Research Article

Risk Appraisal of Itagunmodi Mining Site for Heavy Metals

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Abstract

Heavy metal contamination of agricultural soils and crops surrounding the mining areas is a serious environmental problem in many countries including Nigeria. Mining and smelting operations are important causes of heavy metal contamination in the environment. The pollution characteristics of Cu, Ni, Cd, Cr, Zn and Fe in goldmine tailing were studied. The results indicate that the contamination degree followed the sequence of 5>1>3>2>4. The concentrations of Cu, Zn Ni and Cr in the soil were low, so their potential ecological risks were far lower than other heavy metals and exerted no potential harm to environment.

Keywords: Heavy metals, Ecological, Geoaccumulation index, Index, Potential

Introduction

Mining and smelting operations are important causes of heavy metal contamination in the environment due to activities such as mineral excavation, ore transportation, smelting and refining.[1] Moreover, wastewater, waste gas and solid waste generated in the process of mining and smelting activities will lead to the release and migration of heavy metals thus cause heavy metals pollution of soil near the mining area.[2] Heavy metal contamination of soils in the vicinity of mining areas has been regarded as a great environmental concern.

Mining gives rise to soil erosion and environmental contamination by generating waste during the extraction, beneficiation, and processing of minerals. After closure, mines can still impact the environment by contaminating air, water, soil, and wetland sediments from the scattered tailings, as well as pollution of groundwater by discharged leachate, unless the proper remediation is conducted.[3]

Mining activities can contribute to heavy metal pollution of the environment.[2,4] Progressive accumulation of heavy metals in soils surrounded by mines, result in increased heavy metal uptake by food plants. This is worrisome because of potential health risk to the people leaving in the surrounding areas.[5]

Elements like Pb, Cd, Cr and Ni, are said to be non biodegradable thus, persist everywhere in the environment and have the ability to be deposited in various body organs which poses a great threat to the human health.[6] Several researches have shown that food plants, growing in heavy metal contaminated soils have higher concentrations of heavy metals than those grown in uncontaminated soil.[7] It has been reported that serious health problems have develop as a result of high accumulation of heavy metals such as Cd, and Pb in the human body.[1] Despite Zn and Cu being essential elements in the diet, high concentration in food plants is of great concern because they are toxic to humans and animals.[8] Pb and Cd metals are believed to be potential carcinogens and are implicated in the ontology of many diseases, especially

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cardiovascular diseases, kidney, nervous system, blood as well as bone ailments.[9] Therefore in this study the level and risk of the heavy metals in the goldmine tailings of Itagunmodi, Nigeria was studied.

Material and Method

The Study Area

Itagunmodi gold community lies between latitudes 7°30' and 7°33' N and between longitudes 4°36' and 4°39' E in Atakumosa West Local Government Council southwestern Nigeria. The study area is a rural community of about 2,400 to 2,600 people that engage predominantly in subsistence farming and cocoa plantation.

Sample Collection and Pretreatment

Soil samples were oven dried at 40^{0}C for two weeks. Samples were sieved through a 0.8mm mesh and stored in clean polythene bags for further analysis.

Determination of Total Heavy Metal in Soil

Dried and powdered soil sample of 1.2 g was digested with aqua regia (3:1 HCl: HNO_3) in 100 mL conical flask on a hotplate and diluted to volume with distilled water. Fe, Cr, Cu, Zn, Cd, and Ni in the digest were determined using 210 VGP (Buck Scientific) atomic absorption spectrophotometer. The detection limit of the atomic absorption spectrophotometer used is 0.01.

Geo accumulation index (I_{geo})

The contamination levels of heavy metals in soils were assessed by geo accumulation index ($_{Igeo}$).

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

Where C_n is the measured concentration of heavy metal n in the soils, B_n the geochemical background concentration of metal n, and 1.5 is the background matrix correction factor due to lithogenic effects [muller].

Table 1.Geo-accumulation Index Classes[10]

Classes	Ranges	Indications
0	Igeo<0	Practically uncontaminated
1	0<igeo<1	Uncontaminated- moderate
2	1<igeo<2	Moderately uncontaminated
3	2<igeo<3	Moderately-heavily contaminated
4	3<igeo<4	Heavily contaminated
5	4<igeo<5	Heavily- extremely contaminated

Contaminant Factor and Degree of Contamination

Assessment of soil contamination is performed by the contamination factor (C_f^i) and degree of contamination (C_d).[11]

$$C_f^i = C_s^i / C_n^i, \quad C_d = \sum_i^m C_f^i$$

Where C_s^i is the content of metal I and C_n^i is the reference value, baseline level, or national criteria of metal i.

Table 2.Descriptive Classes of Contamination Factor[11]

Classes	Indications
$C_f<1$	Low contamination
$1<c_f<3$	Moderate contamination
$3<c_f<6$	Considerably contaminated
$6<c_f$	Very high contaminated

Table 3.Degree of Contamination[11]

Classes	Indications
$C_d<8$	Low degree of contamination
$8\leq c_d<16$	Moderate degree of contamination
$16\leq c_d<32$	Considerable degree of contamination
$32\leq c_d$	Very high degree of contaminated

Ecological Risk Factor

An ecological risk factor (E_r^i) to quantitatively express the potential ecological risk of a given contaminant also suggested by Hakanson is $E_r^i = T_r^i C_f^i$

The toxic-response factor T_r^i of heavy metals i are: $T_r^{Zn} = 1$; $T_r^{Pb} = 5$; $T_r^{Cd} = 30$; $T_r^{Cu} = 5$; $T_r^{Ni} = 5$; $T_r^{Cr} = 2$.

Table 4.Descriptive Table for Ecological Risk Factor (E_r)[11]

Classes	Indications
$E_r^i \le 40$	low potential ecological risk
$40 \le E_r^i < 80$	moderate potential ecological risk
$80 \le E_r^i < 160$	considerable potential ecological risk
$160 \le E_r^i < 320$	high potential ecological risk
$E_r^i \ge 320$	very high ecological risk

Ecological Risk Index (I_r)

$$I_r = \sum_i^n E_r^i = \sum_i^n T_r^i C_f^i = \sum_i^n T_r^i C_s^i / C_n^i$$

Table 5.Descriptive Table for Ecological Risk Index (I_r)[11]

Classes	Indications
$I_r < 150$, low ecological risk	Low ecological risk
$150 \le I_r < 300$	Moderate ecological risk
$300 \le I_r < 600$	Considerable ecological risk
$I_r > 600$	Very high ecological risk

Results

Table 6.Result for Geo-accumulation Index (I_{geo}) in the Study Area

Heavy metal	Igeo	Pollution level
Cu	0.174	Uncontaminated- moderate
Ni	0.390	Uncontaminated- moderate
Zn	1.445	Moderately uncontaminated
Cr	-3.520	Practically uncontaminated
Cd	1.361	Moderately uncontaminated
Fe	-5.322	Practically uncontaminated

Table 7.Result for Contamination Factor (C_f) and Degree of Contamination (Cd) in the Study Area

Location	Cu	Ni	Zn	Cr	Cd	Fe	C_d
1	1.60	2.0	0.76	0.06	3.08	0.04	9.54
2	1.02	1.95	0.61	0.10	4.34	0.03	8.06
3	1.06	2.20	0.60	0.13	4.86	0.04	8.89
4	0.60	1.40	0.48	0.19	2.98	0.03	5.67
5	2.17	2.29	1.57	0.18	4.00	0.04	10.10
Average	1.29	1.97	0.80	0.13	3.85	0.035	

Table 8.Result for Ecological Risk Factor (E_r) and Potential Ecological Risk Index (I_r) in the Study Area

			E_r			
Location	Cu	Ni	Zn	Cr	Cd	I_r
1	18.0	10.0	0.76	0.11	92.4	121.3
2	5.1	9.75	0.61	0.21	130.2	145.9
3	5.3	11.0	0.60	0.27	145.8	163.0
4	3.0	7.0	0.48	0.37	89.0	99.9
5	10.85	11.45	1.57	0.35	120.0	144.2
Average	8.45	9.84	0.80	0.26	115.48	

Discussion

Muller descriptive Table 1 is used to categorize the average values of Igeo for each metal and their pollution levels. To further determine the environmental pollution and the ecological damage of heavy metals in the soil, potential ecological risk index method proposed by Hakanson L was employed and the descriptive Table 2-5 was used to categorize them.[11]

Geo-accumulation Index (Igeo)

The I_{geo} values were calculated by the heavy metals (Cu, Ni, Zn, Cr, Cd, Fe) average concentrations in soil samples. The average values of Igeo for each metal and their pollution levels are shown in Table 6. Results indicate that the soils of the study area can be categorized as follows: practically uncontaminated with Cr and Fe, uncontaminated-moderate

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with Cu and Ni, moderately uncontaminated with Zn and Cd. The assessment results were in the following trend: Zn>Cd>Cu>Ni>Cr>Fe.

Contamination Factor and Degree of Contamination

For description of contamination factor and degree of contamination, descriptive table 3.0 and 4.0 are used to categorized them. Cd is greater than 3 and less than 6 which indicated that it is considerable contaminated while Cu, Ni were greater than 1 and less than 3 which indicated moderate contamination. Zn, Cr and Fe were less than 1 which indicated low contamination.

As can be seen from Table 7, the contamination degrees of location 1, 2, 3 and 5 were greater than 8 and less than 16, which indicated that they were within moderate degree of contamination. The contamination degree of location 4 is less than 8 which indicated that they were within low degree of contamination. The average contamination degree of all soil samples was 8.45, which suggested that they were within moderate degree of contamination. The order of contamination degree of each sampling area was 5>1>3>2>4.

The Ecological Risk Factors and Potential Ecological Risk Index

According to Table 8, the potential ecological risk factor of Cu, Ni, Zn, Cr were much less than 40, indicating low ecological risk. The potential ecological risk factor of Cd was greater than 80 and less than 160, indicating considerable potential ecological risk. The order of the potential ecological risk factor of heavy metals was Cd>Ni>Cu>Zn>Cr. The potential ecological risk index for each location was in the order of 5>1> 3>2>4. In addition, the potential ecological risk index for location 1, 2, 3, 4 and 5 was less than 150, indicating that the potential ecological risk was low. Among them, the I_r value of location 1 was greater than 150, indicating moderate potential ecological risk index.

The concentrations of Cu, Zn Ni and Cr in the soil were low, so their potential ecological risks were far lower than other heavy metals and exerted no potential harm to environment.

Conclusion

The Igeo values suggest that the soil samples were practically/ moderately contaminated with the heavy metals. The assessment results show that the contamination degree from considerable to low in soil is Cd>Ni>Cu>Zn>Cr>Fe.

The potential ecological risk index for each location is in the order of 5>1>3>2>4. The order of the potential ecological risk factor of heavy metals is Cd>Ni>Cu>Zn>Cr.

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