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Preliminary Investigation of Trace Elements Concentration in Dust from Tin Processing Mills in Jos - Bukuru Area, Northcentral Nigeria

Daspan, R.I., Bello, A.O., Dibal, H. U, Lekmang, I. C, A.S. Chup and Azi,B.J.
Department of Geology, University of Jos.

Abstract
The Jos – Bukuru Biotite Granite is the largest of the biotite granite belonging to the Younger Granite province of Nigeria. The rock hosts the tin and columbite mineral which on weathering released them forming the alluvial deposits mostly along stream channels. These minerals were extensively mined in the early 19th century and remained active until late 1970s. Mining and processing of these minerals is still ongoing but on smaller scales around the Jos – Bukuru area. The aim of this work was to determine the concentration of trace element in dust generated during milling and processing of Tin and associated minerals. Fifteen dust samples were collected during the air floating and after floatation operations in nine different processing sites by placing filter papers at designated locations. Dust samples were analysed by Inductively Coupled Plasma Optical Emission Spectrometry. Generally, in all the processing mills Pb, Zn, Th, U are quite high. Pb ranges from 204.5 – 1177, Zn, 67.0 – 1,272, Th > 200 in all samples, U, 186.5 – 1623, As, 0.3 – 233.7 ppm respectively. Anthropogenic factor and index of geo-accumulation calculated for some of the trace elements indicate that the contamination level of trace elements ranges from uncontaminated (Ni), Uncontaminated to moderately contaminated (V, Co, Fe, Cr, Ti), contaminated to highly contaminated (Cu Se, Pb, U, Th, Zn, As and Mo). The use of mask to cover the nose and other protective clothing for other parts of the body during floating operations is not practiced, hence inhalation of this dust by workers posses a great risk to health.
Keywords: Younger Granites, Columbite, Tin, Dust, Anthropogenic, Geo-accumulation, contaminated

1. Introduction

Tin occurs in the Younger Granite rocks, particularly in the biotite granites, which are the largest rock types of the Younger Granite Complex of the Jos Plateau, North Central (Macleod *et al*, 1971). On weathering the rocks release the tin which are transported and deposited along river channels as alluvial deposits.

Tin was discovered around 1700-1750 in Naraguta Village, Jos Plateau in a river channel by some subsistence farmers, who soon realized that by mixing tin and iron, they could have stronger agricultural instrument (Mallo, 1999). Tin mining and processing began to develop in local villages and trade occurred with those who came from Tripoli and across the Sahara (Mallo, 1999). By 1760-1770, there were thirteen indigenous blacksmith smelters in Naraguta village, located north of Jos (Adiukwu-Brown, 1997). The Berom ethnic group mined and processed tin along the Dilimi River for the European traders.

Tin occurs naturally in the earth's crust with concentrations of approximately 2-3 ppm (Budavari, 2001). Tin compounds are found in various media in both inorganic and organic forms from both natural and anthropogenic sources and a component of many soils. Inorganic tin compound may be released in dust from wind storms, road and agricultural activities (source). Tin processing mills are found within residential areas in both Jos and Bukuru Metropolis with over 100 of such processing houses. However, not more than 30 of these houses are in operation at the moment.

Sieving and floating of tailings before they are run in the magnetic separators generates a lot of dust. These dusts could be carriers of trace elements that could be potentially harmful to workers and people living within the vicinity where such activity is taking place. The focus of this research is to determine the concentration of trace element composition of these dusts and possible health implication.

2. Methodology.

2.1 Sampling

Fifteen dust samples were collected from different tin processing mills within the Jos - Bukuru areas (Fig.1). Samples were collected from dust that have settled from previous milling activities on machines used for floatation and from dust being generated at the time of floatation of the materials where papers were positioned in designated points for the dust to settle on.

2.2 Sample Preparation for Analysis

Samples were prepared prior to geochemical analysis through the following processes.

- **Drying:** The wet samples were placed in evaporating dishes and oven dried for six hours.
- **Sieving:** Samples above the required mesh fraction were sieved using 80 mesh screen size. This sieving

further homogenized the samples for analysis.

2.3 Laboratory Analysis

Geochemical analysis of the dusts was carried at ACME laboratory, Canada using the ultra trace Inductively Coupled Plasma-Mass Spectrometry (ultra-trace ICP-MS) to determine their trace elements composition. It is a multi-acid digestion method which combines a strong multi-acid digestion that dissolves most metals with a choice of ultra-trace ICP-MS analysis to give near total value for all elements. In this method, a 0.25g split is heated by HNO3-HClO4-HF to fuming and taken to dryness. The residue is dissolved in HCl. Although the method is considered near total, it only enables only partial digestion for some Cr and Ba minerals and oxides of Al, Fe, Hf, Mn,Sn,Ta and Zr. In addition, volatilization during fuming may result in the loss of As,S and Sb.

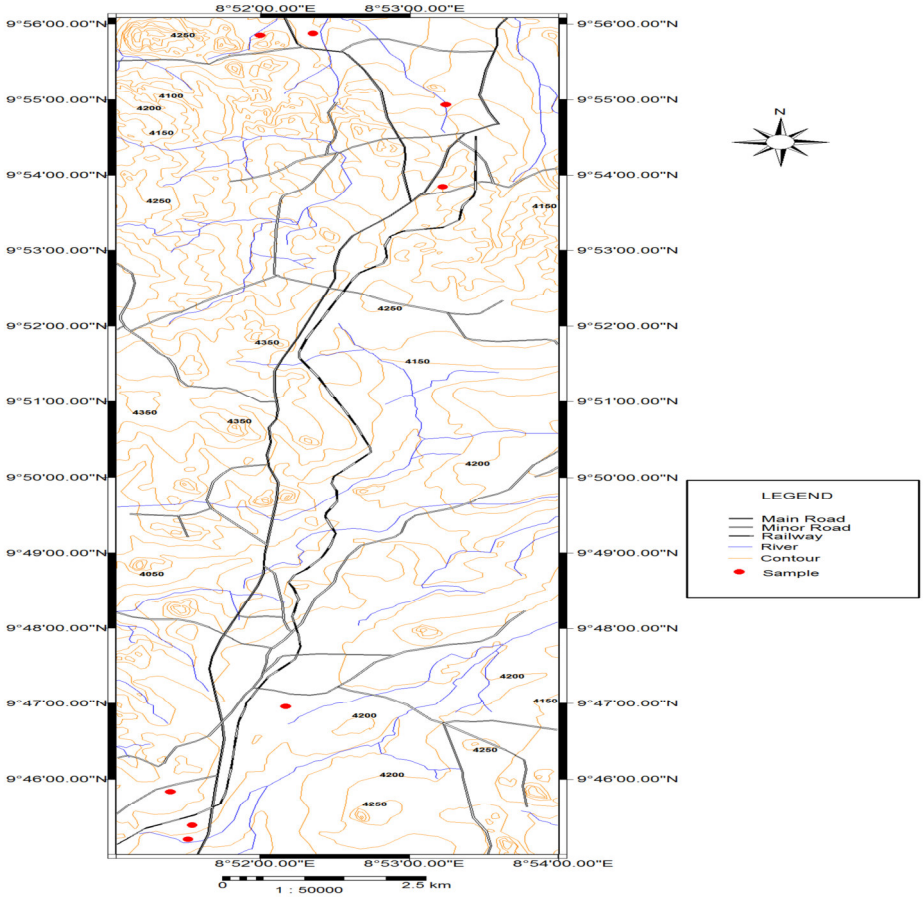

Fig 1: Map showing sampling sites in Jos Bukuru Town and Environs.

Samples were analyzed for trace elements content at the ACME Laboratories, Canada using the Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) technique.

Calculation of Index of Geoaccumulation, Anthropogenic and Enrichment factor

Geoaccumulation index, Anthropogenic and Enrichment factors were calculated using the following formulae.

AF=Mean concentration ÷ Crustal abundance---------- (1)

Where;

AF=Anthropogenic Factor)

Igeo=Log2Cn÷ 1.5Bn---------- (2)

Where;

Igeo= Geoaccumulation index

Cn=Average concentration of elements in tested soil

Bn=Background content of element

The value 1.5 is a factor for possible variation in the background concentration due to lithologic differences. In this work, Bn is taken from literature (Rose et al, 1979) and uncultivated soil background.

The Enrichment Factor was calculated as follows:

EF=Cn÷Cref---------- (3)

Where;

EF=Enrichment factor

Cref = Content of examined elements in reference environment (Singah*et al.,* 1997, Manjunatha, 2001, Tijani*et al.,* 2004)

3. Results and Discussion

3.1 Results

The results of the analysis carried out for the dust samples are given in Table 1. The anthropogenic factor (AF) and Index of geo-accumulation of selected trace elements in dust samples within the study area is shown in Tables 2 and 3 respectively. Table 4 gives the summary of quantitative indices (Kump, 1976) with respect to trace element contamination in dust samples of the study area. The concentrations of the elements vary with the individual processing mill locations (Table 1). Copper ranges from 5.17 – 379.5mg/kg with 33% of values falling below 40mg/kg. Lead varies between 236.0 – 1177mg/kg with 27% of the values falling below 300mg/kg. Zinc ranges between 67.0 – 1185mg/kg with 13% of the values falling below 100mg/kg. Iron ranges between 9,000 – 71,000mg/kg with 6.7% of the values 20,000 and Arsenic 0.3 – 233.7mg/kg. Uranium and Titanium varies between 226.8 – 1,102mg/kg and Titanium 1,990 – 3585mg/kg with 33% and 6.7% of their values falling below 300 and 2,000 respectively. All the values of Thorium are greater than 200mg/kg.

Table 1: Trace elements concentration in dust of the study area

	Coordinate	Mo	Cu	Pb	Zn	Ni	Co	Fe	As	U	Th	V	P	Cr	Ti	Se
AOB 1	9^{0}54'02.63"N 8^{0}53^{T}34.63"E	157.6	64.70	646.8	1185	25.8	21.7	34900	4.5	186.5	> 200	99	930	119	9440	< 0.3
AOB 2	9^{0}55'15.42"N 8^{0}53^{T}02.56"E	14.51	69.22	977.9	661.6	16.4	11.8	48900	9.8	414.3	> 200	106	2200	144	20910	< 0.3
AOB 3	9^{0}55'15.42"N 8^{0}55^{T}02.56"E	7.18	38.42	514.5	370.7	10.9	7.3	31100	6.6	220.2	> 200	59	1000	84	12760	< 0.3
AOB 4	9^{0}56'19.11"N 8^{0}52^{T}24.14"E	13.47	126.5	659.8	739.3	23.4	13.9	71100	2.4	669.6	> 200	131	2170	460	33840	< 0.3
AOB 5	9^{0}56'19.11"N 8^{0}52^{T}24.14"E	13.47	41.00	806.6	684.8	13.7	10.9	64300	1.4	1077	> 200	143	3180	452	31440	< 0.3
AOB 6	9^{0}56'26.19"N 8^{0}51^{T}59.41"E	17.74	379.5	774.4	579.6	12.5	11.8	73200	233.7	1251	> 200	144	2350	382	31400	< 0.3
AOB 7	9^{0}56'26.19"N 8^{0}51^{T}59.41"E	11.98	90.10	785.0	523.0	20.3	12.4	46200	10.3	1102	> 200	167	5090	277	16890	< 0.3
AOB 8	9^0'47.405"N oo8^{0}53^{T}51.897"E	11.39	25.28	236.0	314.6	9.9	7.6	43000	1.3	267.1	> 200	71	900	175	21230	< 0.3
AOB 9	9^{0}47'405"N 008^{0}5^T.897"E	15.28	36.44	358.6	350.5	16.9	10.0	49800	1.3	859.0	> 200	1076	1080	1000	20120	< 0.3
AOB 10	9^{0}45'634"N 008^{0}5^T.586"E	9.08	41.09	283.9	1272	17.8	22.0	50800	1.1	233.0	> 200	74	660	188	17110	< 0.3
AOB 11	9^{0}45'634"N 008^{0}5^T.589"E	5.70	39.20	204.5	514.5	23.1	18.3	63300	1.4	226.8	> 200	104	1430	173	35850	< 0.3
AOB 12	9^{0}45'297"N 008^{0}5^T.741"E	2.75	5.17	328.1	67.0	2.3	0.9	9000	0.3	1623	> 200	203	640	107	1990	< 0.3
AOB 13	9^{0}45'191"N 008^{0}5^T.094"E	9.98	63.42	1177	68.3	10.5	4.7	25000	9.2	589.9	> 200	56	770	79	4570	< 0.3
AOB 14	9^{0}45'191"N 008^{0}5^T.094"E	9.84	104.1	1006	587.9	6.2	3.7	29600	2.4	649.0	> 200	42	370	70	4440	< 0.3
AOB15	9^{0}46'214"N 008^{0}5^T.474"E	6.43	242.4	666.7	1057	12.3	7.6	46700	1.6	464.4	> 200	33	490	123	8070	< 0.3

TABLE 2: ANTHROPOGENIC FACTOR (AF) OF SELECTED TRACE ELEMENT IN DUST SAMPLE OR TIN THE STUDY AREA

SAMPLE	Mo	Cu	Pb	Zn	Ni	Co	Fe	As	U	Th	V	P	Cr	Ti	Se
AOB 1	105.06	1.176	49.75	16,92	0.344	0.368	0.698	2.5	103.61	> 277.77	0.36	0.88	1.19	2.14	< 6
AOB 2	9.67	1.258	75.22	9.45	0.218	0.472	0.978	5.44	230.16	> 277.77	0.78	2.09	1.44	4.75	< 6
AOB 3	4.78	0.678	39.57	5.29	0.145	0.292	0.622	3.66	122.33	> 277.77	0.43	0.95	0.84	2.9	< 6
AOB 4	8.98	2.3	50.75	20.56	0.312	0.556	1.422	1.33	372	> 277.77	0.97	2.06	4.60	7.69	< 6
AOB 5	8.95	0.745	62.04	9.78	0.182	0.436	1.286	0.77	598.33	> 277.77	1.05	3.02	4.52	5.87	< 6
AOB 6	11.82	6.9	59.56	8.28	0.166	0.472	1.464	129.83	695	> 277.77	1.06	2.23	3.82	7.14	< 6
AOB 7	7.98	1.274	60.38	7.47	0.270	0.496	0.924	5.92	612.22	> 277.77	1.23	4.84	2.77	3.83	< 6
AOB 8	7.59	0.45	18.15	4.49	0.132	0.304	0.86	0.72	148.38	> 277.77	0.52	0.85	1.75	4.82	< 6
AOB 9	10.18	0.66	27.58	5.00	0.225	0.4	0.996	0.72	477.22	> 277.77	0.79	1.02	10.00	4.57	< 6
AOB 10	6.05	0.74	21.13	18.17	0.237	0.88	1.016	0.61	123.88	> 277.77	0.54	0.62	1.88	3.88	< 6
AOB 11	3.8	0.912	15.73	7.35	0.308	0.732	1.266	0.77	126	> 277.77	0.77	1.36	1.73	8.14	< 6
AOB 12	1.83	0.094	25.23	0.95	0.030	0.036	0.18	0.16	901.66	> 277.77	1.50	0.60	1.07	0.45	< 6
AOB 13	6.65	1.15	90.53	9.54	0.14	0.188	0.5	5.11	327.72	> 277.77	0.41	0.73	0.79	1.03	< 6
AOB 14	6.56	1.89	82	8.39	0.082	0.148	0.512	1.33	360.55	> 277.77	0.51	0.35	0.70	1.00	< 6
AOB 15	4.28	4.40	51.28	15.1	0.164	0.304	0.934	0.88	258	> 277.77	0.32	0.46	0.02	1.83	< 6

TABLE 3: INDEX OF GEOACCUMULATION OF SELECTED TRACE ELEMENT IN DUST OF THE STUDY AREA

SAMPLE	Mo	Cu	Pb	Zn	Ni	Co	Fe	As	U	Th	V	P	Cr	Ti	Se
AOB 1	21.08	0.23	9.98	3.39	0.06	0.17	0.14	0.50	20.79	> 55.74	0.07	0.17	0.23	0.43	< 1.20
AOB 2	1.44	0.25	15.09	1.89	0.04	0.09	0.19	1.09	46.18	> 55.74	0.15	0.42	0.28	0.95	< 1.20
AOB 3	0.96	0.14	7.94	1.06	0.02	0.05	0.12	0.73	24.54	> 55.74	0.08	0.190	0.16	0.58	< 1.20
AOB 4	1.80	0.46	10.64	2.11	0.06	0.11	0.28	0.26	74.64	> 55.74	0.19	0.60	0.92	1.54	< 1.20
AOB 5	1.79	0.14	12.45	1.96	0.03	0.08	0.25	0.15	120.06	> 55.74	0.21	0.44	0.90	1.17	< 1.20
AOB 6	2.37	1.38	11.95	1.66	0.03	0.09	0.29	26.05	139.46	> 55.74	0.21	0.97	0.76	1.43	< 1.20
AOB 7	1.60	0.25	12.11	1.49	0.05	0.09	0.18	1.14	122.85	> 55.74	0.24	0.19	0.55	0.77	< 1.20
AOB 8	1.52	0.09	3.64	0.90	0.02	0.06	0.17	0.14	29.77	> 55.74	0.10	0.17	0.35	0.96	< 1.20
AOB 9	2.04	0.13	5.53	1.00	0.04	0.08	0.19	0.14	95.76	> 55.74	0.15	0.20	2.00	0.91	< 1.20
AOB 10	1.21	0.14	4.38	3.64	0.04	0.17	0.20	0.12	24.86	> 55.74	0.10	0.12	0.37	0.78	< 1.20
AOB 11	0.76	0.14	3.15	1.47	0.06	0.14	0.25	0.15	25.28	> 55.74	0.15	0.29	0.34	1.63	< 1.20
AOB 12	0.36	0.01	5.06	0.19	0.00	0.00	0.03	0.03	180.93	> 55.74	0.30	0.12	0.21	0090	< 1.20
AOB 13	1.33	0.23	18.16	1.91	0.02	0.03	0.10	1.02	65.76	> 55.74	0.08	0.14	0.15	0.20	< 1.20
AOB 14	1.31	0.37	15.52	1.68	0.01	0.02	0.11	0.26	72.35	> 55.74	0.06	0.07	0.14	0.20	< 1.20
AOB 15	0.86	0.88	10.29	3.03	0.03	0.06	0.18	0.17	51.77	> 55.74	0.06	0.09	0.24	0.00	< 1.20

Results from the summary of quantitative indices with respect to trace element contamination in dust samples of the study area show that nickel is uncontaminated. cobalt, iron and vanadium are uncontaminated to moderately contaminated; while copper is contaminated to highly contaminated. Phosphorous, chromium and titanium are moderately to highly contaminated.Elements that are highly contaminated to very highly contaminated are molybdenum, zinc and arsenic. Lead, uranium, thorium and selenium are very highly contaminated.

TABLE 4: SUMMARY OF QUANTITATIVE INDICES WITH RESPECT TO TRACE ELEMENT CONTAMINATION IN DUST OF THE STUDY AREA

Element	AF		Igeo		
	Range	Mean	Range	Mean	Summary of Contamination
Mo	1.83 – 105.06	13.61	0.36 – 21.08	2.72	Highly to very highly contaminated
Cu	0.094 – 4.40	1.62	0.01 – 0.46	0.329.72	Contaminated to highly contaminated
Pb	15.73 – 90.53	48.64	3.15 – 18.16	1.82	Very highly contaminated
Zn	0.95 – 18.17	9.11	0.19 – 3.39	0.03	Highly to very highly contaminated
Ni	0.030 – 0.344	0.19	0.00 – 0.06	0.08	Uncontaminated
Co	0.036 – 0.88	0.43	0.00 – 0.17	0.17	Uncontaminated to moderately contaminated
Fe	0.18 – 1.464	0.91	0.03 – 0.29	2.13	Uncontaminated to moderately contaminated
As	0.16 – 129.83	10.63	0.03 -26.05	73	Highly to very highly contaminated
U	103.61 – 901.66	363,80	20.79 – 180.93	>55.74	Very highly contaminated
Th	> 277.77	> 277.77	> 55.74	0.44	Very highly contaminated
V	0.31 – 1.50	0.73	0.06 -0.30	0.06	Uncontaminated to moderately contaminated
P	0.35 – 4.84	1.47	0.07 -0.97	0.50	Moderately contaminated to highly contaminated
Cr	0.70 – 4.60	2.55	0.14 – 2.00	0.01	Moderately contaminated to highly contaminated
Ti	0.45 -814	4.00	0.0 – 0.94	0.8	Moderately contaminated to highly contaminated
Se	< 6	< 6	< 1.20	< 1.20	Very highly contaminated

3.2 Discussion

The lack of use of mask and other covering for other parts of the body is not practice during the floating activities; hence dust is inhaled directly through the nose and the mouth. Some of the elements may also be absorbed through the exposed parts of the body through the skin since they do not use laboratory clothing.

Zinc is an element that is essential for human health. When people absorb too little zinc they may experience a loss of appetite, decrease sense of taste and smell, slow wound healing and skin sores. Although humans can handle proportionally large concentration of zinc, too much zinc can still cause eminent health problems, such as stomach crump, skin irritations, vomiting, nausea and anexema. Very high level of zinc can damage the pancreas and disturb the protein metabolism, and cause arteriosclerosis (WHO, 1995). Extensive exposure to zinc chloride can cause respiratory disorder. It can also be a danger to unborn and newborn children. When mothers have absorbed large concentration of zinc, the children may be exposed to it through blood or milk of their mothers. Although, no such disease of public health concern have been reported in the study area, the high to very highly contaminated level of zinc in the study area may pose a great health risk to the workers and inhabitants of the area.

Uncontrolled large amount of thorium may be found near waste site where thorium has not been disposed according to the proper procedures. People that live near these hazardous waste site may be exposed to more thorium than usual because they breathe in wind – blown dust and because it ends upon crops that are grown near the site.

People that work in the tin processing mills may also experience thorium exposure that exceeds natural thorium exposure. Breathing in thorium in work place may increase the chances of developing lung disease, lung and pancreas cancer many years after people have been exposed. Thorium is radioactive and can be stored in

bones because of these facts it has the ability to cause bone cancer many years after the exposure has taken place. Thorium levels of the biotite granites, which serve as the raw materials for the tin, have been found to be quite high (Solomon, 2007). Although no radiation level has been measured during this study, the high level of Th and U is a source of concern and pose a great risk to health not only to the workers, but to residential houses located close to the milling houses.

Prolong exposure of the eyes to iron dust may cause conjunctivitis and chronic inhalation of excessive concentration of iron oxide fumes or dust may result in development of a benign pneumoconiosis, called siderosis, Inhalation of excessive concentration of iron oxide may enhance the risk of lung cancer development. Recently there has been a rising level in the cases of cancer diseases on the Jos Plateau (Lar and Tejan, 2008), although this may not be directly linked to the present study, there is a need to give attention to the activity of tin processing on the Jos Plateau.

Lead is one of four metals that have the most damaging effect on human health. It can enter the human body through uptake of food (65%), water (20%) and air (15%0. Lead can cause several unwanted effect such as: Disruption of the biosynthesis of hemoglobin and anemia (Canfield et al, 2003), A rise in blood pressure, Kidney damage, miscarriage and subtle abortion, Disruption of nervous system, Brain damage, Decline fertility in men through sperm damage, Diminished learning abilities in children (WHO 1995), Behavioral disruptions of children such as aggression, impulsive behavior and hyperactivity. Lead can enter a foetus through the placenta of the mother, because of this; it can cause serious damage to the nervous system and the brains of unborn children (www.lenntech.com/periodic). There is high level concentration of lead in the dust samples of the study area. Reported lead poisoning leading to the death of many children in Zamfara State (Lar et al, 2014) is a clarion call of concern.

4.Conclusion

The processing of tin around the Jos - Bukuru area is a source of great concern, because of the high level of toxic trace and radioactive elements in the dust generated during and after the milling activities. The inhalation of this dust directly through the nose, mouth and the skin by workers and inhabitants living close to these milling processing and waste disposal sites pose a great risk to human and animal health.

5. Acknowledgement.

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