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Application of environmental geochemistry research to public health issues in Nigeria

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Abstract: Public health is threaten by imbalances in the distribution of chemical elements in the environment resulting from natural or/and anthropogenic activities. Of significance are toxicities resulting from anthropogenic activities such as mining, ore mineral processing, indiscriminate waste disposal, and the use of pesticides in agriculture etc. To reduce the impact of these chemical elements on the environment and their consequence human health effects, there is need for the establishment of toxicological health facility in the vicinity of the mining communities in other to minimize the problem of wrong diagnosis as often is the case. Unfortunately, modern geochemical data are rarely available for developing countries, or may be inadequate for environmental purposes, having been collected principally for mineral exploration. Geochemical surveys (ideally incorporating data for soil, stream-sediment, natural/mine dust, vegetation and water samples) are of considerable value in studies linking the environment, food and health. Geochemical maps are pointers to potential areas of chemical element deficiency or toxicity, enabling expensive veterinary or medical investigations to be better targeted. The understanding of the geochemistry of the environment is necessary for the development of sound principles, strategies, programs and approaches that will minimize public health risks. Thus, to comprehensively and extensively address the issues of public health emanating from chemical element toxicities and deficiencies, mine/natural dust associated with geologic material, mining and mineral processing, there is need for closer collaboration, synergy and partnership among the public health researchers (physicians, environmentalists, nutritionists, geochemists, botanists, biochemists, atmospheric chemists and others). On the part of public health centres, there should be enhanced and improved medical record-keeping, sources from which reliable epidemiological data about incidence, prevalence and trends in disease occurrence can be extracted. The analytical capacity of research centres should be enhanced to enable the contents of nutritional and toxic elements to be measured at the very low concentrations needed for making tangible correlations between geology and environmental health conditions.

Keywords: Environment, Chemical Elements, Partnership, Developing Economies, Toxicological Centres and Public Health, Geochemistry

1. Introduction

Environmental geochemistry is concerned with the study of the complex interactions between the rock-soil-water-air-life system which show marked variation from place to place, while public health has to do with the state of being well and free from illness of the body or mind. It evaluate the impacts of geologic materials and processes on human and animal health and in collaboration with the geosciences, biomedical, biochemist and public health researchers seek solutions to solving or minimizing a wide range of environmental health problems. The effects of chemical elements in the environment and their consequent effects on human and animal health are a matter of increasing public concern. They are implicated in various health conditions such as pulmonary fibrosis, carcinogenesis, skin diseases, neurological problems, bone disorders, the malfunction of several vital organs etc. Many developing countries are particularly liable to trace element toxicities and deficiencies because of local geological, anthropological engagements, climatic and socio-economic conditions, and further compounded by the consequences of land degradation, pollution, urbanization and industrialization resulting from rapid economic and population growth.

The distribution of chemical elements in the Earth's crust is not random but is controlled by physico-chemical processes which are becoming better understood as a result of progress in geochemistry. Understanding the processes that influence the distribution, concentration, geo and bioavailability of potentially toxic metallic elements such as As, Cd, Pb, Hg, Se, and Zn is critical for successful management of the affected ecosystems (Fig. 1). Such understanding of processes can be used to identify and target those pathways that have the greatest immediate and long-term impact on the environment and health of biota. It therefore provides the scientific foundation for making decisions, developing strategy, and assessing mitigation and remediation alternatives by authorities charged with minimizing the environmental and health impacts of the toxic elements and chemicals.

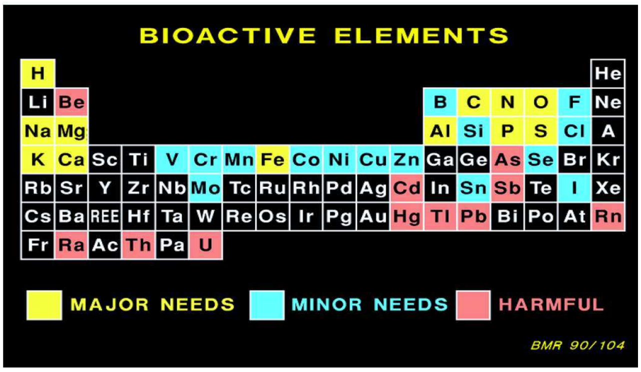

Fig 1. *Bioactive elements*

2. Public Health Impact of Trace Element Distribution in the Environment

Trace elements (TE) correspond to a group of elements, that are potentially toxic to human, animal and plants when the available content is in excess (Fig. 1). They occur in minute but detectable quantities in minerals and rocks (Lar, 2013). Trace elements play an essential role in the normal metabolism and physiological functions of animals and humans. Twelve elements are established as being essential for good health. Calcium, P, Mg, and F for example, are required for structural functions in bone and membranes (Bunnell et.al., 2005, Lar, 2013; Fig 1). Sodium, K, and Cl are required for the maintenance of water and electrolyte balance in cells (Bunnell et.al., 2005). Zinc, Cu, Se, Mn, and Mo are essential constituents of enzymes or serve as carriers (iron) for ligands essential in metabolism (Bunnell et.al., 2005). Chemical elements are also important in the functioning of the endocrine system. For instance, iodine is an essential component of the thyroid hormone thyroxine, and chromium is the central atom of the hormone-like glucose tolerance factor. Because these are all critical life functions, the tissue levels of many "nutritionally essential elements" tend to be regulated within certain ranges, and dependent on several physiological processes, especially homeostatic control of enteric absorption, tissue storage, and/or excretion (Fordyce, 2005; Bunnell et.al., 2005). Changes in these physiological processes may exacerbate the effects of short-term dietary deficiencies or excess of trace elements. Food is a major source of trace elements in humans and animals. However, other sources such as the deliberate eating of soil (geophagia), inhalation and potable water may also contribute to dietary intake of trace elements into the human body system. Endemic diseases correlative with the deficiencies in selenium and iodine in the soils have been described in at least two general cases, the juvenile cardiomyopathy "Keshan Disease" (Fordyce, 2005) and the Iodine deficiency disorders (IDD) including goiter and myxedematous cretinism (Fordyce, 2005).

Environmentally significant elements in terms of PHEs include but not limited to Al, As, Cd, Cu, Fe, Hg, Mo, Pb, Sb, Se, Zn U and Th (Fig. 1). Diseases due to trace element deficiencies as well as excesses are known for I, Cu, Zn, Se, Hg, Mo, Mn, Fe, Ca, As, and Cd (Lindh, 2005). TE build-up in the food chain results from massive quantities of TE being discharged into the environment, in which plants constitute an important link. Although TE contents are low sometimes, TE could be transported and concentrated through the food chain, and accumulated in the human body, leading to chronic poisoning with long-term exposure (Lar et.al.. 2013). Thus, the concentration levels of trace elements in drinking water and food pose potential health risks to man and therefore require great attention (Davies, 2010, Lar et.al., 2013). Human beings might be exposed to metallic hazards, due to abnormally high natural contents in food or water particularly associated with indiscriminate mining and manual processing of mineral ores and associated materials (Figs. 2 and 3), indiscriminate dumping of waste 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, inhalation of particulate matter and dust in the mining environment or from other industrial sites, disposal of domestic and industrial wastewater, direct dermal contact with ores and associated materials). A human health concern is usually associated with excessive exposures to trace elements that cause toxic effects to biological organisms. Toxicity (of PHEs includes hypertension, atherosclerosis, as well as alterations in carbohydrate, lipid metabolism, glycosuria, proteinuria, shortened longevity, reproductive abnormalities and weight loss in older persons (Tchounwou et al., 2003).

Trace-element deficiencies or imbalances in soils and forages are also responsible for low production and reproduction problems (Appleton, 1992).

Fig 2. *Indiscriminate small-Scale mining and manual bagging of Pb and Zn ores and other materials in Nigeria*

Fig 3. *The small-scale mining activities undertaken along the river bed in denawase, Ghana*

3. Public Health and the Environment

3.1. Case Studies

A Releases of trace elements from mining/mineral processing

A most devastating Pb poisoning episode occurred recently (June, 2010) in Zamfara, northwestyern Nigeria, which drew worldwide attention (Plumlee et al., 2011). Ingestion of Pb released from gold mining activities caused the death of at least 400 people, mostly children between the ages of 5 and 11 years and illness (355+). Although the death toll from Pb poisoning in this episode is on the rise, the local miners continue to ignore advice from local environmental auditors (Lar et al., 2013) . If Pb-Zn mining methods in New Zurak remain unchecked, we may be waiting for yet another calamity similar to the Zamfara one, in the near future (Lar et al. 2013). In the New Zurak mining district, central, Nigeria, galena is mined and processed indiscriminately and manually. Children play on the mine tailings and dumps and are engaged in the processing the commodity and thereby inhale Pb in the atmospheric dust or ingest it by putting their hands in their mouths (Ngozi-Chika, 2012; Lar et al., 2013) Other routes of exposure to Pb are from drinking water and food consumption. The mining communities live on subsistence agriculture; and ground water as a major source of potable water (Ngozi-Chika, 2012; Lar et al., 2013). The small-scale mining activities undertaken along the river bed at Dwenase, in the Bekwai District of the Ashanti Region of Ghana was simple mechanisation performed with two heavy caterpillar machines for excavation (Fig. 3). It was observed that none of the workers wore any protective gear both the females and the males (Fig. 3). In some areas within the Lake Victoria region of Kenya, soils and water catchments show remarkable high concentrations of metals that may cause metal exposure to the local populations (Oyoo-Okoth et al., 2000).

B Trace elements in food crops

The concentration of certain essential trace elements (such as Se) in crops (rice, corn, soybean) has been shown to correlate with the concentrations in the soil in which they are grown (Appleton, 1992); and, regionally, levels in fine-fraction stream sediments give a good indication of likely soil concentrations (Appleton, 1992). Although under nutrition is the most important problem for livestock in tropical areas, trace-element deficiencies or imbalances in soils and forages are also responsible for low production and reproduction problems. For grazing livestock, deficiencies of Co, Cu, I, Fe, Mn, Se and Zn, and excesses of Cu, F, Mn and Mo may lead to adverse effects; As, Pb, Cd, Hg and Al also cause toxicity (Appleton, 1992). Geochemical mapping can therefore be a cost-effective method of indirectly investigating the chemical composition of crops. Rural communities in developing countries offer a particularly valuable opportunity for examining the relationship between geochemistry, diet and health (Appleton, 1992).

C Exposure to mineral dust

Exposure to mineral dust can cause a wide range of respiratory problems. The dust can be generated by mining rocks or coal, sandblasting, and smoke plumes from fires (both natural and man-made) or simply from the wind dispersing fine-grained minerals from the earth's surface. The dust from mining and processing and handling of these materials can cause serious and fatal illness, not only in those with heavy occupational exposure, but also in people who live near the industrial site or even simply in the same household with exposed workers (Figs. 4, 5 and 6). The illnesses include a nodular pulmonary fibrosis (silicosis) which may be chronic, accelerated or acute, progressive pulmonary fibrosis, chronic obstructive pulmonary diseases, lung cancer and an increased risk of tuberculosis (Hnizdo and Murray, 1998).

Asbestos is a diverse group of minerals with several common properties; separation into long thin fibers, heat resistance, and chemically inertness. In the 1980s the U.S. medical community recognized that exposure to respirable asbestos fibers can cause severe health problems including mesothelioma (maglinant tumor, usually associated with exposure to asbestos dust), lung cancer, and asbestosis. Hence, many commercial asbestos mines were closed and a concerted effort was made to remove asbestos from schools, work places, and public buildings.

Unfortunately, the problem did not end there. Recently, it was found that small amounts of asbestos associated with commercial deposits of vermiculite, a micaceous mineral used for insulation, packaging, kitty litter, and other applications, has caused significant health problems in the mining community of Libby, Montana, USA (Van Cleve et al., 1991). Lung abnormalities (such as pleural thickening or scarring) occurred in about 18 percent of the adults tested (Van Cleve et al., 1991).

Dust can also be stirred up by earthquakes such as happens in the arid regions of the southwestern U.S. and northern Mexico. This dust carries spores of a fungus (Coccicioides immitis) responsible for Valley Fever, a serious respiratory problem that can lead to fatigue, cough, fever, rash, and damage to internal organs and skin, bones, and joints. Dust exposure can even take on global dimensions. For example ash ejected from volcanic eruptions can travel many times around the world. Of greatest concern for its affects on human health are the finer particles of respirable (inhalable) dusts. In this regard, considerable work is being conducted to identify dust particles derived from soils, sediment, and weathered rocks.

D Exposure to agricultural pesticides

Some organic compounds such as Dichlorodiphenyltrichloroethane (DDT), Polychlorinatedbiphenyls (PCBs) and Dioxin - 2,3,7,8-tetrachlorodibenzo para dioxin *(TCDD)* may be classified as carcinogens, neurotoxins or irritants; others may cause reproductive failure or birth defects (World Health Organization, 1988)

Fig 4. *Exposure to mine dust through manual mining and processing of mineral ores*

Fig 5. *Exposure to lead particles and dusts in Nigeria Village. Source: Alo, 2014*

Source: Alo, 2014

Fig 6. *Grinding of Raw Ore for Gold and Lead exposure in Nigerian community.*

3.2. Establishment of Toxicology Centres in Mining and Industrial Areas

The benefits of addressing issues of environment and public health resulting from physical interactions of human population with their immediate environment and beyond are far-reaching. These require sound strategies and remediation to communities with obvious contamination necessitating the cleaning up of such contaminated areas and places where epidemic is eminent. In the emerging and developing economies, this approach should be of utmost importance as it is practiced in the developed economies. Thus, there is urgent need for closer and more collaborations, advocacy, synergy and partnership amongst the stakeholders (physicians, environmentalists, nutritionists, geochemists, botanists, biochemists, atmospheric chemists and others) .as such partnership will among other benefits enhance and eliminate the problem of wrong diagnosis as often is the case from exposure to mine dust, effects of chemicals in the environment, trace-element toxicities and deficiencies

4. Conclusion

There is the need for toxicological centres closer to the mining communities in other to eliminate the problem of wrong diagnosis as often is the case of health conditions emanating from exposure to mine dust, effects of chemicals in the environment, trace-element toxicities and deficiencies. Application of geochemistry in public health is to identify harmful geologic agents, determine the conditions of exposure that promote deteriorating health conditions and develop sound principles, strategies, programs and approaches necessary to eliminate or minimize health risks. Interaction, communication and collaboration are necessary between the geosciences, biomedical and public health researchers to protect human health from the damaging effects of physical, chemical and biological agents in the environment. Thus, there is need for closer and further collaborations, advocacy, synergy and partnership amongst the stakeholders (physicians, environmentalists, nutritionists, geochemists, botanists, biochemists, atmospheric chemists and others), such partnership will among other benefits enhance and eliminate the problem of wrong diagnosis as often is the case particularly in the developing economies. Geochemical surveys (ideally incorporating data for soil, stream-sediment, natural/mine dust, vegetation and water samples) are of considerable value in studies linking diet and health. Geochemical maps, can indicate areas where there is the potential for trace-element deficiency or toxicity, enabling expensive veterinary or medical investigations to be better targeted. Rural communities in developing countries offer a particularly valuable opportunity for examining the relationship between geochemistry, diet and health. The value of geochemistry in identifying environmental and health problems resulting from trace-element imbalances, chemicals, natural/mine dust or contamination and in formulating strategies to reduce their impact cannot be overemphasize. Unfortunately, modern geochemical data are rarely available for developing countries, or may be inadequate for environmental purposes, having been collected principally for mineral exploration.

The improved understanding of the metal pathways allows the land-management agencies responsible for areas affected by mining or mineralization better plan for mitigating the impacts of chemical toxicity in sediment, water, and biota.

Acknowledgement

This paper bring to the fore the urgent need for modern geochemical data and reliable epidemiological data as well as the establishment of toxicological health facility in the vicinity of the industrial and mining communities of emerging economies in other to minimize the problem of wrong diagnosis as often is the case.

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