

Effect of Lead Mining Activities on Crop Plants and Water: A Case Study of Tunga Tsauni, Gurara, Niger State, Nigeria

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Abstract

Lead mining activities have been identified in Tunga Tsauni, Gurara Local Government Area of Niger State, Nigeria. This study has been carried out to find out the impacts of the mining activities, especially those due to lead, on the ecological system and the inhabitants of the immediate environment. Using the samples taken at varying distances from the mining site, the effects of the mining activities on water and crop plants at the mining environs were investigated by testing for the presence as well as the concentration of lead. Furthermore, the values of the lead concentrations obtained were compared with the set limits (standard) of World Health Organization. It was discovered from the results obtained that most of the water samples were polluted with lead and, thus, unsafe for domestic use and aquatic life. Also, the concentration of the lead in the crop plants was found to be higher than that of the control sample. It has, thus, been discovered that the mining activities of lead have significant effects on the crop plants and the water in the mining area (Tunga Tsauni) of Niger State because the soil and the water in the area were found to be contaminated with lead, which is toxic and dangerous. Therefore, there is the need for urgent and serious measures to regulate the mining activities at the site in order to significantly reduce the effects of this poisonous substance (lead) on the crop plants and the water of the area.

Keywords: Lead, heavy metals, crop plant, water, Tunga Tsauni.

1.0 INTRODUCTION

Uncontrolled mining activities in Nigeria have resulted in generation of environmental hazards, enormous amount of wastes and different types of pollutants (Onyedika and Nwosu, 2008). These mining activities have raised serious concerns on the qualities of crop plants and water source within and around the mining sites. They have also resulted in life-threatening contamination which is being experienced within the immediate natural ecosystem in Nigeria. These, actually, might have been due to poor government policy and lack of good-will to properly implement law on uncontrolled mining activities (Warhate *et al.*, 2006) to control the mining of poisonous substances like lead.

Lead has been classified as potentially hazardous and toxic to most forms of life (Awofolu, 2005; Okoronkwo *et al.*, 2005). It is responsible for quite a number of ailments in humans such as chronic neurological disorder, neuromuscular and behavioral problems (Pearce, 2007), resulting in behavioral and attitudinal changes with progressive retardation in human body system and environment. It has been reported that lead damages liver, kidney, brain, central nervous and reproductive systems of man and aquatic organisms, thereby causing all kinds of diseases.

Applications of lead in various technological developments and the abundance of lead ores gave rise to its mining, especially uncontrolled one, which has been reported as leading into pollution of crop plants and water in many mining sites (Aremuet *et al.*, 2010; Dan'azumi and Bichi, 2010). Several cases of lead poisoning have been reported in the past (Spellman and Drinan, 2000; Davydova, 2005). Concentration of lead may build up in plants and animals from areas where air, water, or soil are contaminated with lead (Onyedika and Nwosu, 2008; Muhammed *et al.*, 2008).

In Nigeria, several incidents of lead poisoning have been reported. An instance is the lead poisoning reported in Zamfara State, where more than 100 children in the villages of Daretu and Yargalma were seriously affected with a mean blood lead concentration of 119 $\mu\text{g}/\text{dl}$ (levels as low as 10 $\mu\text{g}/\text{dl}$ are associated with impaired neurological development in young children). Moreover, lead concentrations in soil of more than 100,000 ppm were found in and around the habitations in the villages (Galadima and Garba, 2012).

Soil is the major recipient of lead pollution from the mining activities (Mahram *et al.*, 2007), and possible transmissions of lead may exist from contaminated soil to the plants grown on the polluted soil to the animals that consume such plants (Onyedika and Nwosu, 2008). A positive correlation between lead in soil and blood lead concentration have been established and researchers have reported that excessive amounts of lead in human body can cause hypertension and brain damage (Itana, 2002).

It is therefore deemed crucial in this work to investigate the effect of uncontrolled mining activities in Nigeria for the purpose of understanding their impacts on the environment, and estimating the possible negative impacts on the crop plants and water in such an environment. It is expected that the results of this work will provide basis for the formulation of government policies that will discourage uncontrolled mining activities, especially of lead, in Nigeria.

2.0 METHODS

All the laboratory analyses outlined in this section of the work were conducted at the National Cereals Research Institute (NCRI), Badeggi Niger State, Nigeria.

2.1 Materials and Chemicals

The major materials used in this work include samples of water and crop plants obtained from the study site and its vicinity. The study site is a lead mining site located at Tunga Tsauni in Gurara Local Government Area (LGA) of Niger State, Nigeria. Major chemicals used during the experimental work include nitric acid (HNO_3 - 96% purity), hydrochloric acid (HCl - 95% purity) and lead nitrate (PbNO_3 - 95 % purity), all of which were analytical grades manufactured by Analar BDH and purchased from National Cereals Research Institute, Badeggi, Niger State.

2.2 Sampling Methods

Samples collected for this study include crop plants: (guinea corn (*Sorghum* spp.) and rice (*Oryza sativa*), and water. Forty (40) samples of the crop plants were collected along the same four cardinal directions North, South, East and West (N, S, E, and W), with the aid of compass at an interval of 10 m each and stored in polythene bags, while a total of seven (7) water samples were collected from the available water sources (wells: W_1 is 10 m, W_2 is 15 m, W_3 is 250 m, W_4 is 500 m, streams: R_L is 400 m, R_U is 600 m and boreholes: B is 200 m, all relative to the mining site) in the mining environment. The samples were stored in clean plastic cans, kept in ice chests (4°C) and transported to the laboratory for necessary analysis.

2.3 Sample Preparation and Pre-Treatment

Samples of the crop plants used were rinsed with distilled water, cut into small portions and ground using laboratory mortar and pestle. They were then placed in Thomas milling machine (ED – 5/1998) where they were milled into fine powder. They were sieved using 0.2 mm sieve in accordance with the procedure reported by Aremu *et al.* (2010).

For the water samples, the temperature of each of them was taken immediately at the site of collection using a simple thermometer calibrated in $^\circ\text{C}$, while the pH was determined using a pH meter. The samples collected were thereafter stored in a deep freezer for further analysis, as outlined in the work of Yang *et al.*, 2004.

2.4 Sample Labelling

Samples used were given specific labels to avoid misrepresentation in the course of processing and analysis. The labelling was done based on the established cardinal points (N, S, E and W), and distance/location (1, 2, 3...10).

2.5 Digestion of Samples

(a) **Blank digestion:** 50 mL of digestion mixture was put in a clean 100 ml beaker, and the mixture was heated for 1hr at 200°C . The digest was allowed to cool to room temperature before it was filtered using a Whatman filter paper and sizeable funnel into a 1000 mL standard flask and the filtrate was made up to the 100 mL mark of the flask with distilled water. The filtrate (digest) was then transferred into clean labelled plastic containers.

(b) **Digestion of crop plants sample:** 2 g of the pre-digested crop plants, rice and guinea corn, were weighed with a digital weighing balance (AR 3130) into a digestion flask (glass tube) of 100 mL capacity. 50 mL of digestion mixture (20 mL of H_2SO_4 , 15 ml of hydrochloric acid, and 15 mL of nitric acid) was added. Samples were taken into fume chamber (digestion tube fixed in a rack) and were heated at 200°C for 1hr until a light colored solution was obtained (an indication that the digestion process was already complete, according to Atayese *et al.*, 2009). The sample solution was, thereafter, filtered and the filtrate was allowed to cool and diluted to make up 100 mL and the contents mixed thoroughly by shaking. The sample digest was run on Atomic Absorption Spectrophotometer (AAS) for the determination of presence and concentrations of metals.

(c) **Digestion of water sample:** For the water sample, 50 mL of digestion mixture were added to 250 mL of water, heated at 100°C for 1 hr and evaporated to 100 mL. The concentrate was transferred into a labelled bottle container after cooling, and finally run on AAS machine to determine the presence and concentrations of metals.

2.6 Sample Analysis

Analyses of metal ions in all the samples were carried out in Atomic AAS using distilled water and chemical reagents (analytical grade) mentioned in Subsection 2.1.

2.7 Characterization procedures

All the samples collected for this study (crop plants and water) were subjected to AAS analysis in the chemical laboratory to determine the presence and concentration of various heavy metals (chromium, lead, zinc, and cadmium). Other parameters analyzed include pH, temperature, COD, BOD, DO, TDS, TSS, total solid, magnesium, silver, calcium, sodium, manganese and ammonia.

3.0 RESULTS AND DISCUSSIONS

The results of the experimental analysis (determination of lead presence and concentration) carried out on all the water and the crop plant samples collected are hereby presented and discussed.

3.1 Characterization of Water Samples

Table 1 shows the results of the characterizations that were carried out on the water samples obtained from the surroundings of Tunga Tsauni lead mining site. The results includes tests on NH₄, pH, chemical oxygen demand (COD), phenol, dissolved oxygen (DO), biological oxygen demand (BOD), K, N, Ca, Mg, Na, P, Zn, Pb, Cu, Cr, Fe, Mn, carbonate and nitrate compositions in the selected water samples.

Table 1. Biological properties and essential nutrients of the characterized water sample

Source	D (m)	NH ₄ mg/L	pH	COD mg/L	Phenol mg/L	DO mg/L	BOD mg/L	K mg/L	N mg/L	Ca mg/L	Mg mg/L	Na mg/L	P mg/L	CO ₃ mg/L	NO ₃ mg/L
W ₁	10	0.2	7.15	98	0.001	4	100	0.1	0.3	23.16	53.14	0.084	34.24	400	8.64
W ₂	15	0.1	7.54	99	0	ND	ND	0.1	0.39	22.34	48.24	0.098	24.52	300	6.52
W ₃	250	0.3	7.14	100	ND	ND	ND	0.08	0.43	32.41	64.32	0.084	16.18	200	0.78
W ₄	500	0.2	6.83	110	0.001	3	120	0.1	0.61	24.76	52.16	0.098	23.24	300	0.66
R _L	400	0.1	7.42	112	0	ND	120	0.18	0.48	23.62	48.18	0.046	24.12	350	0.88
R _U	600	0.4	4.15	110	ND	4.5	110	0.2	0.43	22.74	44.32	0.042	32.18	380	0.7
B ₁	200	0.2	6.71	ND	0.001	ND	120	0.13	0.3	32.18	64.12	0.042	24.42	ND	ND
Control		0.07	6.8	5	0.001	2.5	4.5	1.2	3	0.4	0.2	2.9	0.02	114	0.53

Key: ND – Not Detected, D – Distance from mining site.

As can be seen from Table 1, the pH value of the water samples analyzed were found to fall within the reported WHO permissible pH range of 6.5 – 8.5 for safe waste water that can be used for irrigation purposes except for Upper River (R_U) water sample whose pH value was discovered to be 4.15. The observed lower value in the pH value of the Upper River was an indication of its high acidity due to bacterial decay of organic matter in the water that was producing high level of CO₂, and subsequently decreasing the survival of aquatic organisms. The pH value of 7.54 obtained from a well sample (W₂) was found to be the highest given by the water samples, while that of the control was 6.8. This was discovered to be an implication that the pH of the water samples obtained from the Tunga Tsauni lead mining areas were within the acceptable limits for waste water which are suitable for irrigation purposes, and, they were, therefore, found safe for crop cultivation. Furthermore, it is known that water in its pure form is neutral with a pH of 7.0, but the pH values obtained for the water samples collected from Tunga Tsauni lead mining site are either slightly acidic or slightly basic which indicated that they were polluted and, thus, not suitable for drinking.

Also in Table 1, the results of some vital analyses of the water samples in terms of chemical oxygen demand (COD), dissolved oxygen (DO) and biochemical oxygen demand (BOD) are given. From the table, the highest values of COD, DO and BOD obtained for the water samples were found to be 112 mg/L, 2.5 mg/L and 120 mg/L, respectively. These values, especially COD and BOD, were seen to be worrisome when compared with those of the control because its own COD, DO and BOD were 5.0 mg/L, 3.0 mg/L and 4.5 mg/L, respectively and with those of the Federal Environmental Protection Agency (FEPA), Nigeria that gave COD, DO and BOD limits to be 40, 20 and 10 mg/L, respectively. As can be seen from the table, the water samples collected from Tunga Tsauni mining site and environs were found to contain low levels of dissolved oxygen as a result of heavy biological oxygen demand and chemical oxygen demand, possibly, caused by the contamination of the surface and the underground water resulting from the mining activities. These compositions show clearly that the water samples are polluted making the water bodies unsuitable for drinking, irrigation or any other use.

From Table 1, it was also discovered from the characterization results that the water samples contain elements like K, N, Ca, Mg, Na and P. Higher values of Ca and Mg may be an indicator for high water hardness in the characterized water samples. This may occur due to the flow of water out of the excavated pit which might have reached the water table. Based on the results obtained, the highest nutrient values of the selected water samples are: Potassium (K) 0.20 mg/L, Nitrogen (N) 0.61 mg/L, Calcium (Ca) 32.41 mg/L, Magnesium (Mg) 64.32 mg/L, Sodium (Na) 0.098 mg/L and Phosphate (P) 34.24 mg/L respectively, as against WHO, USEPA and FEPA values of 1-2 mg/L Potassium (K), 50 mg/L Calcium (Ca), 37 mg/L Magnesium (Mg) and 200 mg/L Sodium (Na) reported by Dami, *et al.* (2013).

Table 2. Heavy metals in the characterized water sample

Source	Zn mg/L	Pb mg/L	Cu mg/L	Cr mg/L	Fe mg/L	Mn mg/L
W ₁	11.5	0.08	0.02	0.001	0.5	35
W ₂	7.1	0.06	0.014	0.001	0.3	40
W ₃	4	0.02	0.001	0	0.12	28
W ₄	3.18	0.01	0.001	0	0.11	24
R _L	6.8	0.04	0.002	0.002	0.08	30
R _U	5.2	0.01	0.001	0	0.2	35
B ₁	4.15	0.023	0	0.001	0.34	47
Control	0.3	0.01	0.34	0.001	0.04	0.7

Presented in Table 2 are the results of the heavy metal analysis of water samples studied with the concentrations measured as Zn (11.50 mg/L), Pb (0.08 mg/L), Cu (0.02 mg/L), Cr (0.002 mg/L), Fe (0.50 mg/L), Mn (47 mg/L), Carbonate (400 mg/L) and Nitrate (8.64 mg/L). These values were relatively on the high side when compared to that of the control samples that were measured as Zn (0.30 mg/L), Pb (0.01 mg/L), Cu (0.02 mg/L), Cr (0.001 mg/L), Fe (0.04 mg/L), Mn (0.7 mg/L), and the permissible limits of WHO, USEPA and NAFDAC: Cr (max. 0.05 mg/L), Pb (max. 0.01 mg/L), Cu (max. 1.0 mg/kg), Fe (max. 0.3 mg/kg) and Zn (max. 3.0 mg/L) as reported by Dami, *et al.* (2013). It could be seen that the concentrations of lead and zinc were higher than the maximum limits recommended by these agencies, while the analyses also revealed that Mn, Co and nitrate were slightly below the recommended limits of WHO. All these are showing the level of the contaminations of the water samples.

3.2 Experimental Analysis of Lead Concentration in Water Samples

The effects of lead mining activities on water sources available to the inhabitants of the Tunga Tsauni town and its environs were also investigated through experimental analysis of presence and concentration of lead metal in the samples of the selected water sources. Figure 1 shows the experimental results of lead concentrations obtained in well, stream and bore-hole water samples that were randomly obtained around the vicinity of the mining site. It can be observed from the figure that the investigated water sources were contaminated with heavy metal, lead (Pb), possibly resulting from the mining activities being carried out at Tunga Tsauni mining site.

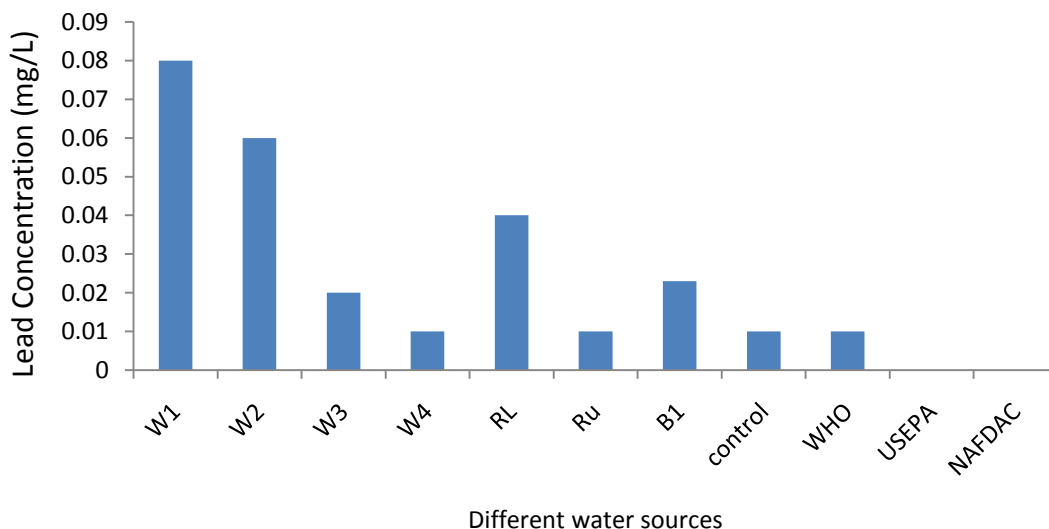


Figure 1. Lead concentrations in well, stream and bore-hole water samples obtained around the mining site.

Based on the analysis of Figure 1, sample W₁ (taken at about 10 m away from the mining site) shows the highest lead concentration of 0.08 mg/L, followed by samples of W₂, R_L, B₁ and W₃ with 0.06, 0.04, 0.027 and 0.02 mg/L, respectively. These values were considered higher compared to 0.01 mg/L set limit of World Health

Organization (WHO) as reported by Dami *et al.* (2013), except for samples W_4 (obtained at about 500 m from the mining site) and R_u (taken from 600 m away from the mining site) that just contained the allowable limit value of Pb concentration of 0.01 mg/L as stipulated by WHO, but slightly above the set limit of 0.0 mg/L specified by the United State Environmental Protection Agency (USEPA) and National Agency for Food and Drugs Administration and Control (NAFDAC), as reported by Duruibe *et al.* (2007). The obtained results also revealed that W_1 and W_2 were more polluted with Pb when compared to the control value of 0.01 mg/L. With lead being the most significant toxic of the heavy metals even at low concentration, which could also be absorbed through ingestion of any polluted water, it is therefore highly dangerous to drink from the water sources around the Tunga Tsauni lead mining site. It is also obvious that aquatic life will be severely affected by the contaminations.

3.3 Characterization of Crop Samples

The results of the characterization conducted on the taken crop samples are as presented in Table 3. Analysis of the results revealed that the crops stem samples obtained around Tunga Tsauni lead mining site contains essential mineral elements (K, N, Ca, Mg, Na, P) in different concentrations as well as heavy metals such as Zn, Pb, Cu, Cr, Fe and Mn.

Table 3. Essential nutrients and heavy metals in the characterized crop samples

Cardinal point	Location	K	N	Ca	Mg	Na	P	Zn	Pb	Cu	Cr	Fe	Mn
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
N	N_{G1}	0.63	0.52	0.64	0.22	0.95	0.15	64.4	44.4	130	0.5	2.5	11.5
	N_{R1}	0.34	0.64	0.52	0.4	0.88	0.06	7	0.6	ND	ND	3	2.6
S	S_{G1}	0.54	0.43	0.24	0.18	1.08	0.18	45	13	121.5	ND	5.3	3.1
	S_{R1}	0.3	0.42	0.3	0.28	0.72	0.16	20	10	0.2	ND	5.02	1.3
W	W_{G1}	0.52	0.32	0.23	0.46	1.12	0.18	23.1	11.2	122.5	ND	2.12	4.2
	W_{R1}	0.22	0.38	0.48	0.56	1.24	0.24	18.5	0.8	ND	ND	4.24	1.8
E	E_{G1}	0.32	0.84	0.5	0.56	1.08	0.58	34	14.5	0.2	0.01	1.08	3.2
	E_{R1}	0.18	0.14	0.36	0.64	1.14	0.12	24.4	18.1	ND	ND	2.14	ND
Control (Rice)		10.4	15.35	25.75	12.5	7.12	9.67	1.04	0.12	2.01	0.01	0.3	0.07
Control (G/corn)		15.21	17.45	29.53	14.62	9.35	11.21	3.65	0.18	2.73	0.02	0.35	0.09

According to Table 3, it can be seen that rice and guinea corn stem samples used contain K, N, Ca, Mg, Na and P, with Na having the highest concentration of 1.24 mg/kg in a rice sample and 1.12 mg/kg in a guinea corn sample, which were lower than 7.12 mg/kg and 9.35 mg/kg obtained from the control. Concentration of metals discovered in guinea corn samples were K (0.32 – 0.63 mg/kg), N (0.32 – 0.84 mg/kg), Ca (0.23 – 0.64 mg/kg), Mg (0.18 – 0.56 mg/kg), Na (0.95 – 1.12 mg/kg) and P (0.15 – 0.58 mg/kg), while for rice stem samples, the concentrations ranged from K (0.18 – 0.34 mg/kg), N (0.14 – 0.64 mg/kg), Ca (0.30 – 0.52 mg/kg), Mg (0.28 – 0.64 mg/kg), Na (0.72 – 1.24 mg/kg) to P (0.06 – 0.24 mg/kg) as against the values obtained for samples of rice and guinea corn from the control site (non-mining site), which were K (10.40 mg/kg), N (15.35 mg/kg), Ca (25.75 mg/kg), Mg (12.50 mg/kg), Na (7.12 mg/kg) and P (9.67 mg/kg), respectively. These analyses revealed that the concentration of the samples obtained from the surrounding of the mining site were lower compare to the control area, and this may be due to the presence of heavy metals in the crop samples.

Also, Table 3 shows the heavy metal analysis in rice and guinea corn stems samples used. The results revealed the presence of different heavy metals with varying concentrations: Zn (23.1 – 64.4 mg/kg), Pb (11.2 – 44.4 mg/kg), Cu (0.2 – 130.0 mg/kg), Cr (0.01 – 0.5 mg/kg), Fe (1.08 – 5.3 mg/kg) and Mn (3.1 – 11.5 mg/kg) obtained in the guinea corn samples, while for rice samples: Zn (7.0 – 24.4 mg/kg), Pb (0.6 – 18.1 mg/kg), Cu (0.0 – 0.2 mg/kg), Fe (2.14 – 5.02 mg/kg) and Mn (1.3 – 2.6 mg/kg). The observed results in the present study is worrisome when compared to Zn (1.04 and 3.65 mg/kg), Pb (0.12 and 0.18 mg/kg), Cu (2.01 and 2.73 mg/kg) and Cr (0.01 and 0.02 mg/kg) obtained for heavy metals in rice and guinea corn samples cultivated on the control area. Based on the analysis, it may be deduced that lead mining activities at Tunga Tsauni could be responsible for the observed increase

in the concentration value of lead, Pb at that area. The observed results in both rice and guinea-corn samples were found to exceed 100, 0.3 and 0.05 mg/kg maximum limits stipulated by World Health Organization for Zn, Pb and Cr respectively as well as maximum limit of 50, 2 and 20 mg/kg for Zn, Pb and Cu, respectively as the standard set by NAFDAC, Nigeria.

3.4 Experimental Analysis of Lead Concentration in Crop Plant Samples

Figures 2 - 9 show the results of lead concentrations in guinea corn and rice samples at different locations from the mining site, specifically along the South, the East, the North and the West cardinal directions. Locations 1, 2, 3, 4 and 5 represent distances 10, 20, 30, 40 and 50 m, respectively from the mining site.

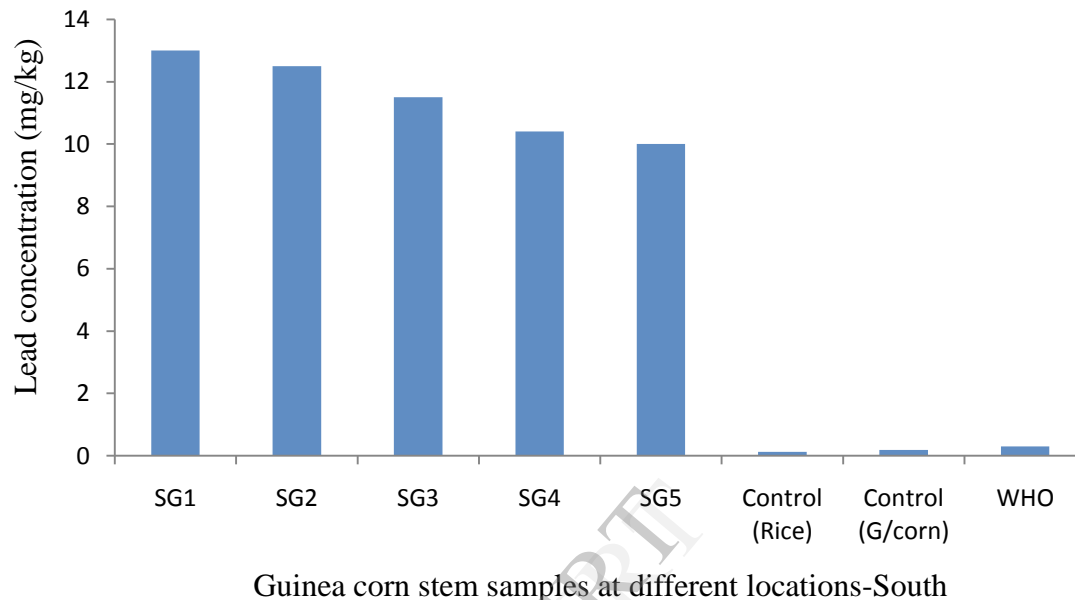


Figure 2. Lead concentration in guinea corn stem samples obtained at different locations along the South cardinal direction

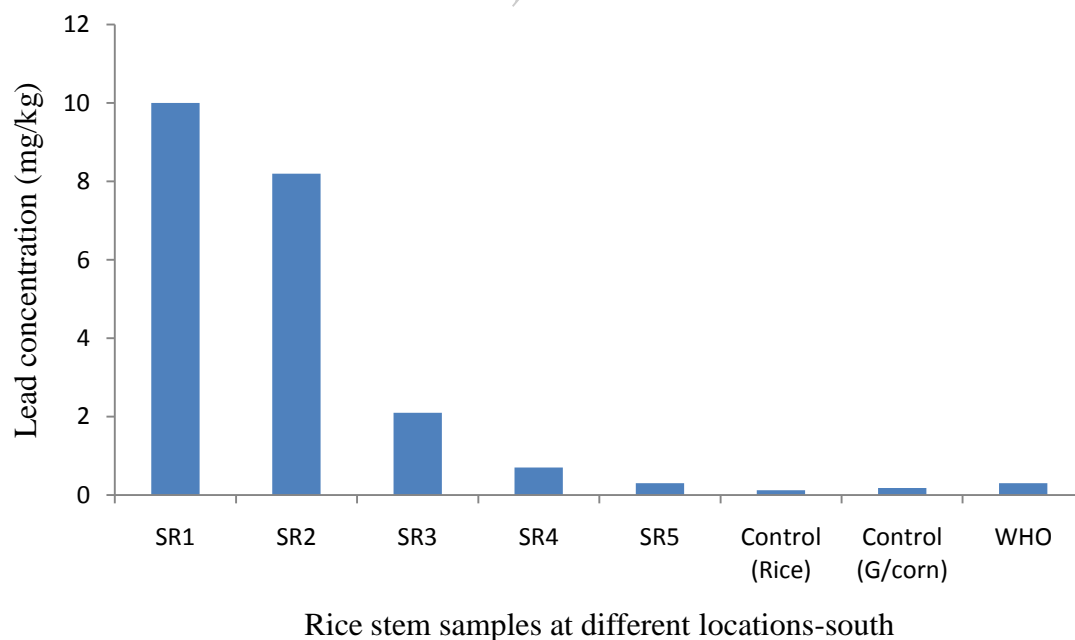
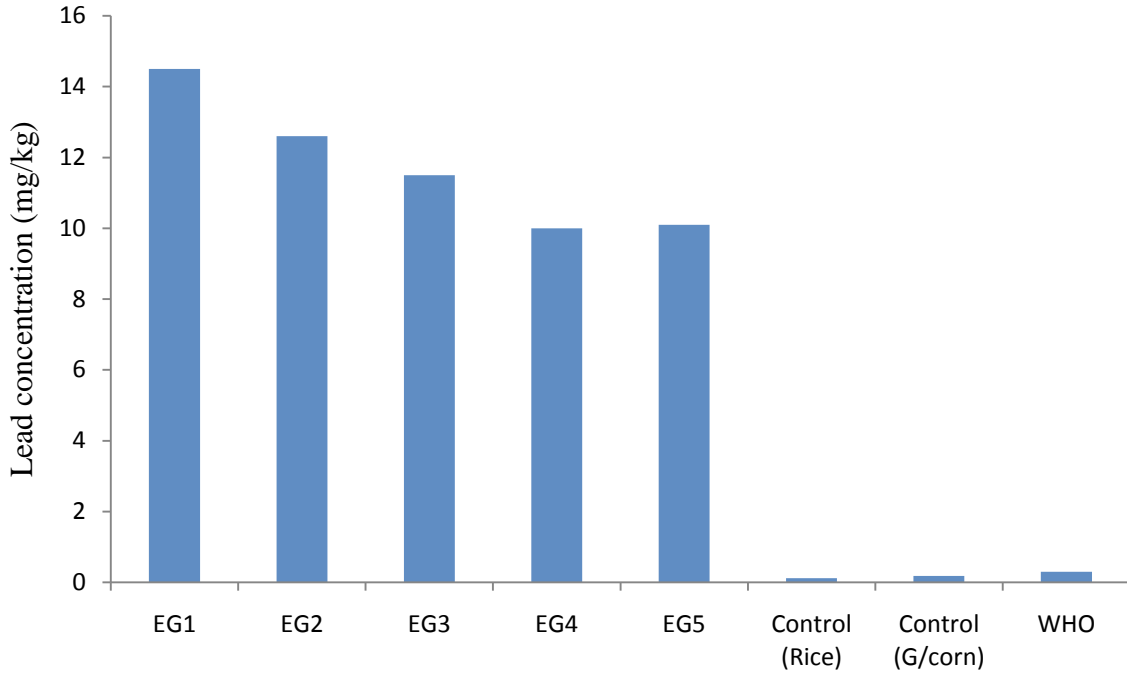
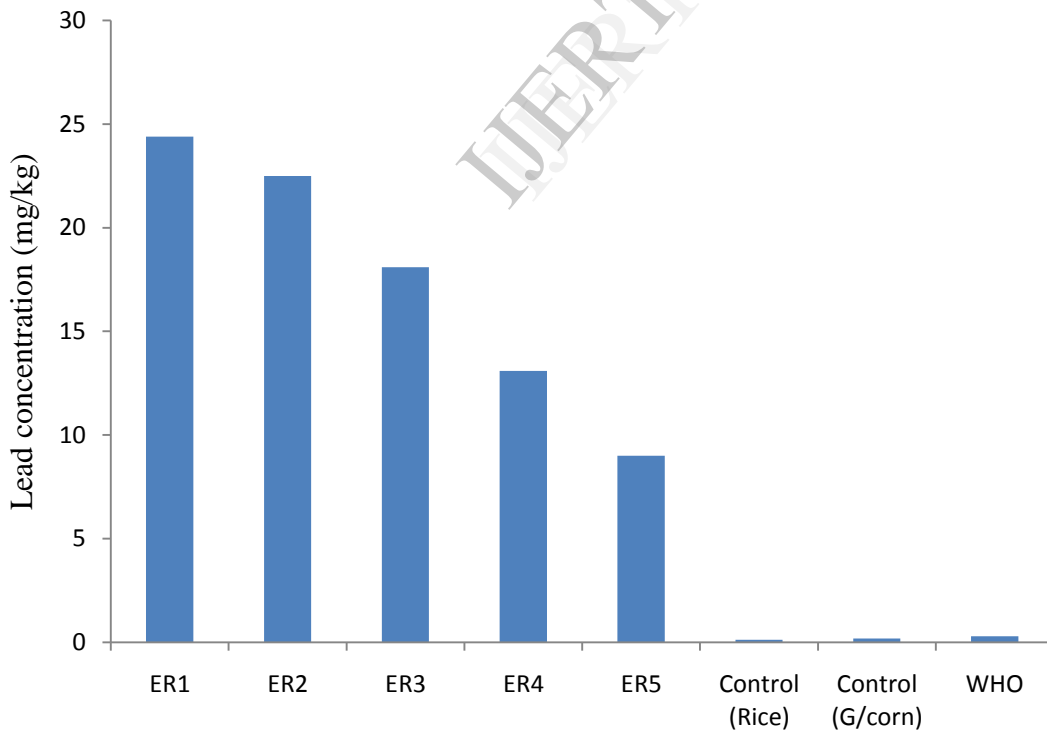


Figure 3. Lead concentrations in rice stem samples obtained at different locations along the South cardinal direction



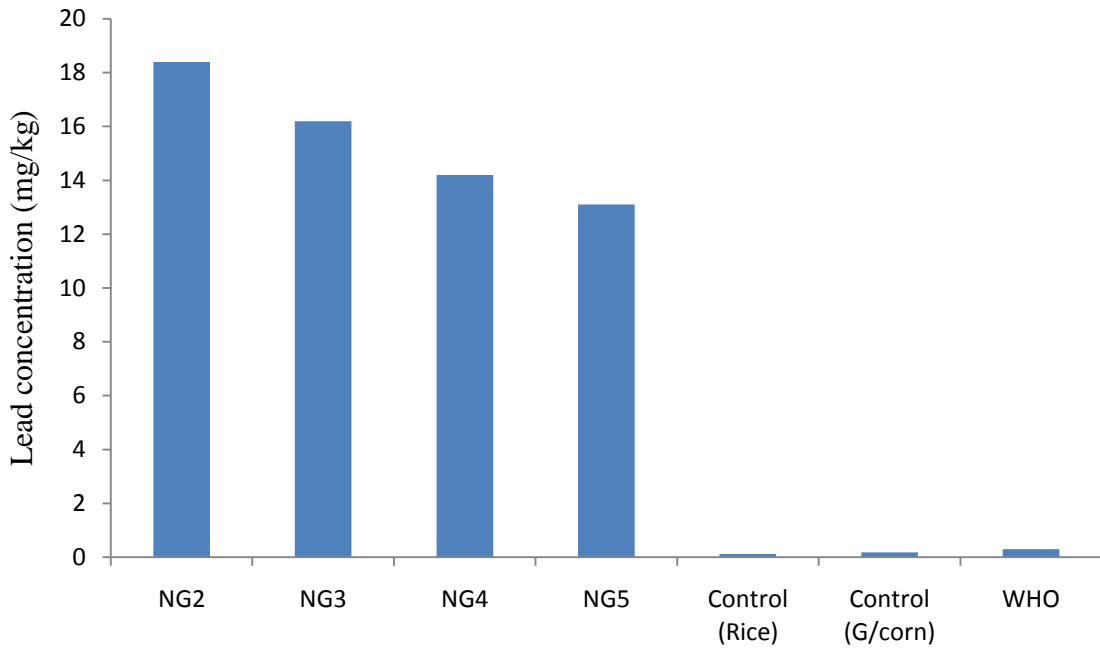
Guinea corn stem samples at different locations- East

Figure 4. Lead concentrations in guinea corn stem samples obtained at different locations along the East cardinal direction



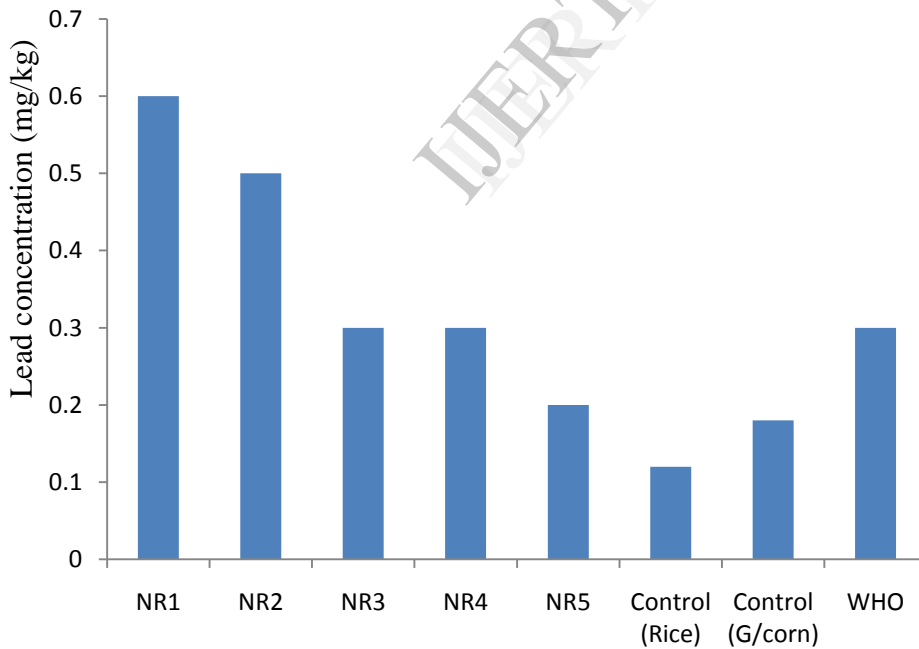
Rice stem samples at different locations- East

Figure 5. Lead concentrations in rice stem samples obtained at different locations along the East cardinal direction



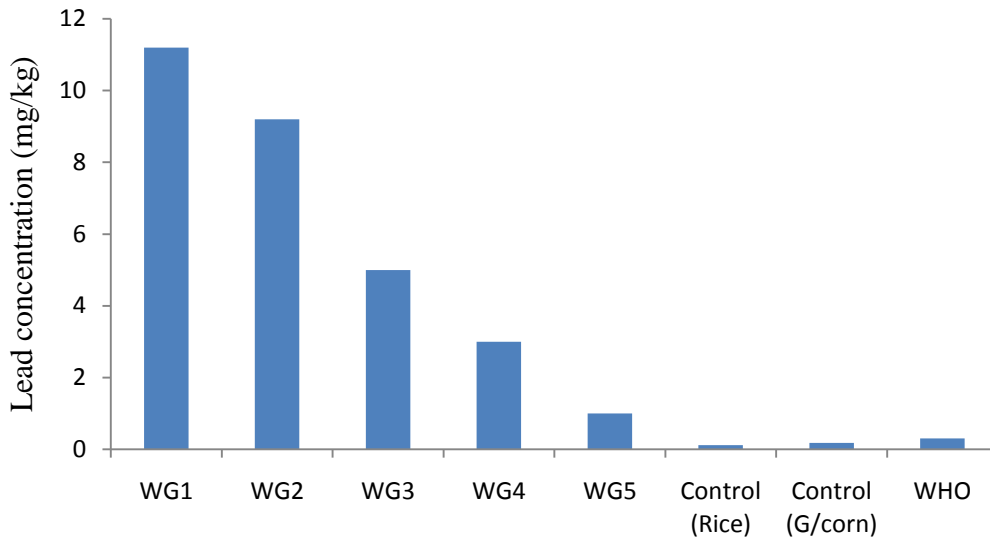
Guinea corn stem samples at different locations- North

Figure 6. Lead concentrations in guinea corn stem samples obtained at different locations along the North cardinal direction



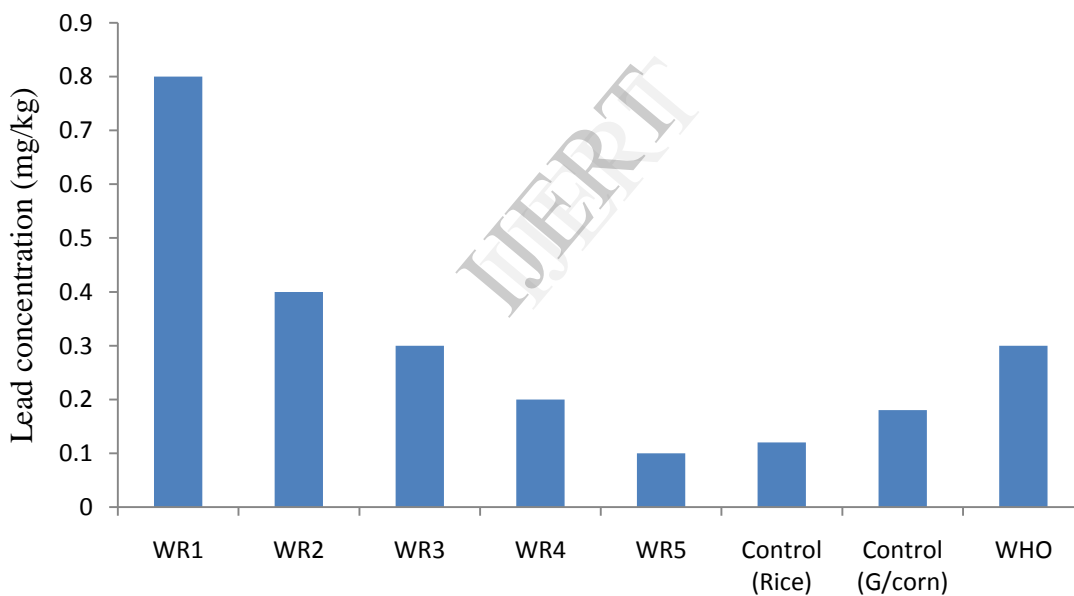
Rice stem samples at different locations- North

Figure 7. Lead concentrations in rice stem samples obtained at different locations along the North cardinal direction



Guinea corn stem samples at different locations- West

Figure 8. Lead concentrations in guinea corn stem samples obtained at different locations along the West cardinal direction



Rice stem samples at different locations- West

Figure 9. Lead concentrations in rice stem samples obtained at different locations along the West cardinal direction.

The experimental results given in Figures 2 – 9 revealed the presence of lead in the samples of rice and guinea-corn obtained from the vicinity of the mining site under investigation. Analyses of these results showed that the concentrations of lead in the used samples (guinea-corn and rice) decreased with increase in the distance of sample location away from the mining site. It was also observed that the concentration of lead shown in Figures 2 – 9 were higher in the guinea corn than rice samples obtained from the vicinity of the mining site. This is an observation that could be attributed to variation in the accumulation of potential toxic element from plant to plant which over time may pose serious health hazards to man. Observed experimental values for the samples were found to be above the concentration value of the control samples (rice (0.12 mg/kg) and guinea corn (0.18 mg/kg)) and 0.3 mg/kg limit value recommended by WHO and EC. This analysis confirmed that the selected crop plant samples were contaminated with lead, possibly through the water intake from the contaminated water and soil in the vicinity of the mining site.

3.5 Characterization of Soil Samples

The results of the characterization conducted on the soil samples are as presented in Table 4. Analyses of the results revealed that the soil samples obtained around Tunga Tsauni lead mining site contain essential mineral elements (K, N, Ca, Mg, Na, P) in different concentrations as well as heavy metals (Zn, Pb, Cu, Cr, Fe and Mn).

Table 4. Essential nutrients and heavy metals in the characterized soil samples

Cardinal point	Location	K mg/kg	N mg/kg	Ca mg/kg	Mg mg/kg	Na mg/kg	P mg/kg	Zn mg/kg	Pb mg/kg	Cu mg/kg	Cr mg/kg	Fe mg/kg	Mn mg/kg
N	N	11.23	4.52	21.34	43.22	2.45	34.5	100.2	44.4	125.5	0.5	12.2	14.2
S	S	13.52	7.63	23	52.18	2.38	42.18	43.5	13.3	15.4	0.3	2.4	13.8
W	W	12.54	6.32	42.24	46.5	2.12	50.18	42	45.5	16.2	0.24	2.12	6.4
E	E	13.2	5.84	39.5	58.56	1.08	42.58	75.5	45.8	45.8	7.5	1.08	13.2
Control		34.06	41.6	26.15	72.12	4.69	ND	3	1.13	1.7	ND	ND	ND

From the results given in Table 4, it can be seen that the soil samples studied contained K, N, Ca, Mg, Na and P, with Mg having the highest concentration of 58.56 mg/kg for soil sample obtained along the West cardinal direction. The concentration of the metals discovered in all the soil samples were found to be K (11.23 – 13.52 mg/kg), N (4.52- 7.63 mg/kg), Ca (21.34 – 42.24 mg/kg), Mg (43.22– 58.56 mg/kg), Na (1.08– 2.45 mg/kg) and P (34.5– 50.18 mg/kg), whereas those of the control were K (34.06 mg/kg), N (41.60 mg/kg), Ca (26.15 mg/kg), Mg (72.12 mg/kg), and Na (4.69 mg/kg).

Table 4 also showed the results of the heavy metals that were present in the soil samples studied. The results revealed the presence of different heavy metals with different concentrations that included Zn (42.0 – 100.2 mg/kg), Pb (13.3 – 45.8 mg/kg), Cu (15.4 – 125.5 mg/kg), Cr (0.24 - 7.5 mg/kg), Fe (1.08 – 12.2 mg/kg) and Mn (6.4 – 14.2 mg/kg) as against the control sample that contained 3.0 mg/kg Zn, 1.13 mg/kg Pb and 1.70 mg/kg Cu. This observation revealed that the soils samples around the mining site were polluted with the heavy metals, especially lead, as a result of the lead mining activities taking place there.

4.0 CONCLUSIONS

The results obtained from this research work have revealed the presence of lead in the water and the crop plant samples taken from the lead mining site in Tunga Tsauni area of Niger State. In addition, based on the lead concentration level, it was discovered that the water sources W₁, W₂, W₃, B₁, and R_L are very polluted and are, therefore, not safe for domestic use. However, the water sources W₄ and R_U were found to be safe for now. Furthermore, concerning the crop plants, the lead concentrations in the guinea-corn samples were discovered to be higher than those of the rice samples used, but nearly all the crop plants were found polluted with lead. Therefore, it has been discovered that lead mining activities in Tunga Tsauni area of Niger State are really affecting the crop plants and the water resources in the area by contaminating them with lead that is a toxic material. Hence, there is the need for urgent and serious measures to regulate the mining activities at the site in order to minimize the hazardous effects of lead to the environment. As such, it is recommended that environmental law enforcement/regulatory agencies should be empowered for identification and management of the mining activities in that area.

NOMENCLATURES

BOD	Biological oxygen demand
COD	Chemical oxygen demand
DO	Dissolved oxygen
EC	European Commission
FEPA	Federal Environmental Protection Agency
LGA	Local Government Area
NAFDAC	National Agency for Food and Drug Administration and Control
USEPA	United State Environmental Protection Agency
WHO	World Health Organization

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