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ORIGINAL RESEARCH ARTICLE

Assessment of Heavy Metal Pollution and Ecological Risks in Mining Areas of Didango, Taraba State: Bridging Gaps for Environmental Management

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ABSTRACT
This study assessed the extent of heavy metal environmental concerns resulting from the increasing artisanal mining activities in the area. Due to the volume of mining activity in Ruwan Gishiri and Alpha, two mining locations were investigated. Four mining pits were sampled at two depths (0 – 15 cm for top soils and 15 – 30 cm for sub-soils) for each of the two mining locations. Twenty (20) soil samples were collected overall, including two control samples that were also collected from each mining site. The soil samples were analyzed for Al, Cu, Fe, Cd, Cr, Ni, and Pb using a Microwave Plasma Atomic Emission Spectrophotometer (42010 MP-8ES). The study found that the levels of heavy metals in soil samples taken from Ruwan Gishiri and Alpha mining areas were ranked as follows: Al, Fe, Pb, Cu, Cd, Ni, and Cr. The concentration of Cd exceeded the maximum permissible limits for soil. Cd also has the highest ecological risk (ErF = 35.25 – 249.38), followed by Pb (ErF = 0.26 – 10.78), while Cr had the lowest risk factor (ErF = 0.001 – 0.006). The findings also showed that Cd was attributable to 97.17 % of the area's total ecological risk factor. The overall ecological risk of metals under study ranges from low to moderate, according to the risk index (RI) results. These findings demonstrated the urgent need for mining activity controls in the study area to protect the local community and environment from heavy metal pollution.

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Taraba State, artisanal mining, ecological risk, heavy metals, and soil contamination

INTRODUCTION
There were large fluctuations in the amounts of heavy metals found in natural environments. However, anthropogenic sources of heavy metals have become a factor in ecosystems today due to the widespread nature of human activity (Briffa *et al.*, 2020). The global attention and research efforts of scholars have been directed towards the issue of heavy metal pollution of soil in metal mining areas (Chen *et al.*, 2022). The rate at which artisanal mining releases these heavy metals into the soils and the resulting pollution has raised significant environmental concerns. Suruchi and Pankaj (2011) have identified potential toxicity to plants and wildlife as the primary issue. This is because an excess of heavy metals could generate bio-magnification issues, which can arise at many points in the biological food chain and potentially lead to major health issues for humans and animals.

Pollution from heavy metals is still a major environmental concern, particularly in areas where mining, industrial activity, and sewage irrigation occur. Marques *et al.* (2009) identified four primary pathways through which heavy metals can infiltrate the soil ecosystem: mining activities, sewage irrigation, weathering of rocks, and industrial output. Urbanization and industrialization both lead to a rise in the intensity of mineral development and the rate of increase in heavy metal concentrations in the soil.

One of the states in Nigeria with abundant mineral resources is Taraba State. These mineral resources have been studied and exploited in the last few decades. The principal mining operators in Taraba State are small-scale and artisanal miners or individuals or organizations that engage in informal mining activities based on manual labor with basic tools and techniques. According to reports by Oladipo *et al.* (2014) and Ahmed and Oruonye (2016), most surface mining activities in these regions are conducted without using advanced technologies to manage the environment harmed by the mining operations. Large industrial and small-scale artisanal miners engage in extensive mining operations indiscriminately and without regard for the environment, inhabitants, and other users. The ecology is suffering

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more and more due to these careless mining operations. The situation was worsened by the fact that, according to Oruonye and Ahmed (2018), the majority of miners engage in illicit mining activities without official authorization, and some mining sites are not accessible to government personnel. This may have made it more challenging for the government to enforce rules and monitor operations.

Because heavy metals are difficult to break down throughout the biological cycling and energy exchange processes in soil, they are difficult to remove from soils. Over time, this leads to challenges in cleaning up heavy metal contamination in soils (Fytianos *et al.*, 2001). However, crops cultivated in possibly harmful metal-contaminated soil may result in a number of health problems for people, particularly if the concentrations of those metals are higher than what is considered safe (Khalid *et al.*, 2018). Overexposure to heavy metals can be extremely harmful to both plants and animals. Therefore, research on heavy metal pollution of soil, especially in agricultural soils, is crucial to maintaining healthy ecosystems.

The state's artisanal mining business grew in some of the villages, contaminating large expanses of land. Consequently, this study evaluated the degree of soil pollution, the concentration of heavy metals around the mining sites, and the ecological health risk of the heavy metals in soils at these locations.

MATERIALS AND METHODS

Study Area

The investigation was conducted in Didango of Karim Lamido local government area, Taraba State. It is situated between latitudes 8°40′00″ E and latitude 9°29′00″ E, and longitudes 10°51′00″ N and 11°29′00″. Karim Lamido has a mean temperature of 29 °C and a total land area of roughly 6620 km². Oruonye and Abbas (2011) state that the dry season normally begins in mid-November and ends in March, whereas the rainy season usually begins in April and finishes in October. Sedimentary rocks and the basement complex underlie Taraba State, each in a completely different area. The majority of the state is made up of basement complex rocks (~ 80%), whereas sedimentary rocks are mostly found in the valleys of the River Benue and its major tributaries (Oruonye and Abbas, 2011). The primary source of income for the residents of Karim Lamido is agriculture, which includes crop and animal production. Groundnuts, rice, maize, sorghum, millet, cassava, and other crops are farmed significantly in the region. Large numbers of cattle, sheep, and goats are also raised.

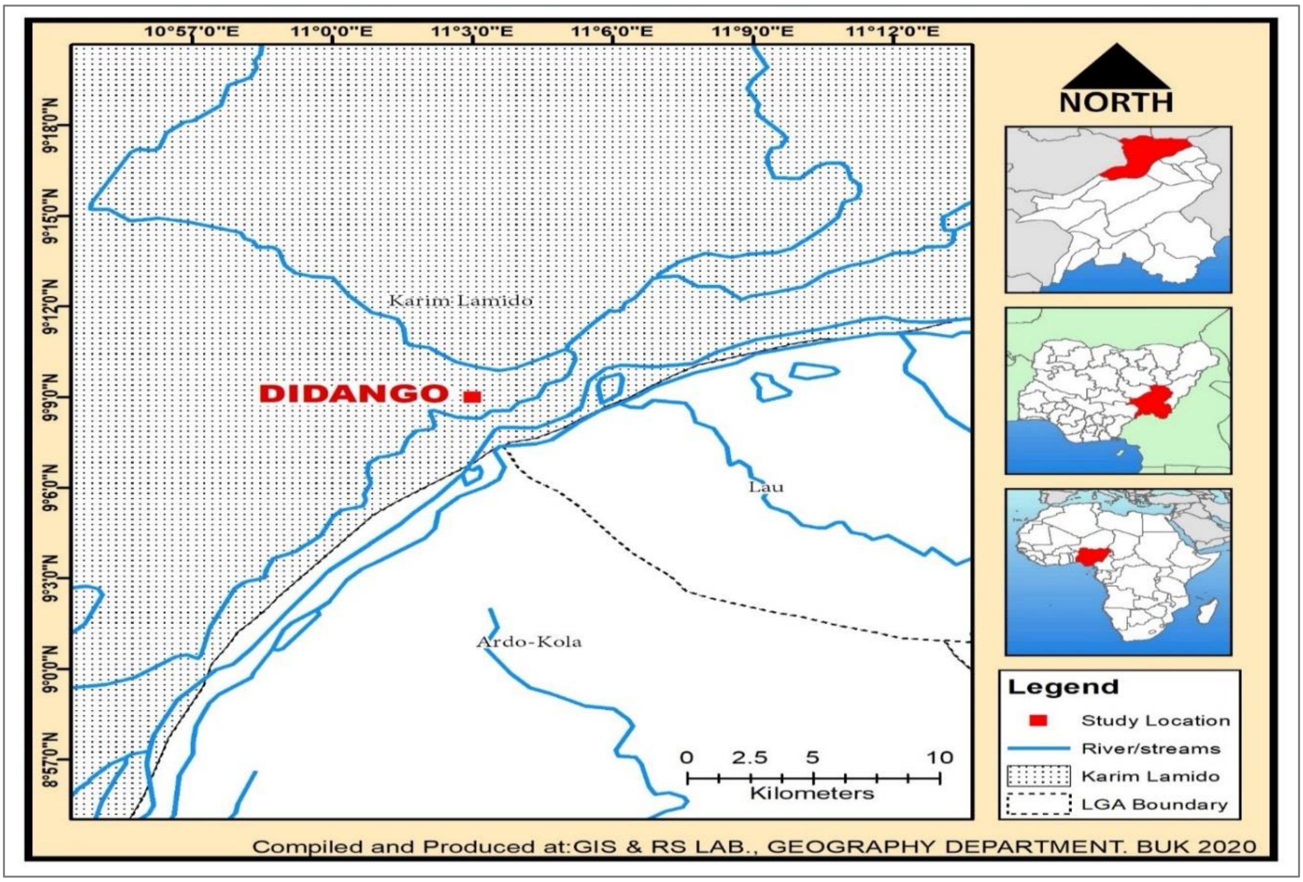

Figure 1: Study area, Didango, Karim Lamido Local Government Area, Taraba State.

Sampling Techniques

Samples of soil were taken from two Didango mining locations (Ruwan Gishiri and Alpha mining sites). In the Ruwan Gishiri mining site, four pits were chosen randomly; these sampling places were referred to as RG1, RG2, RG3, and RG4. Four pits were randomly chosen from the Alpha mining site and were named Alpha1, Alpha2, Alpha3, and Alpha4. According to Shafaqat *et al.* (2014), soil samples were taken during the dry season from two mining sites and two regions at the nearby upland inside the study area. Using a hand-driven soil auger, samples were obtained at two depths: 0–15 cm for top soils and 15–30 cm for sub-soils. In each location, a sample of soil weighing approximately 100 g was collected and tagged using Ziploc plastic bags. In order to achieve this, twenty soil samples were gathered and sent to the lab for investigation.

Sample Treatments

The soil samples were left to air dry at a temperature between 25 and 27 degrees Celsius for 72 hours. After being crushed and put through a 2 mm sieve, the samples were labeled clearly and placed in containers ready for laboratory processing. The necessary quality assurance precautions were followed to avoid contaminating the sample.

Determination of Heavy Metals

The Mehlich 3 extraction method (2016) was utilized to analyze various heavy metals discovered in the soil samples. A soil sample that had been air-dried and weighed at 2.0 g was put into a 50 ml centrifuge tube. Blanks and representative samples and 20.0 ml of Mehlich extraction solution were added. The centrifuge tubes were positioned on their sides on the shaker table for five minutes. After shaking, the suspension is immediately filtered using #41 Whatman filter paper and placed into 23 ml disposable sample vials. After adding and thoroughly mixing 0.25 M EDTA stock solution and 16 ml of 3.7 M ammonium fluoride (NH_4F), Next, 3.3 milliliters of concentrated nitric acid (HNO_3) and 46 milliliters of concentrated acetic acid (CH_3COOH) were added.

Data analysis

Descriptive statistics were computed based on the heavy metal contents, including the lowest, maximum, arithmetic mean values, and standard deviation (STD). Additionally, the results were subjected to an ecological risk assessment using the Haknson (1980) methodology, as reported by Zhang *et al.* (2017) and Okunle and Fatoba (2014).

Contamination Factor (CF)

The heavy metal concentration at each measurement site divided by the metal evaluation criteria yields the contamination factor. The acceptable limit of the metal is one of the evaluation criteria for metals. Consequently;

$$ContaminationFactor\ CF = \frac{Ci}{Cref} \text{........... ......} \quad (1)$$

Ci represents the metal concentrations at each sampling location, and Cref denotes the metal's evaluation criterion.

The following is a description of the level of contamination found: There is no contamination when CF < 1. A value of CF $> 1 \leq 2$ suggests possible contamination. A CF value of $> 2 \leq 3.5$ denotes mild contamination. Moderate contamination is indicated by CF $> 3.5 \leq 8$. When CF $> 8 \leq 27$, serious contamination is indicated. Extreme contamination is indicated by CF $>$ 27.

The Ecological Risk Factor (ErF)

Ecological Risk Factor (ErF) measures the correlation between a single contamination and its ecological risk. It is quantitatively computed through this formula as:

$$ErF = Tri \times CFi \text{.....................................} \quad (2)$$

Where: *Tri* represents a toxic response of metals (Ni = 5, Pb = 5, Cr = 2, and Cd = 30), and *CFi* represents the contamination factor.

The Potential Ecological Risk index (RI)

The RI comprises the sum of all ErFs of all the metals under investigation, keeping in mind the cumulative impact of metals. It is computed through the following formula:

$$RI = (ErF1 + ErF2 + ErF3 + ErF4 + ErF5 + ErF6 + ErF7) \text{.................} \quad (3)$$

Where n is the number of elements analyzed, ErF is the ecological risk factor.

The following terms are recommended for the Er and RI values, per Hakanson (1980): Low ecological risk is indicated by ErF < 40; moderate ecological risk is indicated by $40 <$ Er ≤ 80; significant ecological risk is indicated by $80 <$ Er ≤ 160; high ecological risk is indicated by $160 <$ Er ≤ 320; and serious ecological risk is indicated by > 320. Low ecological risk is indicated by RI < 150, moderate ecological risk is shown by $150 <$ RI ≤ 300, high ecological risk is indicated by $300 <$ RI ≤ 600, and considerably high ecological risk is indicated by RI $\geq$ 600.

RESULTS AND DISCUSSION

Concentrations of Heavy Metals in the Mining Site Soils

Tables 1 and 2, respectively, provide the findings of the concentrations of heavy metals in the soils of the Ruwan Gishiri and Alpha mining sites. The findings indicated that the mean concentration of cadmium (Cd) content in the soils at the Alpha mining site (4.91 ± 1.57 ppm) was significantly higher ($P < 0.05$) than that of 1.41 ± 0.31 ppm. The average cadmium concentration was found in soil samples from the Ruwan Gishiri mining site (Tables 1 and 2). Using phosphate fertilizers containing cadmium and dust from mining operations may cause elevated cadmium levels. The investigation yielded cadmium concentrations above the recommended limit of 0.8 ppm for soil (WHO, 1996).

Furthermore, it was found that various mining activities carried out in the Ruwan Gishiri mining site could not raise the amount of Cd in the soil. Equally, there was no discernible difference between the Cd concentration at the Ruwan Gishiri mining site and 1.45 ± 0.47 ppm at the control site. Cadmium is a very dangerous heavy metal that is not necessary, even in very small doses. According to Hunt (2003), it makes kids hyperactive and creates learning problems.

The concentration of iron (Fe) in the soils at the Ruwan Gishiri mining site ranged from 105.38 to 197.63 ppm, with a mean concentration of 137.22 ppm, which is below the maximum permissible limit of 1500 ppm (WHO 1996). These concentrations were lower than the 235.53 and 341.90 ppm Fe concentrations obtained by Shah *et al.* (2013). From the result (Table 1), the copper content in the Ruwan Gishiri mining site (2.84±0.65 ppm) was considerably ($P < 0.05$) lower than the amount of copper in soil samples originating from the Alpha mining site (8.89±3.13 ppm). This amount is less than the 36 ppm threshold soil total concentration (WHO, 1996), which suggests that there are few anthropogenic effects on the soils of the area.

The amount of Ni present in the soils ranges from 0.18 to 0.29 ppm “Ruwan Gishiri mining site” and 0.48 to 0.76 ppm “Alpha mining site”, with average concentration levels of 0.23±0.03 and 0.57±0.10 ppm, respectively. Throughout the research area, the content of Ni in soil samples is within the 35 ppm allowable limit (WHO, 1996). The result of this study indicates that the mining activities around the study area do not have a notable impact on the soil nickel concentration.

Pb concentrations in soil samples from the Alpha mining site (114.34±74.09 ppm) were substantially higher than those from the Ruwan Gishiri mining site (12.94±8.03 ppm) (Tables 1 and 2). The WHO acceptable limit of 85 ppm for lead concentration was surpassed in the soils of the Alpha mining site (WHO, 1996). Similarly, Bloundi et al. (2009) reported finding significant Pb concentrations in Morocco's Nardo Lagoon sediment—up to 297 parts per million. The discharge of industrial pollutants in the vicinity was also blamed for this. High amounts of lead deposition in the human body can cause anemia, colic, migraines, brain damage, and abnormalities of the central nervous system (Rehman *et al.*, 2013).

Table 1: Concentration of Heavy Metals at Ruwan Gishiri Mining Site (ppm)

Sample Identity	Cd	Fe	Cu	Ni	Pb	Cr	Al
RG 1 (0-15 cm)	1.09	132.56	1.55	0.20	14.70	0.07	206.00
RG 1 (15-30 cm)	1.50	105.38	2.58	0.24	10.00	0.04	302.61
RG 2 (0-15 cm)	0.94	137.28	3.17	0.25	13.10	0.06	195.80
RG 2 (15-30 cm)	1.28	197.63	2.63	0.18	4.69	0.04	216.93
RG 3 (0-15 cm)	1.40	134.02	2.53	0.24	6.44	0.06	296.83
RG 3 (15-30 cm)	1.56	122.46	3.38	0.29	7.68	0.04	439.14
RG4 (0-15 cm)	1.94	141.81	3.29	0.23	17.07	0.12	338.39
RG4 (15-30 cm)	1.54	126.63	3.56	0.22	29.80	0.10	493.51
Min.	0.94	105.38	1.55	0.18	4.69	0.04	195.80
Max.	1.94	197.63	3.56	0.29	29.80	0.12	493.51
Mean	1.41	137.22	2.84	0.23	12.94	0.07	311.15
S.D	0.31	26.85	0.65	0.03	8.03	0.03	109.48
Ctrl 1	1.11	126.45	1.15	0.34	1.65	0.06	192.14
Ctrl 2	1.78	118.75	1.22	0.34	0.69	0.04	222.44
MPL	0.80	1500	36	35	85	100	1500

Abbreviation: RG, Ruwan Gishiri; Control soil sample (Ctrl); Minimum = Min; Maximum = Max; Standard deviation = SD; MPL = maximum permissible limit, according to WHO (1996).

Table 2: Summary Statistics of Heavy Metals Concentration at Alpha Mining Site (ppm)

Sample Identity	Cd	Fe	Cu	Ni	Pb	Cr	Al
Alpha 1 (0-15 cm)	4.28	169.01	6.04	0.51	7.62	0.04	266.81
Alpha 1 (15-30 cm)	5.41	134.48	4.30	0.50	4.44	0.05	343.87
Alpha 2 (0-15 cm)	2.05	289.25	5.57	0.76	87.32	0.04	262.65
Alpha 2 (15-30 cm)	5.68	234.28	5.17	0.66	124.53	0.11	280.43
Alpha 3 (0-15 cm)	3.30	122.40	4.65	0.64	153.91	0.10	287.50
Alpha 3 (15-30 cm)	6.17	244.74	23.09	0.53	183.20	0.07	131.55
Alpha 4 (0-15 cm)	5.71	259.13	17.13	0.50	178.84	0.31	118.18
Alpha 4 (15-30 cm)	6.65	105.00	4.93	0.48	174.82	0.16	295.98
Min.	2.05	105.00	4.30	0.48	4.44	0.04	118.18
Max.	6.65	289.25	23.09	0.76	183.20	0.31	343.87
Mean	4.91	194.79	8.86	0.57	114.34	0.11	248.37
S. D	1.57	70.43	7.14	0.10	74.09	0.09	80.26
Ctrl 1	3.95	134.18	0.94	0.45	15.72	0.14	186.15
Ctrl 2	2.96	121.85	1.49	0.57	0.69	0.13	221.14
MPL	0.80	1500	36	35	85	100	1500

Abbreviation: Control soil sample (Ctrl); Minimum = Min; Maximum = Max; Standard deviation = SD; MPL = maximum permissible limit, according to WHO (1996).

Furthermore, the Ruwan Gishiri and Alpha mining sites have revealed chromium concentrations of 0.07±0.03 ppm and 0.11±0.09 ppm, respectively. The WHO recommended level of 100 ppm for chromium was not exceeded by the chromium concentrations found at the mining sites (WHO, 1996). Consuming fish that could have high chromium content can be detrimental since chromium frequently builds up in aquatic life (Sexana et al., 2006). The Ruwan Gishiri and Alpha mining sites have mean aluminum values of 195.80–493.51 ppm and 118.18–343.87 ppm, respectively (Tables 1 and 2). The aluminum concentrations at the mining sites were below the WHO's 1996 acceptable guideline of 1500 ppm. Acidic soils cause aluminum toxicity, adversely affecting grains and reducing their vigor and output. Al toxicity is also the main factor affecting crop output in 65 % of the entire area with acid soil (Eswaran *et al.*, 1997).

In soil samples taken from the Ruwan Gishiri mining site, the following heavy metal concentrations are found in decreasing order: Al (311.15 ppm), Fe (137.22 ppm), Pb (12.94 ppm), Cu (2.84 ppm), Cd (1.41 ppm), Ni (0.23 ppm), and Cr (0.07 ppm). While for the Alpha mining site, the heavy metal contents were as follows: Al (248.37 ppm) < Fe (194.79 ppm) < Pb (114.34 ppm) < Cu (8.86 ppm) < Cd (4.91 ppm) < Ni (0.57 ppm) < Cr (0.11 ppm).

Heavy Metal Ecological Risk Factor in the Study Area's Soils

Due to a variety of interactions, a heavy metal-contaminated environment can have a detrimental effect on human health as well as pose major ecological risks. The ecological risk factor of soils in the study area for cadmium (Cd) ranged from 35.250 to 72.750, according to the results of the ecological risk factor of heavy metals in the studied soil samples of the Ruwan Gishiri mining site (Table 3). Except for the soil sample taken from RG2 (0–15 cm), which has a low level of cadmium potential ecological risk (LP), all the soil samples taken from the research site had a moderate potential ecological risk (MP) for the other heavy metals.

In soils throughout the research area, Cu, Ni, Pb, and Cr ecological risk factors varied from 0.160 to 0.494, 0.026 to 0.049, 0.041 to 1.753, and 0.001 to 0.002, in that order. According to the findings, soil samples containing Cu, Ni, Pb, and Cr presented a low ecological risk (LP). The outcomes concurred with research conducted on the soils of Zamfara State by Yahya *et al.* in 2021. Additionally, It was similar to the results of Oladipo *et al.* (2014) about the soils in Southwest Nigeria.

The study site's soil has an ecological risk factor in alpha of Cd ranging from 76.875 to 249.375. Five soil samples (Alpha 1 (15-30 cm), Alpha 2 (15-30 cm), Alpha 3 (15-30 cm), Alpha 4 (0-15 cm), and Alpha 4 (15-30 cm)) had high potential ecological risks, while RG1 (0-15 cm) had moderate potential ecological risk for cadmium. Four soil samples (Alpha 1 (0–15 cm), Alpha 3 (0–15 cm), Ctrl1, and Ctrl2) had considerable potential ecological risk (CP) for cadmium. Copper (0.131–3.207), nickel (0.064–0.19), lead (0.261–10.776), and chromium (0.001–0.006) were shown to have low potential ecological harm.

Potential Ecological Risk Assessment of Heavy Metals in Soils

The results in Table 4 displayed the potential ecological risk index of heavy metals in the tested soil samples from each mining area. Having an ecological risk index (RI) range of 36.498–74.246, all soil samples taken from Ruwan Gishiri Mining Sites and control soil samples from the Ruwan Gishiri Community were classified as low ecological risk. Two soil samples, Alpha 2 (0–15 cm) and Alpha 3 (0–15 cm), as well as the two control soil samples from the Alpha community, had potential ecological risk index values of less than 150 (low ecological risk), out of the eight soil samples taken from the Alpha mining site, six of which had potential ecological risk index values of 150 < 300 (moderate ecological risk).

Table 3: Heavy Metal Ecological Risk Factor (ErF) in Soils of Ruwan Gishiri and Alpha Mining Sites

Sample Identity	Cd		Cu		Ni		Pb		Cr	
RG 1 (0-15 cm)	40.875	MP	0.215	LP	0.029	LP	0.865	LP	0.001	LP
RG 1 (15-30 cm)	56.250	MP	0,358	LP	0.034	LP	0.588	LP	0.001	LP
RG 2 (0-15 cm)	35.250	MP	0.440	LP	0.036	LP	0.771	LP	0.001	LP
RG 2 (15-30 cm)	48.000	MP	0.365	LP	0.026	LP	0.276	LP	0.001	LP
RG 3 (0-15 cm)	52.500	MP	0.351	LP	0.034	LP	0.379	LP	0.001	LP
RG 3 (15-30 cm)	58.500	MP	0.469	LP	0.041	LP	0.452	LP	0.001	LP
RG4 (0-15 cm)	72.750	MP	0.457	LP	0.033	LP	1.004	LP	0.002	LP
RG 4 (15-30 cm)	57.750	MP	0.494	LP	0.031	LP	1.753	LP	0.002	LP
Ctrl 1	41.625	MP	0.160	LP	0.049	LP	0.097	LP	0.001	LP
Ctrl 2	66.750	MP	0.169	LP	0.049	LP	0.041	LP	0.001	LP
Alpha 1 (0-15 cm)	160.500	CP	0.839	LP	0.073	LP	0.448	LP	0.001	LP
Alpha 1 (15-30 cm)	202.875	HP	0.597	LP	0.071	LP	0.261	LP	0.001	LP
Alpha 2 (0-15 cm)	76.875	MP	0.801	LP	0.109	LP	5.136	LP	0.001	LP
Alpha 2 (15-30 cm)	213.000	HP	0.718	LP	0.094	LP	7.325	LP	0.002	LP
Alpha 3 (0-15 cm)	123.750	CP	0.646	LP	0.091	LP	9.054	LP	0.002	LP
Alpha 3 (15-30 cm)	231.375	HP	3.207	LP	0.076	LP	10.776	LP	0.001	LP
Alpha 4 (0-15 cm)	214.125	HP	2.379	LP	0.071	LP	10.520	LP	0.006	LP
Alpha 4 (15-30 cm)	249.375	HP	0.685	LP	0.069	LP	10.284	LP	0.003	LP
Ctrl 1	148.125	CP	0.131	LP	0.064	LP	0.925	LP	0.003	LP
Ctrl 2	111.000	CP	0.207	LP	0.081	LP	0.041	LP	0.003	LP

Terminologies related to ecological risk factors: MP stands for moderate potential ecological risk, LP for low potential ecological risk, RG = Ruwan Gishiri and Ctrl = Control.

Table 4: Heavy Metals Potential Ecological Risk Index (RI) in the Soils of the Mining Sites

Ruwan Gishiri Mining Site			Alpha Mining Site		
Sample Identity	**Risk Index (RI)**	**Risk Grade**	**Sample Identity**	**Risk Index (RI)**	**Risk Grade**
RG 1 (0-15 cm)	41.985	Low	Alpha 1 (0-15 cm)	161.861	Moderate
RG 1 (15-30 cm)	57.232	Low	Alpha 1 (15-30 cm)	203.806	Moderate
RG 2 (0-15 cm)	36.498	Low	Alpha 2 (0-15 cm)	82.922	Low
RG 2 (15-30 cm)	48.668	Low	Alpha 2 (15-30 cm)	221.14	Moderate
RG 3 (0-15 cm)	53.266	Low	Alpha 3 (0-15 cm)	133.543	Low
RG 3 (15-30 cm)	59.463	Low	Alpha 3 (15-30 cm)	245.436	Moderate
RG 4 (0-15 cm)	74.246	Low	Alpha 4 (0-15 cm)	227.102	Moderate
RG 4 (15-30 cm)	60.031	Low	Alpha 4 (15-30 cm)	260.415	Moderate
Ctrl1	41.932	Low	Ctrl1	149.247	Low
Ctrl2	66.928	Low	Ctrl2	111.25	Low

Terms that could be used in the ecological risk index are Low = low ecological risk; Moderate = moderate ecological risk; RG = Ruwan Gishiri; Ctrl = Control soil sample.

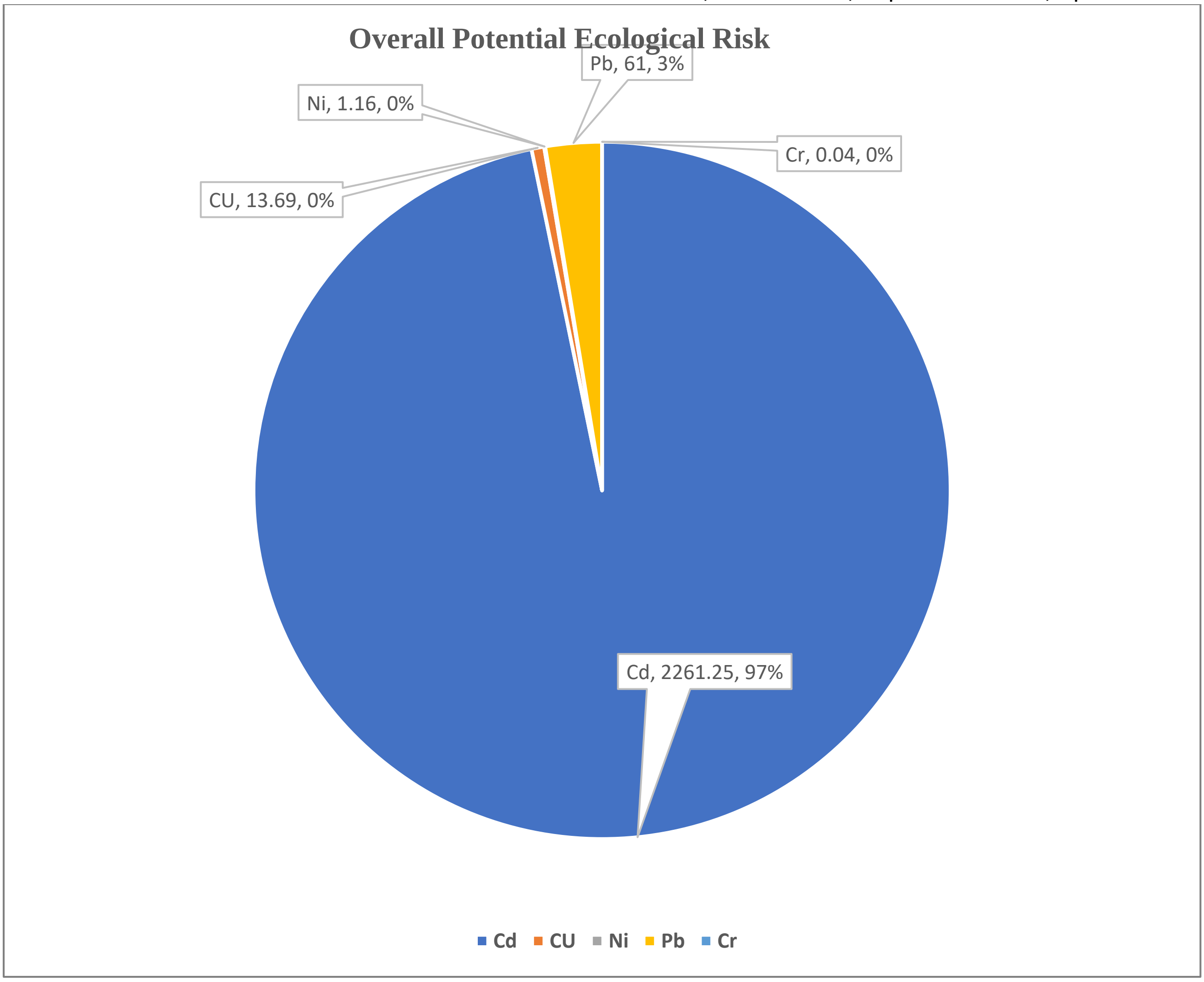

Figure 2: Overall Potential Ecological Risk in the Soils of Mining Sites.

Cd accounted for roughly 97.17 %, and Pb accounted for about 2.61 % of the soil's potential ecological risk. This suggests that metals accounted for 99.78 % of the risk. This conclusion was comparable to the findings published by Fan *et al.* (2017) about the polluted soils of three central Chinese mining regions, where it was discovered that Cd accounted for around 99.77 % of the total risk. Furthermore, a similar finding was reported by Yahaya et al. (2021), who found that Cd contributed 84.25 % to the total potential ecological danger associated with heavy metal-contaminated soils in a few chosen villages in Zamfara State, Nigeria. The potential ecological risk index (RI) for heavy metals was Cd > Pb > Cu > Ni > Cr in soil samples taken from the Ruwan Gishiri mining site. For heavy metals, the probable ecological risk index (RI) for the Alpha mining site was Cd > Cu > Ni > Pb > Cr for soil samples.

CONCLUSION

Based on the study's results, cadmium is the primary factor limiting ecological risk in the area. The operation of the mining activities at these two sites (Ruwan Gishiri and Alpha) is related to the high value of Cd in the soil samples across the mining sites. The findings demonstrated the urgent need for mining restrictions to protect the local community's environment from heavy metal pollution, especially for teenagers. Lastly, it is strongly advised that contaminated areas be cleaned up immediately. Additionally, studies on phytoremediation should be conducted in places affected by heavy metal contamination, particularly using native species. Studies on the accumulation of heavy metals in the crops grown near mining sites ought to be conducted.

DECLARATION

The authors declared that there isn't a conflict of interest.

REFERENCES

Ahmed, Y. M. and Oruonye, E. D. (2016). Ecological impact of artisanal and small-scale mining inpats of Taraba state, Nigeria. Global Advanced Research Journal of Environmental Science and Toxicology (ISSN: 2315-5140) Vol. 5(1) pp. 001-008. Retrieved online garj.org on 6th June, 2022

Bloundi MK, Duplay J & Quaranta G (2009). Heavy metal contamination of coastal lagoon sediments by anthropogenic activities. The case of Nador (East Morocco). J. Envtal. Geology., 56: 833–843. **[Crossref]**

Briffa, J., E. Sinagra, R. Blundell (2020). Heavy metal pollution in the environment and their toxicological effects on humans. Heliyon, 6 (2020), Article e04691, . **[Crossref]**

Chen, R., Han, L., Liu, Z., Zhao, Y., Li, R., Xia, L., & Fan, Y. Assessment of Soil-Heavy Metal Pollution and the Health Risks in a Mining Area from Southern Shaanxi Province, China. *Toxics*, *10*(7), 385. **[Crossref]**

Eswaran, H., Reich, P. and Beinroth, F. (1997). Global Distribution of Soils with Acidity. In: A. C. Moniz, *et al*, Eds., Plant-Soil Interactions at Low pH, Brazilian Soil Science Society, pp. 159-164.

Fan, Y., Zhu, T., Li, M., He, J. & Huang, R. (2017). Heavy metal contamination in soil and brown rice and human health risk assessment near three mining areas in central China. J Healthc Eng. **[Crossref]**

Fytianos, K., Katsianis, G., Triantafyllou, P., & Zachariadis, G. (2001). Accumulation of heavy metals in vegetables grown in an industrial area in relation to soil. Bulletin of Environmental Contamination & Toxicology, 67 (3): 0423 - 0430. **[Crossref]**

Hakanson, L., (1980). An ecological risk index for aquatic pollution control. A sedimentological approach.Water Res. 14(8), 975–1001. **[Crossref]**

Hunt, J. R. (2003). Bioavailability of iron, zinc, and other trace minerals from vegetarian diets," American Journal of Clinical Nutrition, vol. 78, no. 3, pp. 6335–6395. **[Crossref]**

Khalid, S., Shahid, M., Natasha, Bibi, I., Sarwar, T., Shah, A. H., & Niazi, N. K. (2018). A Review of Environmental Contamination and Health Risk Assessment of Wastewater Use for Crop Irrigation with a Focus on Low and High-Income Countries. *International journal of environmental research and public health*, *15*(5), 895. **[Crossref]**

Marques, A. P, Rangel, A. O, & Castro, P. M (2009). Remediation of heavy metal contaminated soils: an overview of site remediation techniques. C R C Critical Reviews in Environmental Control,41 (10), 879 - 914. **[Crossref]**

Ogunkunle, C.O. & Fatoba, P.O. (2014). Contamination and spatial distribution of heavy metals in topsoil. J. Atmospheric Poll. Res., 5: 270–282. **[Crossref]**

Oladipo, O. G., Olayinka, A., & Awotoye, O. O. (2014). Ecological impact of mining on soils of Southwestern Nigeria. Environmental and Experimental Biology, 12, 179–186. eeb.lu.lv (Retrieved 10-03-2024)

Oruonye, E. D. & Abbas, B. (2011). The Geography of Taraba State, Nigeria. LAP Publishing Company,Germany. books.google.com.ng

Oruonye, E. D. & Ahmed, M. Y. (2018). Challenges and prospects of mining of solid mineral resources in Taraba State, Nigeria. International Research Journal of Public and Environmental Health, 5(1), 1–7. .**[Crossref]**

Rehman, A., Ullah, H. Khan, R. U. & Ahmad, I. (2013). Population based study of heavy metals in medicinal plant Capparis decidua. International Journal of Pharmacy and Pharmaceutical Sciences, vol. 5, no. 1, pp. 108–113. Retrieved online file:///C:/Users on 10th October, 2023

Sexana, M.P., Kaur, P., Saxena, H.M. & Kapur-Ghai, J. (2006). Antibiotic Resistant Bacteria isolated from Fish Died on Exposure to Chromium. Journal of Fisheries and Aquatic Science. 1.2:209-212. **[Crossref]**

Shafaqat, K. S., Samra, A., Sana, H., Samar, A., Muhammad, F., Shakoor, B., Aslam, S., Hafiz, B., Tauqeer, M., Sardar, K., Ali, S., Hameed, S., Afzal, S., Fatima, S., Shakoor, M. B., Bharwana, S. A., & Tauqeer, H. M. (2013). Heavy Metals Contamination and what are the Impacts on Living Organisms. Greener Journal of Environmental Management and Public Safety, 2(4), 2354–2276. **[Crossref]**

Shah, A., Niaz, A., Ullah, N., Rehman, A., Akhlaq, M., Zakir, M. and Khan, M.S. (2013). Comparative Study of Heavy Metals in Soil and Selected Medicinal Plants. Journal of Chemistry Volume 2013, Article ID 621265, pp1-5. **[Crossref]**

Suruchi, initials and Pankaj, K.(2011): Assessment of Heavy Metal Contamination in Different Vegetables Grown in and Around Urban Areas Research Journal of Environmental Toxicology 5(3):162-17. **[Crossref]**

World Health Organization (WHO) (1996) Permissible Limits of Heavy Metals in Soil and Plants. Geneva, Switzerland.

Wu, Y., Yang, J., Zhou, X, Lei, M., Gao, D., Qiao, P., & Du, G. (2015): Risk assessment of heavy metal contamination in farmland soil in Du'an Autonomous County of Guangxi Zhuang autonomous region, China. Huan jing ke xue= Huanjing kexue 36(8):2964–2971. **[Crossref]**

Yahaya, S. M., Abubakar, F. and Abdu, N. (2021). Ecological risk assessment of heavy metal contaminated soils of selected villages in Zamfara State, Nigeria. SN Applied Sciences 3(168):1-13. **[Crossref]**

Zhang, Y., Faqi, W., Xinsheng, Z. & Ning, C. (2017). Pollution characteristics and ecological risk assessment of heavy metals in three land-use types on the southern Loess Plateau, China. Environ Monit Assess (2017) 189:470. **[Crossref]**