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Research Paper

Risk Assessment of Heavy Metals in Agricultural Crops Cultivated on/around Abandoned Tin Mine Areas in Jos South LGA, Plateau State, Nigeria

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ABSTRACT
Jos South is one of the tin mining communities in Plateau State of Nigeria faced with serious threat of environmental pollution. Poor agricultural practices on mine areas increased the release of a wide range of xenobiotic compounds to the environment. The concentrations of heavy metals in soils and sediments were investigated by XRF while in water and vegetable samples were determined by ICP-OES. The result of this analysis showed that the pH and EC of the top-soils (0-10 cm), sub-soils (11-20 cm) and 21 - 30 in the area ranged from 5.89 -6.36 and 0.09- 0.28 dS/m respectively. The soil and sediment samples had moderate percentages of clay, sandy and silk soils. Cd and As were detected only in the water samples while Pb was detected in the sediments alone. All the heavy metals concentrations detected in water (except Mn) were above the WHO and NESREA limits for drinking water. The risk analysis of water showed the HI was far greater than one and the tendency of contracting cancer was very high as the values were above the US EPA of $10^{-6} – 10^{-4}$ limit. The Cd and As concentrations in sediments were below ERL (Effect Range Low) and CCME values therefore, are not expected to cause adverse health effects whereas Cr, Mn, Ni, Cu, Zn and Pb concentrations in the sediments were above ERM (Effect Range Medium) and CCME limits and are likely to be very toxic. Cr and Ni tend to decrease with soil depths but the other metals showed irregular patterns in their distributions. Apart from Cd and As that were not detected in most of the soil samples, all other metal concentrations exceeded those of the WHO, DPR and NAFDAC regulatory limits for safe agricultural soils. The ingestion exposure pathway is the dominant pollution pathway for children while dermal in adults. Assessment of contamination index (CI), pollution load index (PLI), Degree of Contamination (CD), Geo-accumulation Index (Igeo) with the NESREA baseline showed anthropogenic influences on the soil quality in the area as they were heavily polluted by mining and agricultural activities. The observed ranges in the concentrations of As, Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn, in the edible parts of tomato, potato, green beans, green pepper and cabbage from the abandoned areas were; ND–0.44 mg/kg, ND–0.004 mg/kg, ND–0.24 mg/kg, ND–0.40 mg/kg, ND–6.54 mg/kg, ND–1.63 mg/kg, ND–0.10 mg/kg, ND–1.05 mg/kg and ND–2.08 mg/kg, respectively with mean concentrations of 0.158, 0.0008, 0.0.048,0.08, 2.258, 0.326, 0.02, 0.31 and 0.722mg/kg, respectively. The values recorded for Cu, Fe, Mn, Ni, Pb and Zn were below the levels recommended by WHO/FAO, EC/CODEX and NAFDAC for metals in foods and vegetables and also were within the normal range of metals in plants. In general, the concentrations of the metals in the vegetables were in the following decreasing order: Fe>Zn>Mn>Pb>As>Cu>Cr>Ni>Cd and the accumulation of the metals in the vegetables was potato>cabbage>tomato>green beans >green pepper. The HI of consuming the five vegetable were less than one signifying safety but the population in the areas may have the potentials of contracting cancer due to arsenic. The abandoned mine areas contain high quantities of heavy metals that should be treated to avoid health risks to the exposed populations. The selection and breeding of crop and vegetable species or cultivars that have low heavy metal accumulation seems to be a suitable method to reduce the adverse health effects of heavy metals. Regular soil and groundwater assessment is also recommended to monitor the contamination potentials in the area.

KEY WORDS: *Risk Assessment, Agricultural Crops, Abandoned mines, Jos South*

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I. INTRODUCTION

The mining process generates large volumes of waste with mineral of interest constituting only a small fraction of the mined material [1]. Furthermore, this industry produces a considerably adverse environmental impact through each single production step: exploration, chemical and physical treatments affecting the soils during operations often having irreversible effects on soil properties, causing infertility as well as inducing an important decrease in biodiversity [2]. This renders many hectares of soil unsuitable for agriculture and generates highly contaminated soils, in which substances will move depending on the physicochemical properties of the substrate and on the climate conditions of the area in which the deposits are located. As the amount of land available for agriculture decreases, the need for more land or at least better use of currently available arable land increases [3].

Abandoned tin mine ponds and lands have been turned to hot spots for irrigation in Plateau due to its ease of water availability, difficulties in reclaiming the shafts and scarcity of freshwater for irrigation during the dry season [4].These abandoned mines are negative legacy of post-mining operations. Although the agricultural soils of these mining areas are contaminated with heavy metals, the farmers cannot afford to leave farmland fallow for remediation because the demand and pressure to produce foodstuffs and vegetables by irrigation is so high. The levels of the heavy metals could be elevated by the addition of fertilizers, manures, pesticides, and other chemical repeatedly to the soils to enhance the agricultural crops.

Although the problems of derelict mining sites are well known in almost all countries, the efforts of the mining industry, governmentsand the host communities towards their rehabilitation have been forgotten. The selection and breedingof crop and vegetable species or cultivars that have low heavy metal accumulation, without having to leave the farmland fallow, seems to be a suitable method to reduce the adverse health effects of heavy metals [5]

II. MATERIALS AND METHODS

Study Area

The Jos Plateau lies in the North Central part of Nigeria. It is approximately 104km (65 miles) from North to South, and 80km (50 miles) from east to West covering an area of 8,600km2. The Southern part of Jos Plateau is in the Benue Lowlands extending towards the River Benue flood plain. Jos Plateau is situated between latitudes 10°11′N and 8°55′N and longitude 8°21′E and 9°30′E.

Collection of Samples

The sample sites were the farmlands on/around abandoned tin mine areas. The concentrations of metals in Nigerian soils from the Department Petroleum Resources (2002) (6) were used as background concentrations.

Water Sampling

Water samples were obtained from ponds and/or streams located on abandoned tin mine sites in Du in Jos South LGA of Plateau State. Water samples were collected in 900ml amber glass bottle previously cleaned by washing in detergent, rinsed with tap water and later soaked in 10% HNO_3 for 24 hours and finally rinsed with deionized water prior to usage. During sampling, sample bottles were rinsed with sample water. At each sampling point, water sample will be collected in triplicate from three points and pooled. The samples collected were filtered in the laboratory through 0.45mm Whatman filter paper. To prevent precipitation of metals and biological growth, few drops of concentrated nitric acid were added to samples.

Collection of Soil/ Sediment Sample

Soil samples from Du in Jos South Local Government Areas of Plateau State were collected from abandoned tin mine agricultural areas. The agricultural soils were taken in triplicate at three depths (0-10cm, 11-20cm and 21-30cm) using spiral auger of 2.5cm diameter and mixed. The soil samples at each depth were then randomly selected and bulked together to form a composite sample before they were placed in clean labeled plastic bags and transported to the laboratory [7]. The samples were used for heavy metals analysis. Sediments were collected from streams in the areas were water samples were collected,

Plants Samples

Approximately 1kg of Tomatoes (LycopersiconesculentumL), potatoes (Solamuntuberosum), green beans (Phaseolus vulgaris) and green pepper (Capsicum annuum L. cv. Lady Bell) each were collected by sampling randomly in minimum of 10 locations on the abandoned sites. For cabbage (Brassica oleracea L. Var. Capatuta), a total composite sample of 10 kg were gathered by collecting 1 kg portions randomly from different location on the sites. These subsamples are then combined and mixed so that a portion taken of the composite was taken to be representative of the whole samples.

Sample Preparation and Analysis

Soil and sediment samples were analyzed for heavy metals with XRF after being pulverized and sieved through a 2mm sieve. Water and plant samples were digested with concentrated HNO_3 and were analyzed for heavy metals with ICP-OES.

III. STATISTICAL ANALYSIS

Each sample was analyzed in triplicate and the values were then averaged. Statistical analyses of experimental data were performed using the SPSS 23.0 package for Windows. All data were tested for goodness of fit to a normal distribution, using a Kolmogorov–Smirnow one-sample test. Data were log transformed where necessary to achieve homogeneity of variance. Evaluation of significant differences among means was performed using one-way ANOVA followed by Turkey's post-hoc test, with $p < 0.05$ indicating statistical significance. Pearson product moment correlation coefficients (r) were used to express the associations of quantitative variables.

IV. RESULTS AND DISCUSSIONS

Physico – chemical quality of soil and sediment at Du in Jos South LGA

The physico - chemical quality of soil and sediment at Du in Jos South LGA were assessed with respect to their pH, EC, OC, N, and OM, minerals, CEC, PBS and texture (Table 1). The pH values obtained ranged from 5.89 at JSD30 to 6.36 JSDS and showed no statistical differences (P<0.05) in soil with depths. The soil pH plays an important role in the mobility of metals as well as their bioavailability to plants [8]. Additionally, a tendency of the pH to decrease with depth was observed even though statistical differences and definite patterns were not found. The tendency of the pH to decrease below soil profile disagrees with the findings of [9]. It was established that, near neutral pH generally results in micronutrient cations being soluble enough to satisfy plant needs without becoming soluble enough as to be toxic [10]. Thus by maintaining proper soils pH, an ideal environment can be created for plants. However, corn and potato thrives on soils with pH lower than normal, 5.0 – 7.0 and 5.0 – 5.5 respectively [11]

Table 1 Physico- chemical properties of soil and sediment of Du in Jos – South LGA

S/N	Sample Code	pH	EC dS/m	OC %	N %	OM %	P ppm	K cMol/kg	Ca cMol/kg	Mg cMol/kg	Na Mol/kg	EA cMol/kg	CEC cMol/kg	PBS %	Clay %	Silt %	Sand %	Textural Class
1	JSDS	6..36	0.11	0.98	0.05	1.68	14.0	0.16	1.74	0.54	0.02	1.61	4.07	60.44	28.44	22	49.56	S,C,L
2	JSD10	6..18	0.09	0.60	0.03	1.03	12	0.16	2.00	0.59	0.03	1.63	4.41	63.04	37.44	26	36.56	C
3	JSD20	6.15	0.09	1.02	0.05	1.76	18	0.15	1.81	0.57	0.03	1.62	4.18	61.24	36.44	24	38.56	C,L
4	JSD30	5.89	0.28	1.7	0.09	2.97	32	0.16	1.76	0.55	0.03	1.62	4.12	60.68	30.44	24	45.56	C,L

Key: JSD: Jos South (Du); S= sediment; Subscripts 10, 20 and 30 represents Soils at the depths 0 - 10, 11 - 20 and 21 – 30 respectively[S= sandy, C= clayed, L= Loamy,

The EC values in the area were from 0.09 dS/m in JSD10, JSD20 to 0.28 in JSD30 indicating that soils/sediments were non - saline. The organic carbon was lowest (0.6%) in JSD10 and highest at (1.73%) in JSD30. The organic matter was highest (2.97) at JSD30 and lowest (1.03) at JSD10. The order of the nutrients in this work was P>Ca>Mg>K>Na. The soils have moderate percentages of clay, sandy and silk soils.

Concentrations of heavy metals in water, sediment and soil of Du, Jos South L.G.A

The result of the analyses of the heavy metals in water, sediment, top-soils (0-10 cm), sub-soils (11-20 cm) and 21 - 30 are shown on Figure 1. As and Cd were only detected in water with the concentrations of 0.62 and1.57mg/kg and were both above the WHO and NAFDAC [12,13] limits. Cr concentrations in water, sediment, surface soil, 11 – 20cm and 21 – 30cm sub- soil were 2.84, 957.90, 670.53, 650 and 629mg/kg respectively and all these concentrations were above the WHO, NAFDAC, DPR and the CCME thresholds for safe water, sediment and soil for agriculture. Mn concentrations in water, sediment, surface soil, 11 – 20cm and 21 – 30cm sub- soil were 0.23, 1161.90, 720.42, 766.9 and 573.24mg/kg respectively and these were below NAFDAC and DPR guidelines for irrigation water and agricultural soils. Fe concentrations in water, sediment, surface soil, 11 – 20cm and 21 – 30cm sub- soil were 3.40, 239944.5, 150577.8, 170488.9 and 163566.7mg/kg respectively and were above WHO, CCME, NAFDAC and DPR guidelines for irrigation water and agricultural soils.

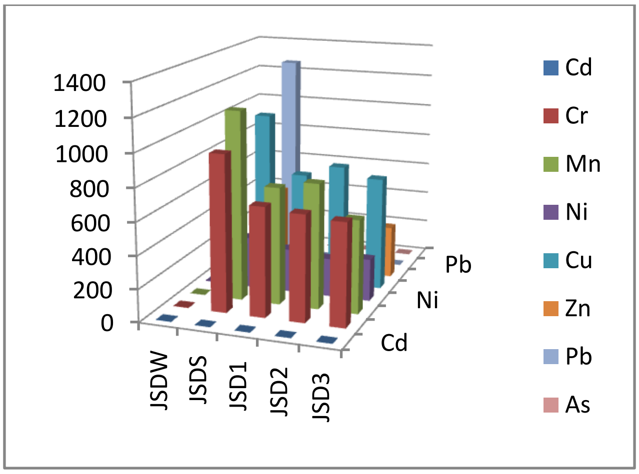

Figure. 1: concentrations of heavy metals in water, sediment and soil of Du, Jos South L.G.A
Key: JSD = Du, Subscripts W = Water; S=Sediment, 1 = 0 – 10cm, 2 = 11 20cm, 3 = 21 – 30cm;

Fe was the most accumulated metal with very high concentrations and therefore displayed on Figure 2. Ni concentrations inwater, sediment, surface soil, 11 – 20cm and 21 – 30cm sub- soil were 5.78, 314.67, 267.47, 236 and 259.6mg/kg respectively were above WHO (2014) and NAFDAC guidelines for irrigation water but were below WHO limits for agricultural soils. Cu concentrations in water, sediment, surface soil, 11– 20cm and 21 – 30cm sub- soil were 2.18, 1038.38, 678.93, 750.82 and 694.91mg/kg respectively were all above WHO, NAFDAC and DPR guidelines for irrigation water and agricultural soils.

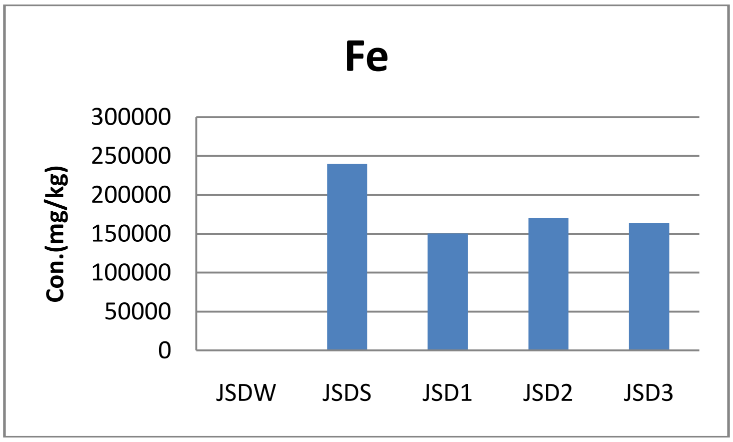

Figure. 2: concentrations of iron in water, sediment and soil of Du, Jos South L.G.A and control
Key: JSD = Du, Subscripts W = Water; S=Sediment,1 = 0–10cm,; 2 = 11 20cm,; 3 = 21 – 30cm;

Zn concentrations in water, sediment, surface soil, 11 – 20cm and 21 – 30cm sub- soil were 0.29, 479.53, 248.77, 353.09 and 320.99mg/kg respectively with only the surface soil slightly below WHO limit but other samples were above NAFDAC and DPR guidelines for irrigation water and agricultural soils. Pb was only detected in sediment with concentration of 1299.55mg/kg. The order of the abundance of metals in the soils was in declining order of Fe>Mn>>Cu>Cr>Zn>Ni>Pb.

The Cd and As concentrations in sediments were below ERL (Effect Range Low) and the CCME values are not expected to cause adverse effects whereas, Cr, Mn, Ni, Cu, Zn and Pb concentrations in the sediments were above ERM (Effect Range Medium), the CCME limits and are likely to be very toxic.

Correlation analysis between metals in the abandoned mine soil/sediment

The computed statistical interrelationship betweenheavy metals showed that As has moderate significant negative correlation with Fe (r = -0.53), Cu (r = -0.62) and Zn (r = - 0.61) while Cr and Ni (r = 0.88) and Fe and Cu (r = 0.81) have strong positive significant correlations and Cr, Mn, Fe, Ni and Cu have weak negative correlation with Cd. Cr has weak insignificant negative correlation with Mn, and Cu (r = -0.49, -0.08 respectively). Lead is moderately significant with Zn (r = 0.58) and Mn(r = - 0.66) and Fe (r = - 0.5)

Health assessment of heavy metals in water

Table 2: Non-carcinogenic (mg/kg/day) and carcinogenic risk associated with drinking Du abandoned mine water

Sample Code	Type of risk	Health quotient of heavy metals (Children)										Health quotient of heavy metals heavy metals (Adult)									
		As	**Cd**	**Cr**	**Cu**	**Mn**	**Ni**	**Pb**	**Zn**	**Fe**	**HI**	**As**	**Cd**	**Cr**	**Cu**	**Mn**	**Ni**	**Pb**	**Zn**	**Fe**	**HI**
JSDW	**Non - carcinogenic**	165.78	252	76	35	3.31	23	53	0.08	39	442	107.83	164	49	23	0.09	6.2	34	0.05	25	277
	Carcinogenic	0.07	0.05	0.114				0.002				0.04	0.031	0.074				0.01			

Table 3: Geo- accumulation, ecological and risk indices of soil and sediment from Du abandoned mine area

Sample	Geo accumulation Index of Soil (Igeo)						I_f	Ecological Factors(Eri)					
Code	Cr	Fe	Ni	Cu	Zn	Pb		Cr	Fe	Ni	Cu	Zn	Pb
JSDS	2.57	5.00	2.58	4.27	1.24	3.39		19.16	44.05	145.37	3.55	76.67	288.81
JSD1	2.16	4.33	2.35	3.65	0.24		2.51	13.41	37.45	95.05	1.78		147.68
JSD2	2.12	4.51	2.17	3.80	0.75		2.62	13.00	33.04	105.11	2.52		153.68
JSD3	2.07	4.45	2.31	3.69	0.61		2.58	12.59	36.34	97.29	2.29		148.51
JSDS	2.57	5.00	2.58	4.27	1.24	3.39		19.16	44.05	145.37	3.55	76.67	288.81

The health risk indices (HRI) values of As, Cd, Cr, Cu, Mn, Zn, and Pb due to water consumption for residents (adults and children) of the study area are listed in Table 2. The HRI values for all the heavy metals in water around the abandoned mines were >>>1 indicating that the residents at these sites may be exposed to very high potential non-carcinogenic health risk mostly due to As, Cd, Cr and Pb metals. The non-carcinogenic health effect is more in children than the adults. The order of the health risks due to metal was As>Cr>Pb>Cd. The risk assessment for Fe, Cu, and Zn was not possible due to the lack of carcinogenic slope factorsbut the carcinogenic hazard indices for As, Pb, Cr, and Ni were estimated (Table 2). With respect to the CRIs of the soil heavy metals, the CRI of Cr was the largest, followed by those of Ni and Pb. It has been reported that exposure to two or more pollutants may result in additive and/or interactive adverse effects. Therefore, it was difficult to assess the potential health risks of multiple metals using each individual HQ value for the HMs [14].With respect to [15] prescriptions of (10^{-6} to 10^{-4}) average carcinogenic risk values obtained for As, Cd, Cr and Pb in this study indicated for a lifetime (70 years) were very high and therefore there would be highprobability of contracting cancer by the residents and bioaccumulation of the metal in soil, sediment and plants of the area [16]. The result also showed that the cancer effect could be more in children than the adults.

Health risk indices of the exposure pathways of soil

The risk exposure pathways involve taking the average daily intake (ADI) of the toxic metals (mg/kg day) following oral ingestion, inhalation and dermal contact route using the methods described by [17].

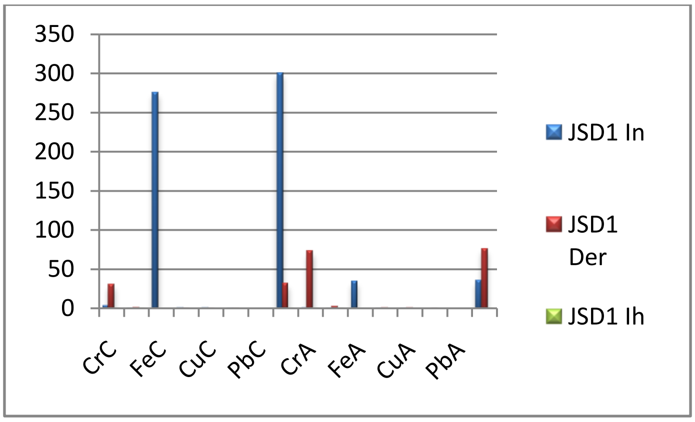

Figure. 3: the health indices of the three exposure pathways

Key: JSD = Du, ing. = ingestion; Der = dermal; Inh = inhalation HI = Health Index, A = Adults; C = Children.

The results indicated that those living around the abandoned mine areas were exposed to potential health risk through the intake of Fe via consuming of soil especially with the children ingesting, playing around abandoned mine areas and homes that are built on reclaimed mine areas. The cumulative non-carcinogenic effect in the study (HI), were all above 1 indicating non - carcinogenic health concern especially with the children as they recorded higher values. HI values of heavy metals for all samples were above 5 (five) by [15, 16] indicated that there was risk from the intake of these soils. The exposure through the dermal route was observed to follow the ranking; Cr>Mn>Pb>Ni>Cu>Zn for both adults and children but was higher in adults than in children. Inhalation contributed insignificantly to the non - carcinogenic risk. The HQ of abandoned mine areas derived from the inhalation are much lower than the US EPA guidelines.

Cancer Risk index (CRI) for heavy metals in adults and children for the three exposure pathways of soils around the Abandoned Mine Areas

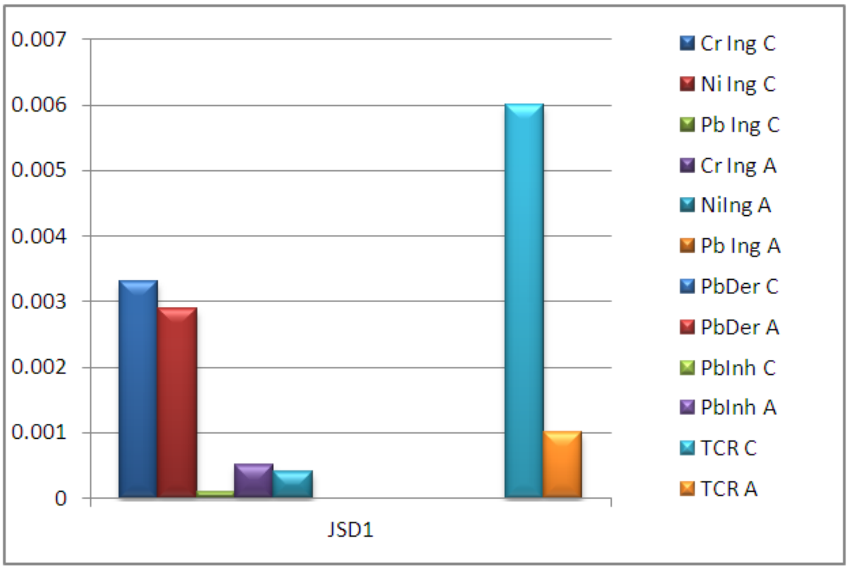

Figure. 4: carcinogenic risk of heavy metals in five vegetables

Key: JSD = Du, ing. = ingestion; Der = dermal; Inh = inhalation TCR –Total cancer risk, A = Adults; C = Children.

The result of carcinogenic risk index (CRI) for the three exposure pathways is presented in Figure 4. The CRIs for the three metals investigated were above the acceptable limits of 10^{-6} – 10^{-4} for both adults and children.

Pollution assessment of heavy metals in soil and sediment

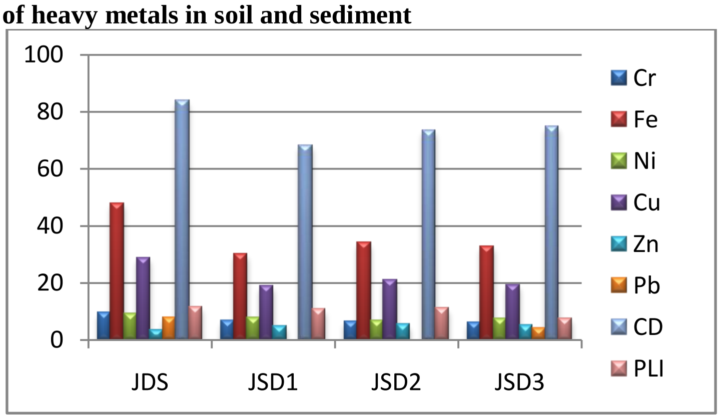

Figure. 5: contamination indices, degree of pollution (CD) and pollution load indices soils and sediment from the abandoned mine area of Du.

Zn at JSDS, JSD1 – JSD3 and Pb in soils were considerably contaminated ($3 \leq CF < 6$) but the contamination factors of other metals in all the locations were at very highly contamination ($CF \geq 6$) using DPR background scenario and therefore had very high risk ($CD > 32$). The contamination factor of soil and sediment were in the order: JSDS>JSD3>JSD2>JSD1 and according to the metals Fe>Cu>Cr>Ni>Zn>Pb. The pollution load Index indicated that the soils and sediment were at extremely heavy pollution ($3 < PLI$) [18, 19, 20].

The average I_{geo} class ($2 \leq I_{geo} < 3$ to $4 \leq I_{geo} \leq 5$) for the Du sediment was moderately polluted to very strongly polluted and I_{geo} class ($0 \leq I_{geo} < 1$ to ($4 \leq I_{geo} < 5$) for the soil were unpolluted to very strongly polluted (Table 3) [20, 21]. I_{geo} values give the advantage of not aggregating all the pollutants into one value and therefore treating each heavy metal independently, giving a good picture of the extent of individual heavy metal pollution. Zn and Cr had low potential ecological risk, Ni had moderate potential ecological risk but Cu and Pb had considerable potential ecological contamination. The risk index for the surface soil and the 21 – 30 subsoil indicated low ecological risk, the 11 – 20cm subsoil and sediment had moderate ecological risk. Nemerow pollution index (I_f) showed that the abandoned mine sites studiedwere in moderately polluted domain and are safe for most benthic/underground organisms [28].Thus, heavy metals contamination of the Du during the period of this study was mostly due to Fe, Cu, Cr and Ni.

Concentration of heavy metals in some selected food crops from abandoned mine sites of Du, Jos South

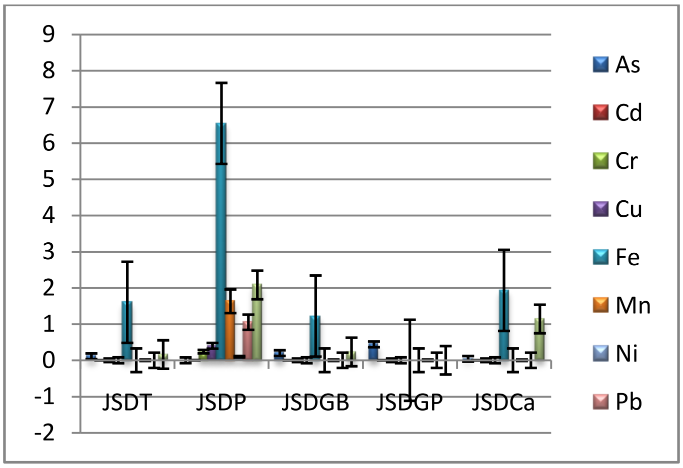

Figure 6: mean concentrations of heavy metals (mg/kg dry weight) in selected food crops from mining site (Du, Jos South)

Key: JSD=Jos South/ Du; T= tomato; P= potato; GB= green beans; GP= green pepper; Ca= cabbage

The concentrations of the heavy metals in the edible parts of the 5 species of vegetables are presented in Figure 6. . Marked variation exists among the different vegetables for each individual metal. The observed ranges in the concentrations of As, Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn, in the edible parts were ND–0.44 mg/kg, ND–0.004 mg/kg, ND–0.24 mg/kg, ND–0.40 mg/kg, ND–6.54 mg/kg, ND–1.63 mg/kg, ND–0.10 mg/kg, ND–1.05 mg/kg and ND–2.08 mg/kg, respectively, with mean concentrations of 0.158, 0.0008, 0.0.048,0.08, 2.258, 0.326, 0.02, 0.31 and 0.722mg/kg, respectively. In all the 5 species of vegetables, the As, Zn and Fe concentrations were accumulated in the edible parts of 4 vegetable species and Cd, Cr ,Cu, Mn, Ni and Pb concentrations in the edible parts of only one vegetable species. Cd was detected only in potato with value lower than the WHO/FAO limit. The values recorded for Cu, Fe, Mn, Ni, Pb and Zn were below the levels recommended by WHO/FAO, EC/CODEX and NAFDAC for metals in foods and vegetables and also were within the normal range of metals in plants [13, 22]. This was in agreement with the work of [23] that found the values of heavy metals in tomatoes from Umuahia Metropolis of Abia State Nigeria were below the permissible levels of metals recommended as dietary intake in tomato. This however, was in variant with the work of [24] that could not detect any harmful metal in tomato. In general, concentrations of the metals and vegetables were in the following order: Fe>Zn>Mn>Pb>As>Cu>Cr>Ni>Cd and potato>cabbage>tomato>green beans >green pepper respectively. The Daily Intake Rate (DIR) estimated for the consumption of vegetables for both adults and children were also evaluated. The DIR was low for many elements at different sites because the vegetables were low accumulators (excluders) of metals. Estimated Daily Intakes of heavy metals for both adults and children through the consumption of vegetable in this study were less than tolerable daily intake limit set by the [17, 25]. This showed that no risk would be due to consumption of vegetables grown on the abandoned mine areas. [26]and[27] in their works also found lower values than tolerable daily intake limits. In the present study, the highest DIR values in vegetables were for Fe (3.20E-03) for adults in potato

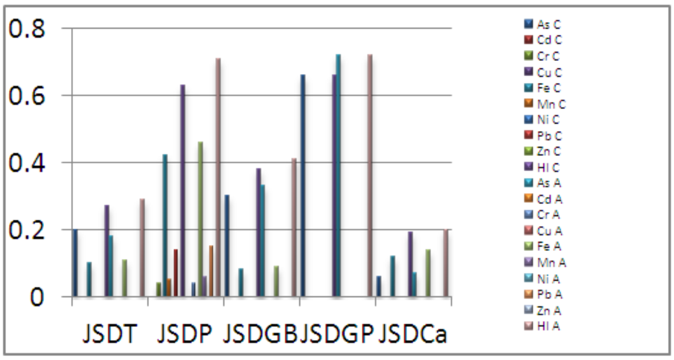

Figure 8: target hazard quotient and health indices of heavy metals in selected food crops for children and adults who consumed vegetables from around mining sites (Jos South)

Key: JSD=Jos/south Du; T= tomato; P= potato; GB= green beans; GP= green pepper; Ca= cabbage,A= adults; C=children; HI=health index

THQ obtained for all the metals were < 1 [23] indicating that the consumers of vegetables from Du abandoned mine may not be exposed to non-carcinogenic health risk due to the metals studied as the lead poisoning which resulted to death of 163 people including children in Zamfara between March and June, 2010. Heavy metals have the ability to accumulate in human body over a period of time before its effect.

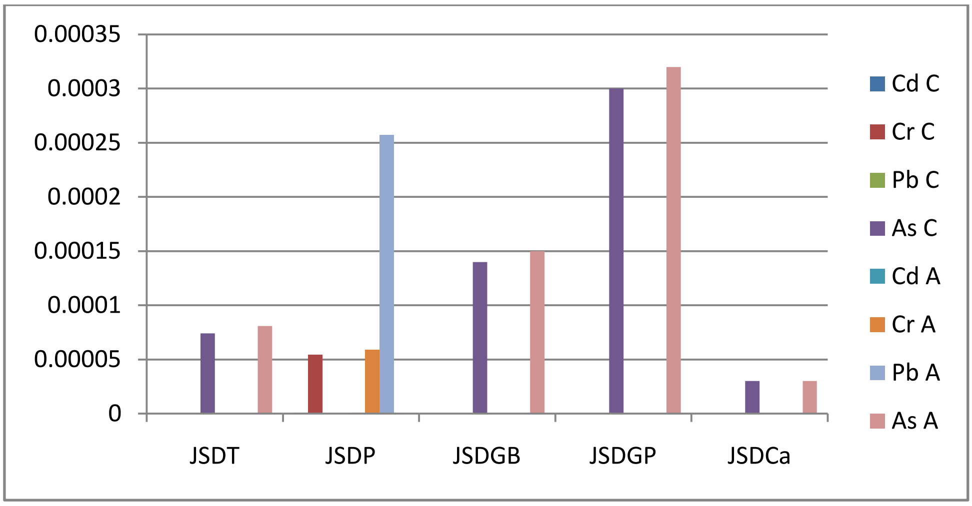

Figure 9:carcinogenic risk of heavy metals in selected food crops from mining site (Jos South)
Key:JSD=Jos/south Du; T= tomato; P= potato; GB= green beans; GP= green pepper; Ca= cabbage,= adults; C=children

With respect to US EPA prescriptions (10^{-6} – 10^{-4}), the average carcinogenic risk values obtained for Cd, Cr, Pb, and As in this study indicated, for a lifetime (70 years), the probability of contracting cancer were mostly within the range except for As in both adults and children for consuming green pepper in the area. This suggests that green pepper should not be cultivated in the area.

V. CONCLUSION

The pH values obtained were acidic and ranged from 5.89 at JSD30 to 6.36 JSDS and the EC of the area was non- saline. The organic matter was highest (2.97) at JSD30 and lowest (1.03) at JSD10. The order of the nutrients in this work was P>Ca>Mg>K>Na. The soils have moderate percentages of clay, sandy and silk soils. Most of the concentrations of the heavy metals in water, sediment, surface soil, 11 – 20cm and 21 – 30cm sub- soil were above the WHO, NAFDAC and DPR guidelines for irrigation water and agricultural soils. The contamination factor of soil and sediment were in the order of location as JSDS>JSD3>JSD2>JSD1 and according to the metals, Fe>Cu>Cr>Ni>Zn>Pb. The pollution load Index and degree of pollution (CD) indicated that the soils were at extremely heavy pollution (3 < PLI) and of high risk (CD>32). The concentrations of the heavy metals in the edible parts of the 5 species of vegetables indicated marked variation among the different vegetables for each individual metal at the different locations. HI obtained for all the metals in the vegetables were < 1 indicating that the consumers of the vegetables from Du abandoned mine may not be exposed to non-carcinogenic health risk due to the metals and carcinogenic risk values obtained for Cd, Cr, Pb, and As in this study indicated the probability of contracting cancer for a lifetime (70 years) were mostly within the range except for As in both adults and children.The accumulations of As in vegetables is likely to cause cancer and therefore cultivation of vegetables where As concentrations is high should be discouraged. Regular soil and groundwater assessment is recommended to monitor the contamination potential in the area. Awareness on the consequences of ingesting food contaminated with heavy metals should be instituted and intensified.The selection and breeding of crop and vegetable species that have low heavy metal accumulation seems to be a suitable method to reduce the adverse health effects of heavy metals.

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