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# The Hidden Dangers of Unknowingly Ingesting Harmful Trace Elements from Food Crops and their Health Implications: A Case Study at Talensi District in the Upper East Region, Ghana

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## Abstract

Food consumed ideally is supposed to improve the health of humans but there are hidden dangers in consuming some staple food crops in Talensi District because of the variability of soil geochemistry and the environmental activities that influence plants uptake of some elements from the surface environment. Evidence of enriched potentially harmful elements in food crops have been demonstrated in 19 food samples collected from different locations in Talensi District. The samples were analyzed using Atomic Absorption Spectrophotometer for concentration levels of Arsenic (As), Lead (Pb), Chromium (Cr) and Selenium (Se) in digested food crops. Using permissible concentration limits of elements in these food crops; their enrichment factors (EF) were computed. Mix enrichment factors were obtained for all elements except Cr that showed enrichment in all food crops sampled in all communities up to about 10-folds. The variable enrichment factors obtained for the same food species was attributed to differences in geological and geochemical environments as well as different human activities. Selenium was found to be enriched in few food crops from some communities but showed general deficiency in many of the food crops in some communities. In conclusion the global averages of the measured As and Pb being lower than the permissible concentration limits do not suggest As and Pb-free cultivated food crops in the District. The study established the conclusions drawn on the basis of the computed average EFs seem to be overly inaccurate and not reflective with events at the local communities and recommends each food crop enrichment factor be analyzed and interpreted for local environmental health policy with respect to the local environment.

***Keywords:*** *Nutrition; Elevated concentrations; Exposure; Enrichment; Health*

## Introduction

Healthy living is a recommendation by all health workers including dieticians as well as food and nutrition workers. However, the act of living heartily depends on many factors. Among them is getting the correct amount of nutrients from what we eat and these include eating fruits, vegetables in combination with the right amount of carbohydrates uncontaminated from sources such as biological and chemical materials. From Arhin., *et al*. [1] trace elements exposures in the environment can be harmful or beneficial to human health relative to concentrations ingested. From Geoscience perspectives rocks that form the foundation of the earth undergo a surficial processes resulting in the release of both essential and toxic elements referred to as trace elements or micronutrients by the nutrition workers. The released trace elements are stored in soils which support human, plant and animal growth. Work by Arhin., *et al.* [1] recognised excessive amounts of some trace elements possible to have adverse health impacts in soils at Datoko-Shega area. Plants and food crops growth depends on type of soil and the contained nutrients. Food crops being tubers, vegetables, cereals, legumes and fruits cultivated in contaminated lands will absorb the trace elements and may be translocated to other parts of the plants. Whilst trying to live healthily by consuming vegetables, fruits, cereals and some legumes for our healthy growth we should also not lose sight about some transferring impacts of soil geochemistry to the cultivated food as the plants do not only filter out the good nutrients but there are some bad nutrient uptake too in the process.

Evidences of reports on trace elements excess uptake by plants and deficiencies due to leaching in surface soils that affect human health have been documented by several researchers [2]. What makes this investigation crucial is that the amount of trace element uptake by plants often are very low, unparalleled to concentrations in soils and may not result in immediate chronic outcome. The dilemma of it is the ability of the trace elements to bio-accumulate when ingested at the low concentration levels and the fact of its bioaccessibility and bioavailability could reach chronic levels with possible adverse outcomes unknowingly. It is a perfect move to advocate for moderate amounts of trace elements or nutrients in our diets but this advocacy should span across the entire food chain where food sold in the markets should be trademarked as either organic or inorganic foods sources. This theory may sound impractical in developing world but the penultimate objective and its significance will be realized from this paper. The major nutrients in similar food crops will be similar but may vary in ancillary trace elements introduced from the local environment and the underlying geology. The chemical contents of the introduced trace elements can be very low in concentration which might not trigger any health implications immediately but health risks may be anticipated depending on the degree of exposure, role of speciation, route of exposure, and length of exposure and these can be injurious [2]. This paper, therefore, examines the contained trace elements in selected staple foods mainly cereals and legumes cultivated and consumed by the people of Talensi District with the objective of establishing the relationship between some of the trace elements and the Public Health concerns.

## Location, geology, physiography and regolith of the study area

### Location and Geology

The study area falls within the Talensi district of the Upper East region of Ghana. The district is about 45 km southeast of the regional capital, Bolgatanga, and is 850 km from Accra the national capital. The area falls within the Bole-Navrongo-Nangodi Birimian gold belt, one of the six Greenstone belts in Ghana [3] (Figure 1). The area is underlain by mafic Birimian volcanic rocks such as basalt, andesite, dacite etc., and Birimian volcano-sedimentary rocks such as amphibole schist, biotite-hornblende schist, sericite schist, and tuff [4] (Figure 1).

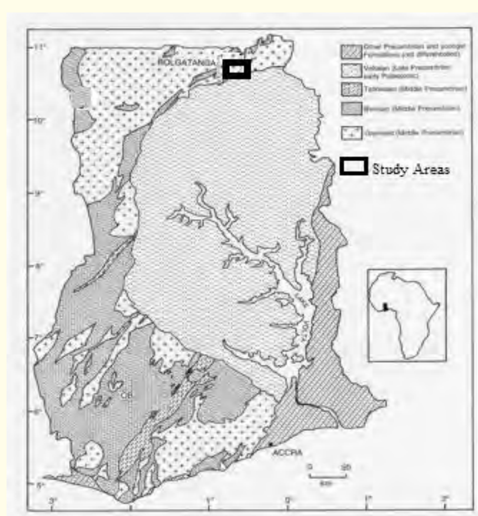


***Figure 1:*** *Geology and location of study area.*

### Physiography

The area is characterized by a dry savannah climatic regime and a solitary rainfall season with annual rainfall of about 600-1200 mm [5]. There is a slow rise in figures for monthly rainfall totals from March which peaks in August after which there is a sharp decrease after October [6]. The average rainfall value is approximately 60 - 100 mm per month while temperatures can vary between 22$^{o}$C at night and rise to more than 40oC during the day. The mean annual temperature is about 35$^{o}$C with the maximum temperature often rising above 40oC recorded between the months of March to April. Lowest temperatures of ≤ 22$^{o}$C occur between November and January due to the harmattan. Relative humidity ranges between 70% and 90% between the months of May and October but may drop to as low as 20% during the long dry season [5].

The streams in the area are of a dendritic pattern and drain north-south along with the 2$^{nd}$ order streams which drain westerly towards the main north-south stream. The stream systems transport most of the weathered materials along with the elements released to the environment by weathering processes.

### Trace elements uptake and distribution in Plants

Soils form the main medium from where plant uptakes trace elements. However, Arhin., *et al.* [1] reports of high concentrations of some potentially harmful trace elements in soils and stream sediments in the study area raises much concern which demands understanding the mechanism of trace elements uptake by plants and its distribution in food crops. Several archival reports testify the similarities between mammals and plants in the absorption and transport of trace elements. Many reported articles indicate the chemistry of trace element uptake from food sources is based on thermodynamics of adsorption on charged solid surfaces embedded in a solution phase of charged ions and metal-binding ligands together with redox systems in the case of iron and some other elements. The absorption of trace metals in plants is normally via divalent ion channels after reduction in the plasma membrane and once absorbed the trace elements can be stored in plants as or transported to active sites by transport-specific ligands. During the absorption and transportation of trace elements from soils to the plants that bear the foods; do so by not selecting only the micronutrients that the plant needs but do so absorbing both the essential and harmful trace elements alike. This thus suggests that nutritionists and dieticians recommendations for certain types of food for healthy growth need in-depth investigations from geoscience perspective and not only considering the fibers, vitamins and other nutrients that the body requires.

### Trace elements in critical zone and their impacts on human health

The trace elements found to contaminate the soils and reported to be prevalent in parts of the study area are Cr, As, Se and Pb [1]. Arhin and Zango [7] thus report of the implications of some of these trace elements on public health. The mechanism of elements uptake by plants and their subsequent translocation to other parts of it including the food is not well understood but it is believed that the root systems absorb the elements in an aqueous phase in soils in search for micronutrients for its food preparation. The absorbed elements that end up in food substances are the concern of this investigation. Thus the health outcomes of related Cr, As, Pb and Se elements enriched in soils and transferred into the food substances in this area are discussed for the purposes of environmental health engineering against any adverse health consequences.

### Chromium (Cr)

Chromium is a naturally occurring element ubiquitous in the earth's crust and exists in two oxidation states $Cr^{4+}$ and $Cr^{3+}$. Research had shown chromium (VI) compounds to be toxic and known human carcinogens whereas chromium (III) is an essential element for plant and animal growth [8]. This element is of great environmental concern due to its high risk inducing diseases across the world. Diseases such as irritation to the lining of the nose, anemia, stomach tumors and respiratory diseases have some relationship with chromium exposures and food crops can unintentionally absorbed them from contaminated cultivated soils.

### Arsenic (As)

Arsenic is also a known carcinogen and from Arhin., *et al.* [1] the soils and sediments in the study area are polluted to some degree. The source of the pollution they attributed them to natural source rather than anthropogenic processes but there are some arsenic- containing compounds produced industrially and have been used to manufacture products with agricultural applications such as fertilizers, insecticides and herbicides. Crop production in Ghana is dependent on rainfall, which is mostly irregular and unreliable particularly in the study area. Meanwhile the efficiency of fertilizer use relies on water availability and uncertainty in this respect reduces the farmers' incentive to use more fertilizers but for avoidance of poor crop yields many farmers now use fertilizers timing accurately when rainfall is available. Assuming the fertilizers used are As-containing compound-base then As will be introduced to the food crop and the As-concentrations in the crops to be consumed by humans and animals will be exacerbated if the cultivated lands naturally are as well enriched in As. Like chromium in the environment, arsenic exists predominantly in the +3 and +5 oxidation states. However As (III) is usually considered to be more toxic than As (V). From factsheet media report of [9], long-term exposure to arsenic from drinking-water and food can cause cancer, kidney, bladder and skin lesions. Excess As levels in food and drinking water has also been associated with developmental effects, cardiovascular disease, neurotoxicity and diabetes.

### Selenium (Se)

Selenium is a naturally occurring element present in small amount in the earth's crust but can be at an elevated level. Although it occurs naturally in the environment, anthropogenic activities such as mining and manufacturing industries contribute to the release of high concentrations [10]. From 'Adoption Nutrition Journal' selenium is needed by the body in small amounts for good health [8]. It is incorporated into proteins to make selenoproteins, which are important antioxidant enzymes. The antioxidant properties of selenoproteins help prevent cellular damage from free radicals that can cause the development of chronic diseases such as cancer and heart disease. Other selenoproteins help regulate thyroid function and play a role in the immune system. However, selenium can be toxic in large amounts [8]. Selenium concentrations in food have been identified in humans both in deficient and elevated levels. Its deficiencies contribute to a development of a form of heart disease, hypothyroidism, and a weakened immune system. There is evidence that selenium deficiency does not usually cause illness by itself. Rather, it can make the body more susceptible to illnesses caused by other nutritional, biochemical, or infectious processes. Known Se-related diseases are Keshan Disease, which results in an enlarged heart and poor heart function in selenium-deficient children; Kashin-Beck Disease, results in osteoarthritis in children; and Myxedematous Endemic Cretinism also results in mental retardation in infants born to mothers deficient in both selenium and iodine. Having the correct nutritional content in our diets is essential but emphasises also ought to be made on associated elements that makes contributions to healthy living placing in context the earth science view.

### Lead (Pb)

Found soils at Datoko-Shega to be enriched in Pb [1]. These areas form part of the study and the fact that Fordyce [11] recognised enriched Se in food crops grown in Se-rich soils; it is possible to have crops cultivated in the Pb-rich soils affecting Pb contents in food crops cultivated in the area. Pb is identified as cumulative toxicant and is able to affects multiple body systems. As reported and updated by WHO [9] Pb in the body is distributed to the brain, liver, kidney and bones. The fact that Pb is able to be stored in teeth and bones, where it accumulates over time makes its evaluation in food significant because of its bioavailability and bioaccessibility in the study area. It has been found that excess concentrations of Pb resulting in the toxic effects can result in suffer profound and permanent adverse health effects, particularly affecting the development of the brain and nervous system of young children. In adults it can cause long-term harm, including increased risk of high blood pressure and kidney damage. Pregnant women exposed to high levels of lead can cause miscarriage, stillbirth, premature birth and low birth weight, as well as minor malformations. Parents passing on the ingested Pb to their unborn children and babies complicate the causes of undernourished children even if they are provided with the required baby food formulas. As identified by WHO [9] the undernourished children are more susceptible to Pb because their bodies absorb more Pb in the absence of other nutrients such as calcium. Trace enrichment of Pb in food is as dangerous as high concentration in soils because of its ability to bioaccumulate.

Particularly in Developing Countries where food and drinking water come from the local environment investigation and education of this nature should be carried on alongside educating communities on nutritional matters. The necessity of this caveat is that, at high levels of exposure, lead attacks the brain and central nervous system to cause coma, convulsions and even death. Children who survive the severe Pb-poisoning may be left with mental retardation and behavioral disorders. At lower levels of Pb-exposure that do not show obvious signs and symptoms of any adverse health issues may be considered safe on the basis of the calculated enrichment factor levels. These subsequently can produce a spectrum of injury across multiple body systems because of bioaccumulations and bioavailability. The non-catastrophic impacts of Pb poising can affects children's brain development resulting in reduced intelligence quotient (IQ), unexpected behavioral changes such as reduced attention span and increased antisocial behaviors, and above all reduce educational standards. Pb-poisoning contributes to many environmental health diseases such as anaemia, hypertension, renal impairment, immunotoxicity and toxicity to the reproductive organs. The neurological and behavioural effects of Pb are believed to be irreversible [9]. Other associated effects of lead poisoning include; abdominal pain, anaemia, arthritis, attention deficit, back problems, blindness, cancer, constipation, convulsions, depression, diabetes, migraine headaches, thyroid imbalances and tooth decay [8].

**Sampling and Methodology**

Fifteen (15) food samples comprising millet, soybean, sorghum, rice, maize and Guinea corn were collected from different sampling sites in Talensi District during the harvesting season. These food crops were grouped into cereals and legumes but the analysis and discussions hinged on the cereals. The notion that environmental activities at a local-scale has the tendency to influence the physical and chemical processes; 4 control samples were taken from Navrongo where there is no record of mining activity contrary to Talensi District where most parts had seen small-scale mining and quarry activities. All the 19 samples were oven dry at a temperature of 80oC after which they ground separately using porcelain mortar and pestle into powder. 30 g weight sub-samples were collected from each sample and were kept in labelled Kraft paper for trace elements chemical analysis. Since this was a follow up investigation after Arhin., *et al.* [1] the concentration levels of As, Pb, Cr and Se were analyzed by flame Atomic Absorption Spectrophotometer.

**Laboratory analysis of Samples**

At the laboratory 0.5g each of a sample were weighed into a beaker. 2 ml of hydrogen peroxide and 20 ml of nitric acid were added to the samples. These samples were then covered and placed on a hotplate. The content of the beaker was heated for 3 hours to digest the mixture until a transparent solution was obtained. The digested material was allowed to cool at room temperature. Thereafter, 30 ml of deionized water was added and the mixture filtered using 45 mm pore space filter paper. The resultant digested samples were then analyzed for Pb, Se, As, and Cr by flame Atomic Absorption Spectrophotometer and concentrations expressed as mg/l for the samples.

## Results

The element concentrations in the nineteen food crop samples analyzed by AAS analytical technique is presented in Table 1.

| Samples ID | Community | Crops | Cr (mg/l) | EF (Cr) | Pb (mg/l) | EF (Pb) | As (mg/l) | EF (As) | Se (mg/l) | EF (Se) |
|---|---|---|---|---|---|---|---|---|---|---|
| KM001/15 | Balungu | Millet | 10.5 | 9.2 | 0.66 | -1.34 | 0.36 | 0.16 | 0.12 | 0.1 |
| KM002/15 | Balungu | Millet | 12.36 | 11.06 | 3.48 | 1.48 | 0.36 | 0.16 | 0.24 | 0.22 |
| KM001/15 | Kaari | Millet | 13.38 | 12.08 | 3.54 | 1.54 | 0.42 | 0.22 | 0.24 | 0.22 |
| KM001/15 | Sheaga | Millet | 12.84 | 11.54 | 0 | -2 | 0 | -0.2 | 0 | -0.02 |
| KM001/15 | Pusunamago | Millet | 12.72 | 11.42 | 2.88 | 0.88 | 0.24 | 0.04 | 0.18 | 0.16 |
| KM001/15 | Pusunamago | Sorghum | 11.94 | 10.46 | 2.88 | 0.28 | 0.24 | 0.04 | 0.12 | 0.1 |
| KM001/15 | Sii | Sorghum | 12.6 | 11.3 | 1.8 | -0.2 | 0.18 | -0.02 | 0.12 | 0.1 |
| KM001/15 | Sii | Sorghum | 11.1 | 9.8 | 3.24 | 1.24 | 0.36 | 0.16 | 0.3 | 0.28 |
| KM001/15 | Tongo | G.corn | 10.86 | 9.56 | 1.62 | -0.38 | 0.12 | -0.08 | 0 | -0.02 |
| KM001/15 | Bundunia | G.corn | 8.58 | 7.28 | 1.5 | -0.5 | 0.12 | -0.08 | 0 | -0.02 |
| KM001/15 | Kaari | G.corn | 8.16 | 6.86 | 0.54 | -1.46 | 0.18 | -0.02 | 0.12 | 0.1 |
| KM001/15 | Tonzug | G.nuts | 14.4 | 13.1 | 0.48 | -1.52 | 0 | -0.2 | 0.3 | 0.28 |
| KM001/15 | Tonzug | G.nuts | 10.32 | 9.02 | 0.3 | -1.7 | 0 | -0.2 | 0 | -0.02 |
| KM001/15 | Vunania | Maize | 10.8 | 9.5 | 1.02 | -0.98 | 0 | -0.2 | 0 | -0.02 |
| KM001/15 | Vunania | Maize | 9.48 | 8.18 | 0 | -2 | 0 | -0.2 | 0 | -0.02 |
| KM001/15 | Gognia | Rice | 10.08 | 8.78 | 2.58 | 0.58 | 0.24 | 0.04 | 0.12 | 0.1 |
| KM001/15 | Navrongo | Rice | 9.84 | 8.54 | 0 | -2 | 0 | -0.2 | 0 | -0.02 |
| KM001/15 | Datoko | Soybean | 11.28 | 9.98 | 1.44 | -0.56 | 0 | -0.2 | 0.12 | 0.1 |
| KM001/15 | Yameriga | Soybean | 8.58 | 7.28 | 0.42 | -1.58 | 0 | -0.2 | 0 | -0.02 |

***Table 1:*** *Concentration levels of elements in food crops.*

**Enriched Values Highlighted*

The table again contains enrichment factors computed using the permissible concentrations of elements in food. The concentrations of elements in food though low compared to similar elements in the same geographic locations in soils and sediments; the characteristics of the elements for the four elements identified to be in excess concentrations in lands used for agricultural activities are plotted and shown in Figure 2-6 for Cr, Pb, As and Se respectively.

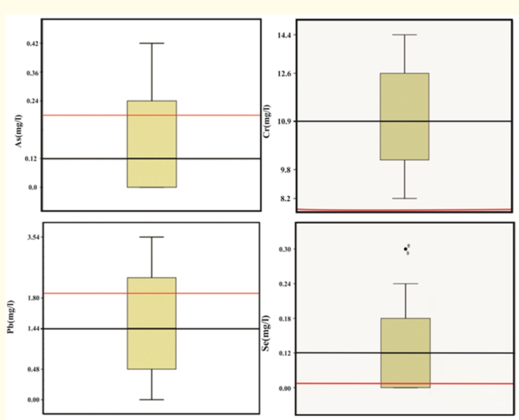

***Figure 2:*** *Boxplot comparing measured means in food crops and the permissible limits.*

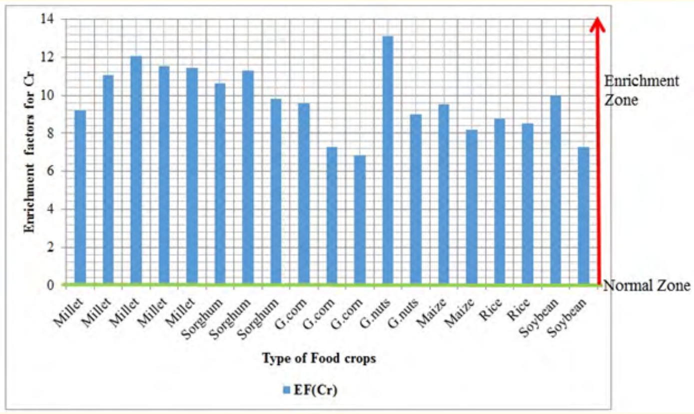


***Figure 3:*** *Cr enrichment levels in food crops.*

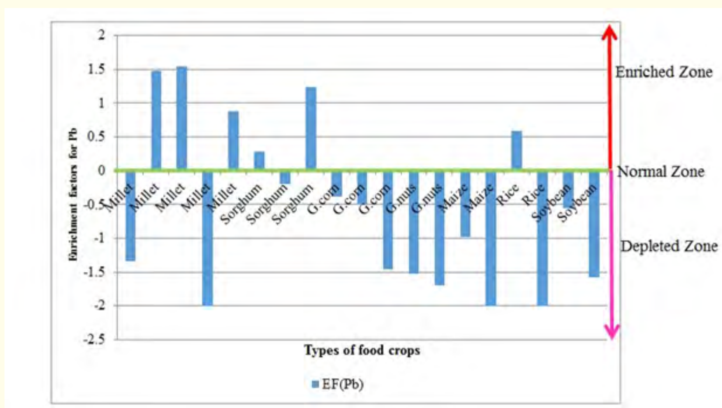


***Figure 4:*** *Pb enrichment levels in food crops.*

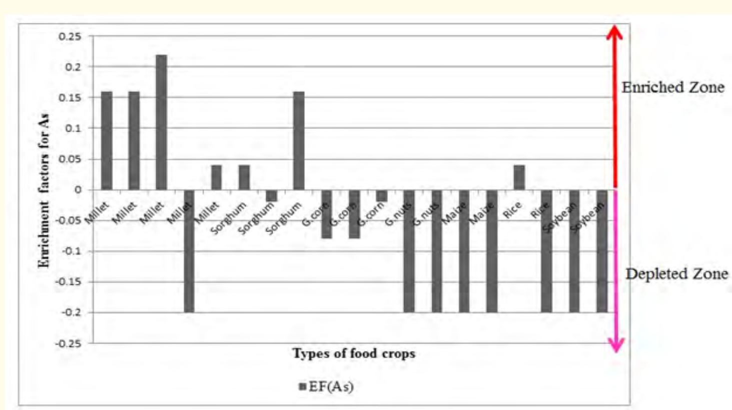


***Figure 5:*** *As enrichment levels in food crops.*

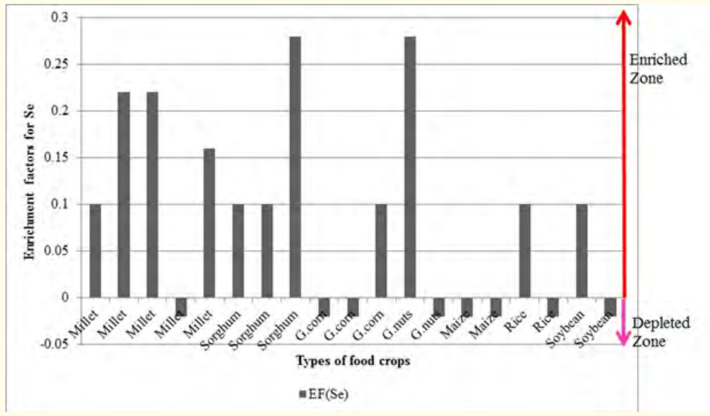


***Figure 6:*** *Se enrichment levels in food crops.*

The degree of these elements concentrations in food even same food crops vary in content geographically which makes the current investigations interesting as the causes may be from several factors of which some may be natural and others from anthropogenic sources. Healthy living is not only dependent on good nutrition but it needs also the correct combination of essential elements devoid of either trace or chronic concentrations of potentially harmful elements in foods that are consumed. Figures 7,8 show the enrichments and depletion levels of Cr, Pb, As and Se in food crops and also show community by community the enrichment and depletions hotspots of the essential and potentially harmful elements.

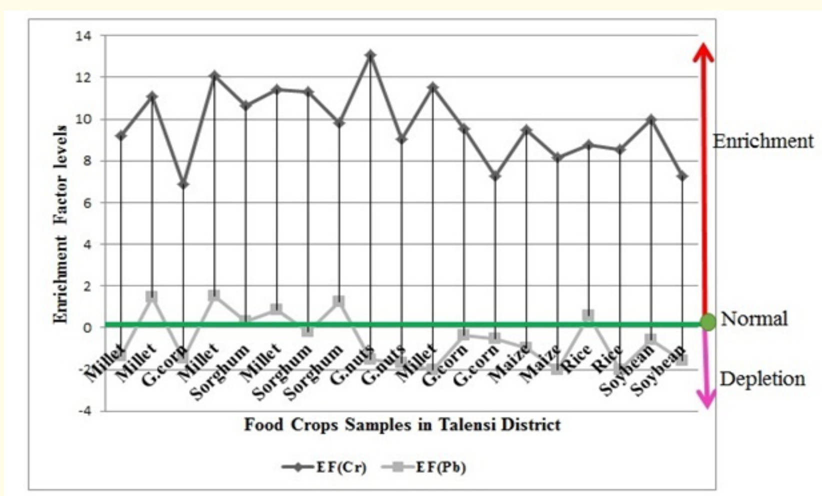


***Figure 7:*** *Enrichment factors comparisons between Cr and Pb in food crops.*

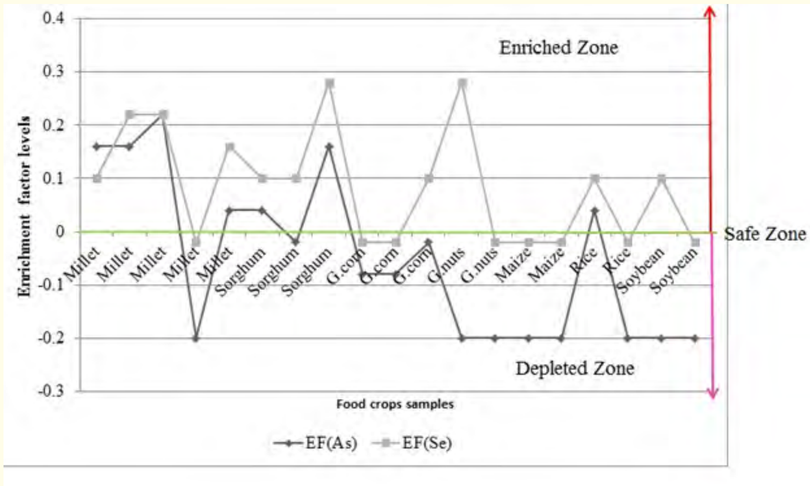


***Figure 8:*** *Enrichment factors comparisons between As and Se.*

The summary statistics of the selected trace elements, the permissible limits of these elements in selected staple food crops in the district and computed enrichment factors are presented in Table 2.

| Trace Elements | Permissible Limits | Max | Min | Median | Mean | SD | EF |
|---|---|---|---|---|---|---|---|
| Cr (mg/l) | 1.3 mg/l | 14.4 | 8.16 | 10.86 | 11.04 | 1.73 | 9.74 |
| Pb (mg/l) | 2 mg/l | 3.54 | 0 | 1.44 | 1.46 | 1.22 | -0.54 |
| As (mg/l) | 0.2 mg/l | 0.42 | 0 | 0.12 | 0.17 | 0.15 | -0.03 |
| Se (mg/l) | 0.02 mg/l | 0.3 | 0 | 0.12 | 0.10 | 0.11 | 0.08 |

***Table 2:*** *Summary statistics of concentration levels of selected food crops, permissible limits and calculated enrichment factors (EFs).*

## Discussions

As seen in Figure 1 the regional geological settings show some variations in rock units at different geographical locations. Similarly, the broad geological units in a class of rocks formed from the same melt even differ in the modal percentages and mineralogical compositions so is the geochemistry which provides the distributions and concentrations of elements from the rocks to the end-stage soils in the environment. As noted by e.g. Turekian and Wedepohl [12] and recently by Rudnick and Gao [13] the opinion that uncontaminated rock of same rock-type transformed to sediments/soils by weathering processes should have the same continental crustal averages for the contained elements in the soils have been questioned because of the local anthropogenic and natural activity characteristics [14]. The notion that rock is an aggregate of minerals and can naturally fractionate into harmful and essential elements during their transfer from the crust to the secondary environment is a likely suspicion that food crops will ingest both essential and harmful elements simultaneously. The consequence is some food crops of same class having different enrichments and deficiencies of certain elements.

From Table 1 some known potentially harmful elements Pb and As show enrichments in some food crops in some communities. Selenium which is an essential trace element that serves as an antioxidant enzyme is only found to be enriched in few food crops from some communities but show general deficiency in many of the food crops in some communities. The concerns are that Se deficiencies contribute to a development of a form of heart disease, hypothyroidism, and a weakened immune system. These observations appeared subdued when averages or accepted baseline values of the elements were used, which seems to be the norm in environmental health investigations. Table 2 and Figure 2 suggest means of the potentially harmful elements Pb and As are much lower than the permissible limits in food crops. This outcome is not reflective assessing these elements on food crops on community basis. Trace concentrations of Pb and As in food may have an adverse consequence on health particularly in the study area because the sampled food crops form the basis of the staple food in the district. Pb has been identified as cumulative toxicant and is able to affect multiple body systems. The same is applied to arsenic as their accidental ingestion through food despite the low concentrations (Table 2 and Figure 2) can cause adverse health effect. Example from Table 1 millet at Balungu, Kaari and Pusunamogo has Pb enrichments of 1.48, 1.54 and 0.88 respectively. Sorghum at Sii and Gognia were 1.24 and 0.58 times the permissible limits. Similar conclusion is deduced for As comparing the measured concentration to the permissible limit. The correct environmental policy to address possible health implications from ingesting food crop enriched in Pb and As may be overlooked. The trace concentrations will bioaccumulate as they are bioavailable and bio-accessible by virtue that the community grow what they eat. In Se that enrichment was expected in the food crops to contribute its antioxidant enzyme for human and animal developments rather showed relatively low enrichment and even depletions in food crops in some communities. For instance, as reported in Table 1 millet at Shega, guinea corn at Tongo and Bundunia, groundnut at Tonzug, rice at Navrongo and soybean at Yameriga all showed Se depletions. The causes of the deficiencies cannot be explained from the current field data but it is possible to have an association with the underlying rocks for combination of factors such as the following:

1. The impact of climate on physical and chemical processes during the elements transport in the oxidized environment,
2. The complicated characteristics of the regolith atop the bedrocks and/or
3. The impact of biogeochemical processes in the surface environment (e.g. influence of microbial community on metal migration etc.).

From Figure 3 Cr is enriched in all food crops sampled in all communities up to about 10-folds [8] reported that $Cr^{4+}$ is a human carcinogen and identified Cr3 as an essential element for plant and animal growth. This paper is unable to report the type of Cr as it only measured the concentrations and will assess the Cr-type in the next research. The oxidation state or Cr specie common in the food crops is of great environmental concern due to their high risk in inducing diseases across the world. Figures 4-6 showed enrichment factors for different crop types, which six crops at different communities' sometimes of the same crop-type showed different degrees of enrichment. Thirteen samples portrayed deficiencies irrespective of the crop types. Therefore, the average enrichment factors computed and presented in Table 2 may not be representative for the entire district and is improper for the average EFs to be used for environmental health engineering policy. Mix elements concentrations are found sometimes in the same food crop and this may be an attribute of the geological, environmental and anthropogenic activities. Arsenic (As) values were generally rich in millet and in sorghum and require more detail investigations to draw conclusions on their associations. Interpreting each situation separately with respect to the geographic location where geology and local-scale human activities can influence the elements mobilization and concentration is useful. Guinea corn, maize, groundnut and soybean seem to show depletion but current data is unable to explain the causes of depletion particularly in the legumes. Again for Se there is no pattern as far as the food crops enrichments are concerned. Similar inference drawn for As may apply also to Se. Bivariate analysis of $EF_{Cr}$ and $EF_{Pb}$ (Figure 7) and that of $EF_{As}$ and $EF_{Se}$ (Figure 8) suggest different factors probably control the concentrations and distributions of micronutrients in the food crops.

To a nutritionist consumption of uncontaminated millet provides copper (Cu), phosphorous (P), Manganese (Mn) and Magnesium (Mg) that contributes in protecting some properties of the heart, helps in the development and repairs of body tissues, play roles in reducing the risk of type 2 diabetes, breast cancer and against childhood asthmas. Similar health remedies are obtained when maize, sorghum, guinea corn and rice are consumed. The unwitting consumption of potentially harmful elements such as Cr, Pb and As found enriched in many of the staple food crops in this investigation suggest coupling earth sciences to health and nutritional issues.

## Conclusion

The regional geology of the study area in the broad sense appears to be underlain by similar rock units but there are vast contrast between the regional geology and the geology mapped at the local-scale. These changes reflect the type of soils formed from the underlying rocks where the food crops were planted. The authors recognized the variations in the geochemical environment and human activities in the local areas contributing to plant intake of micronutrients from the soils. The permissible concentration limits of As and Pb in the food crops were identified to be higher than the calculated means in the field food crops. The danger herein is that the low enrichment of these potentially harmful elements in cereals and legumes that serve as staple food can bio-accumulate in the human system and due to their bioavailability and bioaccessibility re-concentrate and increase to chronic levels to cause adverse health effects. Cr concentrations in all food crops in the study area show enrichment up to about 10-folds. The authors further realized that if the rural people eat what they grow then enrichment factors of the contained elements in the food crops should be analyzed and interpreted with respect to the local environments and not on global averages that will results in overgeneralization of some outcomes. In conclusion anything that is grown in the soils of the earth is geological in nature and may have its food or fruits influenced by the essential and toxic elements in them. Variations in enrichment factors for the same type of food crops example millet in this study suggest the significance role the soil geochemistry and the local-scale human activities have on the distributions and concentrations of elements uptake by plants. Hence to eliminate the undesirable elements that are unintentionally ingested it is being recommended that interdisciplinary research to include health workers, nutritionist and geoscientist be conducted particularly in rural communities in Developing world.

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