000). There are about 10 to 20 million persons involved in artisanal gold mining producing about 12% of the world's gold (330 tons) annually (United Nations Environment Program, 2008). Over the years, there has been an increase in gold mining activities which is the mainstay of the local economy in some villages in Osun State. Mining activities have potentially impacted negatively on public health, environmental safety, and sustainable agriculture in Osun State. Acute lead toxicity can render the soil unsuitable for plant growth and destroys the biodiversity (Ghosh and Singh, 2005). There is a need to determine the concentration and distribution of heavy metals in the soil around the gold mining sites in the study area because of its long history of gold mining activities carried out in the study area. There is a problem of inadequate knowledge regarding the extent of the contamination in this area, which could result in environmental degradation and health risks for the local community due to potential contamination of heavy metals in the soil and environment. The purpose of this study is to ascertain thecontaminationlevels of heavy metals in the soil in a gold mining site at Alaagba, Ile-Ife, Nigeria.

Historical Review:

Mineral resources have become fundamental for economic development throughout the world. In several low and middle income countries that are rich in non-fuel mineral resources, mining contributes to national economic development (Addison and Roe 2018, Ericsson and Löf 2019).Studies have reported that 10 of the 20 countries where mining contributes most have moved up one or two steps of the World Bank's countries classification between 1996 and 2016 (Ericsson and Löf, 2017; Addison and Roe, 2018). African countries have benefitted. Thus, socio-economic development indicators show signs of progress for African mineral-rich countries. In Guinea, for instance, the Papua New Guinea Extractive Industries Transparency Initiative reported that, in 2020, the industries contributed 89% to exports, 29% to gross domestic product (GDP), and 10.1% to corporate tax, salary

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and wage tax, dividends, and royalties (Yamarak, and Parton, 2021).In Kenya, Tanzania, and other parts of developing counties where there is a mining operation, whether on a large or small scale has contributed to per capital income through job creation, resulting in improved livelihood status of residents and communities (Apollo et al., 2017, Mwakesi 2020). In Kenya and Cote d'Ivoire, for instance, mining has been observed to be an off-farm livelihood activity for farmers and other agriculturist (Apollo et al., 2017; Mwakesi, 2020). Notwithstanding the potential contributions of the mining industry to the economies of many developing countries has been observed to be detrimental to sustainable development due to its hard implication on environmental sustainability and management (Christmann, 2021; Yamarak and Parton, 2021).

Nigeria is a gold-rich country. Gold deposits are found in most parts of northern and western part of Nigeria with an average deposit of 21.40 tons (Okore, 2018). Gold Mining in Nigeria resumed in the 1960s but could not be developed as rapidly as expected due to the Civil War between 1967 and 1970. In the 1980s, however, there was a rebirth of this precious metal mining because of the efforts of the Nigerian Mining Corporation. Artisanal Small-scale Mining (ASM) is the most predominant in the southwest region of Nigeria. It accounts for over 95% of the entire mining activities and has been in existence since 1902 which connotes the advent of colonial mining (Aigbedion and Iyayi 2007; Mallo, 2012; Salami et. al., 2003). Several gold-rich rural areas in Nigeria have been dominated by unskilled artisanal miners who are underequipped and have little appreciation for the environment (Sabo, 2018). Most of these artisanal miners are totally ignorant of or uninformed about the implications of mining activities on human health and the environment. In Nigeria, recent cases of heavy metals poisoning and potential significant pollution by heavy metals make their continuous monitoring worthwhile. The largest known incidence of lead poisoning in history, killing 163 people (including 111 children), took place in Zamfara villages, Northern Nigeria in 2010 (CDC, 2016). Unauthorized and illegal mining of gold ores, apparently containing high levels of Pb, caused widespread contamination of soil, and drinking water sources with Pb. High concentration of Pb was detected in the blood of children, many of whom had suffered from headaches, vomiting, abdominal pains, seizures, and death (Orisakwe, 2017). More recently, artisanal mining operations similar to that in Zamfara state have been spreading across the country, and a recent investigation suggests that about two million people in Southwestern Nigeria may be at risk of Pb and Mg poisoning (Nigerian Vanguard (2021).

Materials and Methods:

Study Area

The Alaagba village gold mining site is situated in the southwestern region of Nigeria in Ife Central Local Government Area (LGA), have the geographical grid reference of latitude 7.38429°N and longitude 4.579851°E. The region is known for its tropical rainforest climate, which is characterized by high humidity, frequent rainfall, and warm temperatures throughout the year. The geology of the area is dominated by sedimentary rocks, which have been intruded by gold-bearing quartz veins. The hydrology of the area is influenced by the geology and climatic conditions. The region has several rivers and streams that provide water for domestic and agricultural use. However, the gold mining activities in the area have had a significant impact on the land e.g.,

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deformation of earth surface due to gold mining activities and the water quality, leading to soil pollution and contamination of the water sources. The mining activities have also disrupted the natural drainage patterns, leading to erosion and sedimentation in the rivers and streams.The climatic conditions in the area also influence mining activities, as heavy rainfall during the wet season makes it difficult for the miners to access the sites. The region also experiences dry spells during the dry season, which increases the risk of wildfires and dust storms. In summary, the Alaagba village gold mining site is in a tropical rainforest zone with a complex geology dominated by sedimentary and granite rock.

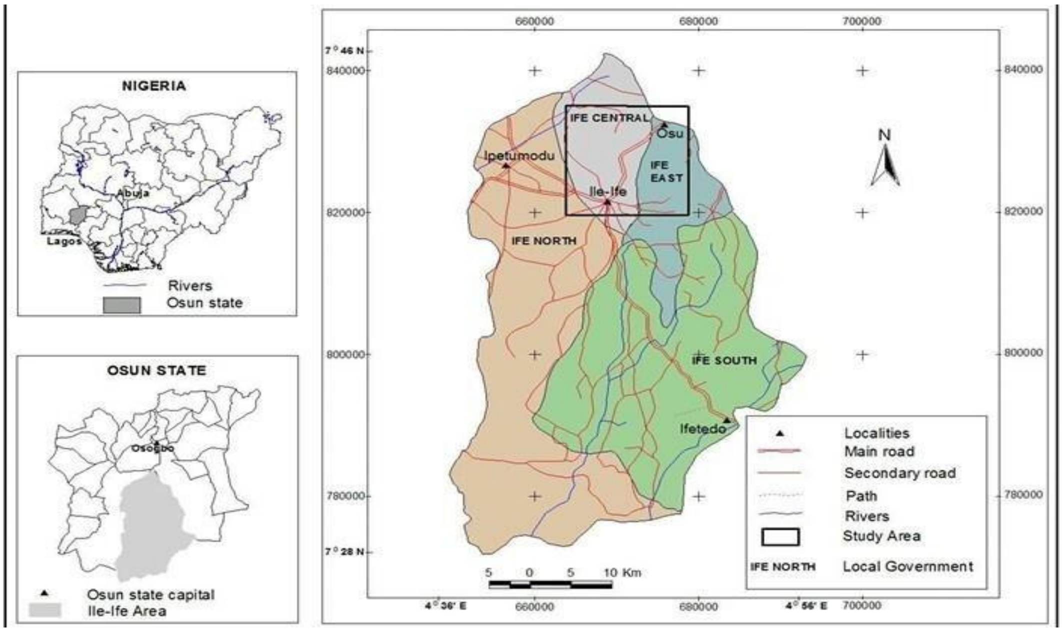

Fig. 1 Map description showing the location of Ile-Ife, Osun State, Nigeria (source: digital archives of the department of geography, Obafemi Awolowo University, Ife)

Fig. 2 The geographical location show where the mining activities were carried out.

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Experimental design

A simple random sampling approach was employed in selecting five locations within the gold mining area for sample collection. The samples were collected from the topsoil layer 0-10cm and from the depth of 10-20cm for three consecutive months i.e., October, November and December. The selected sites cover a representative area of the study area while considering the variability in the site's geology, topography, and the extent of mining activities.

Laboratory analysis

A soil auger was used to collect soil samples at the sites, then stored in labelled plastic bags and transported immediately to the laboratory for analysis. The soil samples were air dried, homogenized, passed through a 2mm sieve, and stored in labelled plastic cans for analysis. The samples were digested according to method described by Prasetyo et al. (2010), Dawakiet et al. (2013), Maguire and Heckendorn (2011) and Bouyoucous (1962), respectively. The digested samples were analyzed for themetals and read using Atomic Absorption Spectrophotometer Pye Unican model Sp-2900.

Statistical analysis:

R Statisticsversion 4.3.0tool was used to carry out aPearson correlation analysis to determine the relationship between the various heavy metals found in the soil samples.

Results:

Table 1 below showed that the concentration of Mg was the highest followed by Fe, Pb, and the least of the heavy metal's concentration was Cu in that order. This shows that the study area is contaminated due to the mining activities carried out in that area. The pollution of Fe in the soil sample is nothing serious likewise Cucompared to Mg and Pb. The Table also indicated higher depositions of heavy metals like Mg and Pb are found at the surface soils (0-10cm).

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Table 1. Distribution of heavy metal samples collected across months.

Month	Samples	Fe	Pb	Cu	Mg
October	Sample1 (Spot close to the river)	0.1730	0.0053	0.0023	0.6177
	Sample 2 (Spot close to the digging spot)	0.1290	0.0065	0.0046	0.3792
	Sample 3 (The digging spot)	0.4367	0.0007	0.0032	0.3981
	Sample 4 (Spot close to the washing area)	0.6755	0.0057	0.0045	0.9404
	Sample 5 (The washing spot)	0.6832	0.0025	0.0021	0.8390
November	Sample1 (Spot close to the river)	0.5836	0.0036	0.0042	0.8634
	Sample 2 (Spot close to the digging spot)	0.6934	0.0042	0.0044	0.9157
	Sample 3 (The digging spot)	0.6789	0.0064	0.0045	0.9935
	Sample 4 (Spot close to the washing area)	0.6902	0.0043	0.0039	0.6932
	Sample 5 (The washing spot)	0.6389	0.0062	0.0062	0.9695
December	Sample1 (Spot close to the river)	0.5964	0.0022	0.0042	0.6752
	Sample 2 (Spot close to the digging spot)	0.6732	0.0045	0.0066	0.9545
	Sample 3 (The digging spot)	0.3067	0.0066	0.0072	0.7686
	Sample 4 (Spot close to the washing area)	0.6422	0.0060	0.0065	0.6620
	Sample 5 (The washing spot)	0.6802	0.0027	0.0046	0.8865

Table 2. shows the correlation matrix of heavy metals in the soils across months in the study area. The correlation coefficient between Pb and Cu was 0.95 in December, which indicates a strong linear correlation at the 0.05 significance level and a common source of these metals. Also, significant positive correlations were observed between Fe in November/Fe in December ($r = 0.90$, $p < 0.05$), Fe in November/Pb in December ($r = 0.82$, $p < 0.05$), Cu in October/Fe in November ($r = 0.82$, $p < 0.05$), Fe in October/Mg in October ($r = 0.77$, $p < 0.05$), Cu in October/Cu in December ($r = 0.76$, $p < 0.05$), Fe in December/Pb in October ($r = 0.73$, $p < 0.05$). However, the correlation coefficient between Pb in October and November was -0.92, which indicates a strong negative correlation at the 0.05 significance level.

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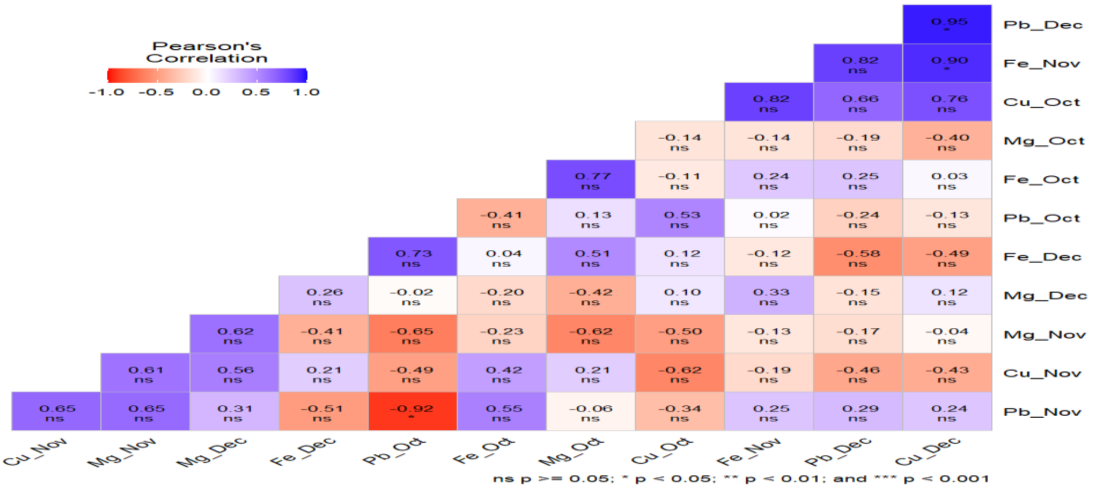
Table 2. Pearson correlation matrix of heavy metals found in the study area across months.



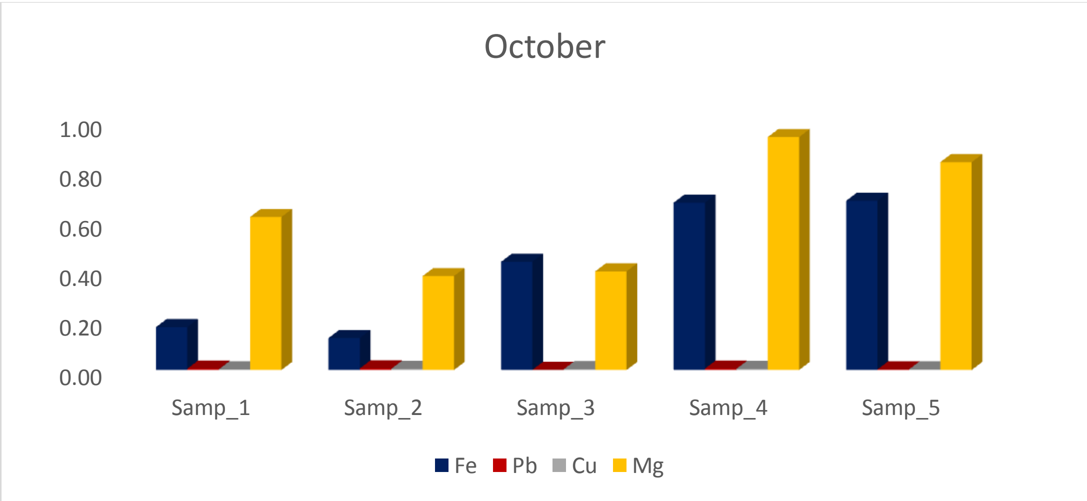


Fig. 3. Concentration levels of heavy metals in soil samples collected in October, 2022.

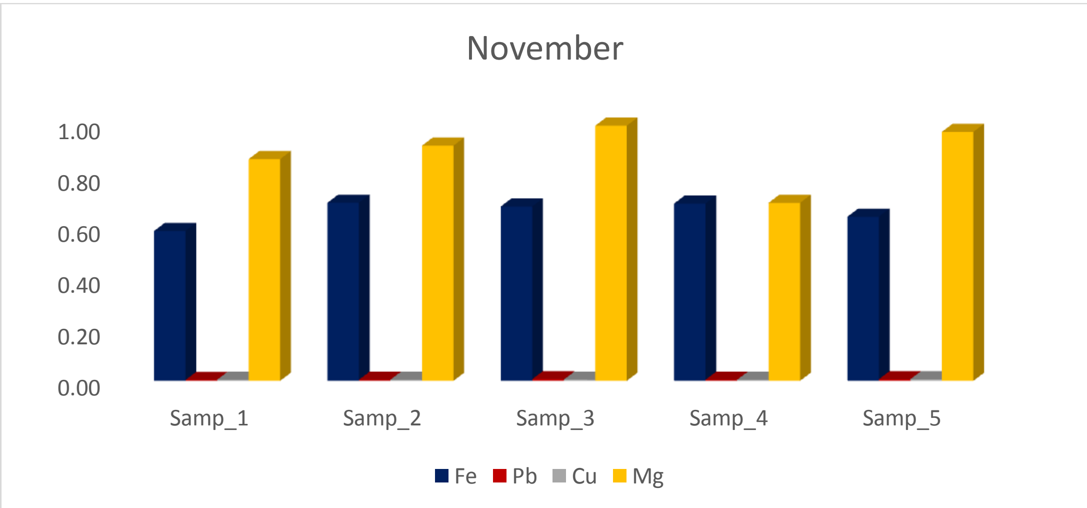


Fig. 4 Concentration levels of heavy metals in soil samples collected in November, 2022.

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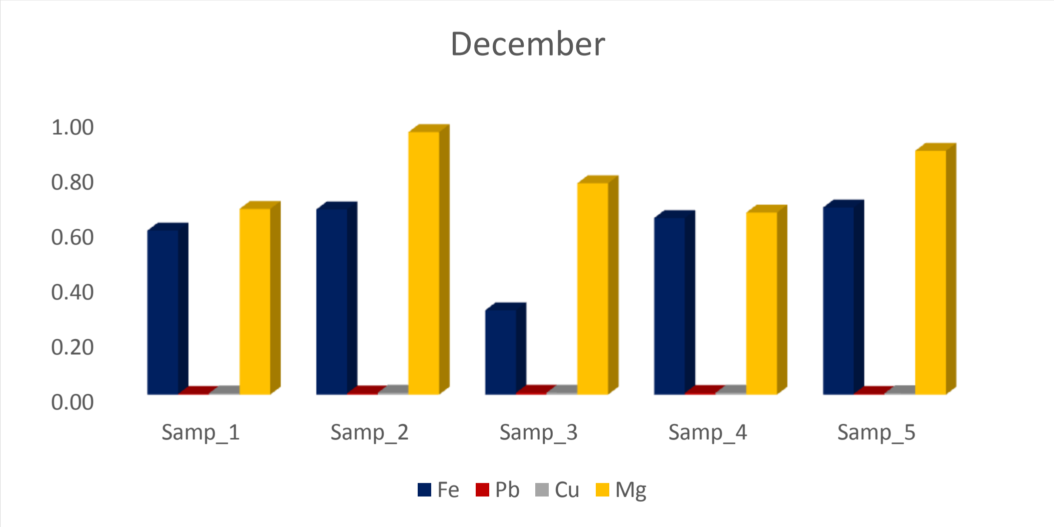

Fig. 5 Concentration levels of heavy metals in soil samples collected in December 2022.

Discussion:
The concentration of the heavy metals was more on the surface soils than in the sub-soils, this above finding shows that accumulations of heavy metals are concentrated at the soil-surface than the sub-surface as supported by Amadi *et al*. (2012); Ololade I. (2014) reported in their findings that surface soils showed remarkably high levels of metals such as copper, iron and zinc decreasing with depth. Also, Anikwe and Nwobodo, (2002) reported that surface soils are better indicators for metallic burdens. Moses (2006) reported that the addition of heavy metals to soil resulted in their accumulation in topsoil.
Positive and negative correlations were noticed from the Pearson correlation between the heavy metals, although not all were significant. The statistically significant positive relationships among the three metals in question (Fe, Pb, and Cu) suggest that they share a common anthropogenic source, which may be related to the nearby gold mining and agricultural activities (manure and pesticides application), which are known to contribute one or both correlated metals to the environment. This agrees with the research of Ahad *et. al.*, (2019) which states that the anthropogenic origins of potentially toxic metals including lead (Pb), and copper (Cu) are mainly attributed to industrial activities. Mg is one of the crustal elements, which increases the probability that it originates from a non-anthropogenic source, such as soil erosion and the inherent weathering of the outer layer of the earth, this is in accordance with their port of Fagbenro *et. al.* (2021). It is significant to note that Mg did not correlate with Cu or Pb, implying that their sources are fundamentally distinct.

Conclusion:
The study emphasizes the need to continue to monitor concentrations of toxic metals such as Pb, Fe, Cu, and Mg in the mined site at Alaagba village to detect their toxicity on time. There should be proper harnessing and reclamation approach for the polluted lands affected by the mining operation. The community is popularly known for its agricultural activities and in no time if remediation action is not considered in this study area, heavy metals may accumulate in plants which may

subsequently be hazardous tohuman health when consumed. Proper monitoring and remediation plans should be put in place to reduce the chances of ground water pollution by leaching contaminants.

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PLATE 1 Shows the mining activities down by large-scale mining companies, and how the site was abandoned after their mining activities.

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PLATE 2 Shows how Artisanal miners carried out their mining activities, and this is far better than the large-scale mining companies because as they dig, they fill up pits behind them.

Here, the artisanal miners are rewashing the gravel washed by one of the large-scale miners.