Hotspots Analysis of Trace Elements in Areas Affected by Illegal Mining Activities: A Case Study at Mpatoam in Amansie West District of Ghana

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Abstract

Elements distributions and concentration levels in surface environments are able to reveal spatially terrains enriched in disease-causing-elements and essential elements deficiency areas. Both scenarios of elements toxicities and deficiencies have health implications to humans. The study area has seen numerous illegal mining operations that will influence elements mobility and concentrations. 25 samples including field duplicates were collected at the alluvial plain areas with controlled samples at the elevated area embankment. The samples were analysed using XRF techniques and the results processed using multivariate factor analysis. PCA 1 representing As-group has relationship to the underlying geology. It thus suggested that As and Cr toxic in kind have their source link to the geology whose spread are facilitated by mining activities. PCA 2 contains essential elements whose sources are from the local geology. The results of the surface geochemistry in comparison with the continental crustal averages (Bn) showed the toxicity of As, Cr, V, Zr, Ni and Mo from the CF and PLI analysis. These also showed Cu, Zn, Pb, Rb, Sr, Ba and Nb were deficient. Igeo value for As indicated moderate pollution while the 12 other elements were marked as unpolluted. The spatial maps for As transformed data indicated Hotspots for As and Cr at all points with highest values from active points for As. Zn generally indicated cold-spots. Disease-causing elements based on their distribution and levels in the area will affect the health of the people which calls for further investigation on water and food crops in the area.

Keywords – *Hotspots, Mining, Potentially toxic elements, Essential trace elements, Public health.*

I. Introduction

Concentration levels of elements in surface soils varies across landscapes and these are attributable to the local activities, the atmospheric depositions and mineral compositions that make up the local underlying rocks in a geographic position [3]. The distributions and concentrations of elements in the surface environment are facilitated by geologic processes. Some of the processes break down the rocks and releases the elements in the natural environment. From Arhin et al.[3] the released elements could be essential and toxic on exposure to human and animal wellbeing. Natural and anthropogenic processes redistribute and re-concentrate elements that consequently impact on the natural environment directly or indirectly on public health. Many studies have shown the link between the elements and various health implications. For example skin disorders from exposure to arsenic [14], gastrointestinal tract diseases from high exposure to lead [20], brain and kidney cancers have link with high exposure of mercury [1], kidney diseases, fragile bones and lung damage have an association to h high exposure to cadmium [5] and exposure to high levels of chromium results in DNA damage [22]. Most cardiac diseases have been identified to have connections with toxic exposures to As and deficiencies of some essential elements such as Mg.

Ghana a known gold mining country has most of the gold discoveries in terrains enriched with chalcophile minerals or sulphur minerals. These minerals include arsenopyrite, chalcopyrite, galena and spharilite that contain As, Cu, Pb, Zn, Cd, Hg etc. and are stable in the reduced environment but unstable in the oxidised environment. The abundance of water and the surficial processes contribute in the mobility of these elements in addition to those released from the underlying rocks through the process of weathering. This environment contains water and thus helps in the movement of the released elements. Other chemicals are introduced into the surface environments and in soils during the mining activities. This generally occurs during gold extraction processes. Again, during mining the subsurface get exposed and because of the changes in the physical environment become unstable and thus get transformed to become stable in the new environment. The spatial distributions of the elements are facilitated by these activities. The link between the earth, environment and health has been demonstrated to be the cause of many noncommunicable diseases whose impact is at the level of communicable diseases [24].

Good life and wellbeing is only not achievable through universal access to health-care but can be attained by preventing the exposure of disease-causing elements and promoting access to essential elements to humans. The key to this depends on the proper management of the elements concentration levels. On the basis of these, the authors attempted to evaluate the hotspots and cold-spots of trace elements that may impact negatively on health in areas affected by illegal mining activities at Mpatoam in Amansie West District of Ashanti Region.

II. Location, Geology and Physiographic Setting of Study Area

Mpatoam is a town located in the Ashanti region of Ghana (Fig. 1). The illegal mining site is located approximately 40 km northeast of the regional capital Kumasi. Travel time between Kumasi and Mpatoam is approximately 1 hour 30 minutes by car. The study area is reached by tarred and secondary lateritic roads.

The Mpatoam area is underlain by Birimian metasedimentary rocks, with lithologies such as shale, phyllites, siltstones, greywackes, and lesser feldspathic sandstones (Fig. 1). This package of rocks contains a system of gold-bearing quartz veins. The source of the auriferous gravel accumulations along the banks of the rivers and streams might have come from the deformed, altered and mineralized rocks in the area. The deposition of the alluvial materials contains diverse sediments and hence concentrations of elements in the catchment may have different concentrations levels and varying distribution patterns.

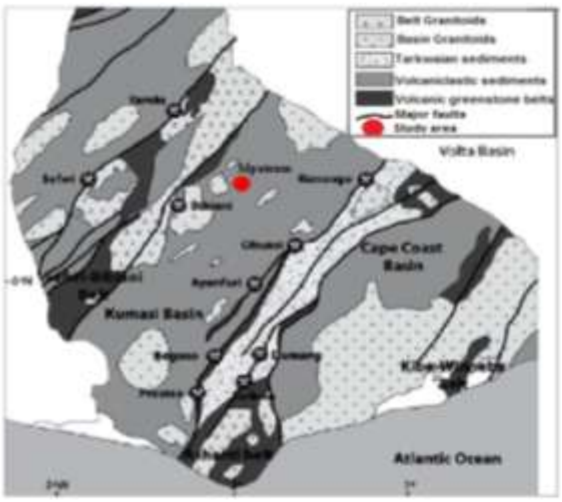

Fig. 1: Study Area

Mpatoam area is situated in rainforest belt with two seasonality of rainfall regime; a major season occurs between March and July while the minor season occurs between September and November. Mean annual rainfall ranges between 855 mm and 1,500 mm with average rainy days between 110 and 120 per year and high humidity characterizes the rainy seasons [11]. The dry season starts from December to March. These periods are characterized by high temperatures with occasional, early morning moist, fog and cold weather conditions. Temperatures are generally high throughout this season with a mean monthly temperature of about 27ºC with an accompanying very low humidity [11].

Characterizing the area is a thick forest with variable vegetation canopies. The vegetation canopies include timber, herbs of medicinal values and fuel wood with the associated undergrowth. Draining the area is Dekyi and Bonte streams and the common crop types include plantain, cocoyam, cassava, maize, legumes, oil palm, cocoa, coffee, citrus and pear [9]. The primary forest that use to have multiple vegetation cover forming different canopies has been degraded in several areas because of increased population, excessive and reckless logging of timber for export as well as unscientific and environmentally unfriendly mining activities.

III. Methodology

The materials used in identifying the hotspots and cold-spots of disease causing elements were field and laboratory work. Subjective or judgement sampling technique was used. This method collected sediments and soil samples across the alluvial plain and along the stream channel.The soil samples were taken in areas outside the active mining sites whilst the sediment samples occupied the main mining areas. Total of 25 samples were collected (Fig. 2); 17 were sediment samples, 3 were soil samples and five field duplicates were also included. The three soil samples were collected at the interface of base of hills and the alluvial plains. The sediment samples were scooped from three areas in the active mining areas using shovel into a plastic bag. 1000 g composite samples were made from the sub samples scooped within 4 km^2 space. The soil samples were taken using locally wedge chisel called ‘soso’. Nominal diameter hole of 30 cm were dug to 20 cm after which the next 10 cm material were collected as sample. The samples were given unique identification numbers in the field. These samples were placed in plastic bags with the unique identification numbers.

All the samples were sun dried for moisture content elimination. The dried samples were sieved to < 125 µm size fraction. They were then homogenized and using riffle splitter 100 g weight sample was collected and placed in a labelled kraft paper.

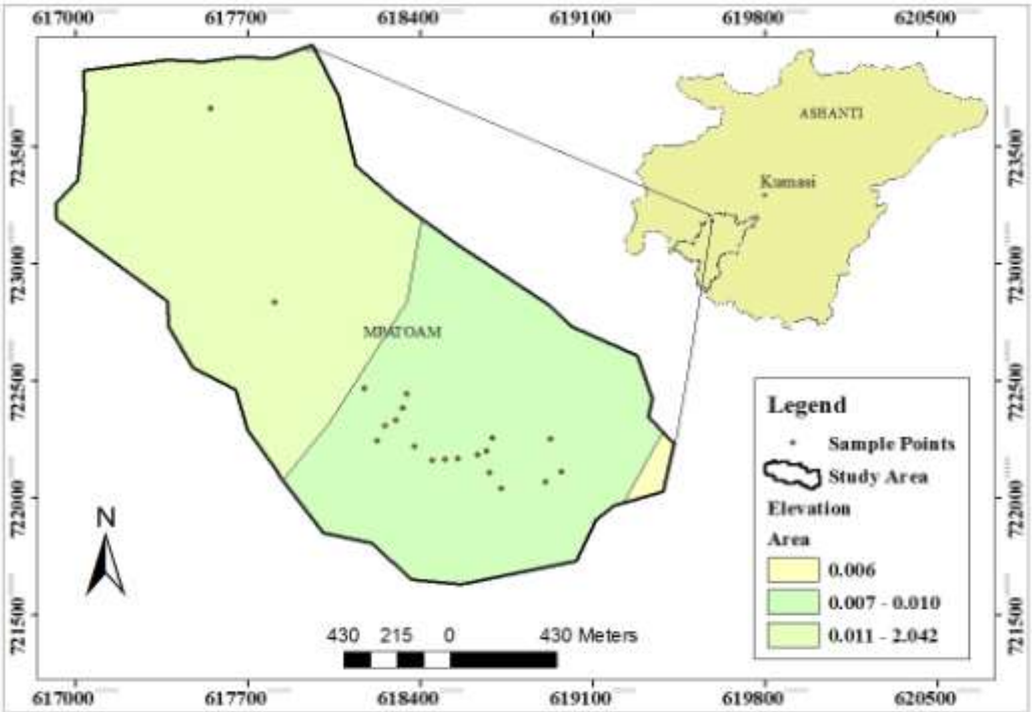

Fig. 2: Distribution of Sample Points in the Study Area

The labelled kraft papers with the sieved samples were sent to Kinross exploration laboratory for elemental analysis using XRF technique. Elements analysed include As, Cr, V, Zr, Ni, Mo, Cu, Zn, Pb, Rb, Sr, Ba and Nb. The results from the elements analysis were examined for the geochemical association using multivariate statistics. The principal component analysis (PCA) was performed on the elements. Other analysis performed on the results was the elements enrichments where the contamination factors were calculated. In addition, Pollution load indices, Geo-accumulation indices and the indicative areas based on pollution and depletion were also assessed. The method according to Muller [21] was used for the Igeo calculations shown below;

$$Igeo = \log 2[\frac{Cn}{1.5Bn}]$$

where Igeo = geoaccumulation index, C_n = measured concentration of the element in the sample and B_n = crustal averages of the elements.

The PLI values were also analysed using the Thomlinson pollution load index approach [2].

$$\text{PLI}= \sqrt[n]{(ConcF1).(ConcF2).(ConcF3)\ldots\ldots.(ConcFn)}$$

where PLI = Pollution Load Index for each sample, n = number of elements and (ConcFn) = (Cn/Bn), concentration factor of each element obtained by dividing the concentration each measured element in the sample (Cn) by the acceptable values of the elements in soils (Bn).

The Contamination Factor (CF) calculation as used by Arhin et al. [4] was as follows:

$$CF = Cn/Bn$$

where Cn is the measured average value of each element and Bn is the Crustal averages of the elements.

IV. Results

The concentration levels of the 13 elements are influenced by several factors. Some of the factors include soil formation processes, the environmental activities and characteristics of the underlying rocks. This makes it difficult to register same concentration levels across the landscape. To assess quickly the pollution status, it is prudent to summarise the descriptive statistics in a tabular form. Table I represent the summary statistics of all elements analysed in this study and shows the minimum, maximum, median, mean and standard deviation.

The mean concentration levels of the analysed elements were compared with crustal averages of same elements in uncontaminated soils (Fig. 3). Further calculations to identify stations based on contamination factors, pollution load and geo-accumulation indices are also presented in Tables II and III. There is an interrelationship among the elements in the soils as they coexist in the landscape and in space. The identification of the sources of the elements is very important in researches that relate to the earth, environment and health. Identifying the elements that loads well helps in distinguishing the elements that relates with the underlying rocks and those that have been introduced via anthropogenic sources can also be defined and outlined.

In this study multivariate statistics using factor analysis provided component matrix (Fig. 4) that showed elements linkages using PCA and the results pictorially presented as a Dendrogram (Fig. 5). The hotspot analysis was established for As, Cr and Zn that have human health implications. The selection was made because of their impact on human health. Example As is a known toxic element whose toxic exposure can cause cardiovascular diseases whilst Cr behaves like two edge sword depending on its oxidation state. Cr (VI) is a known toxic element but Cr (III) is essential for human development.

Total Cr requires speciation examination implying hotspot areas need attention. Zinc is an essential element, which human beings need. Geospatial mapping to outline and define these areas on elements concentrations relative to accepted baseline values are used to determine hotspots and cold-spots of diseasecausing elements. Results of elements concentration levels linked to geographical locations are presented in Figs. 6, 7 and 8.

V. Discussions

Assessment on the degree of impact of the environment in Ghana either uses continental crustal averages or global accepted values set up by world health organization (WHO) and other environmental protection authorities (EPA). The continental crustal averages are calculated from uncontaminated rocks and soils in pristine terrains. Obtaining non-contaminating soils this time of the fourth industrial revolution is very challenging because of chemical additions from atmospheric depositions and diverse environmental activities. The Fourth Industrial Revolution (4IR) is the fourth major industrial era since the initial Industrial Revolution of the 18th century. It is characterized by a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres, collectively referred to as cyber-physical systems. Climate change is an impact of Fourth Industrial Revolution. There is massive industrialization, rapid development in technologies, increased urbanization, excessive deforestation; limitless resource depletion, desertification, rapid population growth, water scarcity, food insecurity etc. are hampering the natural environmental balance of earth. The impacts from all these have influence on element release and mobilization. This makes it unrealistic to adopt background values using continental crustal values or legislated accepted values (baseline values) from regions or countries as the environmental activities may vary despite the similarities in the underlying rocks. As seen in Table I, 7 elements (As, Cr, Ni, V, Mo and Zr) have measured analytical averages in excess of the continental crustal averages. The other 6 elements (Cu, Zn, Sr, Nb, Ba and Pb) have measured analytical averages lower than the continental crustal averages. Elements that are higher and lower in concentration than the continental crustal averages contain toxic elements, essential elements and yet to achieve essential elements status (Table I). Arsenic and Cr exposures to children are associated with kidney injury [7]. Copper and Zn also are essential elements that contribute to human health if exposed to the right amount [6].Included in element found to higher concentration levels more than the continental crustal values was vanadium. This element has been studied by the nutrition community for four decades, yet has not achieved essential status for human beings [12]. From Table I the known toxic elements As and Cr had percentage increase relative to their continental averages of 282.40 and 372.47**.** Lead another known toxic element had percentage decrease relative to its continental crustal average by 35.43.The environmental policies promulgated from the continental crustal values used for the study area will yield deceptive results because of the vast variations between the measured averages and the crustal averages used. To properly manage disease-causing elements based on enrichment and deficiencies, the right baseline values must be used and their determinations should be based on local elements contents rather than on continental crustal averages.

The contamination factors show some elements have high levels of concentration while others show depletion (TablesII and III). Example in this study area Cr, As, will have deleterious impact in human life whilst Ni, Zr, Mo will not impact on human health. Arsenic is a known toxic element that exposures beyond certain levels pose serious health effects in humans. It has been identified to be the cause of many cardiovascular diseases[13]. Chromium whose enrichment is 3.82 times the continental crustal average have different oxidation. Cr(III) is a known essential element whilst Cr (IV) is toxic. Chromium measured in this study was the total Cr. In order not to take chances until the speciation test to identify the oxidation states of Cr, the enriched Cr should be considered as toxic. However, if after speciation test, it turns out to be Cr (III) no detrimental health effect will result after human exposure.

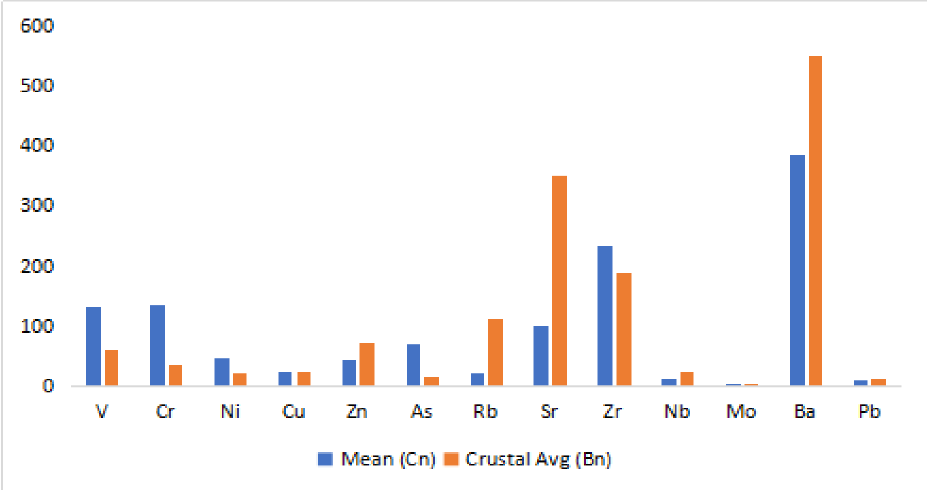

Fig. 3: Comparison of the Measured Mean of Elements with their Crustal Averages

COMPONENT				
Elements	PCA1	PCA2	PCA3	PCA4
V	.928	.226	-.084	-.142
Cr	.725	-.289	-.097	.556
Ni	.556	.478	.490	-.056
Cu	.660	.251	.342	-.454
Zn	.774	-.056	.390	-.210
As	.649	-.404	.362	.251
Rb	.630	-.563	-.412	.224
Sr	.597	-.134	-.663	-.106
Zr	-.094	.817	-.040	.280
Nb	.062	.698	.246	.457
Mo	.497	.289	-.488	-.270
Ba	.241	-.347	.779	.094
Pb	.513	.550	-.379	.179

Fig. 4: Principal Component Analysis

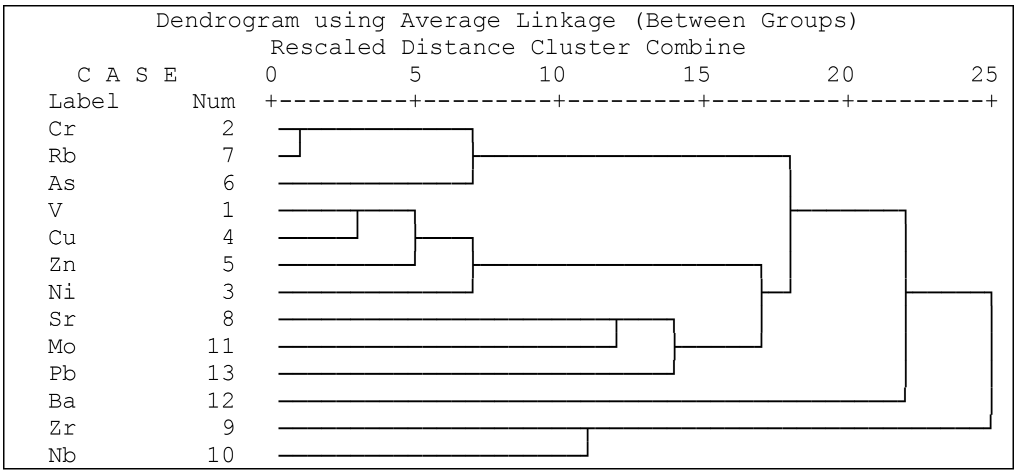

Fig. 5: A Dendrogram Developed Based on Correlation Coefficient

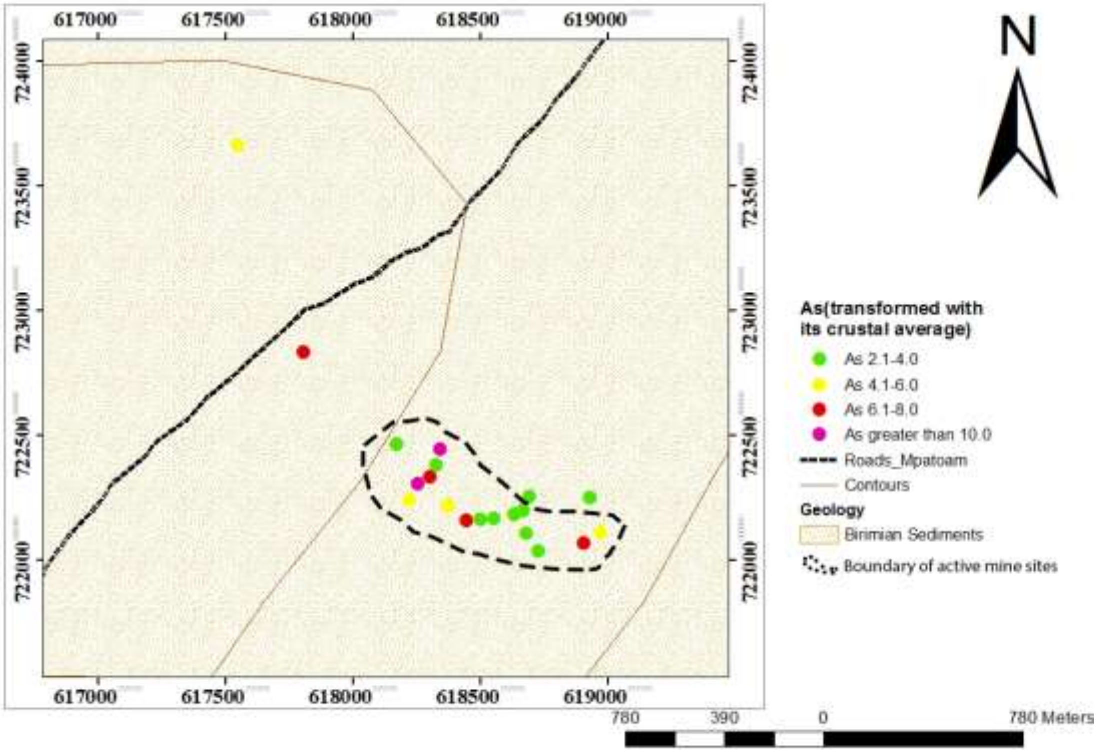

Fig. 6: A Plot of Hot and Coldspots of As

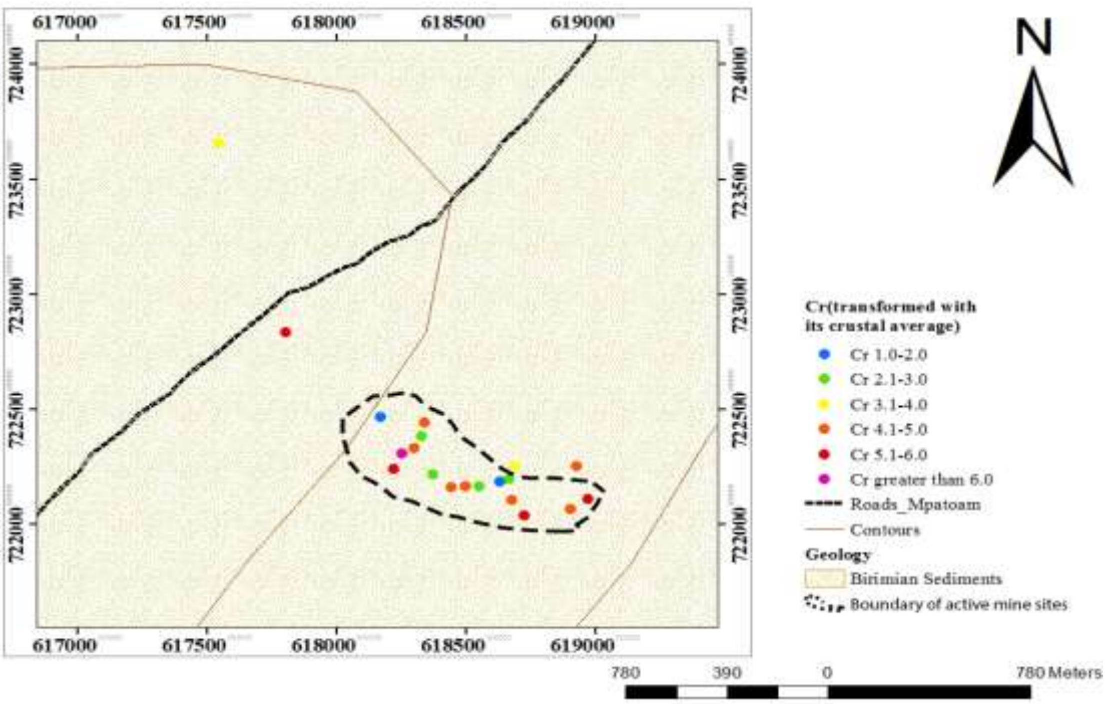

Fig. 7: A Plot of Hot and Coldspots of Cr

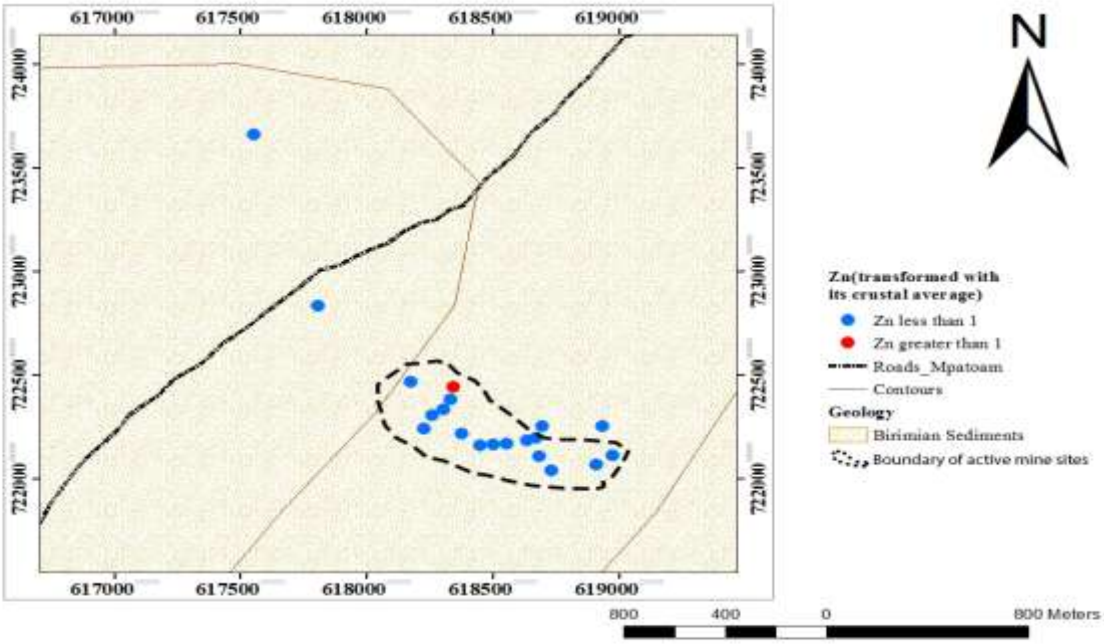

Fig. 8: A Plot of Hot and Coldspots of Zn

TABLE I

Summary Statistics of Results (ppm) and Crustal Averages (ppm) Showing their Percentage Difference.

Elements	**Minimum**	**Maximum**	**Mean (Cn)**	**Std. Deviation**	**Crustal Avg (Bn)**	**Difference (Cn-Bn)**	**Percentage Difference**	**Description**
V	51.52	197.88	130.73	33.56	60	70.73	117.88	Enriched
Cr	39.33	215.74	133.84	48	35	98.84	282.40	Enriched
Ni	28.23	88.77	46.44	18	20	26.44	132.20	Enriched
Cu	15.44	37.6	22.89	6.03	25	-2.11	-8.44	Depleted
Zn	20.02	77.75	45.13	13.14	71	-25.87	-36.44	Depleted
As	30.89	164.86	70.87	35	15	55.87	372.47	Enriched
Rb	7.63	39.25	21.26	6.47	112	-90.74	-81.02	Depleted
Sr	48.15	145.72	99.79	21.66	350	-250.21	-71.49	Depleted
Zr	157.49	309.84	235.25	43.48	190	45.25	23.82	Enriched
Nb	10.76	16.8	13.52	1.5	25	-11.48	-45.92	Depleted
Mo	2.48	8.67	5.4	1.6	1.5	3.9	260.00	Enriched
Ba	214.27	562.72	385.19	103.84	550	-164.81	-29.97	Depleted
Pb	6.02	12.42	9.04	2.06	14	-4.96	-35.43	Depleted

TABLE II

CF, Igeo and PLI Values of the Elements

Elements	CF	Igeo	PLI
V	2.18	0.44	2.01
Cr	3.82	0.77	2.68
Ni	2.32	0.47	2.47
Cu	0.92	0.18	0.63
Zn	0.64	0.13	0.74
As	4.72	1.422	2.96
Rb	0.19	0.04	0.46
Sr	0.29	0.06	0.91
Zr	1.24	0.25	1.22
Nb	0.54	0.11	0.85
Mo	3.6	0.72	1.69
Ba	0.7	0.14	0.72
Pb	0.65	0.13	0.91

CF >1 is Enrichment; CF <1 is Depletion and CF equals (1) is No pollution.
PLI values <1 indicate no pollution whereas PLI >1 represent pollution

TABLE III
Igeo Classification of Pollution Index

Igeo values	Igeo Class	Pollution Intensity
> 5	6	Extremely polluted
4–5	5	Strongly to extremely polluted
3–4	4	Strongly polluted
2–3	3	Moderately to strongly polluted
1–2	2	Moderately polluted
0–1	1	Unpolluted to moderately polluted
0	0	Unpolluted

The Mo high exposure to humans has no adverse effect but it is crucial for the survival of animals. Vanadium plays some enzymic functions in humans but yet to be considered as an essential element for human development by nutrition communities. The last enriched element Zr is not toxic but it can cause contact irritation to skin and eyes. Research had shown that Zr is unlikely to present hazard to the environment. Whilst some areas are enriched in some elements, there are certain areas where elements depletion occur. Example Pb, Cu, Zn, Nb, Ba, Rb and Sr show depletion. The depletion of Pb is good for the population in the areas because of Pb toxicity that can lead to several issues. Conversely depletion of Cu and Zn is bad because they are essential elements that are needed by animals and humans. Zinc supplementation to boost health in the study area needs rapid attention.

From Tables II and III, most of the elements show no pollution where Igeo values range between 0.04-0.77 for 12 elements except 1.42 for As. Comparing CF and Igeo values in Table II, it appears some few maximum values of some elements at some stations influenced the CF values. The PLI values in Table II still confirm As to be most polluted element in the area. It does also include V, Cr, Ni, Zr, Mo to be polluted. The unpolluted elements Pb, Ba, Nb, Sr, Rb, Zn and Cu compares well with the depleted elements in CF. Table II shows the toxicity of As suggesting the possible outbreak of As related diseases to be high. This is assumed to be a potential threat to the community because As is a carcinogenic element that can affect the health of people exposed to it. Arsenic has been observed to be non-destructive in the environment and also soluble in water. This means in water, As can bio-accumulate in fish and shellfish and when consumed could cause diseases such as cancer, stroke (cerebrovascular diseases), Heart disease (hypertension-related cardiovascular diseases), chronic lower respiratory diseases, and diabetes. Chromium pollution is significant from the perspective of results obtained from CF and PLI and therefore require immediate speciation test in order to know whether the area is enriched in good or bad Cr. Lead (Pb) also a known toxic element shows depletion and can be characterized as being weakly polluted likely needs some monitoring because the PLI value is 0.91. This toxic element is bioaccessible and if it is bioavailable in the soils can bioaccumulate and could reach a trigger level where it can be detrimental to human health.

The As level in the study area were elevated as depicted by the CF in Table II. The minimum and maximum values, 30.89 ppm and 164.86 ppm respectively, with an average of 70.87 ppm all fall above the crustal average level of 15 ppm in soils. Consequently, people living in this area are highly prone to the toxicity effects of As. Exposure to As is known to cause skin cancers through dermal contact and this is particularly risky in the studied area since most of the people are farmers who work with the soils ([14], [23]). Other As-related diseases include lung infections when inhaled and heart cancers from excess bioaccumulations in humans. Their toxicity to plants has been identified to result in stunted plants growth, discolouration of roots, and wilting of the plants [15]. This will eventually result in poor yield or shatter plants development. The element As is easily transported through adsorption and desorption processes making it possibly available in water [18] in the area which calls for further research on the rivers and streams in the area and the possible bio-accumulated levels in the aquatic organisms such as fishes that are consumed.

The average Zn concentration of 45.13 ppm in the area of study was found to be far below the crustal average value of 71 ppm as indicated in Table I. Zn is among the most essential trace elements for the healthy functioning of most parts of the human body systems. Its functions involve several biochemical pathways. Due to its essentiality, Zn deficiency cases at either early or severe stages result in several health conditions including impaired immune function, behavioural problems, memory impairment, delayed sexual maturation, impotence, hypogonadism in males, and eye and skin lesions [23]. As a major factor, Zn deficiency may result from low dietary intake ([23], [25]). If it is not bioavailable to plants through the soils, it will be most likely deficient in crops produced from such soils which raises an issue of concern for the people of Mpatoam.

Most importantly, the possible exposure to low levels of essential elements or elevated levels of the potentially toxic elements to plant, animal and humans can be considered as public health risk worldwide ([3], [8]).

The elements Zn, Cu, Ni, V, Cr and Mo are classified as essential or possibly essential trace elements which are required in certain concentrations for the proper functioning of the human body as well as for plants and animals [19]. However, their concentrations either below or above the expected limits can result in deficiency or toxicity health problems and must therefore be carefully considered and dealt with. On the other hand, the potentially toxic elements including As are safer when depleted but pose high health risks even when slightly elevated.

The CF values in Table I indicated that the concentration levels of Cr in the area are elevated. Like Zn, Cr is also a known essential trace element needed for plant, animal and human growth but may have deficiency or toxicity effects when intake levels are depleted or in excess [25]. The toxicity effects are however dependent on the Cr species whereby Cr^{6+} is highly toxic as compared to the essential Cr^{3+} [16]. According to WHO [25] Cr toxicity mostly occurs in areas where the concentrations in the air are high or contact with the skin is frequent and this might be more risky for the farmers and kids possibly playing with the soil. The depleted levels of Cr in soils of the study area therefore indicate risks of the above deficiency effect among the population.

The results of PCA presented in Fig. 4 and Fig. 5 indicated the rotated component matrix, extracted four (4) independent components that explained 80.78% of the total variance of the elements. The first component PCA1 was 34.51% of the total variance representing the geology-group. The elements in this group are Ni, Cr, Cu, Zn, Sr, Rb, Pb, Zr, Nb and Mo. Nine of these elements (As, Cr, V, Ni, Cu, Zn, Sr, Rb and Pb) show high to moderate linkages ranging from 0.9 to 0.5 in PC1. These elements are shown with blue outline (Figs. 4 and 6). Elements Zr, Nb and Mo show weak correlation and had values below 0.5 while Ba has no linkage with the elements in PC1. Ba had negative loading and exhibited with component matrix of -0.094. The strong association of As, Cu, Zn, Pb suggests the presence of chalcophile minerals in association with gold. Kesse [17] and Dzigbodi-Adjimah [10]report of close association of chalcophile minerals with hydrothermal veins in the Birimian rocks in Ghana. This may explain the presence of As in the mining and non-mining areas. It appears the activities involved in mining the auriferous gold at the alluvial plains possibly influenced the spread and concentrations of the As in the area as observed from the CF values (Table II, Fig. 3).

The hotspots of toxic and essential elements potentially to cause harm to humans based on exposure levels presented in Figs. 6-8 had uneven distributions. Arsenic enrichment levels range from 2.1 to > 10. The entire area has concentration levels greater than the accepted values. 30 % of the stations sampled and assessed for As concentration occur in the study area. It is clear from Fig.6 that As related diseases may be prevalent in Mpatoam community as the people eat and drink water that are contaminated with As. Similarly, Cr measured in the study area could be harmful or harmless (Fig. 7) because the oxidation states are yet to be ascertained. If the Cr (III) is the dominant type here then it will be beneficial because the enrichment factor range between 1->6. On the hand if Cr (IV) is the dominant oxidation type then exposure consequence will be detrimental to human health as it toxicity can be fatal. Conversely the concentration levels of Cr are messy and needs to be outlined to proper define the most dangerous areas. However, Zn the essential element seems depleted in the area (Fig. 8) except one station. Poverty level seems high in the area therefore the chances of the population obtaining Zn through diet appears myriad. It is only a single station that the enrichment factor is greater than one. Zn deficiency diseases may be prevalent as many of the people may not be able to afford purchasing Zn supplement drugs. Defining and outlining the Zn deficient areas for the application of Zn based fertilizers may be useful.

VI. Conclusions

The results of the soil geochemical study in the Mpatoam area contained both essential and potentially toxic trace elements with varying concentrations and distributions. The analysed data revealed that:

- Both As and Cr which are known toxic elements were high whereas the essential elements example Zn and Cu were depleted from CF and PLI values. Igeo value for As also confirmed its elevation while showing depletion for all other 12 elements. However, the Cr measured here is total Cr which based on its speciation may be harmless or harmful.
- The component matrix which shows elemental association of the combined elements in the soils gave 4 major groupings. The PCA 1 showing strong association with As, Cu, Zn, Pb depicted relations with chalcophile elements which relate to the local geology. This was clearly displayed for As in hotspots analysis where it showed enrichment both in the active and non-active mine sites as the spread was locally facilitated by human activities.
- The enriched elements (As, Cr etc) could further spread and bio-accumulate into water bodies and to plants through the soils. The depleted essential elements (Zn, Cu) could also reflect in crops produced from such soils therefore presenting associated diseases.

The authors thus recommend further studies on surrounding streams and rivers as well as food crops to determine the bio-available levels of these elements since people living in the depend on directly on the crops and water bodies. By this, possible public health related to these, will be easy to address and more likely prevented.

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