Contamination and Ecological Risk Assessment of Trace Elements in Soils and Sediments at Balungu River Basin of Bongo District: An Index Analysis Approach to Avert Public Health Epidemics

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Abstract

The contained elements in soils determine the health risk of population at a place. So in this study, the impact of soils on public health was determined by collecting 50 soil samples of 1 kg weight per sample. The samples were sun dried and sieved to <125 µm size fraction. Further processing on the sieve samples to form pellets for XRF analysis were carried out. Elements analysed were arsenic (As), lead (Pb), chromium (Cr), cobalt (Co), copper (Cu), manganese (Mn), magnesium (Mg), zinc (Zn), potassium (K), vanadium (V), barium (Ba), iron (Fe) and nickel (Ni). The contamination status at each sample station was calculated for the elements. The results of all the elements except Cr showed lower measured concentrations in the samples compared with the background averages. The measured averages (mg/kg) in this study for As, Ba, Co, Cr, Cu, Mn, Ni, Pb, V, and Zn were 6.89, 263, 8.26, 37.23, 13.41, 02.96, 14.6, 4.54, 58.14 and 27.24 as against Turekian and Wedepohl background values measurements obtained in their 1961 study for As(10mg/kg), Ba (580mg/kg), Co (9.10mg/kg), Cr (8.26mg/kg), Cu (25mg/kg), Mn (550mg/kg), Ni (19mg/kg), Pb (19mg/kg), V (80 mg/kg) and Zn (60mg/kg). , This indicated the non-pollution status of 10 elements except CrCorrespondingly, it found the need for further examination on Cr to know the oxidation states because Cr (VI) has been found to be toxic for humans whereas Cr (III) plays an important role in glucose metabolism in man. The toxic elements As and Pb also showed depletion implying diseases that relate to As and Pb will be non-existence or will be minimal. But the understanding of disease patterns will depend on the knowledge of element distribution and concentration patterns. This thus makes prioritization of ecologic.

Keywords - *Human health, Environment, Pollution load, Geo-accumulation, Essential element*

I. Introduction

Planet Earth, particularly the weathered and the unconsolidated portion that has direct interactions with humans contains essential and toxic trace elements. The sources of these trace elements come from the underlying rocks whose concentration levels in the surface environment vary because of factors such as the geological, geochemical, hydrological, surface processes and environmental activities. Besides, within the same melt or molten magma, the mineral crystallizations occur at different times resulting in different rock formations. The trace elements released from the crystallized minerals called rocks have different concentrations across any of the geologic terrains [1]. Clinical diagnoses identify diseases where there are excesses or deficiencies of elements (Wada 2003). Classic example of deficiency and excesses of some elements leading to adverse health effect is deficiency and excesses of fluoride resulting in dental caries and fluorosis [12]. This re-emphasise the proper functioning of the human body for its wellbeing to depend on the dose of trace elements. From medical perspective an impaired physiological functioning of human body are observed clinically from the lack or excess of particular trace elements [20]. This reiterates the need to control the dose of trace elements exposures [16] especially in humans to maintain healthy responses devoid of possible public health problems.

The preceding decades has seen the relevance of applying knowledge of geochemistry on environmental health because of the widespread awareness of medical geology issues [3]. The challenges in the attainment of internationally agreed goal on good health and wellbeing may be due to lack of attention to environmentally- related- diseases. Ghana has made some progress in achieving some of sustainable development goals (SDGs) but it is yet to achieve the SDG 3, which seeks for good health and wellbeing for all. The published records in the past decade show a growing interest in the role of trace elements in human health and disease [17]. Extensive publications have been published on the effectiveness of addressing environmentally-related-diseases. The articles emphasized the applications of geochemistry and environmental health sciences on trace elements impacts in relationship to public health [17]. Other evidences sit with the regulatory frameworks that the EPAs have sponsored through several conferences that dealt in large part with defining more precisely how trace elements, especially in drinking water, affect human health [4].

II. Case Study Area: Location, Physiography, Geology, Trace Elements and Health

Bongo District is near Bolgatanga the Upper East regional capital. It is 799.6 km from Accra and 559.0 km from Kumasi (Fig. 1) along a first class road. The area falls into savannah grassland and exhibits single rainy season. The monthly totals of rains increase slowly from March and peak in August after which there is an abrupt decrease after October [10]. The average monthly rainfall is 986 mm per month. The area is characterised by constantly high temperatures that averages at 28.6℃ with some monthly variabilities. Occasionally, at the peak of the rainy seasons especially in August, monthly temperatures averages range from 26.4℃ and it increases to an extreme value of ≥32.1℃ in April [7]. These are common for the tropics, diurnal temperature changes exceed monthly variations [7].

The Bongo area forms part of the Bole-Navrongo-Nangodi Birimian Greenstone Gold Belt of Ghana (Fig. 1) with the rocks generally trending northeast-southwest [9]. Rocks underlying the Bongo District are metamorphosed lavas and pyroclastic suite of rocks intruded at places by granodiorites [11]. According to Milési *et al.*[14], three types of granitoids intrude the underlying rocks. The intrusive rocks are Belt, and Basin granitoids, which intrudes the volcanic and the metasedimentary units respectively. A third intrusive body, much younger than the Basin types also intrudes the basinal sedimentary rocks. The younger granitoids-group is very coarse grained with a large composition of potassium feldspars, it is identified only in the region and hence a type locality name of Bongo granitoids. The first two intrusive bodies arecomposed of hornblende, biotite, plagioclase feldspars and other accessory minerals in the case of the belt-type granitoids. The basin-type granitoids on other hand is composed largely of potassium feldspar, biotite, and muscovite together with some accessory minerals. These intrusive bodies are coarse to medium grained. However, the most prominent outcrops in the area are the potash-rich granitoids.

Fig. 1: Location Map of Bongo (Map source: www.mapmaker.com)

The Balungu River Basin in Bongo District serves as a fertile agricultural land for vegetables and cereals cultivations. The inhabitants eat what is cultivated and sell the surplus for their upkeep. The concentration levels of trace elements containing essential and potentially harmful elements (PHE) that may have adverse health effects on the life of people have not been assessed to determine the possible risk of exposures to human health. The insufficient data on the potentially harmful trace elements and deficiencies of essential elements in crops cultivated in the area in terms of types of elements and their concentration levels can lead to widespread sprout of non-communicable-diseases These reasons necessitate the contamination and ecological risk assessments of trace elements in Balungu River Basin sediments and soils against any public health epidemics because they eat what grow.

III. Resource and Method Use

53 soil samples were collected on 200 m x 100 m grid at the Balungu River Basin. The top 10 cm of the sampling points were removed to avoid any chemical interactions with the humus. The next 20 cm of the *in situ* materials were collected as samples. The collected samples were sun dried for 24 hours and later sieved to 2 mm size fraction. Unique sequential sample numbering system was applied. Out of the 53 samples; 3 were field duplicates that were used to assess the precision of the analytical data. Three field duplicates were inserted in the batch of samples sent to the laboratory. These samples were analysed using XRF techniques. At the laboratory, each sieved sample was milled to powder. Seven (7) grams of the milled powder was placed into a small plasticbeaker and weighed with a beam balance. Pressed pellets were formed from the powdered mixture (the powdered mixture was the sieved sample and a binding material) and were placed in the XRF machine connected to a computer with a Spectro X-Lab software which records the elements analysed. 51 suite of elements were analysed by the XRF analyticalmethod but only As, Pb, Cr, Co, Cu, Mn, Mg Ni, Ba, K and Zn were discussed in the study because insignificant concentrations often below detection limits were recorded for many of the elements.

Pollution load and Geo-accumulation indices were calculated for the 11 listed elements for the 50 stations sampled to assess pollution status at the investigated areas. The 11 elements included some known toxic trace elements, essential element and non- essential elements. Pollution load index (PLI) for the area was evaluated using Tomlinson *et al.*[18] method. This method employs the formula:

$$PLI = \sqrt[n]{CF1 * CF2 * CF3 \ldots \ldots \ldots \ldots \ldots \ldots CFn} \quad (1)$$

Where: n = number of metals and CF is contamination factor.

The contamination factor CF is also calculated as

$$CF = \frac{\text{Metal concentration in sample}}{\text{Background values of the metal in sample}} \quad (2)$$

Chakravarty and Patgiri[5] interpret PLI value > 1 as polluted terrain while PLI value < 1 is considered an unpolluted terrain. The PLI do not rank the degree of pollution of the area. Since this work aimed at averting any possible public health issues from element exposures; Geo-accumulation index (Igeo) that ranks the pollution grade was also calculated using Muller [15] technique that employs the formula:

$$Igeo = \text{Log } 2[Cn/1.5Bn] \quad (3)$$

Where: Cn is measured concentration of element n in sample; Bn is globally accepted geochemical background for element n in sample.

The interpretation of pollution grades were obtained using Muller [15] classification scheme (Table 1) that relates the Igeo classes to calculated the Igeo values:

TABLE I
Muller's (1969) Igeo Classes used to Classify Igeo Calculated Values

Class	Value	Soil Quality
0	Igeo<0	Practically uncontaminated
1	0<Igeo<1	Uncontaminated to moderately uncontaminated
2	1<Igeo<2	Moderately contaminated
3	2<Igeo<3	Moderately to heavily contaminated
4	3<Igeo<4	Heavily contaminated
5	4<Igeo<5	Heavily to extremely contaminated
6	5<Igeo<6	Extremely contaminated

IV. Results and Discussion

The results obtained for the 11 elements from the 50 sample stations showing the summary statistics are presented in Table 2. Tables 3 and 4 represent PLI and Igeo information of the 11 elements respectively and portray the pollution status in the study area. Contamination factors (CF) for the respective sample stations are in Table 3.

TABLE II
Summary Statistics

Sample	Min	Max	Median	Mean	SD	Bn
As	1.90	18.60	6.65	6.89	3.62	10.00
Ba	0.00	935.00	263.00	305.14	1.18	580.00
Co	2.90	19.70	8.90	8.26	4.02	9.10
Cr	6.90	174.60	20.95	37.23	35.69	8.26
Cu	3.90	34.90	11.90	13.41	6.90	25.00
Mn	54.00	665.00	287.50	302.96	131.43	550.00
Ni	4.60	34.8	1.85	14.36	5.88	19.00
Pb	2.90	11.40	3.80	4.54	2.07	19.00
V	33.00	118.00	52.00	58.14	19.38	80.00
Zn	18.70	44.10	26.45	27.24	5.36	60.00

Min=Minimum; Max = Maximum; SD = Standard Deviation; Bn= Background Value

Demonstration of contamination and ecological risk pertaining to the investigated area are again presented in Tables 3 and 4. Figures 2 and 3 use the median in the box plots as its centre value to give a brief picture of other importantdistribution values such as the minimum, maximum, the lower and upper quartiles and the median in the data set. The whiskers of the box plots show the minimum and maximum points of the data with the median line between the lower and upper quartiles.Figure4 demonstrates different characteristics of elements behaviour in a sample at a place, drawing attention to variable geochemical associations and concentrations. Elements exhibiting excesses and depletions in the measured concentration levels in the samples relative to background averages of worldwide accepted values are shown in Figs. 5and 6. The stations with concentration levels above and below the worldwide background limits are deductible in Figs. 5 and 6. The distribution of population sets in the data with likely ecological risk can be observed in Figs. 5 & 6. So are the estimates of sample stations with contamination and ecological risk concerns based on element types can be given a better insight from Figs. 5 and 6.

TABLE III
Calculated Values of Contamination Factors (CF) and Pollution Load Index (PLI) at Balungu River Basin

Sample ID	As (ppm)	CF	Cr (ppm)	CF	Pb (ppm)	CF	Cu (ppm)	CF	Mn (ppm)	CF
0803B/A-H05	8.2	0.82	11	1.33	5	0.26	25.7	1.03	452	0.82
0803B/A-H06	3.6	0.36	107	12.95	5.1	0.27	9.2	0.37	537	0.98
0803B/A-H07	8.1	0.81	94.3	11.42	6.4	0.34	8.9	0.36	326	0.59
0803B/A-H08	3.6	0.36	28.3	3.43	6.6	0.35	13	0.52	377	0.69
0803B/A-H09	6.7	0.67	11	1.33	7.1	0.37	10.3	0.41	369	0.67
0803B/A-H10	3.3	0.33	30	3.63	3.6	0.19	10	0.4	158	0.29
0803B/A-H11	2.3	0.23	65.5	7.93	2.9	0.15	14.2	0.57	275	0.5
0803B/A-H12	7.1	0.71	9.4	1.14	6.1	0.32	13.1	0.52	311	0.57
0803B/A-H13	4.8	0.48	69.8	8.45	5.8	0.31	11.9	0.48	178	0.32
0803B/A-H14	3.9	0.39	72.4	8.77	2.9	0.15	10.2	0.41	287	0.52
0803B/A-H15	2.7	0.27	45.9	5.56	2.9	0.15	19.6	0.78	423	0.77
0803B/A-H16	6.2	0.62	11	1.33	3.8	0.2	21.1	0.84	147	0.27
0803B/A-H17	2.4	0.24	49.3	5.97	2.9	0.15	25.2	1.01	239	0.43
0803B/A-H18	3.8	0.38	43.3	5.24	4.2	0.22	16.9	0.68	253	0.46
0803B/A-H19	4.4	0.44	11	1.33	2.9	0.15	11.6	0.46	227	0.41
0803B/A-H20	7.4	0.74	11	1.33	5.3	0.28	11.2	0.45	315	0.57
0803B/A-H21	7	0.7	66.9	8.1	3.2	0.17	7.9	0.32	122	0.22
0803B/A-H22	11.7	1.17	51.5	6.23	5.4	0.28	20.1	0.8	199	0.36
0803B/A-H23	10.7	1.07	11	1.33	3.5	0.18	10.7	0.43	316	0.57
0803B/A-H24	7.8	0.78	85.4	10.34	2.9	0.15	6.1	0.24	54	0.1
0803B/A-H25	12.5	1.25	55.9	6.77	2.9	0.15	17.5	0.7	275	0.5
0803B/A-H26	14.7	1.47	42.1	5.1	4.9	0.26	34.9	1.4	364	0.66
0803B/A-H27	11	1.1	12.2	1.48	3.5	0.18	15	0.6	327	0.59
0803B/A-H28	14.7	1.47	11	1.33	3.4	0.18	13.8	0.55	282	0.51
0803B/A-I01	3.5	0.35	11	1.33	8.3	0.44	4.7	0.19	410	0.75
0803B/A-I02	7.9	0.79	11	1.33	9.4	0.49	6.6	0.26	445	0.81
0803B/A-I03	4	0.4	82	9.93	2.9	0.15	11.9	0.48	542	0.99
0803B/A-I04	6.6	0.66	11	1.33	11.4	0.6	17.1	0.68	665	1.21
0803B/A-I05	4.8	0.48	11	1.33	3	0.16	4.8	0.19	392	0.71
0803B/A-I06	5.1	0.51	11	1.33	11.3	0.59	13.7	0.55	578	1.05
0803B/A-I07	4.3	0.43	36.4	4.41	4.6	0.24	10	0.4	137	0.25
0803B/A-I08	7.1	0.71	9.2	1.11	4.5	0.24	12.9	0.52	330	0.6
0803B/A-I09	7	0.7	11	1.33	6	0.32	9.7	0.39	223	0.41
0803B/A-I10	1.9	0.19	7.2	0.87	2.9	0.15	4.6	0.18	316	0.57
0803B/A-I11	3.8	0.38	17.4	2.11	5.9	0.31	27.2	1.09	470	0.85
0803B/A-I12	8.1	0.81	11	1.33	4.3	0.23	13.8	0.55	71	0.13
0803B/A-I13	5.3	0.53	130.6	15.81	2.9	0.15	3.9	0.16	146	0.27
0803B/A-I14	8.1	0.81	11	1.33	2.9	0.15	12.4	0.5	459	0.83
0803B/A-I15	2.2	0.22	23.6	2.86	2.9	0.15	14.6	0.58	498	0.91

0803B/A-I16	6.4	0.64	23.5	2.85	4.8	0.25	27.2	1.09	205	0.37
0803B/A-I17	6.2	0.62	11	1.33	2.9	0.15	8.4	0.34	288	0.52
0803B/A-I18	8.9	0.89	11	1.33	4.5	0.24	10.2	0.41	210	0.38
0803B/A-I19	7.6	0.76	58.8	7.12	4	0.21	6.1	0.24	186	0.34
0803B/A-I20	9.8	0.98	63.6	7.7	2.9	0.15	4	0.16	182	0.33
0803B/A-I21	3.3	0.33	174.6	21.14	2.9	0.15	7.5	0.3	172	0.31
0803B/A-I22	3.2	0.32	18.4	2.23	2.9	0.15	7.4	0.3	252	0.46
0803B/A-I23	11.5	1.15	6.9	0.84	3.4	0.18	14.2	0.57	270	0.49
0803B/A-I24	9.6	0.96	11	1.33	2.9	0.15	11.2	0.45	269	0.49
0803B/A-I25	18.6	1.86	43	5.21	3.8	0.2	22.4	0.9	297	0.54
0803B/A-I26	10.9	1.09	38.9	4.71	5.7	0.3	25.9	1.04	322	0.59
Background(Bn)	**10**		**8.6**		**19**		**25**		**550**	
PLI	**0.6**		**2.99**		**0.22**		**0.47**		**0.49**	

TABLE IV
Calculated Values of Geo-accumulation Index (Igeo) at Balungu River Basin

Sample ID	As (Cn-ppm)	Cr (Cn-ppm)	Pb (Cn-ppm)	Cu (Cn-ppm)	Mn (Cn-ppm)
0803B/A-H05	8.2	11	5	25.7	452
0803B/A-H06	3.6	107	5.1	9.2	537
0803B/A-H07	8.1	94.3	6.4	8.9	326
0803B/A-H08	3.6	28.3	6.6	13	377
0803B/A-H09	6.7	11	7.1	10.3	369
0803B/A-H10	3.3	30	3.6	10	158
0803B/A-H11	2.3	65.5	2.9	14.2	275
0803B/A-H12	7.1	9.4	6.1	13.1	311
0803B/A-H13	4.8	69.8	5.8	11.9	178
0803B/A-H14	3.9	72.4	2.9	10.2	287
0803B/A-H15	2.7	45.9	2.9	19.6	423
0803B/A-H16	6.2	11	3.8	21.1	147
0803B/A-H17	2.4	49.3	2.9	25.2	239
0803B/A-H18	3.8	43.3	4.2	16.9	253
0803B/A-H19	4.4	11	2.9	11.6	227
0803B/A-H20	7.4	11	5.3	11.2	315
0803B/A-H21	7	66.9	3.2	7.9	122
0803B/A-H22	11.7	51.5	5.4	20.1	199
0803B/A-H23	10.7	11	3.5	10.7	316
0803B/A-H24	7.8	85.4	2.9	6.1	54
0803B/A-H25	12.5	55.9	2.9	17.5	275
0803B/A-H26	14.7	42.1	4.9	34.9	364
0803B/A-H27	11	12.2	3.5	15	327
0803B/A-H28	14.7	11	3.4	13.8	282
0803B/A-I01	3.5	11	8.3	4.7	410
0803B/A-I02	7.9	11	9.4	6.6	445
0803B/A-I03	4	82	2.9	11.9	542
0803B/A-I04	6.6	11	11.4	17.1	665
0803B/A-I05	4.8	11	3	4.8	392

0803B/A-I06	5.1	11	11.3	13.7	578
0803B/A-I07	4.3	36.4	4.6	10	137
0803B/A-I08	7.1	9.2	4.5	12.9	330
0803B/A-I09	7	11	6	9.7	223
0803B/A-I10	1.9	7.2	2.9	4.6	316
0803B/A-I11	3.8	17.4	5.9	27.2	470
0803B/A-I12	8.1	11	4.3	13.8	71
0803B/A-I13	5.3	130.6	2.9	3.9	146
0803B/A-I14	8.1	11	2.9	12.4	459
0803B/A-I15	2.2	23.6	2.9	14.6	498
0803B/A-I16	6.4	23.5	4.8	27.2	205
0803B/A-I17	6.2	11	2.9	8.4	288
0803B/A-I18	8.9	11	4.5	10.2	210
0803B/A-I19	7.6	58.8	4	6.1	186
0803B/A-I20	9.8	63.6	2.9	4	182
0803B/A-I21	3.3	174.6	2.9	7.5	172
0803B/A-I22	3.2	18.4	2.9	7.4	252
0803B/A-I23	11.5	6.9	3.4	14.2	270
0803B/A-I24	9.6	11	2.9	11.2	269
0803B/A-I25	18.6	43	3.8	22.4	297
0803B/A-I26	10.9	38.9	5.7	25.9	322
Background(Bn)	**10**	**8.6**	**19**	**25**	**550**
Igeo	**0.14**	**0.9**	**0.05**	**0.11**	**0.11**

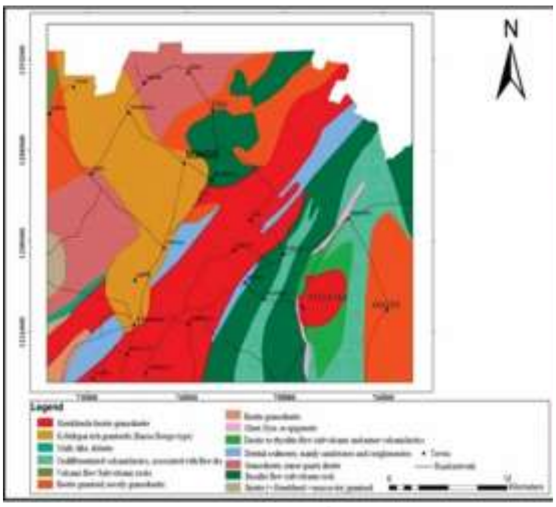

Fig. 2: Bongo Geology

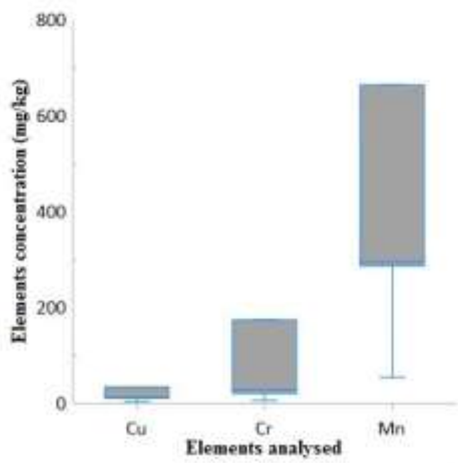

Fig. 3: Boxplot of Essential Trace Elements

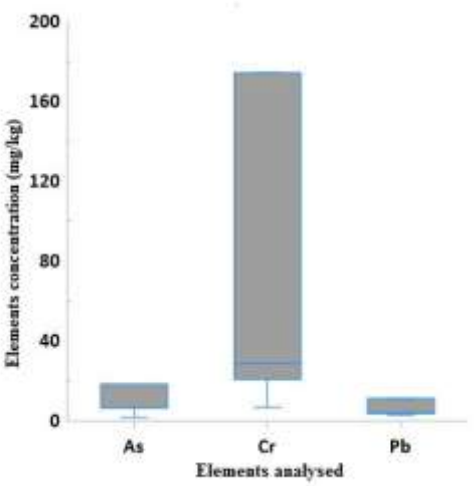

Fig. 4: Boxplot of Known Potentially Harmful Elements

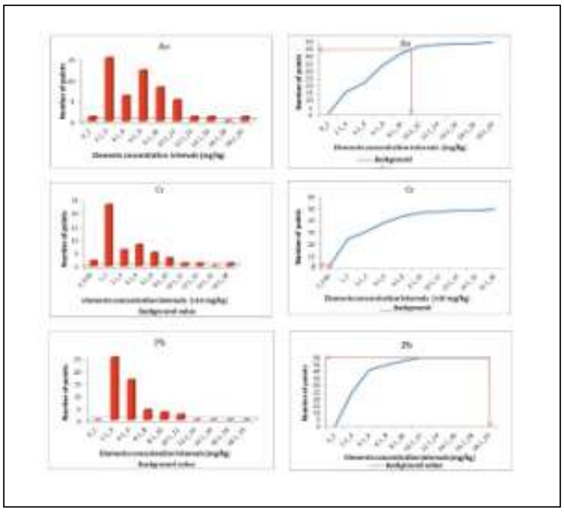

Fig. 5: As, Cr and Pb Comparison with Background Averages

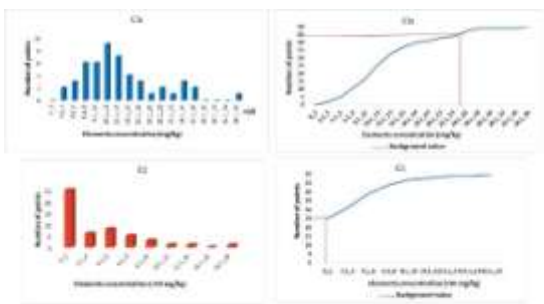

Fig. 6: Copper and Cr Comparison with Background Averages

The integrity of the laboratory results were considered precise and good to work with because there were insignificant difference between the original sample and its corresponding duplicates concentration values. For example in Table 2, the average measured concentrations of elements investigated have average values lower than the global accepted background averages measured by Turekian and Wedepohl [19]. The only exception was Cr that recorded 37.2 mg/kg measured average value compared to the global background average of 8 mg/kg. This is a fact from the available data and that the consequences from their departure from the norm may occur. Also the standard deviations (SD) from the measured means appear generally low with the exception of Ba and Mn. The low standard deviations as seen in Table 2 indicate that the spread of measured concentrations of elements distance from the means are not far. This makes the comparison of the measured averages appropriate to compare with the worldwide background averages of elements and the vice versa. The elements excesses and deficiencies make it prudent to assess the contamination and ecological risks of population that may be exposed to the toxic and essential elements. The impact of elements exposures depend on factors such as the degree and extent of exposure, type of element exposed to, as well as the exposure pathways.

The Balungu River Basin is known for its crop farming activities and thus ingestion and dermal contact may be the main pathways of elements uptake. The simple analysis of the measured averages and background averages for Cr shows a percentage increase of Cr in soils to be in the excess of > 100%. This level may be too high and dangerous if exposed to and should be of public health concern. Cr generally is an isotopic element, which occurs in several oxidation states in the environment ranging from Cr^{2+} to Cr^{6+}. Among the Cr isotopes, it is only Cr (VI) that has been found to be toxic for humans [8].Other several research indicates that Cr (VI) exposure can be detrimental to human health. Some of the related diseases of Cr toxicity are respiratory, gastrointestinal, immunological, haematological, reproductive, and developmental problems [21]. Conversely, Cr (III) has also been identified as an essential nutritional supplement for animals and humans and thus plays an important role in glucose metabolism. The insufficient information on Cr at the Balungu River Basin makes it indispensable to conduct chemical speciation analysis because of the dual and different functions of Cr (VI) and Cr (III) respectively. Correspondingly, there are some essential elements that the human body need for physiological functions for development but the measured averages seemed lower than the background averages. Examples from Table 2 are essential elements Cu, Mg, Mn that markedly showed deficiency in the current study. Toxic elements such as As and Pb also depicted deficiencies. Areas deficient in essential elements may pose some kind of future health risk as the area is a mark out area for farming. Crops cultivated there may not have enough essential micronutrients because the health of soils impact their characteristics to crops cultivated there.

Alternatively, dangers associated with toxic element uptake may not be an issue in terrains with deficient As and Pb. Fig. 2 also confirms the information in the summary statistics and showed all elements analysed to be deficient except Cr.

Tables 3 and 4 provided indication that the PLI and Igeo values for all the elements except Cr fall in class '1' at all the sampling locations. Thisindicates that there is no pollution for ten elements except 1 at the Balungu River Basin soils and sediments. The index analysis also found the Igeo values to be consistent with those derived for PLI (Figs. 5 and 6). The results from Figs. 5 & 6 as well as Tables 3 & 4 portrayed elements As Ba, Co, Cu, Mg, Mn, Ni and Pb to have measured average concentrations below the worldwide background averages. This was deemed not to be good for some aspects of human development. Revelations in environmental geochemistry studies and health had shown the need to maintain some levels of essential elements for our wellbeing while those identified to be harmful should be prevented from getting access to the human system. But from Tables 3 and 4, the overall pollution grade is no-pollution at all stations for As Ba, Co, Cu, Mg, Mn, Ni and Pb but there are some stations that displayed evidence of contamination at some local station. Demonstration of element deficiencies and excesses are further presented in Figs. 2-6 where elements concentrations are not fixed but depict different concentration levels in the same geological and geochemical province.

A. Health Implications of Elements Studied at Balungu River Basin

Out of the 11 elements interpreted with respect to human health on trace elements exposures, K and Mg are nutritionally important minerals. Mg supports bone and membrane structure, whilst K aids in water and electrolyte balance. Cr, Co, Cu, Mn and Zn are known essential trace elements that play significant physiological functions in human wellbeing. For instance Cr (III) plays part in metabolism of sugar whilst Co is a constituent of Vitamin B-12, and Cu is involved in metabolism and production of haemoglobin, Mn is also involved in bone growth and metabolism whilst Zn is important for body growth and also plays part in the immune system. However, despite the important physiological functioning of these elements on human development; the dose should not exceed a particular limit.

Balungu River Basin, the cultivated land showed total Cr enrichment with PLI value of **2.99** and Igeo value of **0.78.** Calculation done using Tomlinson *et al.*[18] technique to assess ecological risk areas in the Basin found the area to be polluted but could not divulge the degree of pollution. Since the degree of pollution is an important factor in devising mitigation techniques, the Igeo was computed to compliment the result of the PLI. The result of the Igeo indicated that the Basin pollution ranges from uncontaminated to moderate contamination. Cr occurs in several oxidation states in the environment ranging from Cr^{2+} to Cr^{6+}. Cr (III) is a known essential nutritionalsupplement for animals and humans and has an important role in glucose metabolism but Cr (VI) has been found to be toxic to humans [8]. The normal yearning for excess concentrations of essential elements in soils really do not apply to Cr because of its double-edged characteristics. Until chemical speciation analysis is done to confirm the type of Cr-isotope in the basin, the threat of unintentionally ingesting and inhaling Cr remains in the area. This implies that the ecological risk of Cr cannot be overruled because the uptake of Cr (VI) compounds through inhalation and ingestion is faster than that of Cr (III) compounds. The other essential elements useful for human developments are Cu, Mg, Mn, Zn, Co. The source of these elements to the population is through diets. The poverty levels in the area make it challenging for them to acquire the essential elements by purchasing food supplements. The good health and wellbeing of people depends on the concerted contributions of the essential elements but as seen in tables 3 and 4, the essential elements show depletion in the soils. Therefore, this is of great public health concern because epidemiological studies [17] had shown the absence or deficiency of a single essential element requirement in human physiological process may lead to health problems. Hence if the study area shows deficiencies of these essential elements then diseases related to their deficiencies will be prevalent. For instance, Balungu River Basin with PLI value of **0.15** and Igeoof **0.04** for Cu suggest Cu depletion in soils. Balungu River Basin with PLI value of **0.15** and Igeoof **0.04** for Cu suggest Cu depletion in soils. Cu uptake from soils by crops cultivated in this Basin, when eventually ingested by animals and humans may have insufficient concentrations for essential physiological functions. The under absorption of Cu from the environment by the crops would pose health problems to the consumers because it is needed for various body functions such as enzymatic and metabolic processes both in adult and children alike. It combines with proteins to produce enzymes that act as a catalyst to boost biological processes. It is also believed to be responsible for the formation of the pigment melanin and consequently contribute to skin pigmentation. Cu subsequently plays part in the formation of bone and connective tissue while maintaining the integrity of the myelin sheath of nerve fibres. Epidemiological studies had further shown that Cu deficiencies can result in anaemia, pancytopenia, and ataxia. Similarly, the deficiencies of the other essential elements such as K, Mg, Mn, Zn, Co and V. Potassium (K) plays a role in biological processes and works with other essential trace elements in general physiological roles. It is important for water and electrolyte balance and is a major cation of intracellular fluid.It regulates intracellular osmotic pressure and acid-base balance. It also has a stimulating effect on muscle irritability as well as playing part in glycogen and protein synthesis plus the metabolic breakdown of glucose. This essential element that is deficient in Balungu River Basin plays many roles in the bodies of human beings. The good health expectancy by people that consume food from this Basin will be impaired because of its deficiency. Similarly, Co the vital element of vitamin B12 is deficient in Balungu River Basin. This element is required in the human system and works contemporaneously with the vitamin to form a compound called cobalamin. The formed compound is important for preventinganaemia while assisting in red blood cell production. Co contributes in regulating some enzymes as well as promoting a healthy nerve function. The human brain needs Co in the form of cobalamin to maintain the protective 'sheet' covering the brain called meninges. Researches have linked lack of cobalt to increase risks of anaemia, heart disease, diarrhoea, and various nerve-related dysfunctions. The other essential element Mn, is not likely to be enriched in the cultivated food crops because of its deficiency in the soils. It is apparent that the health of soils determines the health of people who depends on the soils in their environment for food and water. The population around the study area consumes food crops from this Basin. Therefore, it can be deduced that the population here may be lacking the essential functions of Mn as an antioxidant, etc. in their body.Right amount of Mn in the body may help to regulate blood sugar levels in diabetics and may improve neurological disorders as well. Lack of manganese can lead to Hypertension (high blood pressure), bone malformation, infertility, and serious memory loss. The only essential element that has known anti-carcinogenic property vanadium (V) [6] is also deficient in the environmental soils at the Basin. Its deficiencies in humans can lead to slow growth, increased infant mortality, infertility, elevated cholesterol, elevated triglycerides, hypoglycaemia, hyperinsulinemia, diabetes, cardiovascular disease, obesity. From Tables 3&4 and Fig. 5, Zn is also deficient in the area, with PLI of **0.45** and Igeo of **-0.22**. This element helps in antioxidant protection, regulation of thymulin. Adequate amount of zinc is essential in maintaining immune system function. But from Tables 3 and 4 Zn deficiency diseases such as complications of pregnancy and childbirth, low birth weight and poor growth in childhood and increased infectious disease morbidity may not be uncommon. The dangers of Zn-deficiencies has been identified by many researchers; it has been linked to several health problems such as premature labour and miscarriages in pregnant women, inefficient labour and delivery, stillbirths, lowmental ability in children, retarded foetal growth and low immunity of both mother and baby. The presence of essential elements has proven to be vital to the health of humans; therefore, effective monitoring and maintenance of their concentration levels at source (thus in soils sediments and water) needs to be monitoring at all times. Diseases emanating from their deficiencies and excesses are preventable through proper monitoring, this act of prevention can help avert many public health epidemics.

On the contrary, As and Pb are toxic trace elements, they are harmful to life processes at any concentration. Their deficiencies in the study area are lifesaving as the reported concentrations cannot have negative effects on the functioning of the heart, kidney, fertility and the nervous system. The PLI and Igeo of As are PLI<1 (**0.60**) and Igeo≤0 (-0.04). These calculated concomitant PLI and Igeo values suggest unpolluted As environment and as such might minimize the risk of As-related diseases among the population. Although no pollution has been identified for the area using PLI and Igeo techniques but from Table 3, certain stations are identified to be polluted and this requires some attention. Nine out of the 50 stations showed slight contaminations and long term exposures can lead to chronic As-related health issues. The prevalence of As-related diseases such as cancer of the skin, lungs, bladder and kidney, gastrointestinal symptoms involving severe vomiting, disturbances of blood and its circulation, damage to the nervous system, and eventually death (Arhin et al., 2016) may be absent. The other toxic element that showed no pollution as indicated by PLI<1 (**0.22)** and Igeo≤0 (**-0.50)** values are Pb. This element is known to disrupt various plant physiological processes. The results displayed in Figs. 3-5, Tables 3 and 4 shows the impossibility of acute exposure to Pb to cause loss of appetite, headache, hypertension, abdominal pain, renal dysfunction, and fatigue. Chronic exposure of lead can result in mental retardation, birth defects, psychosis, autism, allergies, dyslexia, weight loss, hyperactivity, paralysis, muscular weakness, brain damage, kidney damage and may even cause death [13].

In addition to risks of essential and toxic elements deficiencies and toxicities impact on human health, some health issues are also attributable to non-essential elements. Example of a non-essential element found to be deficient in this study was Ni. The PLI value calculated was **0.70** and the Igeo was **0.003219**. This element is active in many chemical reactions, but it is not been clearly identified as an essential element in humans. No metabolic or biochemical function has been identified for it in higher animals. However, it isfound in many tissues where it interacts actively with other elements/metals, vitamins and proteins. Its deficiency in the study area is good sign contrary to the deficiencies of the essential elements because the body needs very small amounts for its functions in the body. Ni is used for increasing iron absorption, preventing iron-poor blood (anaemia), and treatment of weak bones (osteoporosis).

V. Conclusions

The Balungu River Basin sediments and soils contain essential, non-essential and toxic trace elements. Besides toxic elements whose exposure at high levels can cause adverse health effects on life, all the other elements play an important role in the wellbeing of humans. The sources of these groups of elements coexist in minerals that make up the rock, the foundation block of the earth and the host of all terrestrial life. Isolating the toxic elements from the essential elements in soils is practically impossible but the concentration levels can be monitored beyond its trigger points to avert possible health impacts from its exposure. The research found the potentially harmful elements As and Pb deficient as well as the essential (Cu, Co, Mn, Zn, Mg, K and V) and non-essential element (Ni). The only essential element with excess concentrations beyond the worldwide accepted background value is Cr, which exist in several oxidation states. Cr (III) is known essential nutritional supplement for animals and humans and has an important role in glucose metabolism meaning could help in controlling diabetes if sufficient amount of it is obtained through diets. Conversely, Cr (VI) has been found to be toxic for humans and can be lethal on toxic exposures. This investigation was not set for isotope speciation and thus conclude that isotope studies be done to know the type of Cr-isotope in the area. Total Cr is measured in this study and it will be to the advantage of the population if the speciation test shows enriched Cr (III) instead of Cr (VI) but will be disadvantageous if Cr (VI) is the dominant type. Another revelation was the general deficiency of essential elements that the human body needs for its development. Many of the essential elements found deficient in the study have links to some common diseases. Example Fe and Cu deficiency can cause anaemia, Cr (III), Mn, Mg and V regulate blood glucose and their deficiencies can cause diabetes and hypertensions. Observations at cardiac clinics in Ghana confirm the huge numbers of patient diagnosed to be suffering from a cardiac related illness. Although these diseases are non-communicable, they can affect millions of people and have negative impacts on the community just like communicable diseases. Remedies to control deficiencies of essential elements related diseasesand toxicity of potential harmful elements related diseases dwell in the ability to assess the ecological risks of all trace elements. In conclusion, the authors recommend the use of index-analysis approach to define and outline the risk areas for proper mitigation of the identified risk in order to avert the associated public health epidemics. Additionally, further analysis on how to improve or supplement the level of essential elements that are inadequate in the study area; adequate amounts of essential elements plays vital role in the health of individuals and the community as a whole, as such the low levels in the area should be of public health concern.

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