



Characterization and Evaluation of Human Health Risk of Heavy Metals in Tin Mine Tailings in Selected Area of Plateau State, Nigeria

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Abstract

Tin mining tailings are unprocessed waste materials that overlie an ore which are displaced during mining activities. This research work is aimed at characterizing and evaluating the human health risk of heavy metals in tin mine tailings in Zabot (S3) and Tafan (S4) districts in Barkin Ladi Local Government Area of Plateau State, Nigeria. The samples were characterized using EDX-XRF and SEM. The concentrations of seven heavy metals (Pb, Cr, As, Ni, Cd, Cu and Zn) were determined in S3 and S4. The results showed that Cr, Ni, Cd, Cu and Zn were within the USEPA permissible limits, except for Pb and As with range of (270-300) mg/kg and (40-70) mg/kg respectively for both mining and control sites of S3 and S4. The SEM results revealed small particles size with fine porous structure, and rough areas with varying sizes and pores distributed over the surface for S3 and S4 respectively. Results of the risk assessment showed that the hazard quotient HQ and HI values were greater than 1 indicating high risk. The Carcinogenic and non-carcinogenic risks associated with Pb, Zn, Cd, Cr, Ni and As were evaluated for S3 and S4 for the three exposure pathway and it was found that the mining sites pose more risk than the control and the children were more exposed than the adults. The carcinogenicity of these samples were due to the high hazard quotient for ingestion and dermal exposure pathway. The R_{total} results for As, Cr, Pb and Ni for mining site S3 were found to be $(1.39 \times 10^2, 2.02 \times 10^{-7}, 3.30 \times 10^3$ and $8.17 \times 10^{-8})$, and control site $(3.42 \times 10^3, 2.64 \times 10^{-5}, 38.30 \times 10^1, 6.90 \times 10^{-8})$ for As, Cr, Pb and Ni respectively. From the R_{total} results As and Pb were more than the acceptable threshold, while Cr and Ni were below the threshold of 1×10^{-4} . For the mining site S4, the R_{total} were found to be $(5.70 \times 10^2, 1.82 \times 10^{-7}, 3.63 \times 10^4$ and $9.64 \times 10^{-9})$, and the control $(1.16 \times 10^3, 1.71 \times 10^{-7}, 31.1 \times 10^2$ and $1.51 \times 10^{-8})$ for As, Cr, Pb and Ni respectively. From the results of the mining and control sites, As and Pb R_{total} were higher than the acceptable threshold, while Cr and Ni were below the threshold of 1×10^{-4} .

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1. Introduction

Tin mining tailings are wastes fractions of an ore or mineral body which are discarded during mining operations without being processed. Tin tailings contains both magnetic minerals

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(iron ore, columbite) and non-magnetic minerals (cassiterite, monozite, zircon sand in large quantity and silica) [1]. They are used in preparation of fertilizer, animal feeds, refractory products, for building roads and backfilling of tailing storage facilities [2].

In the 1960s, Nigeria was regarded as one of the world's leading tin producing country, but production later decreased towards the end of the twentieth century. However, mining activities are still going on in these areas. Apart from tin which is the primary target, tin mining generates tin tailings, which are by-product of the ore. The amount of tailings produced ranged from 90-98 % for copper ores and 20-50 % for other minerals [3]. Some of the heavy metals found in contaminated tailings are Pb, Cr, As, Zn, Cd, Cu, Ni and Hg [4, 5, 6]. Heavy metal contamination and their human health threats are some of the serious environmental problems limiting mining activities [7, 8].

With the development of mining, smelting and other industrial activities, heavy metals are increasingly being found in the environment which can pose severe threats to humans and the environment. Pollution by heavy metals such as lead (Pb), chromium (Cr), arsenic (As), nickel (Ni), cadmium (Cd), copper (Cu) and zinc (Zn), affects the quality of the ambient air, soil and water bodies which in turn threatens the life of both animals and humans through the food chain [2].

During mining activities huge waste tailing ponds are created which have a high environmental impact on the surrounding ecosystems and populations when used [9, 10]. In order to evaluate the risk posed by tin mine tailings activities to human health, there is need to assess the level of heavy metal pollution in these sites and the rate at which they affects human life. This is based on preliminary studies on waste properties, heavy metals concentration and their relation to the environment as they affect the individuals who participated in these tailings activities and the community [11].

Human health risk assessment involves the evaluation of possible human health effect in the contaminated environmental media [12]. The health effect of contaminants on humans depends on the level of exposure, nature of the contaminants and vulnerability of the individual affected [13]. Health effects may include risk of cancer, hypertension, acute foetus neurological disorders, organ dysfunction, respiratory difficulties, physical and mental disorder, reduced life expectancy and weakening of the body's immune system [12].

Therefore, this research is aimed at characterizing and evaluating the human health risk of heavy metals in tin mine tailings in Zabot and Tafan district both represented by S3 and S4 respectively in Barkin Ladi Local Government Area, Plateau State, Nigeria.

2. RESEARCH METHODOLOGY

2.1. Sample Location and Description

This research work was carried out in Zabot (S3) and Tafan (S4) district of Barkin Ladi Local Government Area of Plateau State, Nigeria. It is located between latitude 9051'30"N and longitude 8048'00"E. The state is located in the middle belt of Nigeria, with an area of 30.91 km (11936 square mile). The state has a population of about three million people in estimate. The name Plateau State was given because of its topography with wonderful rock formations. The height of the mountains ranges from 1,200 to 1,829 meters above sea level. Mining and subsistence farming are the major occupation of its residents. The sampling locations and points are as shown in Figure 1, using the geographical positioning system (GPS) to locate Zabot (S3) and Tafan (S4).

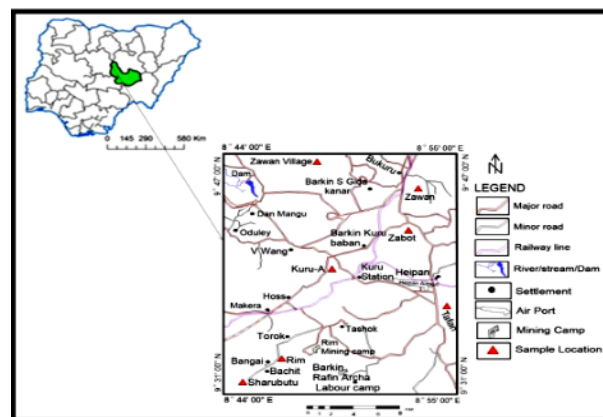


Figure 1. GPS Map Showing the Sites of Sample Collection.

2.2. Sampling collection and preparation

The random sampling technique was applied for sample collection with little modification. Two samples of 50 g each were taken from mining sites in Zabot (S3) and Tafan (S4) in Barkin Ladi Local Government Area of Plateau State, with their respective control. The tin mine tailings and soil samples were washed, dried and pulverized into the required particle sizes of 2 mm. Pre-treatments which does not alter the chemical composition of the analytes were done to obtain the original concentration of the analyte found in the sample.

2.3. Determination soil pH and Temperature

1.0 g of soil sample from both mining and control sites were mixed with 100 cm³ of deionized water in 250 cm³ conical flask and stirred using a magnetic stirrer for 10 minutes. The temperature and pH were determined using Hanna portable pH meter (model HI8043) and thermometer respectively. The readings were taken in triplicates and the average recorded accordingly.

2.4. Sample Characterization

2.4.1. Elemental analysis

The concentrations of the various heavy metals contained in the samples were determined using Energy dispersive X-ray fluorescence spectrometer EDX-XRF (MiniPAL4). The XRF analysis was done directly on solid powdered specimen for accurate results with no risk of contamination. Sample preparation involves milling of the sample to less than $75 \mu\text{m}$ in fraction. Retsch RS 200 vibratory disk milling machine was used at 1500 min^{-1} motor speed for 5 minutes. The milled sample was collected in XRF cup and placed in the XRF spectrometer and analyzed for chemical composition.

2.4.2. Determination of Surface Morphology

The surface morphology of the tailings was determined using scanning electron microscope (SEM-MVE016477830). The sputter coater was operated in an argon atmosphere using a current of 6 mA for 3 minutes.

2.5. Human Health Risk Assessment Parameters

The carcinogenic and non-carcinogenic risks were evaluated using the human health risk assessment model for dermal contact, ingestion and inhalation exposure pathways [13]. The health risk assessment is centered on the exposure factors and guidelines handbook of United States Environmental Protection Agency (USEPA) [14]. The average daily dose (ADD) via inhalation (ADD_{inh}), ingestion (ADD_{ing}) and dermal contact (ADD_{derm}) for both children and adults were evaluated using equations (1) - (3) as adopted from Qing et al., [13].

$$\text{Ingestion dose } D_{ing-s} = \frac{C_s \times \text{IngR} \times \text{EF} \times \text{ED} \times \text{CF}}{\text{BW} \times \text{AT}} \quad (1)$$

$$\text{Inhalation dose } (D_{inh-s}) = \frac{C_s \times \text{InhR} \times \text{EF} \times \text{ED}}{\text{BW} \times \text{AT} \times \text{PEF}} \quad (2)$$

$$\text{Dermal dose } (D_{der-s}) = \frac{C_s \times \text{SA} \times \text{SL} \times \text{EF} \times \text{ED} \times \text{CF}}{\text{BW} \times \text{AT}} \quad (3)$$

where C_s is the concentration of the analyte in the tailing from the exposure point (mg/kg), IngR - tailing ingestion rate for the receptor (mg/d), InhR - soil inhalation rate for the receptor (m^3/d), EF - exposure frequency (days/year), ED - exposure duration (years), PEF - soil-to-air particulate emission factor (m^3/kg), SA - skin surface area available for exposure (cm^2), SL - soil-to-skin adherence factor ($\text{mg}/\text{cm}^2/\text{event}$), BW - time-averaged body weight (kg), AT - average time of non-carcinogenic and carcinogenic risks (days) and ABS - dermal absorption factor (dimensionless). The hazard quotient, hazard index and total cancer risk were evaluated using equations (4) – (6) as adopted from Man et al., [15].

The Hazard Quotient is given as:

$$HQ = \frac{D}{\text{RfD}}, \quad (4)$$

where D = Dose (ingestion, inhalation or dermal), RfD = Reference dose. The Hazard index HI is given as:

$$HI = HQ_{ing} + HQ_{inh} + HQ_{derms} \quad (5)$$

Total cancer risk (RT) is given as:

$$RT = D \times SF, \quad (6)$$

where D = Dose, SF =Slope factor.

Risk characterization was considered separately for carcinogenic and non-carcinogenic effects [16, 17]. Health risks were obtained by comparing the calculated HQ, HI and R_{total} values with recommended maximum values shown on Table 1.

3. RESULTS AND DISCUSSION

3.1. Determination soil pH and Temperature

The results of the pH and Temperature obtained from the study area are presented in Table 2.

The pH and temperature results of the samples are presented in Table 2. The pH obtained from the mining and the control sites were (5.23, 5.11) and (7.48, 7.21) for Zabot and Tafan respectively. The pH results showed that the two mining sites were slightly acidic, while the control sites were slightly alkaline. The soil temperatures were within the range of 29 to 30°C , which are suitable for plants growth [19].

4. Scanning Electron Microscopy of Tin Mines Tailings

The results of scanning electron microscopy (SEM) for tin mine tailing site S3 and S4 are as shown in Plates 1 (Figure 2) and 2 (Figure 3), respectively.

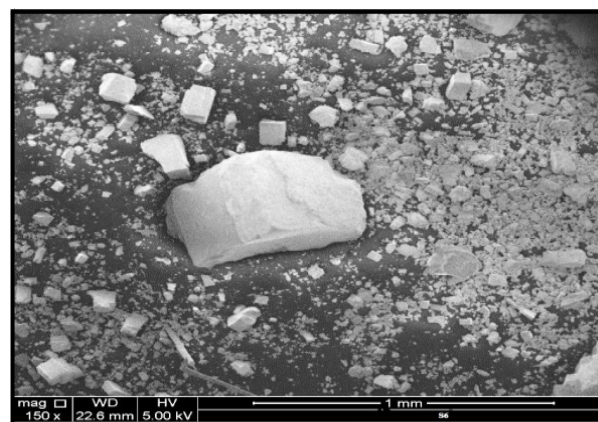


Figure 2. Plate 1: The Scanning Electron Microscope Micrograph (SEM) of Zabot S3.

Result of S3 on Plate 1, showed homogenous small size particles with fine porous structure. While results on plate 2 (S4), showed a micrograph with rough area having different irregular shapes of varying sizes and pores distributed over the surface. The more the number of pores the better the soil aeration [20, 21]. From the two results (Plates 1 and 2), it can be seen that the S4 has more pores than the S3.

Table 1. USEPA Reference Doses for Non carcinogens and Slope Factor for Carcinogens Source: [18]

	Rf D _{ing}	Rf D/mg.kg ⁻¹ .d ⁻¹	Rf D _{dermal}	SF _{ing}	SF/kg.d.mg ⁻¹	SF _{inh}	SF _{dermal}
As	3.00E-04		1.23E-04	1.50 E+00	1.51 E+00		3.66 E+00
Cr	3.00E-03	2.86 E-05	6.00 E-05		4.2 E+01		
Cu	4.00 E-02	4.02 E-02	1.20 E-02				
Pb	1.40 E-03	3.52 E-03	5.25 E-05	8.50 E-03			
Ni	2.00 E-02	2.06 E-02	5.40 E-03		8.40 E-1		
Zn	3.00 E-01	3.00 E-01	6.00 E-02				
Hg	3.00 E-04	8.57 E-05	3.00 E-05				

RfD=Reference dose and SF=Slope factor

Table 2. pH and Temperature of Tin mine Tailings and Control Soil

Sample	pH	Temperature °C
Tin Mine Site S3	5.23	30
Control S3	7.48	29
Tin Mine Site S4	5.11	29
Control S4	7.21	30

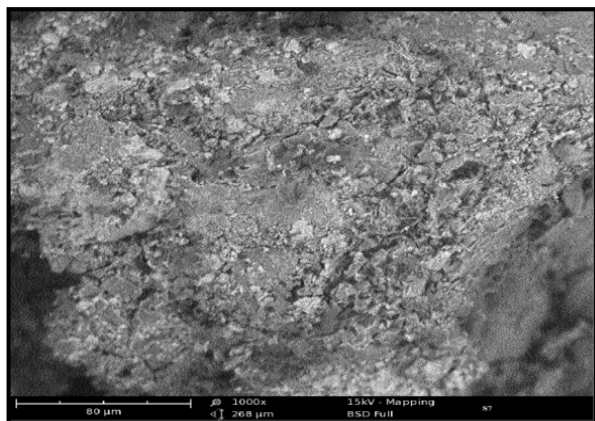


Figure 3. Plate 2: The Scanning Electron Microscope Micrograph (SEM) of Tafan (S4).

4.1. Heavy Metal Concentration in Tin Mine Tailings and Control Sites

The heavy metals concentrations of Pb, Cr, As, Zn, Cd, Ni and Cu in Tin mine tailings and control sites are presented in Table 3.

The results on Table 3, belong to the heavy metals concentrations of the tin mine tailings and the control site in Zabot of Barkin Ladi Local Government Area. These were determined using Energy dispersive X-ray fluorescence spectrometer EDX-XRF (MiniPAL4). The results showed that the heavy metals concentrations were within the USEPA permissible limits of the soil, except for Pb and As with range of (270-300) mg/kg and (40-70) mg/kg respectively, which are higher than the USEPA permissible limits of 80 and 0.07 mg/kg for both Pb and As respectively [22]. The high concentration of As and Pb may be traceable to the tin mining activities, farming activities such as application of agricultural chemicals and atmospheric deposi-

tions by transport mechanism on the site [19]. This agrees with the work reported by Bwede et al., [3]. The extreme concentration of As and Pb may be via bioaccumulation in plant which then enters the food chain when these plants are consumed [22]. Also, the concentrations of the heavy metals from the mining sites are significantly higher than the control sites which may be due to anthropogenic activities within the environment [23]. Zn found in the area may be as a result of its natural abundance in the parent material [24]. This agrees with the work reported by Banerjee [25], that iron oxides adsorb some quantities of Zn in the lattice structure.

4.2. Human Health Risk Assessment of the Site

The human health risk assessment results for the non-carcinogenic and carcinogenic are shown in Tables 4 - 7 for children and adult respectively. For the non-carcinogenic risk (Tables 4 and 5), if the hazard quotient (HQ) and hazard index (HI) are greater than 1, then adverse health effects may occur [15, 16]. Also for carcinogenic risk level (Table 6-7), total cancer risk (R_{total}) values greater 1×10^{-4} represents elevated risks, R_{total} less than 1×10^{-6} does not pose any significant health risk, and R_{total} values between 1×10^{-4} and 1×10^{-3} are generally considered acceptable [26, 17].

4.2.1. Non-carcinogenic risk assessment (NCR) for S3 and S4

The results on Tables 4 - 5, are the non-carcinogenic risk assessment of (Pb, Zn, Cd, Cr, Ni and As) for S3 and S4. The three human exposure routes considered in this study were ingestion, inhalation and dermal exposure. For mining site S3, values of HQ for ingestion and dermal for children are all greater than 1, except for inhalation which are all less than 1. According to Huang et al., [16], HQ and HI greater than 1 are indication of high cancer exposure risk, while values less than 1 indicates that there are no significant effects. Therefore, since the ingestion and dermal values are greater than 1, they have high risk exposure. Similar results were observed for adults, except for Cr (1.69×10^{-1}) which is less than 1 for ingestion.

For the control (S3), the results of children for the three exposure pathways are greater than 1, except for Cr, Pb and Ni with values (7.05×10^{-5} , 1.32×10^{-4} and 0.60×10^{-6}), respectively which are less than 1 indicating no risk [16]. Similar results were observed for adults, except for Ni (2.10×10^{-6})

Table 3. Heavy Metals Concentration in Tin Mine Tailings and Control Samples in Zabet, and Tafan in Barkin Ladi Local Government Area of Plateau State, Nigeria in (mg/kg)

Heavy metal	Tin mine Tailing		Control		USEPA (2009)
	S3	S4	S3	S4	
Pb	300	1,900	280	270	80
Cr	900	1,000	170	1,600	100,000
As	40	60	70	60	0.07
Zn	ND	200	BDL	180	23,000
Cd	ND	ND	BDL	BDL	1.7
Ni	210	50	70	79	1,600
Cu	ND	ND	BDL	BDL	3,000

BDL: Below detection limits

Table 4. Human Health Risk Assessment of Non-Carcinogenic Hazard of Heavy Metals for Zabet (S3)

Non Carcinogenic hazards S3							
	Group	Heavy Metal	HQing	HQinh	HQdern-s	HI	
Tin mine tailing from mine site	Children	As	2.65×10^6	NC	2.19×10^5	2.87×10^6	
		Cr	9.43×10^6	8.78×10^{-5}	4.84×10^5	9.91×10^6	
		Pb	1.9×10^7	1.67×10^{-4}	5.83×10^5	1.95×10^7	
		Ni	3.43×10^4	0.74×10^{-6}	0.15×10^3	3.46×10^4	
		Zn	7.73×10^4	2.33×10^{-7}	4.43	7.73×10^3	
		Sum	3.12×10^7	2.56×10^{-4}	1.29×10^6	3.23×10^7	
		Adult	As	4.03×10^5	NC	4.46×10^4	4.48×10^5
	Cr	1.69×10^{-1}	4.44×10^{-3}	1.21×10^2	1.27×10^2		
	Pb	2.91×10^6	0.86×10^{-4}	1.17×10^5	3.02×10^6		
	Ni	0.53×10^4	3.85×10^{-7}	0.03×10^3	5.33×10^3		
	Zn	1.18×10^3	1.06×10^{-7}	8.87	1.19×10^3		
	Sum	3.35×10^6	4.53×10^{-3}	1.62×10^5	3.48×10^6		
	Soil from agricultural farmland around mine site	Children	As	2.03×10^6	NC	1.79×10^5	2.21×10^6
			Cr	7.86×10^6	7.05×10^{-5}	4.02×10^4	7.72×10^6
Pb			1.50×10^7	1.32×10^{-4}	4.60×10^5	1.54×10^7	
Ni			2.76×10^4	0.60×10^{-6}	0.12×10^3	2.77×10^4	
Zn			7.33×10^3	1.96×10^6	4.22×10^1	7.37×10^3	
Sum			2.49×10^7	1.96×10^6	6.79×10^5	2.54×10^7	
Adult			As	3.37×10^5	NC	3.71×10^4	3.71×10^4
Cr		0.68×10^3	5.56×10^3	0.51×10^5	5.72×10^4		
Pb		2.29×10^6	0.66×10^4	0.92×10^5	2.88×10^6		
Ni		4.22×10^3	2.10×10^{-6}	0.02×10^3	4.24×10^3		
Zn		1.12×10^4	1.43×10^{-7}	8.43×10^{-3}	1.12×10^4		
Sum		2.64×10^6	1.22×10^4	1.80×10^5	2.99×10^6		

NC: Not Calculated

Table 5. Human Risk Assessment of Non-carcinogenic Hazard of Heavy Metals in Tafan (S4)

Non Carcinogenic hazards S4						
	Group	Heavy Metal	HQ _{ing}	HQ _{inh}	HQ _{derm-s}	HI
Tin mine tailing from mine site Soil from agricultural farmland around mine site	Children	As	1.80×10 ⁻⁸	2.70×10 ¹	2.19×10 ⁴	2.87×10 ⁶
		Cr	9.43×10 ⁶	2.54×10 ¹	4.84×10 ⁵	9.91×10 ⁶
		Pb	1.9×10 ⁷	1.67×10 ⁴	5.83×10 ⁵	1.95×10 ⁷
		Ni	3.45×10 ⁴	0.74×10 ⁻⁶	0.15×10 ³	3.46×10 ⁴
		Zn	7.73×10 ⁴	2.33×10 ⁷	4.43×10 ¹	7.73×10 ³
		Sum	2.85×10 ⁷	2.33×10 ⁷	1.09×10 ⁻⁶	3.23×10 ⁷
		Adult	As	4.03×10 ⁵	5.48×10 ⁷	4.46×10 ⁴
	Cr	5.63×10 ¹	7.24×10 ³	1.21×10 ²	1.27×10 ²	
	Pb	2.91×10 ⁶	0.86×10 ⁻⁶	1.17×10 ⁵	3.02×10 ⁶	
	Ni	0.53×10 ⁴	3.85×10 ⁷	0.03×10 ³	5.33×10 ³	
	Zn	1.18×10 ³	1.06×10 ⁷	8.87×10 ⁵	1.19×10 ³	
	Sum	3.32×10 ⁶	1.45×10 ⁸	1.62×10 ⁵	3.47×10 ⁶	
	Children	As	2.03×10 ⁶	2.20×10 ¹	1.79×10 ⁵	2.21×10 ⁶
	Cr	7.86×10 ⁶	2.11	4.02×10 ⁴	7.72×10 ⁶	
	Pb	1.50×10 ²	4.64×10 ⁷	4.60×10 ⁵	1.54×10 ⁷	
	Ni	5.51×10 ²	2.76×10 ⁴	0.12×10 ³	2.77×10 ⁴	
	Zn	7.33×10 ³	1.96×10 ⁷	4.22×10 ¹	7.37×10 ³	
	Sum	2.49×10 ⁷	6.60×10 ⁷	6.79×10 ⁵	2.32×10 ⁷	
	Adult	As	3.37×10 ⁵	NC	3.71×10 ⁴	3.74×10 ⁵
	Cr	2.03×10 ³	5.56×10 ³	0.51×10 ⁵	5.72×10 ⁴	
	Pb	2.29×10 ⁶	0.66×10 ⁻⁴	0.92×10 ⁵	2.38×10 ⁶	
	Ni	4.22×10 ³	2.10×10 ⁶	0.02×10 ³	4.24×10 ³	
	Zn	1.12×10 ⁴	1.43×10 ⁻⁷	8.43×10 ⁻³	1.12×10 ⁴	
	Sum	2.65×10 ⁶	2.11×10 ⁶	1.80×10 ⁵	2.83×10 ⁶	

NC: Not Calculated

Table 6. Individual Carcinogenic Risk at the site Zabot (S3)

Group	Heavy Metal	Carcinogenic Risk S3			R _{total}
		R _{ing-s}	R _{inh-s}	R _{derm-s}	
Tin mine tailings from mine site	As	1.17 × 10 ²	1.14 × 10 ⁻⁸	22.18	1.39 × 10 ²
	Cr	NC	1.64 × 10 ⁻⁷	NC	2.02 × 10 ⁻⁷
	Pb	3.30×10 ³	NC	NC	3.30 × 10 ³
	Ni	NC	8.17 × 10 ⁻⁸	NC	8.17 × 10 ⁻⁸
	Sum	3.41 × 10 ³	2.57 × 10 ⁻³	22.18	16.41 × 10 ⁶
	Soil from agricultural farmland around mine site	As	7.61×10 ²	2.12×10 ⁻⁸	1.60×10 ¹
Cr	NC	2.64×10 ⁻⁵	NC	2.64×10 ⁻⁵	
Pb	2.16 × 10 ¹	NC	1.67×10 ¹	38.30×10 ¹	
Ni	NC	6.90×10 ⁻⁸	NC	6.90×10 ⁻⁸	
Sum	78.26×10 ²	2.64×10 ⁻⁵	32.70×10 ¹	3.80×10 ⁹	

NC: Not Calculated

Table 7. Individual Carcinogenic Risk at the site Zabot (S3)

Group	Heavy Metal	Carcinogenic Risk S3			R_{total}
		R_{ing-s}	R_{inh-s}	R_{derm-s}	
Tin mine tailings from mine site	As	4.55×10^2	4.16×10^{-8}	115.14	5.70×10^2
	Cr	NC	1.82×10^{-7}	NC	1.82×10^{-7}
	Pb	3.63×10^4	NC	NC	3.63×10^4
	Ni	NC	9.64×10^{-9}	NC	9.64×10^{-9}
	Sum	36.76×10^3	2.33×10^{-4}	115.14	9.64×10^9
Soil from agricultural farmland around mine site	As	1.14×10^3	3.46×10^{-8}	2.4×10^1	1.16×10^3
	Cr	1.71×10^{-7}	NC	NC	1.71×10^{-7}
	Pb	2.05×10^2	NC	106.11	31.1×10^2
	Ni	NC	1.51×10^{-8}	NC	1.51×10^{-8}
	Sum	1.34×10^3	4.97×10^{-2}	130.11×10^2	4.27×10^3

NC: Not Calculated

and Zn (1.43×10^{-7}) that are less than 1 and pose no risk [16]. Also, the HI values were all greater than 1, indicating significant effects. The summation of HQ for ingestion in the mining and control sites are (3.12×10^7 and 3.35×10^6), and (2.49×10^7 and 2.64×10^6) for children and adults respectively. From the results, it is observed that the mining site poses higher risk than the control site, and the children are at higher risk than the adults due to their high values [27]. Similar results were reported by Ngole-Jeme and Fantke [28] for, studies on ecological and human health risks associated with abandoned gold mine tailings contaminated soil.

The non-carcinogenic risk (NCR) results for Tafan (S4) are presented in Table 5. For mining site, the HQ values for children were found to be greater than 1, except for As and Ni with values (1.80×10^{-8} and 0.74×10^{-6}) via ingestion and inhalation respectively. According to Man et al., [15], HQ greater than 1 is an indication of high risk exposure. For the adults, the HQ were found to be greater than 1, except for Pb with value 0.86×10^{-6} which is less than 1 indicating significant and no significant effect respectively [28].

For the control site (S4) results for children (Table 5), it was observed that both the HQ and HI values were all greater than 1 representing significant effects [16]. The adults result for As, Cr, Pb, Ni and Zn also showed that HQ and HI values were all greater than 1, except for Zn which has values of 1.43×10^{-7} and 8.43×10^{-3} for inhalation and dermal less than 1, indicating cancer and non-cancer risk respectively [15]. The summation of HQ for ingestion in the mining and control sites are (2.85×10^7 and 3.32×10^6), and (2.49×10^7 and 2.65×10^6) for children and adults respectively. In terms of population group for NCRs, it is observed that the mining site pose more risk than the control site, and the children are at higher risk than the adults due to their high values [28]. From the results for the three different exposure pathways of metals for children and adults, the contribution of HQ is in the order of ingestion greater than dermal and dermal greater than inhalation for As, Cr, Pb, Ni and Zn in the studied mining and control areas for S4.

4.2.2. Carcinogenic Risk Assessment for S3 and S4

The Carcinogenic risks associated with As, Cr, Pb and Ni were evaluated as presented in Table 6. From the S3 results, the R_{total} for mining site were found to be (1.39×10^2 , 2.02×10^{-7} , 3.30×10^3 and 8.17×10^{-8}), and control site (3.42×10^3 , 2.64×10^{-5} , 38.30×10^1 , 6.90×10^{-8}) for As, Cr, Pb and Ni respectively. For carcinogenic risk (Table 6), total cancer risk (R_{total}) values greater than 1×10^{-4} represents elevated risks, R_{total} less than 1×10^{-6} represents no significant health risk, and R_{total} values between 1×10^{-4} and 1×10^{-3} are generally considered acceptable [26, 17]. From the mining and control results, it was observed that the values of the R_{total} for As and Pb were more than the acceptable threshold, while Cr and Ni were below the threshold representing elevated risks and no significant health risk respectively [17]. Similar results were observed by Narsimha and Haike [26] for, studies on distribution, contamination, and health risk assessment of heavy metals in surface soils from northern Telangana, India.

From results of the mining site S4 (Table 7), the R_{total} were found to be (5.70×10^2 , 1.82×10^{-7} , 3.63×10^4 and 9.64×10^{-9}), and the control were found to be (1.16×10^3 , 1.7110^{-7} , 31.1×10^2 and 1.51×10^{-8}) for As, Cr, Pb and Ni, respectively. From the results of the mining and control sites, it is observed that the values for As and Pb R_{total} were higher than the acceptable threshold, while Cr and Ni were below the threshold. These results showed that As and Pb pose elevated risks, while Cr and Ni does not pose any significant health risk [26, 17]. Furthermore, values from the mining site indicate more pollution than the control.

5. Conclusion

The results of the analysis of this research work showed that both the mining and control sites in Zabot and Tafan in Barkin Ladi L.G.A and environs contains certain concentration of heavy metals (Pb, Ni, Zn, Cr, Cd, As and Cu) in different fractions. The surface morphology of the tin mine tailings through the use of scanning electron microscopy (SEM)

technique revealed homogenous sized particles with fine porous structure, and rough area having different irregular shapes of varying sizes and pores distributed over the surface for both S3 and S4 respectively. From the hazard quotient (HQ) and human health risk derived from carcinogenic and non-carcinogenic hazards for adults and children, it is observed that the mining site pose more risk than the control site, and children are at higher risk than the adults due to their high values. From the results for the three different exposure pathways of metals for children and adults, the contributions of HQ are in the order of ingestion > dermal > inhalation for As, Cr, Pb, Ni and Zn in the studied mining and control areas for S4.

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