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Assessment of Heavy Metals in Soil Samples from Mining Site in Gura Topp, Jos, Plateau State, Nigeria

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Abstract

Mining activities have been seen to greatly expose heavy metals to the surface of the earth and largely exposing soil and water bodies to the toxic metals thereby causing adverse effect to human due to its bioaccumulation. This studies is aimed at assessing the levels of contamination of 12 soil samples to determine the concentration of 16 heavy metals in Gura Topp Jos Plateau. Fluorescence Spectrometers (XRF) was used to determine the level of the toxic metals in the soil samples. The results revealed that Arsenic (As) with mean concentration of 38.27 ± 2.17 ppm, Gold (Au) with mean concentration of 2.32 ± 0.51 ppm, Cobalt (Co) with mean concentration of 202.23 ± 20.94 ppm, Cupper (Cu) with mean concentration of 248.20 ±4.52 ppm, Iron (Fe) with mean concentration of 58930.80 ± 8.92 ppm, Mercury (Hg) with mean concentration of 3.67 ± 1.12 ppm, Manganese (Mn) with mean concentration of 332.55 ± 15. Ppm , Molybdenum (Mo) with mean concentration of 48.68 ± 1.53 ppm ,Nickel (Ni) with mean concentration of 88.64 ± 4.81 ppm , Lead (Pb) with mean concentration of 135.54 ± 2.82 ppm, Rubidium (Rb) with mean concentration of 340.65 ± 1.77 ppm , Selenium (Se) with mean concentration of 1.83 ± 0.27 ppm, Strontium (Sr) with mean concentration of 26.58 ± 0.59 ppm , Tungsten (W) with mean concentration of 73.17 ± 5.08 ppm , Zirconium (Zr) with mean concentration of 4500.78 ± 4.80 ppm and Zinc (Zn) with mean concentration of 138.51 ± 3.19 ppm. These results indicates a high level of toxic metals that will cause health challenge to consumers of crops produced from those areas as reported by WHO.

Keyword: Heavy Metal, Gura Topp, Soil Samples, Mining Activity.

INTRODUCTION

Mining is a process which involves the selective recovery of specific minerals from the earth crust for the benefit of mankind. Two basic methods are used; they are the surface (opencast) and the underground mining all of which causes significant environmental damages, hazards pollutions and possibly contaminations to the land. Likewise the processing, packaging and transporting of such minerals and their respective waste and waste disposal pollute the soils (top-soil and subsurface soils), sediments and waters (surface, underground) around such mines or mining plant(s) which may pose serious health risks to the population in particular and generally in ecosystems around the sited mines . However, mining is one of the important pathways by which soils are contaminated. This soil serves as a direct source of radio-nuclides and heavy metals leading to the contamination of all agricultural products. Contaminated soils generally mining exploration and exploitation directly or indirectly affects both the living

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and non-living things through the physical and chemical modification of the soil environment (Adewole and Adesina, 2011).In this study we would determine the concentration of 16 heavy metals in the soil samples.

MATERIALS AND METHODS

Sampling/Sample Collection

Twelve (12) samples were collected from twelve (12) sampling points using random sampling technique with a depth range of approximately 0 -10cm of the soils in the study area around Gura-topp tin mining plant Jos-plateau. Global positioning system (GPS) was used to determine the location of each point and a tape rule was also used to measure the sample depth for each of the sampling points around the mines (site).

Table 1. Shows the locations and elevations of each sampling points where the samples were collected and each sample was labeled accordingly with a waterproof indelible marker.

Table 1. SAMPLE CODE AND GPS COORDINATES

SAMPLING CODE(S)	GPS COORDINATES		
	N	E	(METRES)
GT J1	9º 49′ 51.1″	8^0 54′ 48.0″	1,306
GT J2	9º 49′50.3″	8^0 54′ 42.9″	1,294
GT J3	9º 49′ 58.9″	8^0 54′ 40.9″	1,295
GT J4	9º 49′ 0.49″	8^0 51′ 50.3″	1,317
GT J5	9º 50′8.7″	8^0 54′ 34.6″	1,295
GT J6	9º 50′8.6″	8^0 54′ 27.1″	1,291
GT J7	9º 50′ 1.2″	8^0 54′ 28.1″	1,296
GT J8	9º 50′0.9″	8^0 54′ 32.5″	1,297
GT J9	9º49′ 56.6″	8^0 54′ 21.6″	1,284
GT J10	9º 49′ 50.4″	8^0 54′ 35.5″	1,232
GT J11	9º 49′49.6″	8^0 54′ 41.1″	1,299
GT J12	9º 49′50.5″	8^0 54′ 38.3″	1,296

SAMPLES ANALYSIS

Sample Preparation

The samples collected were taken to the laboratory of Mineral Resources Engineering Kaduna Polytechnics, Kaduna. The samples were crushed and sieved to 90µm, the pulverized samples were then finally air-dried. About 10g each of the samples were weighed into a clean transparent, sealable mini-tablet's polythene bags and taken for XRF analysis at the Nigerian Institute of Mining and Geosciences (NIMG), Jos; Plateau state.

Sample Analysis using XRF Technique(s)

This is a laboratory measuring instrument that is used for the elemental and radionuclide detection, identification and measurement of various types of samples in elemental concentration part per million (ppm) or milligram per kilogram (mg/kg).

XRF is operated on the principle that incident x-ray beams cause's rearrangement (displacement) of the orbital electrons resulting in an electron atomic instability from usually inner orbital electrons to outer orbital electrons with the release of energy when electron atomic stability is re-attained within a sample for a particular radio-nuclides or elements. The amount of energy released and intensity in terms of the photons are detected by a semiconductor detector and are displayed as spectral line plot on the screen of the analyzer proportional to the elemental concentration.

However, each radio-nuclide and element(s) has a characteristic intensity or photo-peak intensity that is proportional to the amount of energy released in the process. Thus, no two radio-nuclides or metals have the same amount of energy releasing characteristic.

In addition, the XRF analyzer provides one of the simplest, most accurate and economical methods for multi-element analysis. It is basically the emission of characteristic “secondary” (or fluorescent) X-ray from a material that has been excited by bombarding with high-energy x-ray or gamma ray. The phenomenon is widely used for elemental analysis and chemical analysis, particularly in the investigation of metals, glass, ceramics and building materials, and for research in geochemistry, nuclear physics, forensic science and archaeology. [IAEA, 2004].

RESULTS AND DISCUSSION

Table 2: Concentration of some Elements (ppm)

S/N	Sample code	CONCENTRATION				
		As	**Au**	**Co**	**Cu**	**Fe**
1	GT J1	120.29±4.88	25.00±4.64	175.74±27.98	1288.44±14.54	33071.81±107.12
2	GT J2	21.94±1.59	<LOD	322.63±22.82	62.75±2.71	71115.33±89.31
3	GT J3	80.64±4.19	<LOD	188.51±24.22	652.81±9.33	33597.23±93.00
4	GT J4	24.74±1.89	<LOD	156.14±17.58	133.51±3.40	39534.77±68.63
5	GT J5	23.20±1.61	<LOD	255.14±21.21	73.76±2.79	61824.63±83.07
6	GT J6	14.98±1.20	<LOD	111.03±12.69	38.92±2.10	28620.36±49.49
7	GT J7	24.33±1.57	<LOD	201.62±21.18	60.67±2.66	63212.32±83.34
8	GT J8	24.95±1.52	<LOD	191.11±19.43	63.31±2.65	54455.60±76.27
9	GT J9	27.52±1.83	<LOD	188.48±19.73	115.26±3.08	54998.19±77.52
10	GT J10	39.61±2.15	<LOD	188.61±23.99	212.95±4.29	64504.45±94.46
11	GT J11	32.34±1.92	2.92±1.50	308.54±25.42	131.25±3.45	80046.74±99.82
12	GT J12	24.68±1.72	<LOD	139.24±15.09	142.83±3.34	30357.90±58.61
	MEAN	38.26±2.17	2.32±0.51	202.23±20.94	248.20±4.52	51278.27±81.72
	MIN.	14.98±1.20	2.92±1.50	111.03±12.69	38.92±2.10	28620.36±49.49
	MAX.	120.29±4.88	25.00±4.64	322.63±22.82	1288.44±14.54	0046.74±99.82

Table 3: Concentration of some Elements (ppm

S/N		CONCENTRATION				
	Sample code	**Hg**	**Mn**	**Mo**	**Ni**	**Pb**
1	GT J1	<LOD	747.36±30.45	194.62±5.34	311.42±10.22	190.39±6.30
2	GT J2	<LOD	242.28±12.86	15.83±0.80	54.07±4.20	104.23±2.02
3	GT J3	<LOD	460.17±22.52	132.36±3.74	198.23±7.69	228.83±5.71
4	GT J4	5.65±1.62	150.82±11.71	62.71±1.33	33.15±3.79	136.82±2.49
5	GT J5	4.21±1.45	227.00±12.42	14.11±0.77	45.20±3.99	102.50±2.07
6	GT J6	4.73±1.20	172.49±9.53	6.96±0.52	26.86±2.91	71.88±1.56
7	GT J7	3.61±1.41	191.13±12.14	18.07±0.82	51.99±3.99	101.06±1.99
8	GT J8	4.22±1.36	229.01±11.98	20.53±0.78	64.39±3.91	95.18±1.90
9	GT J9	4.47±1.42	583.45±14.32	22.47±0.88	47.22±3.86	149.68±2.35
10	GT J10	6.58±1.81	487.78±16.33	42.00±1.33	135.96±5.14	144.22±2.75
11	GT J11	5.51±1.61	275.70±14.14	26.44±1.02	58.39±4.57	128.89±2.48
12	GT J12	5.09±1.56	223.38±11.69	28.21±1.11	34.89±3.55	112.87±2.24
	MEAN	3.67±1.12	332.54±15.00	48.69±1.54	88.46±4.81	135.54±2.82
	MIN.	3.61±1.41	150.82±11.71	6.96±0.52	26.86±2.91	71.88±1.56

Table 4: Concentration of some Elements (ppm)

S/N	Sample code	CONCENTRATION (PPM)				
		Rb	Se	Sr	Zr	Zn
1	GT J1	13.23±1.89	22.04±3.30	25.33±1.32	23839.60±18.58	65.33±5.44
2	GT J2	16.83±0.51	<LOD	45.15±0.56	999.15±2.20	43.42±2.16
3	GT J3	1693.64±5.68	<LOD	21.39±1.03	14783.97±12.68	253.23±5.74
4	GT J4	132.16±1.17	<LOD	17.99±0.47	3344.35±4.12	116.92±2.72
5	GT J5	502.68±2.01	<LOD	17.31±0.42	760.95±1.94	238.39±3.34
6	GT J6	374.84±1.52	<LOD	15.16±0.34	166.52±0.87	258.08±2.90
7	GT J7	30.93±0.62	<LOD	30.91±0.49	1089.88±2.28	49.98±2.15
8	GT J8	59.19±0.76	<LOD	31.64±0.48	916.31±2.07	41.61±2.00
9	GT J9	277.34±1.50	<LOD	43.25±0.56	1285.69±2.47	130.72±2.69
10	GT J10	482.24±2.22	<LOD	18.97±0.52	2786.01±4.06	154.55±3.31
11	GT J11	51.98±0.86	<LOD	42.79±0.59	1638.76±2.98	40.12±2.34
12	GT J12	452.75±1.94	<LOD	9.07±0.40	2398.27±3.40	269.80±3.47
	MEAN	340.65±1.77	1.83±0.27	26.58±0.59	4500.79±4.80	138.51±3.18
	MIN.	13.23±1.89	22.04±3.30	9.07±0.40	916.31±2.07	40.12±2.34
	MAX.	1693.64±5.68	22.04±3.30	45.15±0.56	23839.60±18.58	269.80±3.47

Table 5: Concentration of some Elements (ppm)

S/N	Sample Code	CONCENTRATION
		W
1	GT J1	285.84±12.46
2	GT J2	34.76±3.74
3	GT J3	234.30±9.75
4	GT J4	52.38±4.18
5	GT J5	27.43±3.83
6	GT J6	21.20±3.17
7	GT J7	33.17±3.68
8	GT J8	23.43±3.51
9	GT J9	26.83±3.70
10	GT J10	50.96±4.78
11	GT J11	42.67±4.13
12	GT J12	45.08±4.09
	MEAN	73.17±5.08
	MIN.	21.20±3.17
	MAX.	285.84±12.46

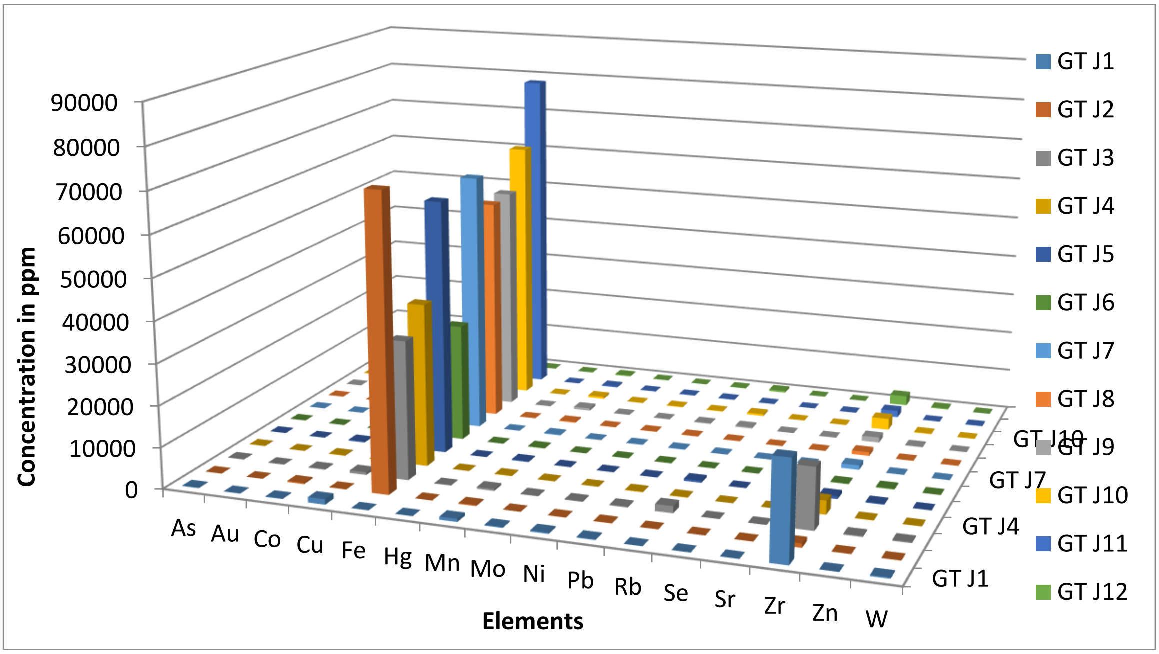

Fig.2: .Elemental concentration of all metals in samples (ppm)

RESULT DISCUSSION
Soil contamination is the presence of elevated concentration of substances in the environment above the natural level for the area or organism whereas *soil pollution* is the 'introduction by man, directly or indirectly, of substances or energy into the environment (including estuaries) resulting in such deleterious effect as harmful to living organism and hazards to human health'. (FAO, 2011 and Sciortino *et al.* 2000).

Arsenic (As) contributed 0.05% to the total elements percentage abundance as seen with a mean concentration of 38.27 ± 2.17 ppm which is above compared to the maximum permissible concentration (MPC) of 5 ppm. Thus, the sampling point(s) concentration ranking in the decreasing order is as follows: **GT J1**>GT J3 >GT J10 >GT J11 > GT J9 >GT J8 >GT J4 >GT J12 > GT J7 >GT J5 >GT J2 >**GT J6**; with the maximum concentration of 120.29 ± 4.88 ppm at **GT J1** and minimum concentration of 14.98 ± 1.20 ppm at **GT J6** as shown in Table 2. Above. Hence, it can be suggested that the site is contaminated with arsenic as shown in Table 2, **above**.

Gold (Au) contributed 0.004% to the total elements percentage abundance as can be seen which is high compared to the background range set by ATSDR of <0.005 ppm. Thus, the sampling point(s) concentration ranking in the decreasing order is as follows: **GT J1>GT J11**>GT J2=GT J3= GT J4=GT J5 =GT J6 =GT J7= GT J8= GT J= GT J= GT J; with the maximum concentration of 25.00 ± 4.64 ppm at GT J1 and minimum concentration of 2.92 ± 1.50 ppm at GT J11which are also higher compare to the standard in US. Hence, the site can be said to be contaminated with gold.

Cobalt (co) contributed 0.3% to the total elements percentage concentration abundance with a mean concentration of 202.23 ± 20.94 ppm which is above compared to the permissible concentration of 15 ppm, the sampling point(s) concentration ranking in the decreasing order is as follows: GT J2>GT J11>GT J 5 >GT J7 > GT J8>GT J10 >GT J3 >GT J9 > GT J1 >GT J4 >GT

J12 >GT J6; with the maximum concentration of 322.63 ± 22.82ppm at GT J2 and minimum concentration of 111.03 ± 12.69 ppm at GT J6 as shown in Table 2. Above.

Copper (Cu) contributed 0.006% to the total elements percentage concentration abundance with a mean concentration of 248.20 ±4.52 ppm which is above the maximum permissible concentration (MPC) of 20 ppm , the sampling point(s) concentration ranking in the decreasing order is as follows: GT J1 >GT J3 >GT J10 >GT J12 > GT J4>GT J11 >GT J9 >GT J5 >GT J8 >GT J2 >GT J7 >GT J6; with the maximum concentration of 1288.44 ± 14.54 ppm at GT J1 and minimum concentration of 62.75 ± 2.71 ppm at GT J6 as shown in table 2. **Iron (Fe)** contributed 89.9% to the total elements percentage concentration abundance with a mean concentration of 58930.80 ± 8.92 ppm which is above compared to the standard found in soil .Thus, the sampling point(s) concentration ranking in the decreasing order is as follows: GT J11 >GT J2 >GT J10 >GT J7 > GT J5 >GT J9 >GT J8 >GT J4 > GT J3 >GT J1 >GT J12 >GT J6; with the maximum concentration of 80046.74 ± 99.82 ppm at GT J11 and minimum concentration of 28620.36 ± 49.49 ppm at GT J6 as shown in Table 2. Hence, the site can be said to be highly contaminated with iron.

Mercury (Hg) contributed 0.06%to the total elements percentage concentration abundance with a mean concentration of 3.67 ± 1.12 ppm which is above compared to the maximum permissible concentration (MPC) of 0.1 ppm in considering it carcinogenic effects on humans. Thus, the sampling point(s) concentration ranking in the decreasing order is as follows: GT J10 >GT J4 >GT J11 >GT J12 > GT J6 >GT J>9 GT J8 >GT J5 > GT J7= GT J1=GT J2=GT J3; with the maximum concentration of 6.58 ± 1.81 ppm at GT J10 and minimum concentration of 3.61 ± 1.41 ppm at GT J7 as shown in Table 3. Hence, the site can be said to be highly contaminated with mercury.

Manganese (Mn) contributed 0.5% to the total elements percentage concentration with a mean concentration of 332.55 ± 15. ppm which is below 900ppm .the sampling point(s) concentration ranking in the decreasing order is as follows: GT J1>GT J9>GT J10 >GT J3 > GT J11 >GT J2 >GT J8>GT J5> GT J12>GT J7>GT J6>GT J4; with the maximum concentration of 747.36 ± 30.45 ppm at GT J1 and minimum concentration of 150.82 ± 11.71 ppm at GT J4 as shown in Table 3. **Molybdenum (Mo)** contributed 0.07% to the total elements percentage concentration with a mean concentration of 48.68 ± 1.53 ppm which is above the maximum permissible concentration (MPC) of 2 ppm , the sampling point(s) concentration ranking in the decreasing order is as follows: GT J1>GT J3>GT J4>GT J10> GT J12 >GT J11 >GT J9 >GT J8 > GT J7 >GT J2 >GT J5>GT J6; with the maximum concentration of 194.62 ± 5.34 ppm at GT J1 and minimum concentration of 6.96 ± 0.52 ppm at GT J6 as shown in Table 3. Hence, the site can be said to be highly contaminated with molybdenum.

Nickel (Ni) contributed 0.15% to the total elements percentage concentration abundance with a mean concentration of 88.64 ± 4.81 ppm which is high compared to the maximum permissible concentration (MPC) of 20 ppm, thus the sampling point(s) concentration ranking in the decreasing order is as follows: GT J1>GT J3>GT J10>GT J8> GT J11>GT J2>GT J7>GT J9> GT J5>GT J12>GT J4>GT J6; with the maximum concentration of 311.42 ± 10.22 ppm at GT J1 and minimum concentration of 26.86 ± 2.91 ppm at GT J6 as shown in Table 3. Hence, the site can be said to be contaminated with nickel.

Lead (Pb) contributed 0.20% to the total elemental percentage contribution with a mean concentration of 135.54 ± 2.82 ppm which is very high compared to the maximum permissible concentration (MPC) of 10ppm , the sampling point(s) concentration ranking in the decreasing order is as follows: GT J3>GT J1>GT J9>GT J10> GT J4>GT J11>GT J12>GT J2> GT

J5>GT J7>GT J8>GT J6; with the maximum concentration of 228.83 ± 5.71 ppm at GT J3 and minimum concentration of 71.88 ± 1.56 ppm at GT J6 as shown in table Table 3. Hence, the site can be said to be highly contaminated with lead.

Rubidium (Rb) contributed 0.50% to the total elements percentage concentration abundance from graph (3) with a mean concentration of 340.65 ± 1.77 ppm which is high compared to the standard. The sampling point(s) concentration ranking in the decreasing order is as follows: GT J3>GT J5>GT J10>GT J12> GT J6>GT J9>GT J4>GT J8> GT J11>GT J7>GT J2>GT J1; with the maximum concentration of 1693.64 ± 5.68 ppm at GT 3 and minimum concentration of 13.23 ± 1.88 ppm at GT J1 as shown in Table 4. Which is above the maximum the permissible limit .Hence, the site can be said to be contaminated with rubidium.

Selenium (Se) contributed 0.002% to the total elements percentage concentration with a mean concentration of 1.83 ± 0.27 ppm which is high compared to the maximum permissible concentration (MPC) of1 ppm .Thus, the sampling point(s) concentration ranking in the decreasing order is as follows: GT J1>GT J2=GT J3=GT J4= GT J5=GT J6=GT J7=GT J8= GT J9=GT J10=GT J11=GT J12; with the maximum and minimum concentration of 22.04 ± 3.30 ppm at GT J1.Hence, the site can be said to be moderately contaminated with selenium.

Strontium (Sr) contributed 0.040% to the total elements percentage concentration abundance with a mean concentration of 26.58 ± 0.59 ppm which is above compared to the acceptable limit , the sampling point(s) concentration ranking in the decreasing order is as follows: GT J2 >GT J9>GT J11>GT J8> GT J7>GT J1>GT J3>GT J10> GT J4>GT J5>GT J6>GT J12; with the maximum concentration of 45.15 ± 0.56 ppm at GT J2 and minimum concentration of 9.07 ± 0.40 ppm at GT J12 as shown in Table 4. Which is above standard

Zirconium (Zr) contributed 6.9% to the total elements percentage concentration abundance with a mean concentration of 4500.78 ± 4.80 ppm which is high compared to the background values in soil of 250 ppm (Amaral *et al.,* 2006) .Thus, the sampling point(s) concentration ranking in the decreasing order is as follows: GT J1 >GT J3 >GT J4 >GT J10> GT J12>GT J11>GT J9>GT J7> GT J2>GT J8>GT J5>GT J6; with the maximum concentration of 23839.60 ± 18.58 ppm at GT J1 and minimum concentration of 166.52 ± 0.87 ppm at GT J6 as shown in table 3.3.Hence, the site can be said to be highly contaminated with zirconium indicating high site contamination with the metal as shown in Table 4.

Zinc (Zn) contributed 0.20% to the total elements percentage concentration abundance with a mean concentration of 138.51 ± 3.19 ppm which is high compared to the maximum parmisivity Thus, the sampling point(s) concentration ranking in the decreasing order is as follows: GT J12>GT J6>GT J3>GT J5> GT J10>GT J9>GT J4>GT J1> GT J7>GT J2>GT J8>GT J11; with the maximum concentration of 269.80 ± 3.47 ppm at GT J12 and minimum concentration of 40.12 ±2.34 ppm at GT J11 as shown in Table 4. Hence, the site can be said to be contaminated with Zinc.

Tungsten (W) contributed 0.111% to the total elements percentage concentration abundance with a mean concentration of 73.17 ± 5.08 ppm which is above compared to the range of 0.98 to 1.3 to 1.7 ppm suggested by ATSDR in the USA. Thus, the sampling point(s) concentration ranking in the decreasing order is as follows: GT J1 >GT J3 >GT J4 >GT J10 > GT J12 >GT J11 >GT J2 >GT J7 > GT J5 >GT J9 >GT J8 >GT J6; with the maximum concentration of 285.84 ± 12.46 ppm at GT J1 and minimum concentration of 21.39 ± 1.03 ppm at GT J6 as shown in Table 5. Hence, the site can be said to be highly contaminated with tungsten.

CONCLUSION

In this study soil samples from different sampling points within the site were sampled and analyzed using XRF. Sixteen elements were detected all were heavy metal with relative variations compared to the maximum permissible concentration (MPC).

In addition, it was observed that concentration of all elements in this research are above the permissible limit by WHO 2011, suggesting that the contamination level is high. Therefore, from the foregoing, it can be inferred that the site of study is contaminated and polluted with a contamination degree value of 40.29 or 46.5 indicating an ultra-high degree of contamination.

This implies that with continuous and ongoing poorly regulated metal (tin) mining in the area; the ecological, agricultural, and health effect of the soils could be of grave potential concern in the nearest future with serious health and environmental consequences that may become hereditary.

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