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Heavy metals pollution in Nigeria: causes and consequences

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ABSTRACT

The paper reports key issues associated with recent incidences of heavy metals pollution in Nigeria. Factors such as poor government policies, poverty, ignorance and inappropriate prevention and control measures are the key reasons responsible for the problem. Different diseases and subsequent deaths have been documented. For example, Zamfara lead poisoning that claimed the lives of over 500 children, and left thousands in severe health situations in 2010, is the worst of its kind in the global record of the year. To address the issue complete phasing-out of leaded gasoline and policies against illegal mining are necessary. Environmental education (especially in the rural areas) and effective poverty alleviation programmes are required to ensure good understanding of the gravity of the problem and compliance with applicable laws. Adequate funding of health sector is essential to promote training of health personals and good treatment of affected people.

Introduction

Environmental pollution has been studied to cause severe illness and sudden death in human beings for many centuries. It can be air, water or land and can result from mining, automobile exhaust, agricultural and industrial activities among others. Heavy metals were since classified among major causes (Adedokun et al., 1989; Galadima et al., 2011). They are chemical elements with a specific gravity that is at least 5 times the specific gravity of water. The specific gravity of water is 1 at 4°C (39°F). Some well-known toxic metallic elements with a specific gravity that is 5 or more times that of water are arsenic, 5.7; cadmium, 8.65; iron, 7.9; lead, 11.34; and mercury, 13.546. The definition stated here includes some heavy elements from group III to V in the periodic.

Heavy metals occur as natural constituents of the earth crust, and are persistent environmental contaminants since they cannot be degraded or destroyed. Although these elements are lacking in abundance they are not lacking in significance (Chen and Chen, 2001). Mercury and lead for example are widely used in technology but are so toxic that minute quantities can destroy life. In Nigeria today numerous studies indicated that industrial activities release heavy metals either as solid, gas and most especially liquids in the form of waste water or effluents allowed draining into water ways or bodies. Small scale road side activities are also significantly contributing to the transmission of these toxic species (Bryee-Smith, 1971; Garba et al., 2010; Galadima et al., 2010). A good number of food items such as kolanuts, eba, moi-moi and agidi are wrapped in thick layers of leaves (which are good heavy metals sources), usually disposed off on the streets. In most cases the leaves on the streets find their way to gutters and when there is a heavy down pour, lakes, dams, streams and other water bodies used by local communities for drinking and other household activities. Toxicities of heavy metals can range from severe illness to death of both plants and animals. The paper reports recent issues on heavy metals pollution from different parts of Nigeria.

Sources of Heavy Metals in Nigerian Environment

Heavy metals can generally be introduced into the environment and consequently living organisms through air, water, food or soil (Ayodele and Abubakar, 2001; Ibeto and Okoye, 2010). However, the degree of concentration and re-concentration depend on the type of heavy metals and the activities taken place in a particular area. In Nigeria today several ways were identified through which specific heavy metal can be transmitted to living species.

Continuous use of leaded gasoline contributed greatly to the number of cases of childhood lead poisoning. Leaded gasoline in Nigeria contain lead in the concentration range of 0.65 to 0.74 g/L (table 1), the Clean Air Initiative proposed to reduce the concentration to 0.15 g/L and finally to zero level. However, numerous studies revealed that, the initiative is just on paper (Orisakwe, 2009) due to government negligence. The consequences have been severe environmental problems.

Upon the combustion of the leaded petrol in the engine, the organic lead is oxidized to lead oxide (equation 1).

i.e. $2Pb(C_2H_5)_4 + 27O_2 \longrightarrow 2PbO + 16CO_2 + 20H_2O$ (1)

The lead oxide formed reacts with the halogen carriers to form lead halides like $PbCl_2$, $PbBr_2$, or PbClBr, which escape in to the air through vehicles exhaust pipes. About 80% of lead in petrol was noticed to escape. Lead pollution from automobile emissions in Nigeria had been extensively studied and documented in various Nigerian and international publications. Nriagu et al. (1997) investigated blood lead levels in 87 children aged 1-6 years from Kaduna state. An average of 10.6 µg/dl was found, with some children having up to 30 µg/dl. The values exceed the maximum allowed limit of 10 µg/dl recommended by Centre for Disease Control (CDC) and correlated linearly with

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the distance of house from highly trafficking roads, as well as, whether a family owns a car or not. At the beginning of 21st century Federal Environmental Protection Agency (FEPA) of Nigeria examined the lead concentrations in soils from roads, markets and motor parks of Lagos, Aba, Abuja, Ibadan, Kaduna and Port Harcourt. The results revealed elevated and health threatening concentrations (table 2). It could be seen that, the highly trafficking cities of Lagos, Ibadan and Kaduna recorded the highest lead levels. Sridhar et al. (2011) reported high degree of contamination in different samples from Ibadan and Lagos. Drinking waters exhibited up to 2.16 mg/L, foods contained 18.5 mg/Kg and soil samples from residential and mechanic areas showed 81.91-4060.7 and 140.0-5454.6 mg/Kg respectively. The highest concentrations in all cases correlated linearly with level of traffic and gasoline usage.

Human beings, animals and soil are the ultimate recipients of the lead particulate. It sometimes exists in soil as lead (II) sulphate ($PbSO_4$). Concentrations of about 100 to 1000 ppm have been recorded depending on the nature of the activities, carried out in a particular area (Galadima et al., 2010; Garba et al., 2010). Other anthropogenic sources include mining and metallurgic industries, manufacture of batteries, sheet, ammunition, pipe, cable sheeting, solder, saint and trash incineration. The principal route of exposure for people in the general population is food and lead in contaminated drinking water, working and hand to mouth activities of young children living in polluted environments (figure 1) and the lead dust brought home by industrial workers on their clothes and shoes.

Figure 1: Village children harrowing in a lead contaminated soil from Zamfara state, Nigeria, 2010.

Paints containing lead are the most common high dose sources of lead exposure for school and pre-school children. Most of them contain up to 50% of lead in the form of lead sulphide (PbS). Children can get seriously lead poisoned when renovations, modelling and construction activities take place in a house or class that contains lead paints. Inhalation or swallowing of debris of the paints during regular playing causes the accumulation of the metal in the children body.

Although industrial and commercial utilisation of mercury and mercury products is regulated, occupational exposure, contamination of rivers and agricultural farmland with mercury based chemicals are considered the major contributors to mercury poisonings in Nigeria. Most of the known mercury compounds are poisonous but with cases reported mainly due to Hg, CH_3Hg, HgCl and $HgCl_2$. Some skin whitening products contain the toxic HgCl as the active ingredient. When applied, the chemical readily absorbs through the skin into the blood stream. Recently, some products were discovered to contain between 9,000 and 60, 000 times the recommended international limit. Eating of exposed aquatic plants and animals like fishes (figure 2), and intoxicated meat and inhalation in air are also consistent contributing factors.

Figure 2: Mercury poisoned fishes from a local market in Lagos, southern Nigeria.

Arsenic is another identified key contaminant for many decades that occurs in a variety of minerals including Arseno pyrite (FeAsS), Realgar (As_2S_2), Orpiment (As_2S_3), Arsenolite (As_4O_6), native Arsenic in ores of Copper, Lead, Cobalt, Nickel, Zinc, Silver, and Tin and also as nickel glance (NiAsS) or mispickel. Arsenic is chemically very similar to its predecessor phosphorus, so much that it will partly substitute for it in biochemical reactions and is thus poisonous. When heated it rapidly oxides to arsenous oxide, which has a garlic odour. Arsenic and some arsenic compounds can also be sublime upon heating, converting directly to a gaseous form. Elemental arsenic is found in two solid forms; yellow and grey limetallic, with specific gravities of 1.97 and 5.73 respectively (Garba et al., 2010). The most toxic of arsenic compounds are those in which the element lost all its three 4p electrons, that is when it exist in the +3 oxidation state (As^{3+}). One of the major mechanism by which Arsenic exerts its toxic effect is through an impairment of cellular respiration by inhibition of various mitochondrial enzymes and the uncoupling of oxidative phosphorylation. The level of arsenic in natural waters varies between land 2 mg/L. Concentrations may be elevated however, in areas containing natural sources value as high as 12 mg/L have been reported.

Chromium is one of those heavy metals whose concentration steadily increases due to industrial growth, especially the development of chemical and tanning industries. Cement producing plants and potential source of atmospheric chromium particulate that are deposited on land and water; and are eventually carried out to river by runoff water (Dan-Azumi and Bichi, 2010). Other Industrial sources of chromium include wastewater from chrome plating, metal finishing industries and textile industries. Other sources of chromium permeating the environment are air, water erosion of rocks, power plants on liquid fuels, brown and hard coal, industrial and municipal waste (Fatoki, 2003).

Cadmium is a by-product in the production of zinc and lead and the pyrometallurgy production of Zinc (Zn) is the most important anthropogenic source to the environment. Other major sources are fossil fuel combustion and waste incineration (Su and Wong, 2003). Cadmium is used in a wide spectrum of applications including alloys, pigments, metal coatings, batteries and in the electronic industry. It is also a contaminant in chemical fertilizer, manure and sewage sludge (Ademoroti, 1996a; Ademoroti, 1996b; Ladigbolu and Balogun, 2011).

Nickel is a ubiquitous heavy metal and occurs in soil, water, air and in the biosphere. The average content in the earth's crust is about 0.008 %. Farm soils contain between 3 and 1000 mg nickel/kg. Levels in natural waters have been found to range from 2 to 10 µg/L (fresh water) and from 0.2 to 0.7µg/L (marine). Atmospheric nickel concentrations in remote areas range from <0.1 to 3 ng/m^3. Nickel from various industrial processes and other sources finally reach wastewater. Residues from wastewater treatment are disposed of by deep well injection, ocean dumping, land treatment and incineration. Effluents from wastewater treatment plants have been reported to contain up to 0.5 mg nickel/L. International Agencies have legalised the allowed concentration of heavy metals in both domestic and industrial products and effluents (Ayodele and Gaya, 1994; Ladigbolu and Balogun, 2011).

The EU Directive 94/62/EC (amended by 2004/12/EC) on Packaging and Packaging Waste sets out a maximum limit of 100 mg/kg for all Pb, Cd, Cr (VI), Cd and Hg in packaging materials. This limitation must be controlled for polymeric packaging materials and for calculate a possible heavy metal enrichment provoked by recycling processes of organic polymers. World Health Organisation sets a tolerance limit of 0.05, 0.05, 0.01, 0.05, 0.05, 1.0, 5.0 and 0.3 ppm for Mn, Pb, Cd, Cr, Ni, Cu, Zn and Fe in drinking water respectively. The Federal Environmental Protection Agency of Nigeria (FEPA) approved a maximum tolerance limit of 1.0, 1.0, 1.0, 5.0, 20 and 1.0 ppm for Pb, Cr, Cu, Mn, Fe and Zn for industrial effluents respectively (Galadima and Garba, 2011).

Heavy Metals with Biological Significance

In small concentrations, some heavy metals are nutritionally essential for animals' health. They are referred to as the trace elements. Examples include iron, copper, manganese, and zinc. These elements, or their compounds, are commonly found naturally in foodstuffs, in fruits and vegetables, and in commercially available multivitamin products. Diagnostic medical applications include direct injection of gallium during radiological procedures, dosing with chromium in parenteral nutrition mixtures, and the use of lead as a radiation shield around x-ray equipment. Heavy metals are also widely used in industrial applications such as in the manufacture of herbicides, fungicides, pesticides, batteries, alloys, electroplated metal parts, textile dyes, and steel e.t.c. Many of these products are in our homes and actually add to our standard of living when properly utilised.

Heavy Metals Toxicities Recorded in Nigeria

Heavy metals become toxic when they are not metabolized by the body and accumulate in the soft tissues. They may enter the human body through food, water, air, or absorption through the skin when they come in contact with humans in agriculture and in manufacturing, pharmaceutical, industrial, or residential settings (Lin et al., 2004; Galadima et al., 2010). Industrial exposure accounts for a common route of exposure for adults while ingestion is the most common route of exposure to children. In terms of potential adverse effects human health, cadmium, lead and arsenic are amongst the elements that have caused most concern. This is because they are readily transferred through food chains and are not known to serve any essential biological function. While the effect of chronic exposure to trace amount of some metals is not well understood, a legacy of incidents tell us about the seriousness of high level of exposure to some metals, especially cadmium and methyl mercury. In Nigeria today different types of illness have been reported to be associated with heavy metals.

The major heavy metal cases in Nigeria were believed to be associated with lead poisoning. They are mostly severe in young children because their brains and central nervous systems are still being formed. Learning disability, stunted growth, poor brain sensation, behavioural problems, kidney damage and impaired hearing are associated with low level of exposure. High concentrations of lead in the body can result to mental retardation, coma and eventual death. Reported symptoms include constant headache, loss of appetite, vomiting, nausea, irritability and/or behavioural problem.

Mercury exposure in young children can have sense neurological consequences, preventing sheaths from forming properly. It damages the central nervous systems, endocrine system, kidneys and other organs. Exposure over long period of time results to death. The element and its compounds are toxic to foetuses and infants. Women who have been exposed to mercury in pregnancy have sometimes given birth to children with serious birth defects (Galadima and Garba, 2011).

Occupational exposure has resulted to many functional disturbances, including erethism, irritability, excitability, excessive shyness, and insomnia. With prolong exposure, a fine tremor develops and may escalate to violent muscular spasms. Tremor initially involves the hands and later spreads to the eyelids, lips, and tongue. Severe exposure has been associated with more subtle symptoms of erethism, including fatigue, irritability, vivid dreams, depression and memory malfunction (Garba et al., 2010, Galadima et al., 2010; Galadima et al., 2011, Nubi et al., 2011).

People that are exposed to arsenic showed related diseases such as; cardiovascular problems, convulsions, inflammation of the liver, cancer, birth defects, organ damage disorder of the nervous system and damage to the immune system. Other heavy metals such as cadmium, chromium, nickel and zinc were reported to be associated with irritation of the eyes and respiratory passages, damage to brain, liver, bones and kidney, bronchitis, dermatitis, emphysema, hypertension, rickets and asthma (Usman, 2000; Galadima et al., 2010). Others are mutagenic, carcinogenic and tetragenic. Even though certain limit of iron is necessary for normal human health, higher concentrations were found to be associated with stomach and intestinal corrosion, leading to bleeding and shock development.

Most Recent Incidences

Zamfara lead poisoning is the worst and most recent heavy metals incidence in the Nigerian records that claimed the lives of over 500 children within seven months in 2010. Between January and July, illegal miners from seven villages of Bukkuyum and Gummi local governments in Zamfara state (figures 3a and b) brought rocks containing gold ore into the villages from small-scale mining operations; however, the villagers did not know that the ore also contained extremely high levels of lead. The ore was crushed inside village compounds, spreading lead dust throughout the community.

Figure 3a: Map of Nigeria showing Zamfara state (shaded portion), where lead poisoning killed over 500 children in 2010.

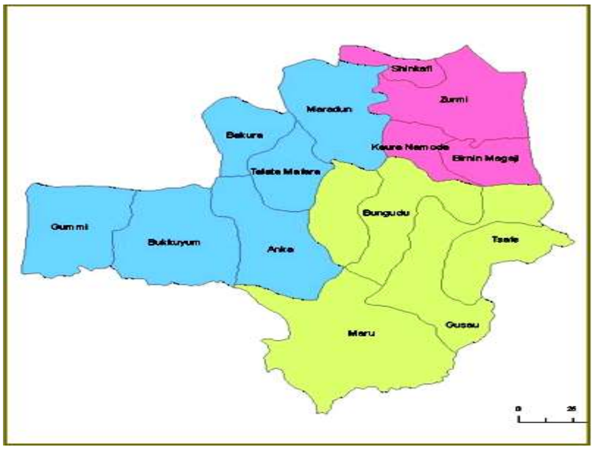

Figure 3b: Map of Zamfara state Gummi and Bukkuyum Local Governments,where lead poisoning killed over 500 children in 2010.

Joined field studies was carried out by international organisations such as Médecins Sans Frontières (MSF), US Centers for Disease Control and Prevention (CDC), Blacksmith Institute, World Health Organisation (WHO) in collaboration with affected local government, Zamfara state and the Federal authorities in Nigeria to measure the blood-lead concentrations in 113 samples from young children in the villages of Yargalma and Dareta. The outcome revealed that 100% of the children had blood-lead levels exceeding 10 μg/ dL (the international standard for the maximum safe levels of lead in blood), 96% exceeded 45 μg/dL, and 84% exceeded 70 μg/dL (BI, 2010; MSF, 2010). It was also discovered that there were 78 deaths in Yargalma (30% of the population was less than 5 years old in the village) and 40 deaths in Dareta (20% of the population was less than 5 years old), totalling 118 deaths in these two communities since the beginning of 2010. 95% of all deaths were in children under the age of five. As of September 2010, it was estimated that a total of 2,500 children have life-threatening levels of lead in their blood. Further investigation identified at least five additional villages where similar ore processing activities are common. In many areas in all villages sampled, including family homes and compounds, the soil lead concentration exceeded 100,000 ppm, far above the recommended maximum of 400 ppm considered acceptable for residential areas. Ingestion of contaminated soil and air inhalation has been the primary pathway of lead exposure. The affected children were generally reported to show severe health symptoms; *"gastro-intestinal upsets, skin rashes, changes of mood; some were lethargic, some partially paralysed, some had become blind and deaf. The worst affected were coming into the small Ministry of Health clinic with seizures that could last for hour and would sometimes lead to coma and then often to death."* (Figures 4a and b).

Figure 4a: Children poisoned by lead from Gummi, Zamfara state, Nigeria.

Figure 4b: Lead poisoned patients admitted at a hospital in Bukkuyum, northern Nigeria, 2010.

Further studies by December 2010 indicated that, the tragedy have so far affected 3,600 children, with further expectations that 180 villages covering around 30,000 people may be affected. However, collaborated effort has been in place to address the problem.

MSF has offered chelation therapy—a treatment for removing heavy metals from the body—to any children testing at critical lead levels. To ensure the children do not return to homes contaminated with lead, Blacksmith Institute conducted environmental decontamination and remediation in several villages in collaboration with local authorities. Local men were being paid to assist with the cleanup operations. Cleanup crews took contaminated soil to a landfill site and brought cleaned replacement soil to the villages. In addition to soil removal, thorough removal of dust from all interior spaces and compounds is essential. Children who have undergone a course of chelation therapy and are ready for discharge from the treatment centre must return to a clean environment.

Several other cases of heavy metals pollution have been reported from different parts of Nigeria in 2010 and 2011. Ibeto and Okoye (2010) conducted a study on 240 people, comprising of children, pregnant/nursing women and men in Enugu state. Nickel, manganese and chromium were detected with concentrations exceeding the allowed limits permitted by WHO in the blood samples of the respondents. Garba et al. (2010) reported a mean arsenic concentration of 0.34 mg/l in drinking water from hand dug wells, boreholes and taps of Karaye Logal Government area, Kano state. The arsenic levels are of serious concerns to regulatory agencies because they by far exceed the upper band (0.01 mg/l) recommended by WHO. Galadima et al. (2010) conducted a study on the levels of heavy metals in waste water from student halls of Usmanu Danfodiyo University, Sokoto. The results showed Fe, Pb and Cr to exhibit concentrations that are more than 20 times the recommended international limits. The pollution was attributed to continuous usage of containing products by the students and the disposal of carrier wastes by the sellers of different items in the residence premises. The higher concentrations of Fe were also associated with its content in the soil of the sampling sites. High lead levels on the other hand were due to anthropogenic emissions from the combustion of leaded gasoline (i.e tailpipe emissions) by the numerous number of students' cars loitering in the sampling area. River Challawa is situated along the industrial area of Kano state. Studies by Dan-Azumi and Bichi (2010) showed water samples from the river to contain elevated levels of Pb, Cr, Cu, Pb and Fe higher than the recommended WHO and FEPA guidelines. The river provides fresh irrigation water to local farmers, indicating that human absorption through food chain and occupational exposure is very possible. Ladigbolu and Balogun (2011) reported the profiles of some heavy metals in sediments from Ibandan, Oyo state. Zn (429.1μg/g), Cu (249.5μg/g), Ni(15.30μg/g), Cd(2.02μg/g), Pb(405.0μg/g), and Cr(67.4μg/g) were all detected with exceeding concentrations. The pollution was attributed to population growth, urbanization, agricultural activities and uncontrolled direct dumping of wastes and sewages into aquatic environment. On a similar trend Nubi eta l. (2011) showed marine water from Lagos coastal area to exhibit concentrations of Fe, Zn, Cu, Cr, Pb, and Cd that are by far greater than the acceptable WHO and FEPA limits.

Numerous of these cases are available in various Nigerian and international publications, the major challenge remain how the problem can fully be mitigated.

Addressing the Problem

The various reports indicated heavy metals pollution to be a recent serious issue crippling human development. Both household and industrial activities are increasingly severing the environment with these toxic species daily. Mitigation options are therefore necessary. Prevention is always better and cheaper than cure, thus the various government agencies should continue to collaborate with non-governmental and international agencies to ensure that, appropriate prevention measures are in place. As the current environmental policies are either deficient on the laws governing the discharge of heavy metals or lack good enforcement mechanisms, new laws should be promulgated base on lessons from developed countries like United Kingdom and United States of America. Industrial effluent should be treated prior to disposal into fresh water ways. Where a company failed to comply with applied laws, prosecution and subsequent closure are necessary, depending on the gravity of the offence. Total phase out of tetraethyl lead (TEL) and methylcyclopentadienyl manganese tricarbonyl (MCT) is necessary to ensure prevention of automobile emissions. Therefore adoption of modern gasoline upgrading methods is required as a replacement. Illegal mining is a serious issue in the minerals zones of the country. Government should therefore ensure that strict measures, involving prosecution of defaulters are applied. For example, the tragic Zamfara lead poisoning could have been averted if appropriate government practices are ensured.

Ignorance coupled with high level of poverty are the major factors responsible for the tragedy, therefore environmental education through attractive media forums, newspapers and community workshops is required to provide the local people with adequate knowledge on the risks of heavy metals pollution. Funding provisions to universities and other environmental research agencies (ERA) are necessary to ensure continuous and sustainable environmental researches that could provide clue on polluted areas, the source of the pollution and appropriate mitigation options.

Emergency response equipments should always be available in our hospitals and primary health cares', such that first aid treatment can be provided to affected people when an incidence occurs. Chelation therapy has long been recognised as the major treatment method for heavy metals poisoning, therefore adequate provision is necessary. Collaboration with international experts would be very important here.

Conclusively, the aforementioned measures can only yield good results if the serious corruption problem in the country is addressed with full implementation, involving not only the masses but the leaders, rich people and their associates.

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Table 1: Amount of TEL in gasoline by country. *Source:* Thomas and Kwong (2001)

Country	TEL Concentration, g/L
Nigeria	0.65-0.74
Algeria	0.60
South Africa	0.33
Libya	0.60
Morocco	0.30
Tunisia	0.50
Sudan	0.40
United Kingdom (UK)	0.00
United States of (USA)	0.00
Highest in the World	1.0

Table 2: Lead levels in soils from some Nigerian cities *Source*: Enemari (2001)

City	Lead Concentration (mg/Kg)
Lagos	24.9-121.61
Ibadan	22.41-121.61
Kaduna	14.40-126.81
Abuja	5.24-89.92
Port Harcourt	28.38-67.78
Aba	2.34-55.01