Environmental Distribution of Trace Metals in the Biu Volcanic Province Nigeria: Exposure and Associated Human Health Problems

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Abstract: This study focuses on the concentration levels of trace metals in the soil and natural waters of Biu Volcanic Province Nigeria as well as human health problems associated with the exposure to these elements. Advance Inductively Coupled Plasma Optical Emission Spectrometry was used to analyze the trace and major elements. The analysis of the soil samples revealed complete leaching of the potentially harmful elements (As, Se, Sb, and Pb) from the surface soils into the water sources. According to pollution index the Soils are contaminated with Cr, Mn, Co, Ni, Zn and Lead, while water is contaminated with As, Pb, Sb and Se. The long term exposure of these toxic elements through the ingestion of water and food could have adverse health hazard to the inhabitants.

Index Terms—: Volcanic Province, potentially harmful elements, health hazard

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1 INTRODUCTION

The Biu volcanic covers a superficial area of 5000Km2 with a thickness of 250m, made up of several simple volcanoes with very large craters (caldera) of greater than 1km, suggesting that quite a large volume of magma, volcanic ash and pyroclastic materials erupted.

Volcanism and related igneous activities redistribute harmful elements, (such as arsenic, beryllium, cadmium, mercury, lead, radon, and uranium) on the surface of the earth.

Through physical and chemical weathering processes, rocks break down to form the soils on which the crops that constitute the food supply are raised for humans and animals consumption.

Drinking water travels through rocks and soils as part of the hydrological cycle and in the process leached elements in solution [5].

Environmental pollution arising from the distribution elements by natural or anthropogenic processes distorts geochemical systems. The natural geochemical composition of rocks and soils that make up the environment where we live may become direct risks to human health and may be the underlying cause of element deficiency and toxicity [6].
The purpose of this study is to determine the concentrations levels of trace metals in the soil and natural waters of Biu Volcanic Province Nigeria as well as human health problems associated with the exposure to these elements.

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2 GEOLOGICAL SETTINGS

Biu Plateau is situated on the structural and topographic divide, a broad E-W ridge or swell of basement between the Benue and Chad sedimentary basins "Fig. 1".

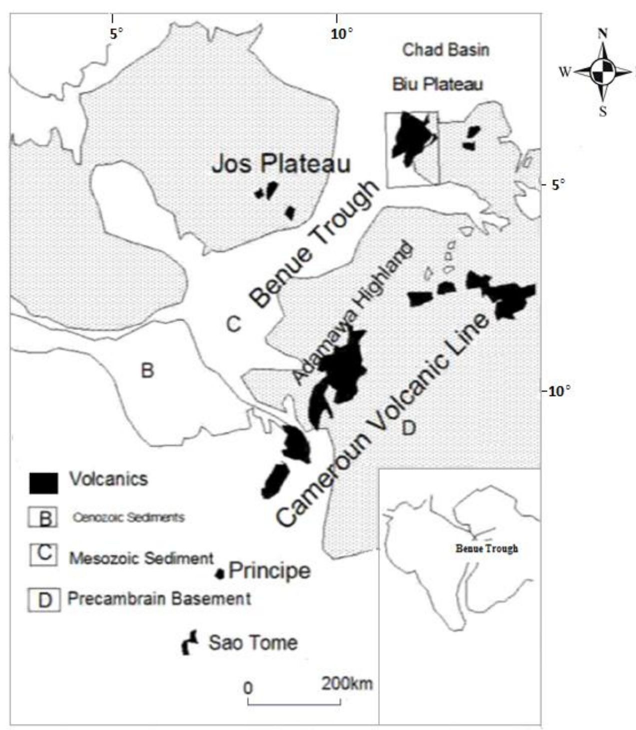

Fig. 1: Location Map of Biu Plateau and other Rock types in Nigeria (After Wright, 1976)

The basalt of the Biu Plateau mainly overlies Basement rocks which are predominantly granites, granite-gneiss and Fayalite-quartz, Monzonite, Bauchites (near Wandali at the SW margin of the plateau), hypersthenes diorite, volcanic and sub volcanic rocks of the Burashika group [13].

Two important post depositional processes affect the Poliocene basalts. The first was internal, the crystallization of zeolites and calcite, which are abundant in vesicular and rubbly interflow horizons. The second is surface weathering to clays and laterites. The basalt of the poorly drained northeastern plains is deeply decomposed to clay presumably a continuing process. Much less widespread, but more significant, is the development of laterite on the high Plateau.

The rocks in the Biu Plateau mostly occur as "flood basalts" in a number of flows and in fact cover nearly 85% of the area with its centre around Biu [13]. However, the basaltic sequence in the Northwestern part of Biu (Miringa area, "Fig. 2" is surrounded by several youthful scoria, cinder cones, tephra rings etc, the pyroclastics are generally restricted to the area west of Biu- Damaturu road.

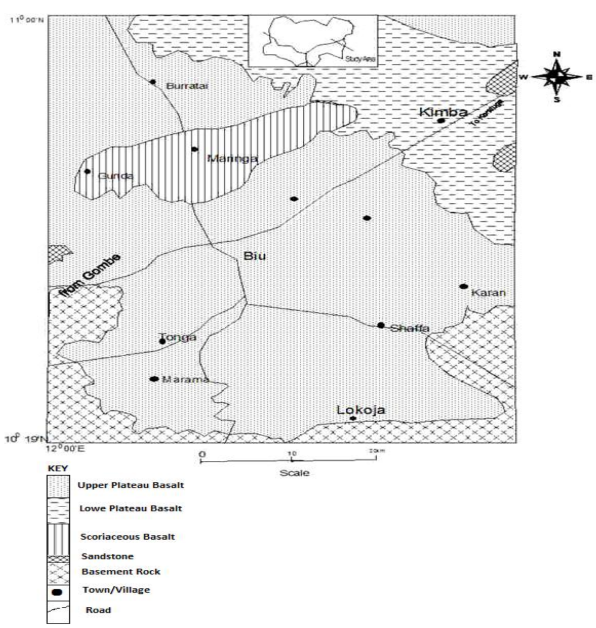

Fig. 2: Geological map on Biu-plateau (after Saidu, 2004)

The volcanoes are built up by essentially basaltic rocks consisting of phenocrysts of both olivine, plagioclase (bytwonite-labradorite), and rarely pyroxene (diopside-augite) set in a groundmass of labradorite laths, magnetite, ilmenite, minor K-feldspars, nepheline and volcanic Glass [10]. The land Sat image "Fig. 3" gives synoptic view of the study area.

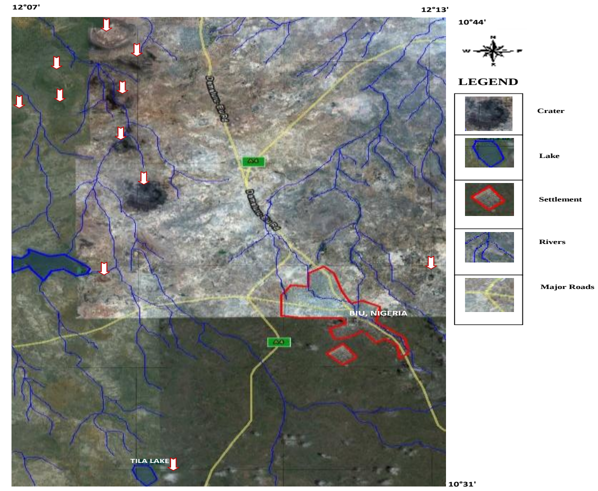

Fig. 3: Landsat image of the Study Area, insert are craters and Tila Lake

3 METHODOLOGY

3.1 Field sampling procedure

Sampling was accomplished during the dry season (March 28-April 25 2009). A total number of thirty seven (37) acidified water samples and thirteen (13) soils samples were collected over an area of 150 km² for geochemical analysis to determine their trace element concentrations. The sampling was done at the peak of dry season. However, care was taken to preserve a uniform distribution of sampling sites over the study area. The sampling locations of the study area are presented in "Fig. 4".

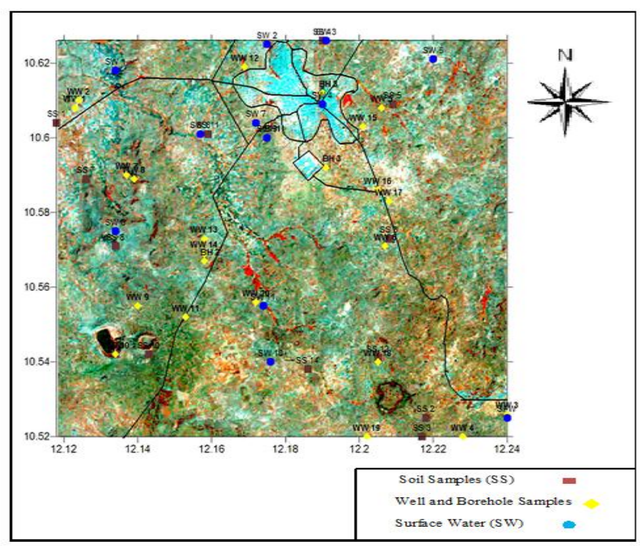

Fig. 4: sampling locations of the study area

In view of the usual low trace element concentrations in water, various measures were taken to prevent the slightest contamination in the collected samples.

They were kept to dry up in an oven at room temperature. The next step was immediate wrapping of the bottle with sterilized thin film ready for sample collection.

The bottles were finally rinsed with distilled water and kept to dry in an oven at 250C. One important step taken was the immediate wrapping of the bottle with sterilized thin film with the top of the bottle folding over a non-contaminating stiffened material attached to the twisted end. With these procedures the bottles were protected and ready for sample collection.

3.2 Sample preparations for geochemical analysis

The water samples ware acidified with one or two drops of HNO3 to keep the ions in solution and to prevent their absorption and precipitation in solution. A test for pH, temperature T and Electric Conductivity EC were done using the pH meter.

Soil samples were also collected at a depth of 10-15cm at each site and stored in sample bags. The soil samples were ground pulverized and digested using Aqua-regia prior to geochemical analysis on ICP-POES.

3.3 Analytical Techniques

Trace and major elements were analyzed using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) at Geochemistry Laboratory, University of Jos, Nigeria.

Both the accuracy and precision of ICP-OES measurements is dependent, in part, upon the calibration technique used in most cases, accuracies and precisions of ~ 1 - 3 % may be expected.

The most common calibration technique options for ICP-OES measurements are calibration curve and standard additions. In addition, the option of using internal standardization is available for the calibration curve technique and the ability of matrix matching. ICP-OES has the added option of using an internal standard that has a known concentration of the element measured.

For quantitative ICP-OES analysis, calibration is most commonly achieved by external standardization. The signal intensities of all analyte isotopes are measured in a blank as well as in one or more artificial or natural standards with different, known analyte concentrations that cover the concentration range of interest.

The (hopefully) linear relationship between the blank-corrected standards on a diagram of signal intensity versus concentration is used to establish a calibration curve that may be used to calculate the concentration of the analytes in samples of unknown composition.

Twenty five elements (Ba, As, Ca, Cd, Co, Cr, Cu, Fe, I, K, Mg, Mn, Mo, Na, Ni, P, Pb, S, Sb, Sc, Se, Sr, Ti, V, Z) were analyzed in the waters samples, while twenty elements (Mg, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Mo, Cd, Sb, Pb, Be, Tl) were analyzed in the soil samples.

4 GEOCHEMICAL RESULTS

Geochemical results of the various sample media are presented in “Table 1 and 2”. Concentration of trace elements of the waters of the study area will be compared with Organization (WHO) admissible levels for drinking water (2008). Average chemical composition (ACC) of Biu Plateau Basalt [11], “Table 3” is used as reference material to understand the distribution and concentration of the elements in volcanic soils of the study area.

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Table 1a: Major and Trace Element Concentration in water

Samples ID	Locality	Coordinates	As (mg/l)	Ba (mg/l)	Ca (mg/l)	Cd (mg/l)	Co (mg/l)	Cr (mg/l)	Cu (mg/l)	Fe (mg/l)	I (mg/l)	K (mg/l)	Mg (mg/l)	Mn (mg/l)	As (mg/l)
BH1	Waka	10°38'00.3"N, 12°10' 50.9"E	0.224	0.025	127.3	0.003	0.002	0.011	0.02	0.005	27.46	<DL	61.83	0.095	0.224
BH2	Hena	10°34'02.5"N, 12°09'48.1" E	0.089	0.019	56.27	0.004	0.001	0.001	0.004	<DL	13.59	<DL	32.72	0.039	0.089
BH3	Army Barrack	10°35'49.5"N, 12°11'46.4" E	0.039	0.017	73.18	0.002	0.001	0.002	0.006	<DL	<DL	<DL	42.32	0.046	0.039
BH4	Biu BCJ	10°36'17.4"N, 12°11'38.7" E	0.07	0.016	48.76	0.002	0.002	0.001	0.005	<DL	12.45	<DL	26.44	0.031	0.07
W1	BCJ	10°36'48.4"N, 12°07'40.2" E	0.04	0.012	22.27	<DL	<DL	<DL	<DL	<DL	<DL	<DL	13.45	0.008	0.04
W2	Wakama	10°36'57.3"N, 12°07'41.5" E	0.315	0.2	299.7	0.006	0.007	0.022	0.048	0.128	0.24	22.51	171.3	0.313	0.315
W3	Yimirshika	10°31'55.8"N, 12°14'38.5" E	0.037	0.014	19.14	<DL	<DL	<DL	<DL	<DL	<DL	<DL	7.346	0.011	0.037
W4	Waka	10°31'17.5"N, 12°13'07" E	0.023	0.014	31.9	<DL	<DL	<DL	0.002	<DL	<DL	<DL	14.84	0.021	0.023
W5	Biu	10°36'40.5"N, 12°12'40.3" E	0.227	0.181	317.6	0.002	0.012	0.013	<DL	1.516	13.6	7.791	89.89	0.65	0.227
W6	biladega	10°34'25.4"N, 12°12'47" E	0.066	0.037	62.83	0.001	0.002	0.001	0.009	<DL	1.778	<DL	25.33	0.051	0.066
W7	Tabra Fulani	10°35'35.4"N, 12°07'57.7"E	0.083	0.037	74.85	0.001	0.001	0.001	0.008	<DL	<DL	<DL	37.58	0.046	0.083
W8	Malan	10°35'35.4"N, 12°08'22.8"E	0.039	0.013	42.03	<DL	0.001	<DL	0.005	<DL	2.21	<DL	17.92	0.027	0.039
W9	Tila	10'33'31.4"N, 12°08'37.8"E	0.059	0.019	46.05	0.001	0.001	<DL	0.007	<DL	<DL	<DL	28.47	0.035	0.059
W10	Tila	10°35'51.6"N, 12°08'05.1"E	0.043	0.012	34.36	<DL	<DL	<DL	0.004	<DL	<DL	<DL	18.44	0.016	0.043
W11	Tila	10°33'13.3"N, 12°09'18.2"E	0.006	0.031	52.54	0.002	0.001	0.001	0.017	<DL	10.49	<DL	36.52	0.05	0.006
W12	Yimirshika	10°37'11.5"N, 12°10'15.6" E	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W13	Hena	10°34'37.4"N, 12°09'46.6"E	0.123	0.025	54.27	<DL	0.002	0.001	0.006	0.032	<DL	2.824	24.17	0.059	0.123
W14	Hena	10°34'11.5"N, 12°09'47.3"E	0.229	0.085	254.8	<DL	0.007	0.016	0.048	0.141	8.145	10.8	99.17	0.409	0.229
W15	BCJ	10°36'20"N, 12°12'04.2"E	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W16	Yimirshika	10°35'14.8"N, 12°12'29.8"E	0.136	0.012	26.4	<DL	0.002	<DL	0.003	0.024	<DL	0.646	9.325	0.042	0.136
W17	Gwarta	10°35' N, 12°12'49.8"E	0.29	0.12	171	<DL	0.008	0.015	0.033	0.07	10.59	5.808	60.19	0.163	0.29
W18	Kunar	10°32'38.1"N, 12°12'27.6"E	0.424	0.06	282.5	<DL	0.004	0.026	0.06	0.247	11.89	11.13	139.9	0.266	0.424
W19	Filin Jirgi	10°31'20.1"N, 12°12'27.6"E	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
W20	Biladega	10°33'36.6"N, 12°10'31.9"E	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
SW1	Wakama	10°37'04.6"N, 12°08'00.9"E	0.067	0.062	33.88	0.002	0.001	<DL	0.004	<DL	9.7	<DL	29.52	0.021	0.067
SW2	Waka	10°37'49.7"N, 12°10'48.4"E	0.389	0.21	340.1	0.007	0.007	0.023	0.053	0.077	87.62	36.16	198.5	0.207	0.389
SW3	Waka	10°37'57.8"N, 12°11'44.1"E	0.087	0.033	53.06	0.001	0.001	<DL	0.007	<DL	<DL	<DL	27.12	0.034	0.087
SW4	Tila	10°37°23.1"N, 12°13'18.2"E	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
SW5	Tabra Fulani	10°34'26.8"N, 12°08'03.2"E	0.041	0.033	67.83	0.001	0.001	0.002	0.017	<DL	<DL	<DL	31.8	0.07	0.041
SW6	Hena	10°36'20.9"N, 12°10'32.4"E	0.074	0.046	85.57	0.002	0.002	0.006	0.027	0.027	15.95	5.87	52.08	0.078	0.074
SW7	Hena	10°36'05.4"N, 12°09'55.6"E	0.116	0.034	67.77	0.001	0.002	0.002	0.009	<DL	7.537	0.012	35.54	0.041	0.116
SW8	Hena	10° 36'01.4"N, 12°10'48.1"E	0.067	0.095	75.39	0.002	0.001	0.001	0.013	<DL	<DL	1.011	46.54	0.065	0.067
SW9	Army Barrack	10°32'39.1"N, 12°10'52.9"E	0.021	0.008	17.57	<DL	<DL	<DL	<DL	<DL	<DL	<DL	7.749	0.006	0.021
SW10	Army Barrack	10°33'36.6"N, 12°10'41.8"E	0.032	0.009	16.92	<DL	<DL	<DL	<DL	<DL	<DL	<DL	6.879	0.012	0.032
SW11	Kunar	10°36'55.6" N, 12°11'39.2"E	0.036	0.023	32.56	0.001	<DL	<DL	<DL	<DL	<DL	<DL	16.56	0.017	0.036
SPW	Yimirshika	10°31'52.2"N, 12°14'41.4"E	0.477	0.092	332.2	0.048	0.084	0.344	0.649	1.678	144	153.7	17.35	2.901	0.477
TLK	Tila	10°31'48.9"N, 12°07'59.6"E	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL

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KEY : <DL = Below Detection Limit, BH = Borehole, W = Well, SW = Surface Water, SPW = spring Water, TLK = Tila Lake

Table 1b: Major and Trace Element Concentration in water

Samples ID	Locality	Coordinates	Mo (mg/l)	Na (mg/l)	Ni (mg/l)	P (mg/l)	Pb (mg/l)	S (mg/l)	Sb (mg/l)	Sc (mg/l)	Se (mg/l)	Sr (mg/l)	Ti (mg/l)	V (mg/l)	Zn (mg/l)
BH1	Waka	10°38'00.3"N, 12°10' 50.9"E	0.041	22.56	0.009	2.134	0.165	131.7	0.034	0.001	0.136	0.733	<DL	0.197	<DL
BH2	Hena	10°34'02.5"N, 12°09'48.1" E	0.009	25.64	0.001	0.447	0.107	0.416	0.012	<DL	0.101	0.447	<DL	<DL	<DL
BH3	Army Barrack	10°35'49.5"N, 12°11'46.4" E	0.009	30.99	0.003	0.505	0.091	8.458	0.019	<DL	0.047	0.466	<DL	<DL	<DL
BH4	Biu BCJ	10°36'17.4"N, 12°11'38.7" E	0.007	77.63	0.003	0.477	0.067	6.036	0.008	<DL	0.11	0.325	<DL	<DL	<DL
W1	BCJ	10°36'48.4"N, 12°07'40.2" E	<DL	67.89	0.002	0.322	<DL	<DL	0.019	<DL	0.026	0.138	<DL	<DL	<DL
W2	Wakama	10°36'57.3"N, 12°07'41.5" E	0.065	49.79	0.009	2.387	0.211	437.7	0.023	0.001	0.262	2.477	<DL	0.221	0.102
W3	Yimirshika	10°31'55.8"N, 12°14'38.5" E	<DL	7.407	0.002	0.169	<DL	<DL	0.017	<DL	0.015	0.103	<DL	<DL	<DL
W4	Waka	10°31'17.5"N, 12°13'07" E	<DL	29.65	0.003	0.402	<DL	<DL	0.018	<DL	0.017	0.182	<DL	<DL	<DL
W5	Biu	10°36'40.5"N, 12°12'40.3" E	0.041	19.72	0.033	1.994	0.134	183.8	0.023	0.001	0.245	1.188	<DL	<DL	0.862
W6	biladega	10°34'25.4"N, 12°12'47" E	0.004	2.4	0.004	0.545	0.01	7.466	0.017	<DL	0.058	0.358	<DL	<DL	<DL
W7	Tabra Fulani	10°35'35.4"N, 12°07'57.7"E	0.007	42.14	0.004	0.979	0.01	2.493	<DL	<DL	0.057	0.533	<DL	<DL	<DL
W8	Malan	10°35'35.4"N, 12°08'22.8"E	<DL	23.44	0.004	0.341	<DL	<DL	0.016	<DL	0.044	0.24	<DL	<DL	<DL
W9	Tila	10'33'31.4"N, 12°08'37.8"E	0.006	36.67	0.003	0.466	0.001	<DL	0.022	<DL	0.036	0.28	<DL	<DL	<DL
W10	Tila	10°35'51.6"N, 12°08'05.1"E	<DL	38.86	0.003	0.496	<DL	<DL	0.019	<DL	0.028	0.182	<DL	<DL	<DL
W11	Tila	10°33'13.3"N, 12°09'18.2"E	0.002	17.12	0.003	0.484	0.037	6.785	0.007	<DL	0.055	0.36	<DL	<DL	<DL
W12	Yimirshika	10°37'11.5"N, 12°10'15.6" E	<DL	6.858	0.001	<DL	<DL	<DL	0.018	<DL	<DL	<DL	<DL	<DL	<DL
W13	Hena	10°34'37.4"N, 12°09'46.6"E	0.013	17.81	0.002	1.005	0.017	<DL	0.015	<DL	0.042	0.444	<DL	<DL	0.811
W14	Hena	10°34'11.5"N, 12°09'47.3"E	0.065	23.53	0.009	3.305	0.212	37.33	0.012	0.001	0.271	1.736	<DL	0.322	1.692
W15	BCJ	10°36'20"N, 12°12'04.2"E	<DL	<DL	<DL	<DL	<DL	<DL	0.025	<DL	<DL	<DL	<DL	<DL	<DL
W16	Yimirshika	10°35'14.8"N, 12°12'29.8"E	0.006	9.561	0.002	0.593	<DL	<DL	0.021	<DL	<DL	0.136	<DL	<DL	0.503
W17	Gwarta	10°35' N, 12°12'49.8"E	0.058	16.84	0.011	1.347	0.178	34.44	0.05	0.001	0.243	1.162	<DL	0.763	1.637
W18	Kunar	10°32'38.1"N, 12°12'27.6"E	0.076	18.83	0.008	3.591	0.308	58.11	0.035	0.002	0.278	1.864	<DL	0.673	2.453
W19	Filin Jirgi	10°31'20.1"N, 12°12'27.6"E	<DL	<DL	<DL	<DL	<DL	<DL	0.043	<DL	<DL	<DL	0.004	<DL	<DL
W20	Biladega	10°33'36.6"N, 12°10'31.9"E	<DL	<DL	<DL	<DL	<DL	<DL	0.021	<DL	<DL	<DL	0.056	<DL	<DL
SW1	Wakama	10°37'04.6"N, 12°08'00.9"E	0.004	27.8	0.003	0.549	0.033	<DL	0.015	<DL	0.039	0.267	<DL	<DL	<DL
SW2	Waka	10°37'49.7"N, 12°10'48.4"E	0.071	53.75	0.023	3.927	0.348	425.8	0.071	0.002	0.441	2.302	<DL	0.059	<DL
SW3	Waka	10°37'57.8"N, 12°11'44.1"E	0.005	42.82	0.005	0.559	0.034	<DL	0.021	<DL	0.056	0.345	<DL	<DL	<DL
SW4	Tila	10°37°23.1"N, 12°13'18.2"E	<DL	112.7	<DL	<DL	<DL	<DL	0.026	<DL	<DL	<DL	0.001	<DL	<DL
SW5	Tabra Fulani	10°34'26.8"N, 12°08'03.2"E	0.004	30.73	0.01	0.748	0.037	16.8	0.025	<DL	0.075	0.377	<DL	<DL	<DL
SW6	Hena	10°36'20.9"N, 12°10'32.4"E	0.021	44.12	0.012	1.33	0.081	70.24	0.013	<DL	0.158	0.724	<DL	<DL	<DL
SW7	Hena	10°36'05.4"N, 12°09'55.6"E	0.007	42.74	0.002	0.946	0.03	11.2	0.015	<DL	0.047	0.359	<DL	<DL	<DL
SW8	Hena	10° 36'01.4"N, 12°10'48.1"E	0.007	25.63	0.006	1.006	0.02	4.378	0.02	<DL	0.025	0.478	<DL	<DL	<DL

SW9	Army Barrack	10°32'39.1"N, 12°10'52.9"E	<DL	17.17	0.003	0.257	<DL	<DL	0.015	<DL	0.009	0.107	<DL	<DL	<DL
SW10	Army Barrack	10°33'36.6"N, 12°10'41.8"E	<DL	48.12	0.003	0.173	<DL	<DL	0.019	<DL	0.012	0.094	<DL	<DL	<DL
SW11	Kunar	10°36'55.6" N, 12°11'39.2"E	<DL	33.89	0.001	0.225	<DL	<DL	0.023	<DL	0.054	0.212	<DL	<DL	<DL
SPW	Yimirshika	10°31'52.2"N, 12°14'41.4"E	1.039	21.27	0.003	44.6	0.374	784.7	<DL	0.024	0.432	22.96	<DL	15.6	17.1
TLK	Tila	10°31'48.9"N, 12°07'59.6"E	<DL	78.73	<DL	<DL	<DL	<DL	0.041	<DL	<DL	<DL	0.001	<DL	<DL

KEY : <DL = Below Detection Limit, BH = Borehole, W = Well, SW = Surface Water, SPW = spring Water, TLK = Tila Lake

Table 2: Major and Trace Element of Soil Samples

Samples ID	Locations	MgO (%)	K2O (%)	CaO (%)	TiO2 (%)	Fe2O3 (%)	V (ppm)	Cr (ppm)	Mn (ppm)	Co (ppm)	Ni (ppm)	Cu (ppm)	Zn (ppm)	As (ppm)	Se (ppm)	Mo (ppm)	Cd (ppm)	Sb (ppm)	Pb (ppm)	Be (ppm)
AD1	10°34'0.63" N, 11°51'29.0" E	1.50	0.65	2.09	0.01	1.12	<DL	34.09	406.9	13.48	43.4	13.49	467.3	<DL	<DL	<DL	1.604	<DL	3.479	<DL
AD2	10°31'48.2" N, 12°14'39.0" E	1.76	0.75	2.31	40.01	49.81	112.2	230.3	791.3	45.87	89.03	51.54	495.6	<DL	<DL	<DL	<DL	<DL	16.83	<DL
AD3	10°31'16.8" N, 12°13'06.8" E	2.34	0.80	0.40	68.67	85.0	82.64	440.9	2074	110.8	227.8	92.21	<DL	<DL	<DL	<DL	<DL	<DL	32.56	<DL
AD4	10°37'56.9" N, 12°11'41.9" E	8.18	0.82	4.16	15.31	28.41	<DL	246.7	1153	59.71	296.7	60.65	252.3	<DL	<DL	<DL	<DL	<DL	6.391	<DL
AD5	10°36'51.1" N, 12°12'50.9" E	3.94	0.72	3.60	3.60	19.33	<DL	151.8	1716	60.29	168.7	37.52	261.7	<DL	<DL	<DL	<DL	<DL	7.9	<DL
AD6	10°34'36.4" N, 12°12'48.1" E	4.11	0.53	4.77	27.07	29.87	<DL	151.5	1507	58.13	221.2	47.15	295.3	<DL	<DL	<DL	<DL	<DL	3.021	<DL
AD7	10°35'34.7" N, 12°07'57.9" E	4.40	0.75	4.13	12.98	34.71	<DL	183.7	3352	111.3	231	45.06	245.6	<DL	<DL	<DL	<DL	<DL	13.58	<DL
AD8	10°34'26.8" N, 12°08'03.2" E	4.54	0.70	3.69	7.35	14.26	<DL	154.3	914.5	41.31	177	42.59	495.6	<DL	<DL	<DL	<DL	<DL	5.161	<DL
AD9	10°32'50.3" N, 12°08'01.9" E	10.81	2.32	11.63	4.37	16.29	<DL	166.3	1857	52.97	170.6	49.62	349.4	<DL	<DL	<DL	<DL	<DL	<DL	<DL
AD10	10°32'50.3" N, 12°08'55.3" E	1.52	0.85	1.49	16.15	30.63	23.64	153.3	862.9	41.68	104	34.09	276.1	<DL	<DL	<DL	<DL	<DL	9.556	<DL
AD11	10°36'08.1" N, 12°09'55.6" E	2.43	0.85	2.62	1.63	23.1	<DL	92.27	1771	46.66	98.06	28.01	268.3	<DL	<DL	<DL	<DL	<DL	42.95	<DL
AD12	10°32'45.2" N, 12°12'30.2" E	6.26	3.09	4.29	6.23	41.16	<DL	163.5	25.28	83.9	250.1	59.97	324.6	<DL	<DL	<DL	<DL	<DL	<DL	<DL
AD13	10°32'29.8" N, 12°11'13.7" E	1.72	0.63	1.92	0.80	13.21	<DL	114.9	8.11	46.61	95.93	29.1	346.6	<DL	<DL	<DL	0.365	<DL	6.803	<DL

<DL = Below Detection Limit

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Table 3: Average Major and Trace Element Composition of Basalt

Elements	Unit Symbol	1	2
MgO	%	11	10.6
K2O	%	10.2	2.07
CaO	%	22	9.95
TiO2	%	10.3	2.23
Fe2O3	%	30	10.71
MnO	%	0.3	1,500
V	ppm	73	250
Cr	ppm	176	170
Co	ppm	59	60
Ni	ppm	176	100
Cu	ppm	45	87
Zn	ppm	339	105
Pb	ppm	14	6
As	ppm	<DL	2
Cd	ppm	1	-
Se	ppm	-	-
Mo	ppm	-	-
Sb	ppm	-	-

1. Average Major and Trace Element Composition of Biu Plateau Volcanic Soils (This study)

2. Average chemical Composition of Parent Rock (ACC) of Biu Plateau Basalt (Saidu, 2004.Unpublished MSc Thesis)

Trace Elements	Surface Water	Ground Water		Soil
	Stream (mg/L)	Well (mg/L)	Borehole (mg/L)	(ppm)
Ba	0.13	0.05	0.02	-
Ca	38	112	76	126
K	39	9	-	173
Mg	29	50	41	123
Na	45	25	39	-
P	5	1	0.89	-
S	22	96	37	-
As	0.49	0.13	0.11	-
Cd	0.01	0.002	0.003	0.02
Co	0.01	0.004	0.002	59
Cr	0.01	0.01	0.003	176
Cu	0.1	0.02	0.01	45
Fe	0.9	0.31	-	46
I	53	8	18	-
Mn	0.3	0.14	0.05	15
Mo	0.14	0.03	0.02	-
Ni	0.01	0.006	0.004	17
Pb	0.5	0.11	0.1	14
Sb	0.03	0.02	0.02	-
Sc	0.01	0.001	-	-
Se	0.48	0.11	0.1	-
Sr	3	0.71	0.49	-
Ti	-	0.003	-	20
V	8	0.49	-	73
Zn	-	1.2	-	34

Table 4: Average concentration of Major and Trace Element surface, well, borehole and soil

4.1 DISCUSSION

4.1.1 Major elements (soil)

MgO, CaO, TiO2 and K2O

These major elements are the most affected by weathering. They are nearly or completely leached away from the weathered volcanic soils. This is clearly observed when the weathered volcanic soils are compared with typical fresh Basalts (Saidu, 2004), for example the concentrations of MgO, CaO, TiO_2 and K_2O are 10.69, 9.95, 2.23 and 2.07 % respectively in parent rock compared with 1, 2, 0.3 and 0.2 % respectively in weathered volcanic soils "Table 2". Fe_2O_3 shows concentration in twelve out of thirteen soils samples with concentrations of 49.81, 85, 28.41, 19.33, 29.87, 34.71, 14.26, 16.29, 30.63, 23.1, 42, and 13 % respectively, higher than average chemical composition of Biu Basalts of 10.71 %. However, near absence in water could be its inability to remain in solution.

4.1.2 Major elements (water)

Ca, K, Mg, and Na

The major elements: Mg (7-199 mg/l) and Na (2.4-78 mg/l) are within the minimum permissible drinking water level when compared with the World Health Organization (WHO) Standard of 500 and 200 mg/l respectively, however, Calcium shows elevated concentrations in wells, surface water and spring water of 300, 318, 255, 283, 240 and 332 mg/l respectively as against WHO admissible standard of 200 mg/l. Potassium also shows elevated concentrations in spring water (SPW), surface water (SW) and well (W) with higher values of 15.37, 22.51 and 36.16 mg/l respectively, when compared with 12 mg/l of WHO standard "Table 6".

The total hardness values of the waters in Biu volcanic Province ranges from 70 to 1666 mg/l indicating that the water from boreholes, wells and surface waters are moderate to very hard, therefore, not suitable for both drinking, washing and bathing. The total hardness was calculated from the equation T = 2.497[(Ca2+) +4.11(mg2+)].

4.2 Trace elements in soils

As, Cd, Co, Cr, Cu, Ni, Pb, Zn, Sb, and Se

These elements As, Se, Cd and Sb are intensively leached away from their weathering profiles resulting in their depletion (Table 2). Compared with parent rock [10], Co recorded high anomaly of 111 and 84 ppm as against average composition of basalts of 60 ppm "Fig. 5", while, Cr has three anomalies of 441, 247 and 230 ppm greater than average composition of basalts of 170 ppm "Fig. 6".

The concentration of Cu is 92 ppm greater than average composition of basalt of 87 ppm in one sample only. Ni has high anomalies of 297, 250, 231, 228, 221, 171, 169 and104 greater than average composition of basalt of 100 pm "Fig. 7". Pb shows elevated concentration of 49, 33, 17, 14, 10, 8 and 7 ppm compared average **composition** of basalts 6 ppm "Fig. 8". Zn present high anomaly greater than average composition of basalt (105 ppm) in all the samples, the concentration ranges from 246 – 496 ppm "Fig. 9".

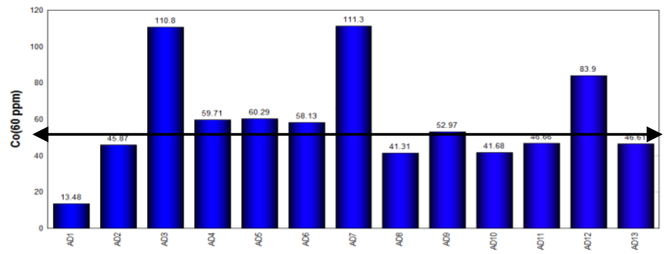

Fig. 5: Co Concentrations in Biu Volcanic Soils

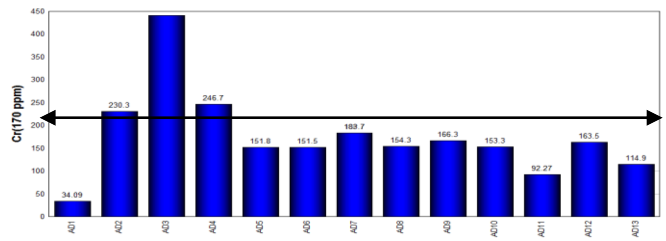

Fig. 6: Cr Concentrations in Biu Volcanic Soils

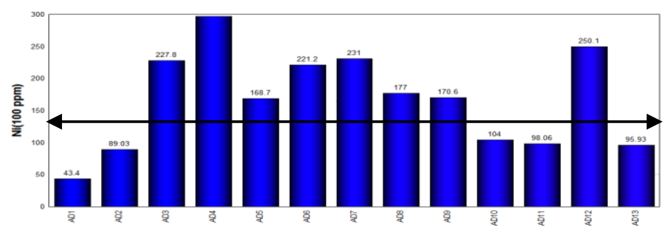

Fig. 7: Ni Concentrations in Biu Volcanic Soils

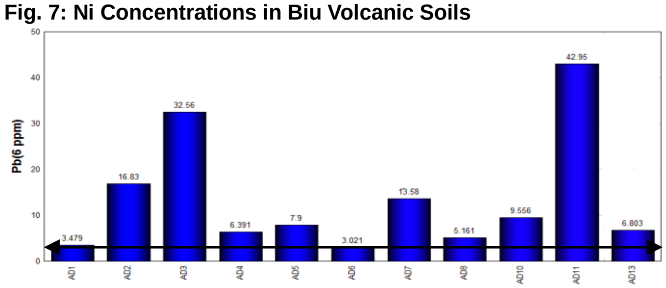

Fig. 8: Pb Concentrations in Biu Volcanic Soils

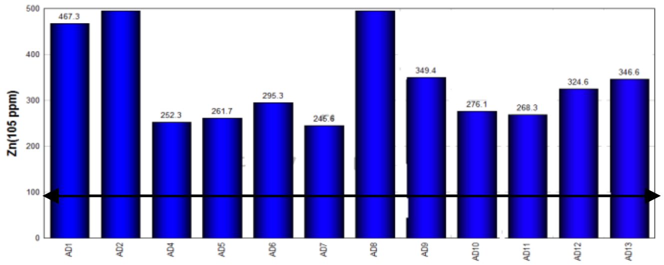

Fig. 9: Zn Concentrations in Biu Volcanic Soils

4.3 TRACE ELEMENTS IN WATERS

As, Se, Sb, Pb and Cd

4.3.1 Arsenic

Arsenic present values as high as 0.45, 0.42, 0.39 and 0.32 mg/l in surface, well and spring water respectively "Table 1". These values are about 10x the WHO admissible value of 0.01 mg/l for safe drinking water. "Fig. 10" shows spatial distribution of As.

Arsenic is a metalloid element found ubiquitously in nature, occurring in rocks and soil, coal, volcanic emissions, volcanic sediments, undersea hydrothermal vents ("black smokers"), hot springs, and extraterrestrial material. It is the twentieth most abundant element in the earth's crust, with an average concentration of 2 mg kg−1.

Worldwide, water contamination is the most common source of exposure to environmental arsenic. A range of health effects have been associated with long-term chronic arsenic exposure, including cancer (skin, lung, bladder, and kidney), atherosclerosis, and peripheral vascular disease. Epidemiological data have also suggested a link with diabetes mellitus, hypertension, and anaemia [11].

When ingested into the body, arsenic is distributed widely, with greatest concentrations in ectodermal tissues including the skin, hair, and nails. As might be expected, the skin is a primary target organ for arsenic toxicity, especially with chronic exposures [8].

The average concentration of As in surface water is 0.49mg/l higher than groundwater with concentration of 0.12mg/l, "Table 4", suggesting that the spring water could have acted as the transport medium for this element released from deep-seated source(s).

Average concentration shows treat of health hazard to the inhabitants.

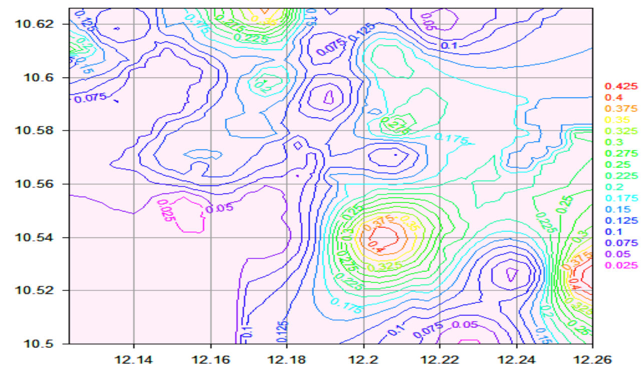

Fig. 10: Shows concentration of As and its spatial distribution in surface and groundwater

4.3.2 Selenium

Se concentration is very high with values of 0.44, 0.43, 0.28, 0.27, 0.26, and 0.25 mg/l above WHO value of safe drinking water of 0.01mg/l in surface, well and spring water "Table 1". "Fig. 11" shows spatial distribution of Se.

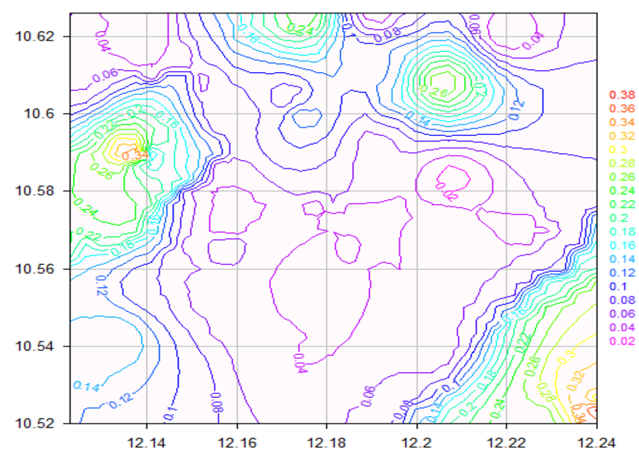

Fig. 11: Shows concentration of Se and its spatial distribution in surface and groundwater

Selenium (Se) is essential to human and other animal health in trace amounts, but is toxic in excess. Acute and fatal toxicities have occurred with accidental or suicidal ingestion of gram quantities of selenium. Chronic selenium toxicity (selenosis) may occur with smaller doses of selenium over long periods of time. The most frequently reported symptoms of selenosis are hair and nail brittleness and loss.

Other symptoms may include gastrointestinal disturbances, skin rashes, a garlic breath odor, fatigue, irritability, and nervous system abnormalities [7].

According to [8], getting sufficient quantities of selenium may increase thyroid hormone metabolism, improve fertility, help fight cancer, and reduce risk of cardiovascular diseases and arthritis. Higher selenium levels can help slow down the replication of the HIV virus. Her study actually found that "AIDS patients with low levels of selenium were 20 times more likely to die from an AIDS-related illness than those with healthy levels of the mineral."

Toxic effects of 'Se' on skin and nails of the inhabitants of the volcanic province were recorded.

The average concentration of Se in surface water is 0.48mg/l higher than groundwater with concentration of 11mg/l "Table 4".

Average concentrationn shows over exposure which is a treat to the inhabitants.

4.3.3 Antimony

Sb presents high value of 0.071, 0.047, 0.041 and 0.034 mg/l in surface, well, spring and borehole waters respectively. These values are about 10x the WHO admissible value of 0.005 mg/l for safe drinking water "Table 1". Spatial distribution of Sb is shown in "Fig. 12".

Antimony is most environmentally available as dusts which, after becoming airborne, deposit on land or in water. Antimony has been used since antiquity as a medicinal, to induce emesis and to treat other conditions; as well as in cosmetics.

However, little was understood concerning antimony toxicity until major processing of ore began at around the turn of the century and specific toxic effects were noticed in workers processing antimony.

These effects included "antimony spots" a form of dermatitis, and later respiratory, pulmonary and heart effects were noted and cancer was suspected [2]

The toxic effect of antimony on the inhabitants of the volcanic province was not encountered. Collaborative effort needs to be done to unravel the relationships between human exposure and human health impact in the study area.

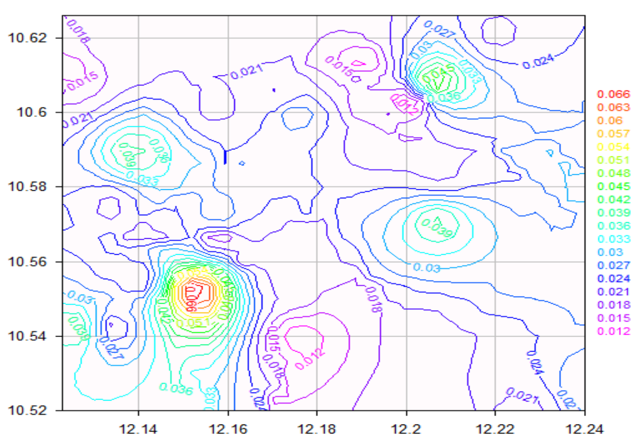

Fig. 12: Shows concentration of Sb and its spatial distribution in surface and groundwater

4.3.4 Lead

Elevated concentration of lead with values of 0.37, 0.35, 0.31, 0.21, 0.21 and 0.17 mg/l were recorded in surface, well, spring and borehole waters respectively "Table 1". These values are about 10x the WHO admissible value of 0.01 mg/l for safe drinking water. The concentration of As is shown in "Fig. 13".

Lead poisoning (also known as plumbism, colica Pictonum, saturnism, Devon colic, or painter's colic) is a medical condition caused by increased levels of the heavy metal lead in the body. Lead interferes with a variety of body processes and is toxic to many organs and tissues including the heart, bones, intestines, kidneys, and reproductive and nervous systems [3]. It interferes with the development of the nervous system and is therefore particularly toxic to children, causing potentially permanent learning and behaviour disorders.

Symptoms include abdominal pain, headache, anaemia, irritability, and in severe cases seizures, coma, and death. Based on the computed average values the concentration of lead in the surface and spring water is 0.5 mg/l compared to 0.11 mg/l of ground water samples, "Table 3".

From the concentration above the inhabitants are overexposed due to high percentage of Pb in drinking the water.

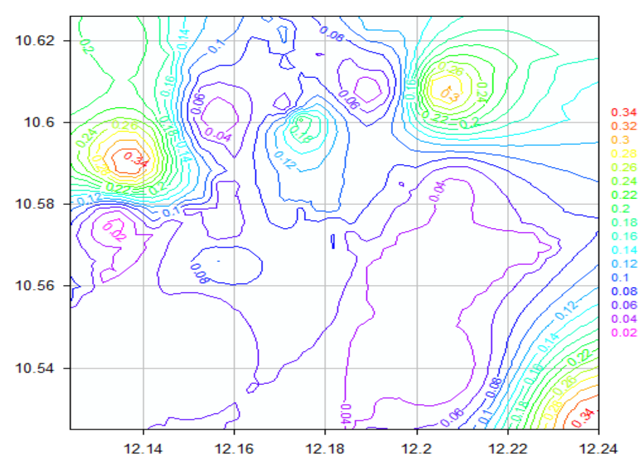

Fig. 13: Shows concentration of Pb and its spatial distribution in surface and groundwater

4.3.5 Cadmium

Cd In the study area has high values of 0.05, 0.007, 0.006 and 0.004 mg/l respectively above WHO admissible standard of 0.003 mg/l in spring, surface, well, and borehole waters "Table 4". "Fig. 14" shows distribution of Cd

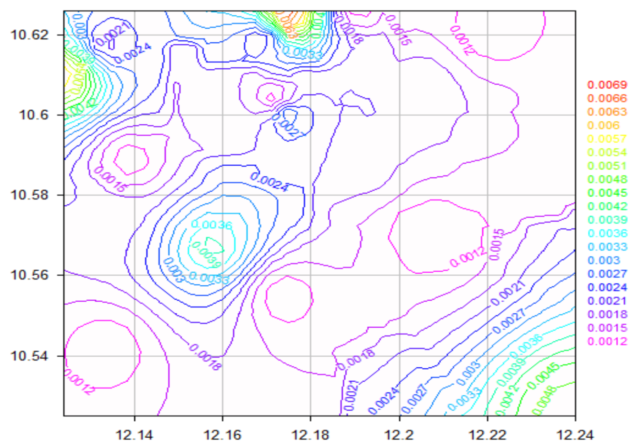

Fig. 14: shows concentration of cd and its spatial distribution in surface and groundwater

Cadmium occurs naturally in the environment from the gradual process of erosion and abrasion of rocks and soils, and from singular events such as forest fires and volcanic eruptions. It is therefore naturally present everywhere in air, water, soils and foodstuffs.

Cadmium is recognized to produce toxic effects on humans. Long-term occupational exposure can cause adverse health effects on the lungs and kidneys [9]. Under normal conditions, adverse human health effects have not been encountered from general population exposure to cadmium.

The average concentration of the element in surface water is 0.01 mg/l higher than 0.003 mg/l "Table 4".

Average concentration shows that the inhabitants are exposed to cadmium.

5 POLLUTION INDEX

[13] had employed a simple method based on pollution load index to assess the extent of pollution by metals in estuarine sediments. Sediment pollution load index was calculated using the equation:

CF = Cmetal / Cbackground

PI = n √ (CF1 × CF2 × CF3 × .... CFn)

Where, CF is the contamination factor,

Cmetal is the concentration of pollutant in sedimentCbackground is the background value for the metal

n is the number of metals.

The PI value > 1 is polluted whereas < 1 indicates no pollution.

"Table 5" gives PI calculation of Biu Volcanic soil. Results showed that Biu Volcanic Soils are not polluted with V and Cu but polluted with Cr, Mn, Co, Ni, Zn and Pb.

Pollution Index of the water shows that it is polluted with As, Pb, Sb and Se but not polluted with Cd "Table 6".

Table 5: Pollution Index of PHS in surface and groundwater's of the study area

metal	Pollution	Index
As	3.1	Polluted
Pb	1.9	Polluted
Sb	1.4	Polluted
Se	4.7	Polluted
Cd	0	non polluted

Table 6: Pollution Index in volcanic soils of the study area

metal	Pollution	Index
V	0.4	non polluted
Cr	2.3	Polluted
Mn	5.6	Polluted
Co	2.1	Polluted
Ni	1.7	polluted
Cu	0.1	non polluted
Zn	1.5	polluted
Pb	2.4	polluted

From the discussion above, geochemical analysis of the volcanic soil revealed the complete leaching of the major elements (Fe_2O_3, CaO, K_2O, MgO, MnO, TiO_2) from the surface soil probably into water sources. This may explain the extremely high CaO and K_2O levels especially in the stream water where they display values of 348mg/l and 36 mg/l as against 200mg/l to 12 mg/l respectively of WHO admissible limits for drinking water. However, the near-absence of Fe_2O_3, MgO and Na_2O in the water could be as a result of their inability to remain in solution as soluble ions. The accumulation of transition metals in the soil (Co 84-111ppm; Cr: 230-443ppm); Ni: 169-237ppm) is geogenic derived from the weathering of the host basaltic rock. Cr, Ni, and Cu do not easily form soluble ions in solution explaining why they display lower levels below their respective WHO admissible limits for drinking water. The absence in the soil profile and the extremely higher values of Potentially Harmful Elements (PHEs) (As, Se, Sb, and Cd) in the spring and stream water as opposed to the lower values in the wells and borehole water suggest their extreme solubility, the leaching and transportation of these elements from parent rocks. The higher values of Zn and Pb (10-40ppm and 246-496ppm respectively) 4x their average abundance in basalts, could be explained like for Co, Cr, Ni, by their absorption and retention in clay minerals structure.

6 EXPOSURE AND ASSOCIATED HEALTH PROBLEMS

Most inhabitants of the volcanic province rely on any of these available water sources (surface and ground waters) for their drinking and other domestic purposes. The over-exposure to Potentially Harmful Elements through the ingestion of water and food could have adverse health hazards. Few of the inhabitants show manifestations of nail deformity (nail thickening and brittleness), and hyperpigmentation of the skin and hand palms. Others present various forms of skin diseases (especially skin growth) which all could be attributed to exposure to As and Se toxicity "Plate (1-10)".

Plate 1: Deformed nails due to As and Se toxicity (12 14'41.4 10 31'52.2)

Plate 2: Deformed nails due to As and Se toxicity (12 14'41.4 10 31'52.2)

Plate 3: Deformed nails due to As and Se toxicity (12 14'41.4 10 31'52.2)

Plate 4: Hyper pigmentation on palms due to As and Se toxicity (12 14'41.4 10 31'52.2)

Plate 5: Roughness of the skin and nails brittleness of (12 years Old boy) due to As and Se toxicity (12 14'41.4 10 31'52.2)

Plate 6: Patches and roughness on palms of (12 years Old boy) due to As and Se toxicity (12 14'41.4 10 31'52.2)

Plate 7: Growth on skin due to As and Se toxicity (12 14'41.4 10 31'52.2)

Plate 8: Growth on the skin and rashes due to As and Se toxicity (12 14'41.4 10 31'52.2)

Plate 9: Growth on the jaw due to As and Se toxicity (12 14'41.4 10 31'52.2)

Plate10: Growth on skin due to As and Se toxicity (12 14'41.4 10 31'52.2)

7 CONCLUSION

The present study revealed that both surface and ground waters are contaminated by Potentially Harmful Elements (PHEs) (As, Pb, Sb and Se) far above WHO admissible standard. The study discovered that due to overexposure of these toxic elements some people are affected with problem of diabetes, loss of hearing, hair loss, deformed nails and various skin problems like: rashes, abnormal growth, skin lesion and roughness, could be attributed to exposure to As and Se toxicity.

These examples underscore the pressing need for the development of collaborative research (with the medics and other scientists) to investigate human health problems associated with the exposure to these trace metals in Biu volcanic province, Nigeria. Such knowledge is essential for the control and management of these health problems.

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