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Evaluation of Heavy Metal Contamination in Mining Ponds and Farms Around Kuru Jantar Mining Sites, Jos South LGA, Plateau State, Nigeria

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Abstract

The use of abandoned mining wells and ponds for dry season irrigation farming may lead to elevated levels of heavy metals in the soils and plants. This study therefore, evaluated levels of some heavy metals in farms and mining ponds around Kuru Jantar mining sites, Jos South, Plateau State, Nigeria. The levels of heavy metals in the soil samples were determined using XRF whereas the levels in water samples were determined using AAS. The results revealed the average concentrations of Zn, Cu, Ni, Cr, Mn, Fe, Ti, and V to be 54.26±6.65 mg/kg, 239.61±0.44 mg/kg, 74.65±6.80 mg/kg, 325.00±29.63 mg/kg, 1048.58±355.17 mg/kg, 59108.23±651.42 mg/kg, 851.29.23±21.35 mg/kg, 322.12±28.01 mg/kg respectively. The levels of heavy metals were above the FEPA recommended permissible limit in agricultural soil, Zn (300 mg/kg; Cu (100 mg/kg); Ni (50 mg/kg); Cr (250 mg/kg); Mn (800 mg/kg); Fe (4000 mg/kg) and V (100 mg/kg) except Zn which was below. The average concentrations of the heavy metals in the farms decreased in the order Fe > Mn > Ti > Cr > V > Cu > Ni > Zn. The levels of the heavy metals in the vegetables were generally within the recommended safe limits in vegetables for Mn (500 mg/kg); Cu (73.00 mg/kg) except Pb, Zn and Fe which were above their safe limits of Pb (0.30mg/kg; Fe (425.50mg/kg) and Zn (60 mg/kg). Similarly, the results of the heavy metals concentration in the water samples were higher than the recommended WHO maximum values Pb (0.02mg/L); Cr (0.05mg/L); Mn (0.40mg/L); Cu (2.00 mg/L); Ni (0.02 mg/L) and Cd (0.03mg/L) in water. The average concentrations of the heavy metals in water samples decreased in the order Zn > Cu > Ni > Cd > Mn > Cr > Ni > Pb. Generally, the concentrations of the heavy metals in the soil and water were higher than their respective controls. Thus, it follows that the illegal mining played a part in the increased values of these heavy metals in the environment. Therefore, the need to keep a check on the illegal mining activities is recommended to reduce health risk and the degree of heavy metals pollution.

Keywords: Contamination; Evaluation; Farm; Heavy Metals; Mining; Water.

Introduction

In many developing countries today, the unprofessional handling of the illegal excavation of minerals have led to deserted mining ponds, dams and fluvial deposits which have immediate and long term ecological and health consequences to the communities concern [1, 2]. Increased heavy metal level in soils is of concern in farming due to the adverse effects on food safety and marketability, crop growth due to phytotoxic effect and soil ecosystem services [3, 4]. This is because excessive deposit of heavy metals in farms through artisanal (illegal) mining and other sources may not only result in soil pollution but also lead to increased heavy uptake by vegetables and thus affect food quality and safety [5, 6]. Many researchers have reported that vegetables have the ability to take up heavy metals and bio accumulate them in their edible and inedible parts in quantities high enough to affliction to both to animals and human beings when they eat these metal-rich crops [6, 7].The use of deserted mining ponds/dams for dry season irrigation farming may lead to increased levels of heavy metals in the ecosystem [8]. Heavy metal pollution often results in the deterioration of soil, vegetables and groundwater qualities and consequently is a threat to human health [9, 10]. Ericsson and Olof Löf [11] in Nimyel and Chundusu [4] reported that “unlike the organic pollutants, metals have the tendency to remain in the environment for a long time”. Hence, the presence of heavy metals in the environment as a result of both natural and anthropogenic activities have endangered the qualities of crop produce when present in excess concentrations in agricultural soils [12].

In most mining areas of Nigeria where illegal mining is commonly practiced, the interaction of solid minerals and the water sources is inevitable [13, 14]. Hence, this research seeks to evaluate the level of heavy metals contamination in farmland soils irrigated with the mining ponds.

Materials and Methods

Description of Study Area

Kuru Jantar is located at latitude 9°42′800″N and longitude 8°52′86″E in Kuru District of Jos South Local Government Area in Plateau State, Nigeria. Artisanal (illegal) mining is still going on around the community within the period of this research leaving behind so many deserted alluvial deposits, mining ponds, dams, and wells scattered all over. Farmers are cultivating vegetables and other crops on the abundant alluvial deposits and irrigate the farms with the water from the ponds and wells.

Figure 1: A Map showing the study area Kuru, Village

Sample Preparation and Analysis

A simple random sampling technique was adopted for the selection of the water samples, vegetables and farms for this study. Top soil samples (1- 15 cm) were collected randomly from four farm lands around the mining sites (Kuru Jantar) in November, 2024 and put in labeled polyethylene bags. The vegetables were also collected at the same points where the soil samples were taken. The samples were air dried in the laboratory, ground with mortar and pestle and then sieved with a 2mm mesh [15]. The sieved samples were stored in labeled polyethylene bags prior to analysis. The water samples from the ex-mining ponds were collected using labeled 1L capacity plastic rubber that has been previously rinsed with distilled water and dilute HNO_3 [15, 16]. To minimize the adsorption and precipitation on the walls of bottles, the samples were acidified with HNO_3 [17]. Control samples were also collected from farms about 100m away from mining the study area. The soil and vegetable samples were quantitatively analyzed for the heavy metals using X-ray fluorescence spectrophotometer (XRF) [18, 19]

Digestion of Water Samples for Heavy Metals Analysis

The volume of the water was reduced from 500 cm^3 to 50 cm^3 by heating on a hot plate in a 1000 cm^3 beaker. This was allowed to cool and then transferred into a 250 cm^3 beaker where 5 cm^3 of concentrated HNO_3 was added and the resulting solution was heated at 85^{0}C until the solution was cleared. [20]. This was allowed to cool, then transferred into a 100 cm^3 volumetric flask and made up to mark with more deionized water. Heavy metals Zn, Cu, Ni, Cd, Mn, Cr & Pb were analysed using Atomic Absorption Spectrophotometer (AAS).

Statistical Analysis

All descriptive statistical analyses (Mean, standard deviation) were computed using Statistical Analysis system Software (S.A.S 9.0, 2008).

Results and Discussion

Concentration of Heavy Metals in Farmland Soil

The results of the heavy metals in the farms irrigated with the mining ponds around Kuru Jantar mining site is presented in Table 1. From Table 1, the concentrations of zinc (Zn) ranged from 48.15 mg/kg -64.20 mg/kg with an average of 54.26±6.65 mg/kg. The results revealed slight differences found in the concentrations of Zn in the farms. Zinc concentrations in this study were within the [21] maximum recommended limit of 300 mg/kg in farm soil but higher than the control. The implication of this, is that there could be a slight level of pollution due to the illegal mining. The concentrations of Zn in this study were within the range reported by [22] but higher than the values reported by [23] at Southwestern Nigeria. However, the results also revealed that the concentrations were lower than the values reported by other researchers [4, 14, 24, 25, 26]. The results of Cu on the other hand, showed almost the same values in the farms with an average of 239.61±0.44 mg/kg (Table 1). The concentrations of Cu in this study were higher than the values reported by [4, 14, 16, 23, 24, 26, 28]. The results also revealed the concentrations of Cu in this study to be above the FEPA maximum recommended limit of 100 mg/kg in agricultural oil and higher than the control. This could also implied that the artisanal mining or irrigation were responsible for the contamination of the farms with heavy metals. In the same vain, the concentrations of nickel (Ni) ranged from 62.87 mg/kg - 78.58 mg/kg with a mean value of 74.65±6.80 mg/kg (Table 1). The values of Ni in this study were similar to the values reported by [26] but much higher than the values reported by other researchers [22, 23, 24]. However, the results were lower than the values reported by [28] at Southwestern Nigeria. From the results it could be seen that the concentrations of Ni in this study were above the WHO maximum recommended limit of 50 mg/kg in agricultural oil and higher than the control. This also implied that there could be a slight level of contamination due to the artisanal mining and irrigation with mining ponds.

The concentrations of chromium (Cr) as presented in Table 1 ranged from 273.68 mg/kg - 342.11 mg/kg with an average of 325.00±29.63 mg/kg. The results of chromium did not show any much dissimilarities in the concentrations of Cr in the farms. However, the results revealed the concentrations of Cr in this study were six times higher than the values reported by [26] at Dorowa in Barkin Ladi. Similarly, the levels of Cr in this research were above the WHO (2007) maximum recommended limit of 50 mg/kg in agricultural oil; [29] limit of 180 mg/kg; UK (64 mg/kg); FEPA (250 mg/kg) and DPR (100 mg/kg) and higher than the control. This could also be postulated that the contaminations of the metals in the farms were due to the artisanal mining and irrigation with mining ponds.

From Table 1, it could be seen that the values of manganese (Mn) ranged from 929.40 mg/kg – 1239.20 mg/kg with a mean of 1048.58±355.17 mg/kg. In a similar pattern, the results did not show much contrast in the concentrations of Mn in the farms however, the values were higher than the control. It could also be postulated that the artisanal mining and irrigation with mining ponds impacted on the level of heavy metals in the farms. The levels of Mn were above the FEPA maximum recommended limit of 800 mg/kg; WHO maximum limit of 700 mg/kg) and DPR maximum limit of 850 mg/kg in agricultural oil. The concentrations of Mn in this research were higher than the findings of other researchers [4, 26, 28]. In like manner, the concentrations of iron (Fe) as presented in Table 1 ranged from 58505.56 mg/kg – 60148.40 mg/kg with an average of 59108.23±651.42 mg/kg.

From Table 1, the results also did not show much differences in the concentrations of Fe in the farms but, the values were higher than the control. This again could mean the artisanal mining and irrigation with mining ponds impacted on the level of heavy metals in the farms. The average concentration of Fe in this research showed that it was higher than the findings of other research reports [13, 14]. The results also divulged that the values of Fe were above the FEPA maximum recommended limit of 4000 mg/kg and DPR maximum limit of 4700 mg/kg in agricultural soil. In the same way, from Table 1 the concentrations of titanium (Ti) ranged from 833.35 mg/kg – 881.26 mg/kg with a mean value of 851.29.23±21.35 mg/kg. The results also revealed that values of Ti in the farms were higher than the control. The level of heavy metals in the farms again could be attributed to the artisanal mining. However, the concentrations of Ti were within the approved maximum threshold of 20,000 mg/kg in soil. The results of Ti in this research agrees with the findings of [30].

The concentrations of vanadium (V) ranged from 280.12 mg/kg - 336.12 mg/kg with an average of 322.12±28.01 mg/kg (Table 1). The levels of V in the farms did not show any significant differences from one farm to the other. In a similar manner, the results revealed that the levels of V in this research were above the WHO approved maximum threshold of 100 mg/kg in soil. However, the values were higher than the control. This could imply that the mining waste had added to the source of soil pollution in the farms. The values of V in this work were higher than those reported by [28] at artisanal gold mine at Luku, Minna, Niger State.

Generally, the average concentrations of the metals in the farms were higher than the control and were also above the FEPA, USEPA WHO and DPR recommended maximum limits in agricultural soil. The average concentrations of the metals decreased in the order: Fe > Mn > Ti > Cr > V > Cu > Ni > Zn. However, the results of the EF revealed deficient to minimum enrichment whereas the pollution index showed slight contamination to very severe contamination.

Table 1: Heavy Metal Concentrations from Farms Irrigated with Mining Ponds around Kuru Jantar Mining Site

	Concentration (mg/kg)							
Farm	**Zn**	**Cu**	**Ni**	**Cr**	**Mn**	**Fe**	**Ti**	**Pb**
A	561.8	239.62	62.87	342.11	1006.85	58609.72	881.26	28.67
B	642.0	239.61	78.58	342.11	1239.20	59169.24	851.29	30.33
C	481.5	239.62	78.58	273.68	929.40	60148.40	839.30	16.92
D	481.5	239.62	78.58	342.11	1006.85	58505.56	833.35	33.62
Average	542.6 ±6.65	239.61 ±0.44	74.65 ±6.80	325.00 ±29.63	1048.58 ±355.17	59108.23 ±651.42	851.29 ±21.35	322.12 ±28.01
Control	80.25	205.42	15.72	102.63	185.20	4133.45	800.90	112.04

Concentration of Heavy Metals in Vegetables

Table 2 is the results of the heavy metals in vegetables collected from the farms within the study area. From the table, lead (Pb) was not detected in all the vegetables samples analyzed except in lettuce. The concentration of Pb in the lettuce was higher than the recommended safe limit of [31] (0.3 mg/kg). The concentration of Pb in this study also was higher than the values reported by [8]. However, the concentration was in agreement with the report of [32] who reported a Pb concentration of 5.5 mg kg^{-1} in spinach and tomato. It has been reported that consumption of vegetables from heavy metals contaminated area may be a source to food chain [33, 35].

On the other hand, the values of iron (Fe) revealed that the maximum value of Fe (2851.39±39.5 mg/kg) was noted in lettuce and the lowest value of 420.88±20.09 mg/kg was noted in pepper (Table 2). Higher uptake of heavy metals in leafy vegetables have been reported by other research workers [15, 36]. The values of Fe in the vegetables were in the order lettuce> spinach> tomato> garden egg> pepper. The values of Fe in the vegetables were higher than the WHO/FAO recommended safe limit of 425.50 mg/kg except for garden egg and pepper. Other researchers have recorded higher values of Fe in vegetables than in this study [32, 37]. Iron is a major component of hemoglobin that carries oxygen to all part of the body.

Table 2: Heavy Metal Concentrations in Vegetables Irrigated with Mining Ponds around Kuru Jantar Mining Site

	Concentration (mg/kg)					
Vegetable	**Zn**	**Cu**	**Ni**	**Mn**	**Fe**	**Pb**
Garden egg	53.56±4.50	31.48±6.22	ND	ND	420.88±20.09	ND
Lettuce	492.33±8.8	13.66±5.18	ND	455.73±24.96	2851.39±39.53	4.61±1.66
Tomato	61.33±4.50	ND	ND	ND	695.87±24.87	ND
Pepper	21.48±2.97	ND	ND	ND	338.63±16.72	ND
Spinach	167.41±5.4	ND	ND	446.32±24.48	1445.40±29.14	ND
Average	83.40±4.32	22.57±5.7	ND	446.32±24.48	826.63±23.57	4.61±1.66
Control	32.86	ND	ND	120.83	157.08	ND

According to Table 2, Mn was only found in leafy vegetables such as spinach (446.32±24.48 mg/kg) and lettuce (455.73±24.9 mg/kg), but it was not found in the tomato, garden egg, or pepper samples that were examined. Mn levels in the veggies were below the FAO/WHO-approved maximum limit of 500.30 mg/kg. [39]. In a similar development, from Table 2, the highest value of Cu (31.48±6.22 mg/kg) was found in garden egg and the lowest value of 13.66±5.18 mg/kg was found in lettuce. There was no copper found in spinach, pepper, or t omatoes. The vegetables' Cu concentrations (Garden egg and lettuce) were below the 73.0 mg/kg WHO/FAO recommended limit. The low concentration of copper found in this may be because copper is found in minerals and can only be released by extremely slow disintegration processes [23, 24]. Cu levels in lettuce were comparable to those in spinach, which were 10.79±0.18 mg/kg, as reported by [4]. Nevertheless, the levels of copper in lettuce and garden eggs were greater than the 1.706 mg/kg that [40] had reported. Latiff *et al.* [41] also reported that Cu is an essential micronutrient that functions as a biocatalyst, required for body pigmentation.

The results also revealed that Zn concentrations in vegetables decreased in the order lettuce> spinach> tomato> garden egg> pepper, with the highest concentration of Zn (492.33 ±8.86 mg/kg) found in garden eggs and the lowest concentration in pepper (Table 2). The Zn concentrations in this study were higher than the 26.7 mg/kg reported by [40] but lower than the values reported by [4]. The findings also showed that ,with the exception of pepper and garden egg, the zinc concentrations in the green vegetables exceeded the [21] specified maximum of 99.0 mg/kg and the [31] advised safe level of 60 mg/kg. This could be attributed to the mining activities and irrigation with the pond water.

Generally, the concentrations of the heavy metals in the vegetables were generally within the recommended safe limits in vegetables except Pb, Zn and Fe which were above their safe limits. The average concentrations of some of the heavy metals in the vegetables decreased in the order: Fe > Zn > Cu (garden egg); Fe > Mn > Cu > Pb (lettuce); Fe > Mn > Zn (spinach) whereas for tomato and pepper, the order was Fe > Zn.

Concentration of Heavy Metals in Ex-Mining Ponds

According to the findings in Table 2 on heavy metals in surface water taken from the former mining ponds, lead (Pb) concentrations ranged from 0.19 to 0.37 mg/L, with an average of 0.28 to 0.06 mg/L. The findings also showed that all of the ponds' water samples had greater Pb concentrations than the control. This could imply that the ponds' heavy metal concentrations were influenced by the mining. This may help to explain why the Pb contents in the water samples used in this investigation exceeded the WHO-recommended upper limit of 0.20 mg/kg.

The Pb concentrations in this study, howe ver, were lower than those reported by [42], but th ey were in agreement with those reported by [16] a t several former mining ponds in Jos South LGA, Plateau State, Nigeria, and [18] at Matara-uku.

Similarly, the concentrations of chromium (Cr) ranged from 0.29 mg/L to 0.43 mg/L with an average of 0.36±0.05 mg/L. The concentrations were also higher than the control (0.13±0.02 mg/L) which implied that the mining could have increased the level of the metals at the ponds. The levels of Cr in this study were almost seven times higher than the WHO recommended maximum value in water (0.05 mg/L). However, the oxidation state determines how Cr affects human health because Cr (III) is a vital dietary component and has a major impact on metabolism, whereas Cr (VI) is extremely carcinogenic and causes liver and cardiovascular disorders. [43]. Additionally, the results showed that the concentrations of Cr in this study were higher than those reported by other researchers [10, 16, 43].

The concentrations of zinc (Zn) ranged from 9.09 mg/L to 10.95 mg/L with a mean value of 9.84±0. 74 (Table 3). The concentrations of Zn in all the water samples collected from the ponds were above the WHO recommended maximum value in water (5.00 mg/L). The mean value of Zn in this research was in agreement with the mean value reported by [14] but higher than the values reported by [22]. Likewise, the value of manganese (Mn) in surface water ranged from 0.18 mg/L to 0.57 mg/L with an average value of 0.38±0.14. In surface water surrounding abandoned Pb-Zn mines in Yelu, Alkaleri Local Government Area of Bauchi State, Nigeria, the mean concentration of Mn in this study was lower than the values reported by [14], but the concentrations of Mn in this study were higher than the upstream values reported by [22] in summer and autumn.

The concentrations of Mn at the ponds were all generally higher than the control, indicating that the mining contributed to the contamination of the ponds. The concentrations, however, were within the recommended WHO maximum value of Mn in water (0.40 mg/L), with the exception of D, which was slightly above the recommended maximum value for water (Table 3).

Table 3: The Mean Concentration of Heavy Metals in Water obtained from the Ex-Mining Ponds around Kuru Jantar

			Concentration (mg/L)				
Pond	**Pb**	**Cr**	**Zn**	**Mn**	**Cu**	**Ni**	**Cd**
A	0.29	0.36	9.09	0.43	2.24	0.79	0.29
B	0.19	0.38	10.21	0.37	2.95	0.52	0.62
C	0.26	0.43	10.95	0.18	3.14	0.61	0.64
D	0.33	0.29	9.36	0.57	5.45	0.41	0.32
E	0.37	0.37	9.63	0.36	2.67	0.75	0.48
Average	0.28±0.06	0.36±0.05	9.84±0.74	0.38±0.14	3.28±1.15	0.61±0.15	0.47±0.16
Control	0.18±0.01	0.13±0.02	7.31±0.66	0.15±0.02	0.94±0.24	0.16±0.02	0.25±0.06
WHO (mg/L)	**0.20**	**0.05**	**5.00**	**0.40**	**2.00**	**0.02**	**0.03**

The average copper (Cu) concentration was 3.28±1.15 mg/L, with a range of 2.24 to 5.45 mg/L. According to the results, the concentration of Cu was 0.94±0.24 mg/L, which was higher than the control. The water samples from the ponds may have had higher Cu levels as a result of the mining. The study's findings also demonstrated that the amounts of copper in the water above the WHO's recommended maximum threshold of 2.00 mg/L. The Cu concentrations in this study were lower than those reported by [22] in all seasons and [14] in abandoned Pb-Zn mines in Yelu, but greater than those reported by other studies [16, 45, 46]. In the same vain, the concentrations of nickel (Ni) ranged from 0.41 mg/L to 0.79 mg/L with an average of 0.61±0.15 mg/L. Similar to the other metals, the amounts of Ni in the pond water samples were greater than the control (0.16±0.02), which suggests that the mining operations are to blame for the water contamination. Additionally, the Ni contents in this investigation exceeded the WHO-recommended maximum threshold of 0.02 mg/L in water. Ni concentrations in water samples above the metal's allowable limit in surface water, which is 0.03 mg/L. The results of Ni in this study much higher than the findings of [44].

From Table 3, the results of heavy metals in surface water (mining ponds) showed that the concentrations of cadmium (Cd) ranged from 0.29 mg/L to 0.64 mg/L, with a mean value of 0.47±0.16 mg/L and a control value of 0.25±0.06 mg/L. The higher concentrations than the control indicated that the mining activities may have contaminated the water samples, and the concentrations of Cd were higher than the WHO maximum recommended limit in water (0.03 mg/L). The concentrations of Cd in this study compared favorably with those of other researchers [16, 45], but higher than those of other researchers [14, 45].

Similarly, the general average concentrations of the metals in the ponds were higher than the control and were also above the FEPA, USEPA and WHO recommended maximum limits in water. The average concentrations of the metals in water decreased in the order: Zn > Cu > Ni > Cd > Mn > Cr > Pb.

Conclusion

From the results in this study, it could be concluded that the farms were contaminated with the heavy metals since the concentrations were above the recommended background values for agricultural soils. However, from the results of the enrichment factor and pollution index, it could be concluded that the farms were contaminated from natural sources rather than anthropogenic sources. This implied that the artisanal mining has not contributed much to the increased values of these heavy metals in the environment. It also be concluded that the ex-mining ponds were contaminated with the heavy metals. So, the soil in these farms may not be quite safe for cultivation of vegetables.

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