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Trace elements and health: An environmental risk in Nigeria

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Abstract: The concentration levels of trace elements in drinking water and food pose potential health risks to man and therefore require great attention. Studies on iodine deficiency disorders (IDD) indicate goiter prevalence in areas underlain by metamorphic Basement and Younger Granite rocks and its near absence in the sedimentary terrains. There are cases of dental fluorosis resulting from the excessive ingestion of fluoride in both children and adults living in both the crystalline and sedimentary terrains in Nigeria with none reported from the coastal areas. Mining/mineral processing predisposes these trace elements to weathering whereby they are released into the environment in the soil and water bodies. The incidence of abnormally high natural radiation (radon gas) associated with most rocks and the exceptionally higher natural radiation associated with cassiterite mill tailings of the Jos Plateau, north central Nigeria, is a source of worry. Epidemiological records have indicated the increasing rate of lung cancer prevalence on the Jos Plateau and studies carried out elsewhere in Europe have linked about 13% of deaths associated with lung cancer to exposure to natural radiation. Preliminary hydro-geochemical study indicates high concentrations of potentially harmful elements (PHE) (Pb, Cu, Zn, As, Cd, Hg, V, Co, Cr, Ni, etc.) in the soils and water bodies in the crystalline and inland sedimentary terrains especially close to sulfide mineralization. In addition, high levels of these elements from anthropogenic sources have also been reported in soils and water in most mining/mineral processing sites and urban centres. The knowledge of the relationships between trace elements and human health issues is at its infancy in Nigeria. To adequately understand these relationships, there is need for geoscientists to intensify research on trace elements in the environment and together with professionals in community health so as to identify health issues arising from trace elements in the environment.

Keywords: Trace Element, Environment; Health, Risks, Nigeria, Anthropogenic Sources

1. Introduction

Trace elements are elements that occur in minute but detectable quantities in minerals and rocks much less than 1% while health has to do with the state of being well and free from illness of the body or mind. The big question here is: What effects do the distributions of chemical elements in any geological environment have on human and possibly animal health? The natural trace element compositions of rocks and soils may become direct risks for human health and may be the underlying cause of element deficiency and toxicity [1]. How do these elements get into the human body? Most elements are taken into human body in air, food and water. Most population in Nigeria and indeed the whole of Africa depend on the land within their immediate environment in their daily lives. Thus, trace elements in the soil we cultivate, find their way into the human body directly from the soils and/or the underlying bedrock or through the food chain [2]. The water we drink has a history of percolation through rocks and soils as part of the water cycle, and leached out chemical elements in solution. Thus, the distribution of elements either by natural and/or anthropogenic sources poses potential health danger to man and therefore require great attention. The link between trace elements and human health issues is still poorly understood. However, there is need for the acquisition of a systematic geochemical database for Nigeria for application in the identification of the relationships between trace elements and associated health problems.

2. Trace Element Distribution in the Nigerian Environment

Geologically, Nigeria is made up of three major geologic terrains viz: The Proterozoic-Lower Palaeozoic metamorphic Basement Complex, the Jurassic Younger Granites, the volcanic provinces and the Cretaceous sedimentary terrains. The Basement complex terrain is granitic, comprising of the metamorphic rocks (gneiss-migmatites, schist and granites associated with amphibolites, charnockites, diorites and serpentinites) [3]. The Younger Granite terrain is also granitic in composition and is centered in north central Nigeria. Tertiary to Quaternary volcanic provinces exist covering essentially the eastern half of Nigeria. This includes the Jos Plateau, the Biu Plateau, the Longuda Plateau and the Benue valley. The sedimentary terrain comprises of the Niger Delta, the Anambra basin, the Lower, Middle and Upper Benue trough, the Chad basin, the Sokoto basin, the Mid-Niger (Bida-Nupe) basin and the Dahomey embayment (Fig.1).

The natural levels of trace elements in soils derived from the Nigerian Basement settings vary widely, depending largely on the nature of parent materials from which the soils form and also on soil - forming processes. The leaching of trace metals into soils and water bodies add to the already existing background values. Generally, most chemical elements are essential in human life. Some are toxic and therefore non-essential. The elements of major needs in the human body are H, Na, Mg, K, Ca, Fe, C, N, O, F, Al, P, and S (Fig.2). V, Cr, Mn, Co, Ni, Cr, Cu, Zn, B, Si, F, Cl, Se, Sn and I are elements of minor needs required for human growth, while Be, As, Cd, Sb, Hg, Tl, Pb, Rn, Ra, Th and U are toxic elements and are directly harmful to human life at minute dosages (Fig. 2).

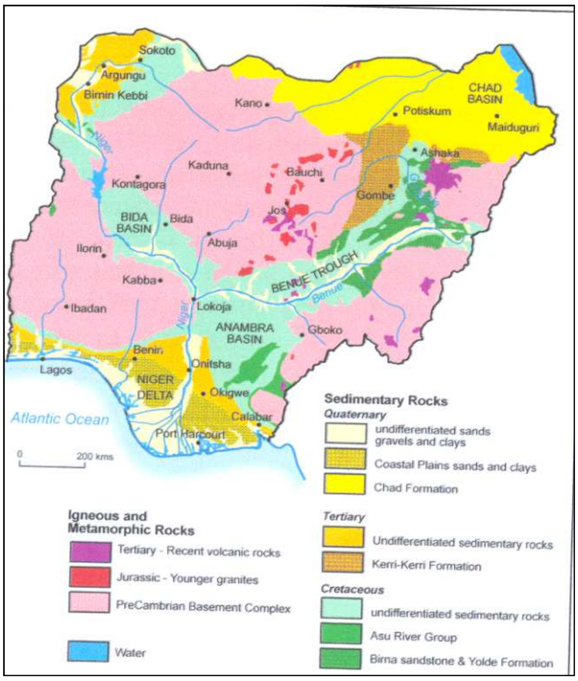

__Fig 1.__ The Geological Map of Nigeria.

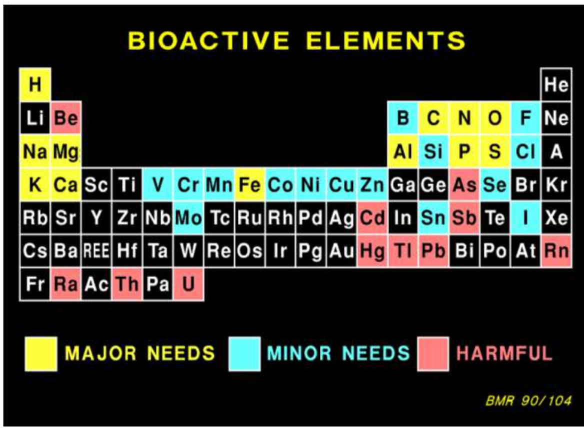

__Fig 2.__ Bioactive elements

Top soil horizons overlying most parts of the Nigerian Basement terrains contain high levels of potentially harmful elements (PHE) (Pb, Ni, Zn, Cr, Co and Ba). Also, high levels of these toxic elements such as Pb, Zn, Cu, Cd, As, Hg, V, Co, Cr etc have been reported in most sedimentary basins in Nigeria [4].

In the Younger Granite province, high values of Pb, Cr, Ni, Co, V, Sr, Zr, As, Th and Nb have been reported in the top soils [5]. It is known that high levels of the element arsenic in drinking water cause serious health problems such as skin pigmentation.

Abnormally high levels of fluoride in water are common in most parts of the Benue Trough and the Younger granite rocks with the basement pegmatite veins. Deficiency in iodine is restricted to the crystalline Basement rock areas.

Iodine is highly mobile in whatever surface conditions it finds itself. Lack of iodine has been associated to incidences of goitre. High natural radiation (radon gas) derived as a result of radioactive decay of essentially uranium bearing minerals (thorite, zircon, monazite and zenotime) is associated with virtually all the rock types in Nigeria (granites and/or pegmatites) or as gangue minerals from the processing of cassiterite and columbite on the Jos Plateau, Nigeria.

Recent studies from the Keana brinefields in the Benue sedimentary basin, have shown that the soils and sediments from stream channels are extremely contaminated with Pb (45 – 105 ppm); Zn, as high as 1080 ppm in the soils to greater than 7000 ppm in the sediments; As : 10 – 70 ppm and iodine 38 – 1800 ppm in the sediments [6]. The groundwater and refined salt from the same area also contain high levels of toxic trace elements (groundwater: Cd=0.56ppm; Sb=0.40ppm and refined salt; Cd=11.6ppm; Pb=16.4; As =11.6 ppm; V = 363 ppm; Cr=283 ppm) [4].

Several anthropogenic activities contribute immensely to influencing trace elements levels in the environment where we live. These include but not limited to, activities such as mining, mineral processing, urbanization and industrialization.

3. Materials and Methods

Three different representative sample media (soils, water and vegetables) were collected. The soil samples were collected from the mining pits, mine dumps/tailings, farmland and uncultivated land using a hand auger. Water samples were collected in 250 ml polythelene bottles from nearby streams/rivers and acidified with one to three drops of Nitric acid. Vegetables (spinach) from the farmlands were also sampled. 100 mg of soil of each of the samples was weighed and attacked with aqua regia (2 mls HNO3 + 6 mls HCL). The solution was heated for about 6 hrs in a sand-bath of 250ºC in a fume cupboard to dryness and then left to cool, 2mls of HCL were added to re-dissolve the dry sample. 10mls of distilled water was then added and heated for 5 minutes. The extract were cooled and the content filtered (using size 42, 125 mm diameter, ashless filter paper) into 100mls volumetric flask and make- up to 100ml mark with distilled ready to be analysed for trace elements. The acidified water sample was filtered and analysed directly, while the dissolution of the vegetable sample was done the same as the soil sample. Some of the samples were analysed for Pb, Hg, As, Cd, Co, Cr, Cu, Fe, Ni, Se, U, V, and Zn using the Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) at the Geochemistry Laboratory, Department of Geology and Mining, University of Jos, Nigeria. The instrument was calibrated prior to the introduction of sample by measuring in-house standards and blank solutions. The quality of the analysis is controlled through the analysis of samples of known compositions along with the unknowns. The results turn-out have an accuracy of ± 2-5% depending on the number of standards used and concentration levels.

4. Results and Discussion

4.1. Trace element Concentrations in Mining Sites

4.1.1. Gold Mining in Zamfara State, NW Nigeria

The range of concentration of Pb in the samples varies from a minimum of 6.91 to a maximum of 4152 ppm, with a mean of 1171.43 ppm. The maximum concentration of 4152 ppm was recorded at a mineral processing site around Anka town. The concentration of Hg varies from 2.15 ppm in Bagega to 12.92 ppm in Anka processing sites with a mean of 6.25 ppm [7].

In respect of the other heavy metals, the highest concentration of As (173.20 ppm) and Cd (10 ppm) were also recorded at the Anka processing site, while the maximum Zn concentration (1657 ppm) was recorded at kwalli mine site [7].

The high concentration of the Pb in the areas is attributable to releases from the mine dumps around Kuba mines,Kwalli and Zuzzurfa mines as well as the the gold sulfide vein which may contain some trace elements. Hg is found in excess concentration of 12.92ppm apparently due to the use of Hg for processing of the gold and from tailings from the mill. Although Hg leaching from tailings seems a slow process, the migration of tailings themselves over the years may be the most important Hg dispersion mechanism [8].

The analysis of Pb in blood samples collected from mainly children in some parts of the mining districts by the Center for Disease Control [9] revealed blood Pb concentrations of 200 mg/dl or more. It also showed average blood Pb levels for children in Anka and environs ranging between 50 and 100 mg/dl i.e. about 5 to 10 times the permissible WHO/EPA maximum of 10 mg/dl.

4.1.2. Galena Mining at Zurak, Central Nigeria

Lead (Pb) display concentrations that vary from 0.14 - 0.56 mg/l in the surface water. Vegetables (spinach) grown around the mining site revealed the following concentrations Pb= 9.4 ppm, Zn = 1309ppm, U =159.3ppm which are significantly high, followed by As (32.06ppm), Se (14.68ppm), Cu (8.566), Cd (0.672ppm), Co (0.139ppm), and Ni (1.066ppm) in that decreasing order [7]. The soils from around the mining site contained extremely high concentration levels of the following: Pb (1806 ppm); Zn (16.7 wt%); U (0.3193 wt%); and As (118.3ppm); and Cd (16.60ppm).

4.1.3. Radon in Tin Mining Reas

High doses of natural radiation (radon gas) (1000 - 2000 bq/g) derived from the radioactive decay of uranium (U) have been recorded in granites and tin mill tailings, particularly in the tin mining fields of the Jos Plateau Nigeria [10]. The dose contribution for uranium and thorium on the environment was found to exceed the maximum permissible dose of 0.5 rem/yr [11].

Reports have shown that igneous and metamorphic terrains of the Jos Plateau tin fields contain radioactive elements (uranium and thorium) concentrations of between 60 - 200ppm and 100 - 3000ppm respectively [11]. The degree of radiation is significantly high in mill tailings, the by-product obtained from the beneficiation of tin ore from these rocks [12, 13]. These mill tailings are disposed indiscriminately all over the minefields and even in residential areas where tin is being processed.

4.1.4. Enugu Coal Mine

The Enugu Coal mine discharges its effluents directly into the rivers (River Ekulu, Nyaba and Atafo) that take their source from the escarpment where the coal seams are hosted. The Coal is known to contain trace metals such as Pb, As, Cd, Cr, Hg etc. The analysis of sediments from River Ekulu shows higher values of trace metals than is found in the coal (Mn=0.256-0.389; Cr=0.214-0.267; Cd=0.036-0.043; As=0.036-0.043; As=0.016-0.018; Ni=0.064-0.067; Pb=0.013-0.017) [14]. The long-term accumulative effect of these toxic metals in the sediments in River Ekulu and the immediate surroundings of the mine could be detrimental to human health and aquatic life.

4.1.5. Abandoned Enyigba Lead-zinc Mines

Enyigba Pb-Zn mines is located 14Km south of Abakaliki town South East of Nigeria. The major mineral constituents are Galena and Sphalerite, associated with siderite (FeCO3); Chalcopyrite CuFeS) and Marcasite (FeS). These minerals are hosted by shales of the Asu River group which is enriched with Cu, Ni, Pb, and Cd. In Enyigba and Ameka area, mine tailings are indiscriminately dumped. The pollution index (P.I), which the average of the ratios of metal concentration to the hazard criteria (i.e. the tolerable level, or the metal concentrations above which crops produced are considered unsafe for human health) of soils around the vicinity of Enyigba mines ranges from 1.3 to 18.7 with an enrichment factor of a range between 12.2 – 155, suggesting an extreme pollution of the soil around Enyigba by Pb, Zn, and Cd [15].

4.1.6. Itakpe iron ore Mine

The biggest iron ore mining company in Nigeria is situated at Itakpe, central Nigeria. Geochemical analysis of soils from the surroundings of the mines shows the following: a mean Fe content of 7.45 mg/kg as against 2.35 mg/kg at the control site; mean Cu content of 3.24 mg/kg as against 2.05 mg/kg; mean Zn content of 3.15 mg/kg as against 2.03 mg/kg [16]. Analysis of water leaves grown on the soils revealed the following: Fe content of 73-78 mg/kg as against 40 mg/kg at the control site; Cu content of 8.8 – 9.5 mg/kg as against 6.4 at the control site and Zn content of 36 – 40 mg/kg as against 28mg/kg at the control site. This suggests that Mine wastes are possible sources of toxic metals contamination of soils and plants at Itakpe. The toxic metals get incorporated into the biogeochemical cycle and thus the food chain.

4.2. Trace elements Concentrations in Urban Centres

Also the indiscriminate dumping of wastes and location of industrial estates in residential areas where the effluents are directly washed into the water bodies could be a major source of heavy metals into the environment. Excellent examples are areas around the Ikorodo industrial estate in Lagos (Cd = 0.2-2.10ppm); Cu = (28-153ppm); Pb = (20-148ppm) and Zn = (61-1133ppm) [3] and Lagos Lagoon (Cd = 3.7ppm; Pb =214.6ppm; Zn =9-36.6ppm; As =28ppm; Sb =11ppm and Te =6ppm) [17] where the concentrations of these elements are visibly high.

The limestone, a raw material in the manufacture of cement used by WAPCO located in Sagamu SW Nigeria has been reported to contained very high levels of heavy metals such as Cd (1.7ppm), Pb (42- 48ppm), Cu (3-11ppm), Zn (7.05ppm), Cr (19-75ppm) [18]. These elements display correspondingly higher concentrations in the surrounding soils and such high levels have been observed in nearby crop samples [18]. The principal route of most of these elements into the human body is through drinking water and food. Other routes are through the inhalation of dust or direct contact with soils

4.3. Trace Elements and Environmental Health Risks

4.3.1. Iodine and Health

The deficiency of iodine in drinking water (when the intake falls below the recommended level of 150 mg/l of iodine per day), causes serious disease conditions in humans referred Iodine Deficiency Syndrome (IDD), the commonest of which is the goiter (Fig. 3). Available information have shown that goiter, is restricted to the Basement metamorphic and igneous granitic terrains of central Nigeria [19, 20]; South Western Nigeria; North Eastern Nigeria and north western Nigeria [21]. This implies very low concentrations of iodine in drinking water from these areas. However, the level of distribution of iodine varies within the terrains.

No cases of goiter have been reported from communities living within the sedimentary basins and coastal areas indicating that there is an appreciable level of iodine in the water consumed by the inhabitants. Recent studies from the middle Benue trough, show that iodine is present in tolerable amount in the groundwater (I = > 150 mg/l), a common source of drinking water [4]. The commonest method of addressing the problem of iodine deficiency is the addition of iodine in food supplement. In Nigeria, the fight against IDD was done through the universal salt iodization program (USI) [22]. Although 98% success has been achieved, there are still some isolated areas that haven't been identified yet.

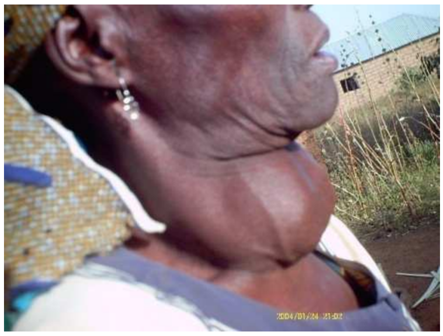

Fig 3. *An elderly woman with goitre, an Iodine Deficiency Disorder, in the Panyam Volcanic province, Jos Plateau, Nigeria.*

4.3.2. Fluorine and Health

Fluorine, when ingested in the correct dose (0.5 - 1.5 mg/l), it reduces tooth decay. Lack of it (< 0.5 mg/l) has long been linked to tooth decay. Flouride concentration of > 1.5 mg/l causes the mottling of teeth and dental fluorosis (Fig. 4). Higher fluoride dose (> 3 mg/l) is associated with skeletal fluorosis and other physiological disorders in humans [23]. Studies carried out in Central Nigeria revealed fluoride concentrations between 0.21 - 8 mg/l [24]. Also, Fluoride values of up to 4 mg/l have been recorded north of the Benue trough [25]. The problem of dental carries is endemic to these areas. Investigation into dental caries shows an overall prevalence among primary school children [26].

Fluoride in groundwater is derived from the crystalline rocks and their derivatives (soils, clays etc), where it occurs in the constituent fluoride bearing minerals (topaz ($Al_2SiO_4(F,OH)_2$), fluorite $(CaF)_2$,fluorapatite ($Ca_5(PO_4)_3$ F), cryolite (Na_3AlF_6)) and/or in mica muscovite ($KAl_2(AlSi_3)O_{10}$ (OH, F) and biotite (MgFeAlK, OH, F). The interaction between water and the soil and the rock formations dissolves their constituent fluoride compounds, resulting in the presence of small amount of soluble fluoride in virtually all water sources.

The deficiency in fluorine is addressed through the addition of fluorine toothpaste to supplement for the needed fluorine. Also, like in most urban centres in Nigeria potentially harmful elements in different surface where there are controlled water supply systems, fluorine conditions are added to water supplies so as to boost the naturally low concentration [23, 24]. In the case of excess fluoride in that between 5 to 13 % of death from lung cancer in drinking water, partial defluoridation is recommended to render the water safe for drinking, the simplest and the most cost-effective of which is direct evaporation technique. The addition of alum into the water reduces fluoride content. Several other methods of defluoridization exist, but must be adapted to suit the Nigerian socio-situation. More needs to be done to create public awareness of the health risk associated with the excess consumption of fluoride by humans.

Fig 4. *Mottled teeth among young children in central Nigeria.*

4.3.3. Natural Radiation (Radon Gas) and Health

The amount or level of radon gas generated is related to the amount of U in the underlying rocks and soils. The exposure and the amount of natural radiation received by man has been identified as the cause of lung cancer. In Nigeria, there hasn't been a systematic effort towards establishing the link between exposure to radon and the possible health risks in humans. Nevertheless, the fast increasing cases of cancer in Nigeria (2-3% of the death) (common news) calls for a multidisciplinary approach in unraveling this. Also, there is great apprehension as to the cause(s) of some cases of malformation in kittens and miscarriages in pregnant women in some parts of the Jos Plateau, central Nigeria has apparently been attributed to natural radiation [26].

Studies carried out in France, have revealed that the risk of lung cancer increases proportionately to the quantity of radon inhaled notably during the previous 25 years before the ailment [27]. Studies carried out on mine workers in France show that the risk decreases with less exposure. A PhD dissertation realized in France revealed that between 5 to 13 % of death from lung cancer in France was as a result of domestic exposure to radon (28). In the UK for example, exposure to radon has been responsible for around 3.3% 0f the 1100 lung cancer deaths each year [29].

4.3.4. Lead (Pb), Arsenic (As) and Mercury(Hg) and Health

As earlier mentioned, these elements occur in groundwater in both the crystalline and sedimentary aquifers. The principal route of entry of these toxic elements into the human body is through the intake of this water. It is a well known fact that the concentration levels of each element in drinking water could cause serious health problems in humans. Arsenic (As) and antimony (Sb) are recognized as carcinogenic and reduce human life span. Arsenic is also known to cause skin pigmentation, keratosis and Bowen disease. The accumulation of Cd in humans can cause damage to the vital organs (lungs and kidneys). Pb on the other hand causes disorders in the human nervous system [30]. According to WHO [31], Pb level of >100mg/l in the blood will reduce intelligence quotient (IQ) in children. Much lower values (0.1 mg/l) have been known to impair intellectual capability in children [32].

Exposure to mercury (Hg) is the causal factor for cardiovascular, neurological or kidney diseases [33]. The inhalation of Ni and Cr dust causes asthma and much higher doses could be cancerogenic (WHO [34]. It is therefore necessary to establish the health impact of the ingestion of these heavy metals in the environments where they are found in high levels in drinking water. The health impact of the ingestion of most of these heavy metals in water in the affected areas has not been established.

5. Conclusion

Trace elements are leached into groundwater as the water percolates through the host rocks and soils coupled with an addition from anthropogenic sources. Also mining predisposes the minerals hosting these trace elements to weathering whereby they are broken down and their constituent elements are released and dispersed into the soil and water. The concentration levels of trace elements in water whether low or in excess could be beneficial or of direct risks to human health. The potentially harmful elements (Pb, As, Cd, Hg, I, F etc.) are of great concern and pose potential health risks in humans particularly those living in sedimentary terrains and in semi-urban and urban centres in Nigeria. This study has revealed some of the environmental high risk areas in Nigeria to include, for Pb (Enyiga, Ameri, Izom, Anka, Bukkuyum , Zurak (and along the Benue trough); U, Th, Ra (Several areas of Plateau State: Granites/mill tailings); Iodine (Egbe, Isanlu – Kogi State, Mangu, Bassa, Plateau State); Fluorine (Benue, Plateau, Gombe, Adamawa (along the Benue Trough, Sokoto Basin) and mining/mineral processing sites, most of which are from anthropogenic activities. The identification of these environmental high risk areas will enable the development of suitable remediation strategies so as to reduce the deleterious effects on human health.

What is worrisome is that about 90% of the Nigerian population rely on ground water (well or borehole) as an alternative to the failed public water supply system. The preliminary steps towards tackling the problem of PHE contents in drinking water is to work towards the acquisition of geochemical dataset of the country, where geochemical risk maps of the country for each of these elements is developed. Once this is done, appropriate mitigation/remediation strategies would be drawn to reduce effects.

This calls for the mapping of the entire country to delineate areas that display the preponderance of one or several chemical elements and their consequent health impact. In achieving the above feat, there is need to establish a closer working relationship between the geochemists and professionals in community health. The geochemists should occupy themselves with understanding the origin and behaviour of these elements, cardinal to understanding the link such elements and human health.

Acknowledgement

This paper brings to the fore some glaring health problems in Nigeria arising from geological materials and processes. The author thanks the anonymous reviewers for their positive criticisms which have improved on the quality of the paper. Last but not the least, is a big Thank you to our host University of Jos for creating the enabling environment to carry out this research work.

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