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Agro-economic damages assessment of artisanal gold mining in Ijesa land, Osun State

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ABSTRACT: To feed the expanding population, agriculture must be practiced in a more sustainable manner that improves productivity and the natural ecosystem. The main components of sustainable production systems that support the health of agro-ecosystems are people and the environment. The extractive nature of gold miners' practices has significant negative effects on the environment, which lower agricultural productivity due to the harm caused to the environment. The study aimed to determine the extent of ecosystem damage induced by bio-geochemical components of soil contaminated with heavy metals, which has an impact on agriculture and public health. Soil samples were collected from eight communities due to noticeable degradation levels, and characterized for heavy metals and other toxicants in the soil adopting standard procedures. The results revealed wider variations in the concentration of heavy metals and other toxicants between the degraded and non-degraded forestland as control. The mean heavy metals (mg/kg) in the soil at Ido Ijesa/Campus area was recorded as Hg (1.07), Cd (8.52), Ar (42.77), and Pb (118.71); At Isua, Hg (0.64), Cd (8.33), Ar (32.74), and Pb (295.72); while Iperindo/Imogara/Odo Ijesa recorded Hg (1.33), Cd (10.47), Ar (21.78), and Pb (115.64) and OOra/Iregun community had Hg (2.06), Cd (6.74), Ar (35.75), and Pb (85.74) respectively. The mean Cyanide contents in degraded site against non-degraded site were recorded as 89.64 mg/kg against 25.50 mg/kg (3.5:1) at Ido Ijesa/Campus area; 102.51mg/kg against 22.68 mg/kg (4.5:1) at Isua, and 92.68 mg/kg against 21.65 mg/kg (4.3:1) at Iperindo/Imogbara/Odo Ijesa. The geo-accumulation index (I_{geo}) of heavy metal in the soil is significantly higher in degraded forestland. The high level of toxicants and contaminants present in the soil water is detrimental to crop yield and human food safety. The cyanidation that occurs in severely degraded areas for gold mining is characterized by low crop growth, yield, and the outcome being a high sensitivity to health challenges. However, if the threat continues unabated, many residents of Osun state would not be protected from a persistent outbreak of water-borne diseases.

Keywords: Artisanal, biodiversity, ecosystem, degradation, epidemic, livelihood, pollution

INTRODUCTION

Trading has been an indigenous trade mark of the Ijesa people among the Yorubas in Southwest Nigeria. Though farming is still observed as a predominant occupation of Ife and Ijesa people. The fertile alluvia soil and topography of the Ife/Ijesa agricultural Zone of Osun State has a distinguishable quality for sustainable production of a good number of cash crops; Cocoa, Kola nut, Oil palm, Banana and Plantain, Timber, food and vegetable crops. Others are food and arable crops such as Rice, Maize, Cocoyam, Cassava and Yam that are known for high turnover rates in production. Unfortunately, the available arable lands are being continually depleted by the ever increasing human population and gold mining operations that ravaged every nook and cranny of Ijesa land. The current crisis stands out clearly as the magnified impact of aggressiveness in forest degradation becomes the most important challenge of many rural communities. According to Mohammed (2022), environmental degradation is a process by which the natural environment is compromised in ways that reduce biological diversity and the general health of the environment. Sustainable land management practices coupled with land use planning is good to protect livelihoods and food security. In Ijesa environs, sources of livelihood for man have been directly and indirectly affected by environmental degradation that has left farmland and water body severely affected (Adejuwon, 2022). Over half of the available arable land in the study area is degraded from mere observation. The continuous destruction of the forest in the study area induced by aggressive gold miners observed to have caused migration of farmers and the allows resettlement of a multitude of northern (Hausa) youths, making most vulnerable communities proliferated. This influx of expatriates and non-Yoruba tribes in the zone may ignite tribal clashes in the nearest future due to the massive displacement of farmers, as well as the massive destruction of farmland. All the environmental factors (land, water, air and man) are dependent on one another and the degradation of one factor leads to the breakdown of the other factors in nature (Mondal and Tripathy, 2020, 2019).

Impact assessment of artisanal gold mining operations

Agriculture is one of the largest contributors to climate change and current agricultural practices are extractive in nature and have enormous environmental impact. The operations of both the controlled and uncontrolled gold mining across Ijesa land are most destructive by human activities despite the fact that gold mining is identified as a booming business in Ijesa land. The practices of gold miners are known to accelerate the destruction of forestland and ecosystem with serious effects on global warming. Land degradation is one of the biggest threats to the livelihoods and food security of smallholder farmers in Nigeria. However, the gradual degradation of the environment as a result of mining makes livelihoods more susceptible to health hazards (Majekodunmi, 2014; Emunze, 2021). The process of tearing down the forest to access rich gold deposit beneath the Earth crust pose extensive detrimental effect on the ecosystem. The result of relationship of human beings with the environment is attributed to atmosphere and soil or groundwater contamination via the degradation of landscape which leads to the high concentration of heavy metals such as Cadmium (Cd), Mercury (Hg), Arsenic (As), Lead (Pb), and Iron (Fe) that are potential risk to environment and public health (Majekodunmi, 2014). Olasunkanmi (2022) asserted that, many pollutants are capable of damaging genetic materials (DNA) or interfering with normal cell division that resulting to birth defects in children, cancer in adult humans as well as sperm cell deformities. Many international organizations recognized environmental degradation as one of the major threats facing the planets, since humans have no other Earth to work with, and if the environment becomes irreparably compromised it could mean the end of human existence (GMET, 2021). Cyanide (CN), Mercury (Hg), and other toxicants are freely released into the environment during mining operations. It is obvious that in most places, the destruction of landscape/forestland is not only limited to one or two communities but heavily noticed in several places of Ijesa land that includes: Isaobi, Ido Ijesa, Odo Ijesa, Omo Ijesa, Igangan, Isua, Igila, Ipole, Ibodi, Epe, Igbade, OOra Ijesa, Idoka, Muroko, Ijana, Mongbara, Igbogi, Igun, Itagun, Iregun, Osu, Iloba and Kajola communities.

Gold mining and health implications

Due to the high probability of domestically utilized water sources becoming contaminated, one in three persons may likely develop diseases transmitted by water. Residents who live in areas where mining operations provide problems are losing biodiversity more quickly than it can regenerate or fertile farmland is deteriorating more quickly, both of which contribute to climate change. Gold mining as an industry, can displace communities and grossly affected food production and sustainability, contaminating natural rivers or streams with Mercury (Hg), Lead (Pb), Iron (Fe) and Cyanide endangering the health of people and the ecosystem (Olasunkanmi, 2022). Ozah *et al*. (2021) opted that gold formation involves amalgamation and cyanidation through the use of chemicals which poses expensive detrimental effects on the ecosystem and public health. Cyanide is highly toxic, substantially harming agricultural land and public health risk if released into the environment. During the processes, the forest is completely degraded and the underground rock is exposed to new air and water which makes the Iron (Fe) and ferrous present in the rock undergo some chemical reactions that involve oxygen (O_2) to form Acid. However, acidic water as waste from the mine site can easily seep/spill into the soil and underground water. Acidic water is toxic to living organisms. Rivers and streams being the major source of water for domestic uses become contaminated with heavy metals such as Cadmium (Cd) which causes liver disease, Arsenic (As) causes skin cancers and tumours, while Lead (Pb) and Lead poison cause disability in learning and impaired development in children. Iron makes rivers or streams smell of rotten eggs. These metals endangering school age children and pregnant mothers. Running waters are caused to carries sediments containing nutrient and heavy metal contaminants to a new location which results in eutrophication and pollution of delicate ecosystems (Bing *et al.* 2013). The constant release of cyanide into the environment as a result of the effects of environmental degradation caused by mining activities may push over 2 million people in the state into a severe health challenge and harm agricultural productivity.

Statement of the problem

In recent years, gold mining activities across Ijesa land have been deplored, given that both controlled and uncontrolled miners and the general public have not considered the danger of this anti-environment and indiscriminate tearing of forestland. This unfriendly act has rather exposed inhabitants of the areas to a series of health challenges (Adejuwon, 2022). In spite of the challenges, only one company has been identified in Osun State to have devoted appropriate concern to the management of waste from the mine site. The acidic water and other heavy metals as waste from mine sites can easily seep/spill into the soil and underground water which is toxic to living organisms just like the oil spillage experienced overtime in Ogoni land, where families were found drinking water from benzene contaminated well water (Olasunkanmi, 2022). Therefore, many gold miners are out there handling the issue of gold ore and their waste products unprofessionally which makes not only many vulnerable communities highly susceptible to health hazards but the entire citizens of Osun State in the future. In consequence, there is the likelihood of forest destruction outstripping the existing food supply in the study area, which has negative implications for the entire population. A statement credited to the Executive Director of a Civil Society Organization revealed that Geographical Information Analysis and Laboratory tests carried out by the organization established the cause of Osun river pollution and affirmed the presence of heavy metals in the water. He also cited gold mining as the cause of the Osun River’s toxic contamination, which endangers the lives of more than 2 million people living in Osun State (Adejuwon, 2022). Olasunkanmi (2022) also attributed that Osun river pollution is linked to the activities of artisanal gold miners and other sources such as agricultural land use, anthropogenic activities, and industrialization. Mining activities in Ijesaland threaten human health and the ecosystem, leading to poor and low agricultural production. It is therefore envisaged that gold mining activities in the Ijesa environs will increase geometrically while food production (farming) increases arithmetically in progression. Small-scale gold miners destroy rivers, leading to reduced participation in agriculture and food production (Adeoye, 2016). Heavy metal excessive levels are detrimental to plant growth just like Hg, Cd and Pb were reported to reduce plant growth in maize crops (Ghani, 2010). Though gold mining is booming in this part of the country due to high gold deposit and the involvement of people in gold trading, makes agricultural labour more expensive for agricultural activities. The magnified effect on food and agricultural production is very devastating as agricultural produce from the Ijesa axis would be continually reduced. Hence, this study aimed to evaluate the degree of agro-economic damage and health risk induced by gold mining activities in Ijesa land, Osun state.

METHODOLOGY

The study was carried out in the Ijesa land of Osun State as shown in Figure 1 which was purposively selected because of the presence of a huge concentration of natural mineral resources and it is characterized as a seat belt of gold in the state. It lies within the rainforest belt of Nigeria with sustainable vegetation. It shares geographical boundaries in the south; Ondo State, west; Ekiti State, north; Boluwadoro Local Government, and east; Ife Central Local Government of Osun State, Nigeria. The nature of soils in Ijesa land is majorly clayey soil and loamy sand. The topography is underlain with the rocks (Sedimentary, Metamorphic and Igneous rock) that give rise to sandstone. The major socio-economic sources of income of the inhabitants are farming, mining, quarrying, trading and lumbering. The fertile alluvia soils are present to substantiate the potential for food and cash crops production. A bulk (160 kg) of equal soil samples were collected during the last rainy season from 8 communities (Ido Ijesa/Campus area, Isua, Iperindo/Imogbara/Odo Ijesa, and OOra/Iregun) (Plates 1-3) and classified together into 4 categories of samples, based on the similar texture, colour and proximity of the samples under different degrees of degradation. Samples were collected at a depth of 0 - 30 cm from degraded and non-degraded forestland. The heavy metals in the soil samples were determined by atomic absorption Spectrophotometer (Model: AA - 320N, Shanghai, China) such as Lead Pb, Mercury Hg, Arsenic Ar, Iron Fe, and Cadmium Cd as well as Cyanide (mg/kg) adopting electronic analytical balance AA - 200DS, Deriver Instrument Company, Germany for weighing and derived from each soil sampled from the laboratory analysis.

Quantification and sample digest

About 0.5 g of each sample was ground and accurately weighed into a digestion tube. 6 ml aqua regia and 1.5 ml H_2O_2 were added into the digestion tube which was then placed in a digestive furnace (model: KDN - 20c, China) and heated at a temperature of 180°C for 3 hours. All the digests were cooled and filtered through Whatman No. 24 filter paper and diluted to 50 ml by double distilled water. Each sample was digested in replicates of five and transferred to acid - washed stoppered glass bottle. The digested samples were determined for the concentrations of heavy metals using a flame atomic absorption Spectrophotometer. The final concentrations of the metals in the soil samples were calculated as adopted by Uwah *et al.* (2012).

$$\text{Concentration (mg/kg)} = \frac{\text{Concentration (mg/L) x V}}{\text{W}}$$

Where V = Final volume (50 ml) of solution, and W = Initial weight (0.5 g) of sample measured.

Sampling and analysis of cyanide

Whatman No. 1 paper (8 x 1 cm) each was dipped into alkaline picrate solution and drained free of excess liquid.

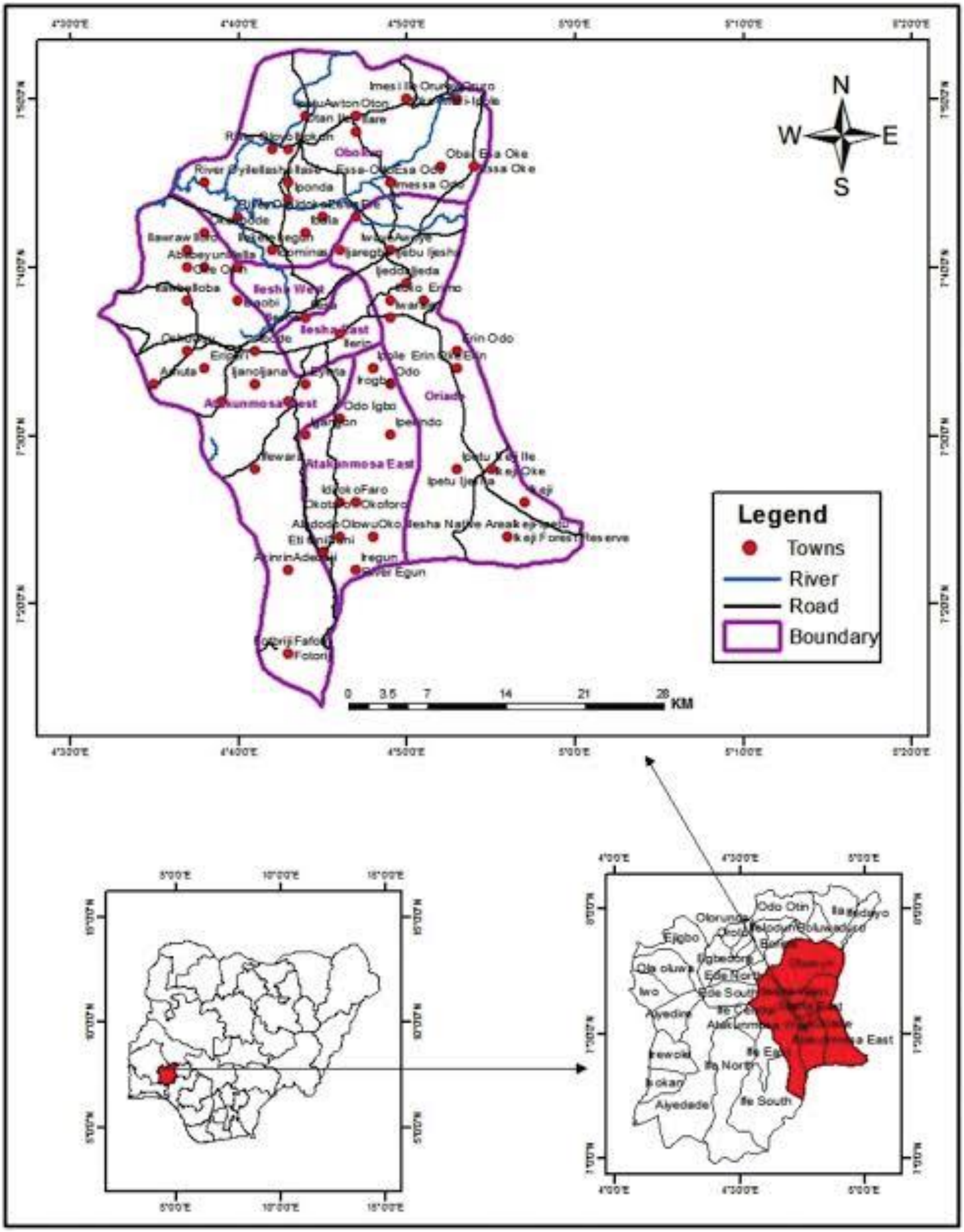

Figure 1. Map of Ijesaland.

Plate 1. Ido-Ijesa.

Plate 2. Iregun/Oora-Ijesa axis.

Plate 3. Imogbara /Odo/Iperindo axis.

Plate 4. Isua axis.

The filter paper strips were prepared under identical conditions. The samples (10 g/sample) were loaded into glass bottles and acidified with 5 ml of hot 20% HCL solution and heated at 80°C. The bottles were sealed with 3 picrate impregnated strips suspended above the acidified samples and incubated at room temperature (28 ± 2°C) for 24 hours. The red coloured picrate paper strips were removed and rinsed in 5 ml of 50% ethanol solution for 30 minutes, and the absorbance of the solution was measured at 510 nm using a spectrum lab (23A Spectrophotometer). Cyanide levels of the samples were extrapolated from the standard curve (Nwokoro *et al*., 2009).

Geo-accumulation (I_{geo}) of metals in soil

According to Emurotu and Onianwa (2017), the extent of each heavy metal in the soil and the contamination level was measured using the index of geo-accumulation (I_{geo}) of metals in the soil.

$$I_{geo} = \log 2 \left[\frac{Cn}{1.5 \text{ x } \beta n}\right]$$

Where: Cn = Concentration of the examined metal in the soil, βn = geochemical background of the same metal, and 1.5 = is the background matrix correction factor.

RESULTS

Heavy metals and Cyanide in Soil

Heavy metal contents of soil samples of the degraded and non-degraded forestland showing the distribution of the heavy metals present in the selected soil samples are presented in Tables 1 and 2.

Heavy metals and cyanide in the soil in degraded forestland

The result in Table 1 revealed the mean concentration levels of the heavy metals in degraded forestland in order of magnitude of concentration:

Ido Ijesa/Campus area- Hg (1.07 mg/kg) > Cd (8.52 mg/kg) > Ar (42.77 mg/kg) > Pb (118.71 mg/kg) > Fe (2391.26 mg/kg).

Isua- Hg (0.64 mg/kg) > Cd (8.33 mg/kg) > Ar (32.74 mg/kg) > Pb (295.72 mg/kg) > Fe (2103.93 mg/kg).

Iperindo/Imogbara/Odo Ijesa- Hg (1.33 mg/kg) > Cd (10.47 mg/kg) > Ar (21.78 mg/kg) > Pb (115.64 mg/kg) > Fe (1755.23 mg/kg).

Table 1. Biogeochemical contents of soil (mg/kg) in the degraded forestland.

Communities	Parameters	Pb	Ar	Hg	Fe	Cd	CN
Idoljesa/ Campus area	Mean value I_{geo}	118.71 (0.94)	42.77 (1.03)	1.07 (0.33)	2391.26 (0.96)	8.52 (0.88)	89.64
Isua	Mean value I_{geo}	295.72 (0.88)	32.74 (1.28)	0.64 (0.31)	2103.93 (0.85)	8.33 (0.66)	102.51
Iperindo/Imogbara/ Odo Ijesa	Mean value I_{geo}	115.64 (1.04)	21.78 (1.21)	1.33 (0.64)	1755.23 (0.88)	10.47 (0.75)	92.68
OOra/Iregun	Mean value I_{geo}	85.74 (0.94)	35.75 (0.75)	2.06 (0.56)	1505.83 (0.66)	6.74 (0.92)	114.44

Figures in parentheses are index of geo-accumulation (I_{geo}) of metals in soil. CN = Cyanide.

Table 2. Biogeochemical contents (mg/kg) of the non-degraded forestland.

Communities	Parameters	Pb	Ar	Hg	Fe	Cd	CN
Idoljesa/ Campus area	Mean value I_{geo}	29.64 (0.94)	2.61 (1.03)	0.56 (0.33)	1004.12 (0.96)	1.66 (0.88)	25.50
Isua	Mean value I_{geo}	103.70 (0.03)	4.66 (0.13)	0.33 (0.11)	1235.37 (0.44)	2.74 (0.12)	22.68
Iperindo/Imogbara/ Odo Ijesa	Mean value I_{geo}	74.60 (0.21)	1.91 (0.25)	0.83 (0.09)	894.35 (0.17)	2.43 (0.31)	21.65
OOra/Iregun	Mean value I_{geo}	26.78 (0.11)	2.12 (0.11)	1.01 (0.18)	235.21 (0.13)	0.61 (0.12)	41.18

Figures in parentheses are index of geo-accumulation (I_{geo}) of metals in soil. CN = Cyanide.

OOra/Iregun- Hg (2.06 mg/kg) > Cd (6.74 mg/kg) > Ar (35.75 mg/kg) > Pb (85.74 mg/kg) > Fe (1505.83 mg/kg)

Heavy metals and cyanide in the soil in non-degraded forestland

The heavy metal contents of soil collected from non-degraded sites are shown in Table 2 and the findings are:

Ido Ijesa/Campus area - Hg (0.56 mg/kg) > Cd (1.66 mg/kg) > Ar (2.61 mg/kg) > Pb (29.64 mg/kg) > Fe (1004.12 mg/kg)

Isua- Hg (0.33 mg/kg) > Cd (2.74 mg/kg) > Ar (4.66 mg/kg) > Pb (103.70 mg/kg) > Fe (1235.37 mg/kg)

Iperindo/Imogbara/Odo Ijesa - Hg (0.83 mg/kg) > Cd (2.43 mg/kg) > Ar (1.91 mg/kg) > Pb (74.60 mg/kg) > Fe (894.35 mg/kg)

OOre/Iregun - Ca (0.61 mg/kg) > Hg (1.01 mg/kg) > Ar (2.12 mg/kg) > Pb (26.78 mg/kg) > Fe (235.21 mg/kg)

DISCUSSION

The maximum value for each metal in the degraded forest followed in the same order and the findings indicated that all the heavy metals are high in contents; however, in the non-degraded forest, the maximum value of each metal in the same order of magnitude of concentrations are moderate except only for Ore/Iregun communities where Hg (0.68 mg/kg) has a higher maximum value than Cd (1.01 mg/kg). The indication is that the soil in Ijesaland contained heavy metal contents (mg/kg) which bring about dangerous pollution of soil to justify Makino *et al*. (2010). Also, the findings imply that all geochemical components of metals were far lower in non-degraded forestland if compare with the values in degraded forestland. The values of metals in the degraded site were outrageous and did not fall within the United States Environmental

Protection Agency (USEPA) regulated baseline limits, for the application of industrial waste to agriculture. The baseline of the United States Environmental Protection Agency (USEPA, 1993); is adopted for the interpretation of acceptable limits, Arsenic (0.11 mg/kg), Cadmium (0.48 mg/kg), Mercury (1.00 mg/kg), Lead (200 mg/kg) and Cyanide (10 mg/kg). The presence of heavy metal contents in the sample collected in degraded forestland are decreasing in the following order; Ido Ijesa/Campus area - Hg > Cd > Ar > Pb > Fe, Isua- Hg > Cd > Ar > Pb > Fe while in Iperind/Imogbara/Odo Ijesa- Hg > Cd >Ar > Pb > Fe and Oora/Iregun- Hg > Cd > Ar > Pb > Fe. A strong tendency towards the decrease of the contents of heavy metals is observed in the sample collected from non-degraded forestland. The results of the extent ofcontamination level by the presence of each heavy metal content in the soil sample obtained for degraded forestland (Ar, Hg, Cd, Pb, Fe & Cn) were analogous. The values of geo-accumulation (I_{geo}) of metals in soil samples from the Ido Ijesa/Campus area, Isua, Iperind/Imogbara/Odo Ijesa, and Oora/Iregun were Ar (1.03, 1.28, 1.21 and 0.75) respectively were considerably exceeded the baseline except for the Oora/Iregun communities. In the non-degraded area, Arsenic content is found higher than the baseline in Ido Ijesa/Campus area while it was moderately low in the rest communities (1.03, 0.13, 0.25 and 0.11). The values of Hg (0.33, 0.31, 0.64 and 0.56) below the baseline and so also the sample from non-degraded. However, values in degraded communities for Cd (0.88, 0.66, 0.75 and 0.92) considerably exceeded the USEPA baseline and in non-degraded. Cadmium content is found lower than the baseline in all the samples with exception of the Ido Ijeas/Campus area where Cadmium is higher (0.88, 0.12, 0.31 and 0.12). More so, the values for Pb and Fe in both degraded and non-degraded are observed high but with more concentration in degraded forestland which brings about dangerous pollution of soil to justify Makino *et al*. (2010). Also, the values for Cyanide in the degraded sample (89.6, 102.5, 92.7 and 114.4) excessively exceeded the baseline and Cn (25.50, 22.68, 21.65 and 41.81) recorded for the non-degraded soil sample. According to Moustakes *et al*. (1994) and Majekodunmi (2014), high concentration of heavy metals in farmland, brings oxidative stress, damage cell tissues, and hamper photosynthetic activities in plants. Iron is essential for the formulation of chlorophyll and functions in some of the enzymes of the respiratory system but excessive content of this metal becomes contaminant (Thompson and Troeh, 1973). With concentration of heavy metals (mg/kg), degraded forestland is exceptionally high and an indication that agricultural production will suffer from poor plant growth and crop yield. There is every tendency that excessive levels of heavy metals in Ijesa land are detrimental to plant growth just like Hg, Cd, and Pb were proven to have reduced plant growth in maize farms (Ghani, 2010). The heavy concentration of metals especially Pb and Cd can result in phytotoxic, erosion and death of human beings through crop consumption. An increase in the contents of Cd in food crops could be of health concern if such crops are ingested. Cyanide is highly toxic and can result in substantial environmental impacts and public health risk if released into environment. Specifically, cyanide spillage affects biological, physical and chemical status of the soil by inhibiting plant respiration, nutrition absorption, and reducing soil pH, bacteria, and fungi count in the soil (Smah *et al*., 2021). Geometrically, increase in heavy metal content (mg/kg) was observed between the degraded and non-degraded forestland meaning that if the pace of increment continues it may lead to high toxicity of heavy metals. However, the accumulation of toxicants in farmland could lead to the contamination of agricultural soil. Once the soil is contaminated, it will not only affect the rapid growth of crops and yields but poses a severe threat to living organisms. Considering the baseline, a contaminant can be regarded as a pollutant when the observed content of the contaminant is high enough to harm living organisms.

Mining sites that spread across these communities pose more risk than the control and children are more exposed than adults (Bwede *et al*., 2021). A statement credited to Hon. Commissioner for Health, according to Daily Trust 12th August 2022 admitted that the Osun river has been heavily contaminated with Mercury, Lead, Cyanide and other injurious elements that are poisonous to human health. Transforming our food system and helping smallholder farmers through decisive actions of stakeholders in protecting our environment is essential if we want to end poverty on our land.

Conclusion

The presence of heavy metals, cyanide and anthropogenic wastes in Ijesa land will definitely bring about poor and low agricultural productivity, and the health of inhabitants is in serious danger. Based on the spot observation and laboratory test analysis, this paper concludes that gold mining is an industry which grossly impaired human health and retard agricultural activities leading to a poor and low food production system. Hence, environmental degradation is an indictment to everyone without exception in the study area.

Recommendations

Base on the findings in the study, the following recommendations are put forward:

1. Federal and State governments should consider the idea of compensating vulnerable communities of degradation.
2. The Federal and State governments should settle dichotomy on the constitutional right of land and mineral resources ownership between themselves.
3. Companies should be forced to adopt standard

practices of industrial waste management.

4. Standard Organization of Nigeria (SON) should ensure best industrial waste practices by Artisan as established by the certified environmental impact assessment.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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