Environmental chemical risk factors of breast cancer in Nigeria III: Metal: Lead

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Abstract
Lead (Pb) is a metalloestrogen and a notable breast cancer risk factor. Lead is an International Agency for Research on Cancer (IARC) group 2A carcinogen. There is no level of exposure to lead that is known to be without harmful effects. Nigeria has literally every known environmental risk factor for lead exposure. Notable sources of lead exposure in Nigeria are lead in contaminated water, paints, artisanal gold ore processing, incineration of lead-containing waste and electronic waste (e-waste). Other sources of lead exposure are ‘tiro’—a lead-laden eye cosmetic, smoked fish particularly those displayed near highways with high vehicular traffic density, vegetables and root crops grown in mining communities, fruit exposed to lead-laden ripening agents, “Calabar chalk”—a lead-laden pica mostly consumed by pregnant women, and children’s toys. Prenatal vitamins supplements, paediatric medication syrups, traditional alcoholic and non-alcoholic drinks such as Kunnu and Zobo were also found as notable sources of lead consumption. Studies in Nigeria on blood lead (Pb) levels in children, pregnant women, and breast milk of nursing women were found to contain high lead levels. Lead exposure is preventable. Hitherto, the neurotoxicity of lead has been the dominant concern as regards lead exposure in children. The breast cancer risk factor now reinforces the zero tolerance for lead exposure.

Keywords: Breast Cancer; Lead, Prevention, Nigeria

Introduction
This is the 3rd of four Publications in this group of serialized systematic review articles (case studies) on Environmental Chemical Risk Factors of breast cancer in Nigeria. Part 1 is a “Broad Overview” on the subject; Part II is on “Adolescent Hormonal Contraceptives Use”; and Part IV is on “Pesticides” The “Broad Overview” contains: (1) what informed the study on breast cancer, (2) the broad and specific objectives of the study. (3) Breast cancer is a hormone dependent malignancy; the relationship between endocrine disrupting chemicals (EDCs) and breast cancer was discussed. (4) What constitute the “environment” within the context of “environmental chemical risk factors” was defined. (5) Method of study: study identification and selection, biological evidence of carcinogenesis, and data extraction and synthesis was described. (6) The result of the search generated the list of notable environmental chemical risk factors of breast cancer highly relevant to Nigeria. The chemicals were listed on a Table and grouped as listed in Committee’s Evidence Review by National Academy of Sciences. The serialized articles in this special themed edition were selected “case studies” on some of the chemicals on the list.
Search engine for Metal: Lead
A review of published studies and documents was conducted in Medline, Scopus, PubMed, Google Scholar, Global Health, Science Direct, EMBASE, and African Journals Online for published studies and documents in English from 2000-2020 that reported studies on the Metal-Lead. Some earlier dates of articles were chosen if found highly relevant to the study. Searches include ‘Breast Cancer”, “Mammary tumors” in combination with Metal: Lead, toxicity, carcinogenicity, breast cancer risk, drinking water; Nigeria, Sources: Nigeria. Lead in artisanal mining, Lead: children, Lead: pregnant women. We paid particular attention to Lead studies in the Nigeria environment even when breast cancer was not on the radar of objectives.

Outline of discourse
The issue of the metal, Lead (Pb), as a breast cancer risk factor is so important in Nigeria that it shall be comprehensively discussed under the following headings:

- A brief overview and adverse health effects of Pb
- Carcinogenicity of Lead
- Studies done in Nigeria – Lead as a breast cancer risk factor
- Lead in drinking water: Scenario in Nigeria
- Lead poisoning from artisanal gold ore processing in Northern Nigeria
- Lead in Gasoline and scenario in Nigeria
- Lead in paint scenario in Nigeria
- Lead in “Tiro” a Nigerian eye cosmetic
- Lead in Food, Food wares, and dietary supplements
- Lead in Toys
- Pica in Nigeria
- Some relevant studies in Nigeria Blood Lead Levels
- Miscellaneous studies on Lead (Pb) levels in Nigeria
- Prevention of Lead exposure; policy implications, WHO efforts.
- Conclusion

1. Lead: overview
Lead is a naturally occurring toxic metal found in the Earth’s crust. Its widespread use has resulted in environmental contamination, human exposure, and significant public health problems in many parts of the world. Important sources of environmental contamination include mining, smelting, manufacturing, and recycling activities; and, in some countries, as leaded paint, gasoline, and aviation fuel. More than three quarters of global lead consumption is for the manufacture of lead-acid batteries for motor vehicles. Lead is used in products like pigments, solder, stained glass, lead crystal glassware, ammunition, ceramic glazes, jewelry, toys and in cosmetics and traditional medicines. Drinking water delivered through lead pipes or pipes joined with lead solder may contain lead. Most lead in global commerce is from recycling. Exposure to lead includes occupational and environmental sources: burning materials containing lead, smelting, recycling, stripping leaded paint, and use of leaded gasoline or aviation fuel, ingestion of contaminated dust, water, and food (soldered containers).1,2

Lead is a toxic non-essential metal with widespread exposure starting in utero.3 Young children are particularly vulnerable to the toxic effects of lead and can suffer profound and permanent adverse health effects, particularly affecting the development of the brain and nervous system.1-3 It causes long-term harm in adults, increased risk of high blood pressure and kidney damage. Lead in the body is distributed to the brain, liver, kidney, and bones. It is stored in the teeth and bones, where it accumulates over time. Human exposure is assessed through measurement of the levels in blood.1-4
The Centers for Disease Control and Prevention (CDC) recommends that public health actions be initiated when the level of lead in a child’s blood is $5 \mu g/dl$ or more.\(^4\) Lead can accumulate in human bodies over time, stored along with calcium in bones. During pregnancy, lead is released from bones with calcium and used in bone formation in the fetus especially with low dietary calcium. Lead can cross the placental barrier exposing the fetus to adverse effects.

### 2. Carcinogenicity of lead

Lead has been reclassified in 2004 by the International Agency for Research on Cancer (IARC) Working Group from a “possible” to “probably” human carcinogen (Group 2A).\(^6\) Lead may be a facilitative or permissive carcinogen; may permit or augment the genotoxic effects of other exposures. Current literature has not displayed a comprehensive understanding of carcinogenic mechanisms of lead. Proposed mechanisms include\(^7\) disruption of the cellular tumor regulation genes, DNA repair system and induction of DNA damage.\(^8\) Evidence to support lead’s role in generating Reactive Oxygen Species (ROS) and altering chromosomal structure and sequence was obtained in a mice study.\(^8\) It was also determined that lead had the potential to disrupt the transcription process by replacing zinc in certain proteins that regulate this system.\(^8\)

The contamination of the soil and water supplies by toxic metals during industrialization was hypothesized to be a major contributing factor to the rising incidence of breast cancer in Nigeria.\(^9\) Elements of interest within this context are lead (Pb), chromium (Cr), cadmium (Cd), zinc (Zn), tin (Sn), and arsenic (As). However, the degree to which these elements might increase breast cancer risk depends on selenium (Se), a nutritionally essential trace element whose anticarcinogenic properties have been demonstrated in animal tumor models. There is evidence that cancer mortalities in different countries are inversely associated with the dietary intakes of selenium.\(^9\) Selenium also interacts with other elements, mostly toxic heavy metals in vivo as part of natural metal detoxification processes, resulting in the metabolic inactivation at sufficiently high exposure levels over time to produce a state akin to selenium deficiency. In studies with female C3H mice carrying the murine mammary tumor virus (MMTV), Pb at subtoxic levels was shown to abolish the cancer-protecting effect of Se at chronic exposure levels as low as $0\cdot5$ppm in the drinking water.\(^10\) In Nigeria, the dietary Se intakes of the population are generally adequate.\(^11\) Lead is an element of major concern because of its many industrial and domestic uses, and the uncontrolled dumping of Pb-containing residues severely contaminating the soil and the water supplies.\(^12,13\)

### 3. Studies done in Nigeria: Lead as a breast cancer risk factor

A large segment of the Nigerian population including children is chronically Pb-exposed. In one study of 218 children aged 6-35 months, 70% had blood lead levels in excess of $10\mu g/dl$.\(^14\) In adults, occupationally Pb-exposed auto-mechanics exhibited mean blood and hair Pb levels of $48\cdot50 \pm 5\cdot16\mu g/g$, respectively,\(^15\) but Pb levels of unexposed controls from the same city in SW Nigeria were elevated, with $33\cdot65 \pm 10\cdot09\mu g$ Pb per deciliter in blood and $14\cdot30 \pm 5\cdot90\mu g$ Pb per gram in hair. A 1998 study found decreased immune status in occupationally Pb-exposed Nigerians, potentially increasing their susceptibility to infectious diseases, inflammatory disorders, and cancer.\(^16\)

Alatise and Schrauzer\(^9\) at Ile-Ife, Osun State, Nigeria found higher levels of Pb in blood and head hair samples of patients with infiltrating ductal carcinoma breast cancer, the most common form, than in controls. Lead levels in hair samples were directly correlated with tumors volumes, while Se levels were inversely correlated with the tumor volumes, consistent with the anti-proliferative effects of Se. Elements, like Cd, Hg, Cr, Sn, and As, were detected in the scalp hair at significantly lower levels than Pb. The researchers concluded that there is evidence that the breast cancer patients were chronically exposed primarily to lead at levels sufficient to abolish the cancer-protecting effects of...
Selenium. This suggests that measures to reduce the burden of lead and other industrial metals must become an essential part of public health programs to reduce breast cancer risk of Nigerian women.

Olayiwa et al\textsuperscript{18} applied particle-induced X-ray emission (PIXE) spectroscopy to investigate the levels of trace elements: (Lead, Cadmium, Aluminium, Chromium, Magnesium, and Selenium) in cancerous and non-cancerous breast tissues and whole blood. They reported similar findings as Alatise and Schrauzer.\textsuperscript{17} Selenium (Se), Zinc (Zn) and Chromium (Cr) were significantly elevated in the malignant tissues inferring that low or high levels of some trace elements in the malignant or non-malignant tissues could be an early indicator of their carcinogenic role, through formation of free radicals or other reactive oxygen species that adversely affect DNA, causing cancer-related diseases. The researchers recommended that for result reliability and correct assessment of the role of trace elements in initiation, promotion, progression, or inhibition of cancer in various organs, there is a need for acquisition of more data from different regions using age, gender, dietary habit, and lifestyle.

Arinola and Charles-Davies\textsuperscript{19} measured the levels of heavy and essential metals in the serum of breast cancer patients, to determine which of them could be of importance in the treatment and prognosis of the cancer. Copper level was significantly reduced in patients with breast cancer supporting the uptake of Cu from the blood by cancer cells. The mean serum zinc and manganese levels were insignificantly low in breast cancer patients; magnesium, iron, chromium, cadmium, lead and selenium were not significantly raised in breast cancer patients; and iron (Fe) in the breast cancer patients was slightly increased. Clinical anaemia and haematological abnormalities are reported in breast cancer cases.\textsuperscript{20} The study reported a non-significant increase in serum selenium, inferring that a higher dietary intake in humans may be protective against cancers.\textsuperscript{21} Arinola and Charles-Davies,\textsuperscript{19} concluded that the exact mechanism responsible for the alterations in trace metals patients with breast cancer is unclear and requires further evaluation. Filomeni et al\textsuperscript{22} suggested that the copper ions and copper complexes react with hydrogen peroxide to form hydroxyl radicals that cause damage to protein, RNA and DNA. The damages are not repairable by cellular mechanisms thus initiating the malignant process.

In conclusion, Nigeria is a milieu with heavy burden of lead in the population. Effective measures to reduce the lead burden of the population must become an essential part of public health programs aimed at reducing the breast cancer risk of Nigerian women.

4.0 Lead in drinking water: Scenario in Nigeria
The availability of safe drinking water is a basic human right, an index of healthy living, and a component of effective policy for health protection.\textsuperscript{23} Different Aquatic environments such as lakes, streams, rivers, creeks, reservoirs, seas, oceans, and rainwater are contaminated and some of the main causes are urbanization, industrialization, agricultural activities, population growth, poor technologies, wars, and climate change. Pollution agents are precipitation, runoffs, discharged effluents and direct waste dumping into water. The result of increased population growth includes increased wastes discharge, bunkering activities, illegal refining of petroleum products, application of pesticides and fertilizers in agricultural forms.\textsuperscript{4} Private wells can be contaminated by lead in pump components or the well seal. Although pipes inside a home are usually the source of lead poisoning, sometimes lead comes from old pipes in the street that supply the water to your home.\textsuperscript{24} Additionally, in Nigeria there are warehouses and markets specific for cheap old second-hand spare parts for plumbing requirements: old lead-coated and rusty pipes, faucets, and joints to replace faulty parts, are other covert sources of lead exposure in drinking water.\textsuperscript{24} Rainwater is a main source of drinking water for some people in both urban and rural areas because of non-availability of potable water supply. Specific protocol for sampling household water is needed and exposure characterization should include rain and well water.\textsuperscript{24}
4.1 Notable chemical mammary toxicants in drinking water

In Nigeria, public and private water supplies are not sufficiently monitored by regulatory agencies such as National Environmental Standards and Regulations Enforcement Agency (NESREA) and National Agency for Food and Drugs Administration and Control (NAFDAC). Hence distribution of unsafe and substandard drinking water. Two notable mammary toxicants are lead and Disinfection byproducts (DBP) in drinking water.\textsuperscript{25,26} The WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation has classified the global drinking water sources which are present in Nigeria (Table 1).\textsuperscript{27} A source in Nigeria not included in the WHO/UNICEF list is ‘sachet water’ otherwise known as “pure water.”

<table>
<thead>
<tr>
<th>Table 1: Definitions of improved and unimproved drinking water sources and facilities\textsuperscript{27}</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Drinking Water</strong></td>
</tr>
</tbody>
</table>
| Improved | • Piped water into dwelling, yard or plot  
• Public tap or standpipe  
• Tubewell or borehole  
• Protected spring  
• Protected dug well  
• Rainwater collection |
| Unimproved | • Unprotected dug well  
• Unprotected spring  
• Cart with small tank or drum  
• Tanker truck  
• Surface water (river, dam, lake, pond, stream, canal, irrigation channel)  
• Bottled water (considered to be improved only when the household uses drinking water from an improved source for cooking and personal hygiene) |

4.2 Safe Levels of Lead in Drinking water

The WHO gives provisional guideline value as 0·01mg/L (10\(\mu\)g/L)\textsuperscript{27} based on treatment performance and analytical achievability. The Safe Drinking Water Act requires United States Environmental Protection Agency (EPA) to determine the level of contaminants in drinking water at which no adverse health effects are likely with an adequate margin of safety. EPA has set the maximum contaminant level goal for lead in drinking water at zero\textsuperscript{4} because lead is a toxic metal, harmful to human health at low exposure levels, persistent, and can bioaccumulate in the body. EPA estimates that drinking water can make up to 20 percent or more of a person’s total exposure to lead.\textsuperscript{4} Infants who consume mostly mixed formula can receive 40-60 percent of their exposure to lead from drinking water. WHO recently withdrew the Provisional Tolerable Weekly Intake (PTWI) value for lead on the grounds that it is not possible to set an intake value that is protective for health.\textsuperscript{1}

4.3 Some important steps to reduce lead in drinking water

Most lead in drinking-water arises from plumbing in buildings, and the remedy consists principally of removing plumbing and fittings containing lead, which requires time and money.\textsuperscript{4} Hence, other measures to reduce total exposure to lead, including corrosion control, should be implemented.\textsuperscript{4} Tap water should be passed through a “point-of-use” filter certified external icon by an independent testing organization (NSF/ANSI standard 53 for lead removal and NSF/ANSI standard 42 for particulate removal) to reduce the amount of lead in drinking water.\textsuperscript{28} Water can be allowed to run off freely from the tap when it has been off for more than 6 hours. Drinking or cooking with cold tap water is advised because warm or hot tap water can have higher levels of lead.\textsuperscript{28} People can also use bottled water that has been certified by an independent testing organization with external icon,
although this may not be cost-effective for long-term use. Several studies have been conducted in Nigeria as regards lead in drinking water when Breast Cancer was not on the radar of objective of study. A summary of the findings is presented in Table 2.

Table 2. Some Studies on drinking water Lead (Pb) concentrations in various locations in Nigeria

<table>
<thead>
<tr>
<th>Author</th>
<th>Location of study</th>
<th>Samples studied</th>
<th>Concentrations</th>
<th>Remarks by authors</th>
</tr>
</thead>
</table>
| Adeyemi et al29 2021          | Ground water in Ota & Shagamu, Ogun State | Water 96 samples (48 samples/season dry and rainy)                              | Ota Wet season 0.003 – 0.199mg/L  
Ota Dry Season 0.009 – 0.06mg/L  
Sagamu Wet season 0.009 – 0.06  
Sagamu Dry season 0.829 – 0.923 | The cumulative Cancer Risk in the study shows a medium-extremely high risk for the analyzed metals. The calculated health risk index indicates major adverse effects on human health. |
| Edori et al30 2020            | Edagberi Creek                         | 3 stations at intervals of 2months for one year                                  | 0.002 ± 0.001; 0.006 ± 0.00  
0.002 ± 0.00; 0.003 ± 0.00      | The creek experienced null to very low degree of Pb contamination             |
| Obasi et al31 2020           | Mining communities in Abakaliki        | Water samples                                                                    | 11.42mg/L                                                                     | Levels of associated metals including Pb are higher in ground water in areas close to the active mines, due to mineralization in the area. Seasonal analysis shows decreased concentration of chemical constituents in the rainy season relative to the dry season. Alternative water supply sources and sensitization on the potential health risk are highly advocated in these communities. |
| Yahaya et al32 2020          | Iwaya, Makoko, and Ilaje in Lagos      | Borehole and well water (20 samples)                                            | Mean ± SD  
Borehole water Iwaya 0.25 ± 0.006;  
Makoko 0.21 ± 0.006;  
Ilaje 0.27 ± 0.006  
Well water; Iwaya 0.25 ± 0.06  
Makoko 0.31 ± 0.015;  
Ilaje 0.37 ± 0.006      | Water could pose some health risks, and the consumers in high-risk areas should consider water treatment before consumption |
| Zacchaeus et al33 2020       | Effects of industrialization on groundwater quality in Shagamu and Ota          | 80 samples of water wet & dry seasons, random sampling 4 control sites          | Range Pb 0.003 – 0.199                                                    | Water in the study location not suitable for consumption without prior treatment and the construction of the boreholes and dug wells are proposed here to follow proper siting regulation |
| Adeyemo et al34 2019         | Selected wells within Bodija municipal in Ibadan SW Nigeria                     | Abattoir (Wₐ) and Residential wells (Wₐ)                                        | Mean concentration of lead Wₐ 0.67±0.26  
Wросл 0.64±0.33              | Virtually all the figures obtained were considered higher than the permissible standard for drinking water. The health status, social and environmental qualities of residents of Bodija abattoir neighborhood will severely be affected. |
Dada et al\textsuperscript{35} 2018  
Residential areas, Lagos State.  
Ebute Metta East  
Ebute Metta West  
Surulere  
Drinking water in 34 taps.  
Ebute Metta East – Mean $0.087 \pm 0.021 \text{mg/l}$ (Mean + SD)  
Ebute Metta West – $0.041 \pm 0.039 \text{mg/l}$ (Mean + SD)  
Surulere – $0.040 \pm 0.173 \text{mg/l}$ (Mean + SD)  
In view of the concentration of Pb in the sampled water and potential adverse effects especially on children and women of child-bearing age, the Lagos State Government and the state water corporation are called upon to immediately institute a monitoring program to identify the sources of contaminants and take appropriate intervention measures.

<p>| Table continued |</p>
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<thead>
<tr>
<th>Author</th>
<th>Location of study</th>
<th>Samples studied</th>
<th>Concentrations</th>
<th>Remarks by authors</th>
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</thead>
</table>
| Bolawa et al\textsuperscript{36} 2017 | Bottled Water and Sachet water in Lagos | Sachets Vee Vee Sachet La monde sachet Bako sachet Fizco sachet Living sachet Bevep sachet Nimbus sachet Chavis sachet Denifol sachet Austin sachet WHO MPL p$>0.05$ Bottled water Cascade Osan Nestle Eva Aquarite Christo Pringad Uncle Toby Mowa Sunar Cway Aqua dominion Shower Aquadana WHO MPL p$>0.05$ | Pb (mg/ml)  
ND  
$0.01 \pm 0.02$  
$0.01 \pm 0.01$  
$0.01 \pm 0.02$  
ND  
$0.02 \pm 0.03$  
ND  
$0.01 \pm 0.03$  
ND  
ND  
ND  
$0.02 \pm 0.01$  
ND  
$0.01 \pm 0.01$  
ND  
$0.01$ | Heavy metals in the water samples showed traces of lead in five sachet water samples and seven bottled water samples together with cadmium in three sachet water samples and three bottled water samples. This may be harmful after being consumed for a long time by the populace. |
| Taiwo et al\textsuperscript{37} 2017 | Ijesha land, Osun State | 54 environmental samples were collected. Surface water groundwater bottom sediments fish & floating plants | All have concentrations higher than the WHO. The relative high concentrations of Mn, Al, and Pb obtained in this study can be attributed to industrial and anthropogenic activities in the study area. Treatment of groundwater before consumption is recommend avoiding possible adverse cumulative effect. Improved waste disposal methods and regular monitoring of toxic elements in ground water of the study area should be adopted to safeguard human health. |
associated with activities of artisanal gold. The cancer risk values of Ni and Pb in water consumed by infants and children were also higher than the acceptable limits of $1.0 \times 10^{-4}$. The results allow us to assert that the activities of the artisanal gold miners clearly affect human health.

**Orosun et al**38 2016

Mining and Smelting activities in Ajaokuta

Well and tap water – 60 samples

Mean concentrations

<table>
<thead>
<tr>
<th>Concentrations</th>
<th>Remarks by authors</th>
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<tbody>
<tr>
<td>0.25 – 0.32ppm</td>
<td>Mining companies should treat their wastes by precipitating out metals thus reducing their mobility through seepage. Construction of ponds with adequate retention times that can enhance the removal and retention of metals is also suggested.</td>
</tr>
<tr>
<td>0.25 ppm well</td>
<td></td>
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<tr>
<td>0.32ppm tap water</td>
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</table>

**Oyeleke et al**39 2016

Assessment of heavy metals in groundwater in the vicinity of an oil depot (an industrial facility for storing oil and/or petrochemical products where these products are transported to end users).

<table>
<thead>
<tr>
<th>Location of study</th>
<th>Samples studied</th>
<th>Concentrations</th>
<th>Remarks by authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ikorodu SW Nigeria</td>
<td>Selected wells and boreholes near textile industries</td>
<td>0.02 – 0.03</td>
<td>Concentrations of Lead was above the permissible limits of WHO and Nigerian Industrial Standard (NIS). A possible source of pollution is seepage of effluent discharge from textile industry through the porous soil into the groundwater and this poses great danger to the health of the people who consume the water.</td>
</tr>
<tr>
<td>Lagos and Ogun states</td>
<td>170 groundwater samples</td>
<td>The order for risk of cancer in groundwater from Lagos State was Pb &gt; Cr &gt; As &gt; Cd; while the order in Ogun State groundwater was Cr &gt; Cd &gt; As &gt; Pb. The relative high concentrations of Mn, Al, and Pb obtained in this study can be attributed to industrial and anthropogenic activities in the study area. A greater threat was posed to children and infants. Treatment of groundwater before consumption is recommended to avoid possible adverse cumulative effect. Improved waste disposal methods and regular monitoring of toxic elements in groundwater of the study area should be adopted to safeguard human health.</td>
<td></td>
</tr>
<tr>
<td>Sagamu Bare hole (n = 45) 0.18 ±0.01</td>
<td>the analysis variance of data obtained from this study shows that bore-hole water samples were safer for drinking than water samples from hand pump, and hand dug wells across the communities.</td>
<td>Sagamu</td>
<td>0.15 ±0.04</td>
</tr>
<tr>
<td>Hand-pump well (n = 40) 0.25 ±0.04</td>
<td></td>
<td>Hand-pump well (n = 50) 0.25 ±0.02</td>
<td></td>
</tr>
<tr>
<td>Hand-dug well (n = 60) 0.04 ± 0.04</td>
<td></td>
<td>Hand-dug well (n = 50) 0.28 ±0.02</td>
<td></td>
</tr>
<tr>
<td>Mosimi</td>
<td>The analysis variance of data obtained from this study shows that bore-hole water samples were safer for drinking than water samples from hand pump, and hand dug wells across the communities.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bore hole (n = 60) 0.23 ±0.04</td>
<td></td>
<td>Bore hole (n = 80) 0.26 ±0.03</td>
<td></td>
</tr>
<tr>
<td>Hand-pump well (n = 50) 0.25 ±0.02</td>
<td></td>
<td>Hand-pump well (n = 65) 0.29 ±0.02</td>
<td></td>
</tr>
<tr>
<td>Hand-dug well (n = 50) 0.28 ±0.02</td>
<td></td>
<td>Hand-dug well (n = 90) 0.28 ±0.04</td>
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<tr>
<td>Ogun</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Authors</td>
<td>Source Description</td>
<td>Methodology</td>
<td>Concentration of Pb metal ions</td>
</tr>
<tr>
<td>------------------------------</td>
<td>-------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>Odogunyan</td>
<td>borehole (n = 75) 0.16 ±0.01, hand-pump well (n = 80) 0.24 ±0.03, hand-dug well (n = 70) 0.19 ±0.01</td>
<td>Water from streams, ponds/lakes and shallow hand-dug wells</td>
<td></td>
</tr>
<tr>
<td>Nwachukwu et al⁴³ 2014</td>
<td>Rural water supply SE Nigeria</td>
<td></td>
<td>Pb 0.38 – 3.04 ppm</td>
</tr>
<tr>
<td>Ehi-Eromosele et al⁴⁴ 2012</td>
<td>Surface, ground and tap waters from some parts of Lagos metropolis</td>
<td>Concentration of Pb metal ions</td>
<td>Sample 1 0.215</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sample 2 0.080</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Sample 3 0.020</td>
</tr>
<tr>
<td>Oluseyi et al⁴⁵ 2011</td>
<td>Drinking water around cement factories in Ewekoro and Shagamu, Ogun State.</td>
<td>6 wells in Ewekoro and 11 wells in Shagamu</td>
<td>2.4 ± 3.3 mg/l</td>
</tr>
<tr>
<td>Oyeku et al⁴⁶ 2010</td>
<td>Dumpsite ground water</td>
<td></td>
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</table>

5. Lead poisoning from artisanal gold ore processing in Zamfara Nigeria

Lead Poisoning Investigation in Northern Nigeria⁴⁷-⁵¹

In May 2010, public health officials learned that hundreds of children had become sick with vomiting, abdominal pain, headaches, and seizures, and many died. Seventeen thousand people were affected in Zamfara state and 7000 children under the age of five were treated but some may have had irrevocable disabilities like neurodevelopmental damage. The cause was unknown initially, and a team was sent to one of the villages to investigate the occurrences. Members included Dr. Lora Davis, a CDC Animal-Human Interface Officer in Nigeria, CDC-Nigeria office in Abuja, the Nigerian Federal Ministry of Health, the Nigerian Field Epidemiology and Laboratory Training Program, the World Health Organization, and Médecins Sans Frontières (Doctors Without Borders).

Investigations of villages in Zamfara State revealed widespread lead poisoning: unsafe levels were found inside most homes, and in water from the community wells. Thousands of children had dangerous levels of lead in their blood. It was the largest known outbreak of lead poisoning in history. Some unsafe practices in the communities exposing adults, children, and animals to harmful levels of lead include mining of gold ore without protective clothing. They return home from the mines with lead dust on their clothing. Many villagers also bring rocks containing lead inside their homes to extract the gold and release lead dust in the house. Children helped to grind the gold ore exposing them to higher levels of lead dust.
Several scientific studies have been conducted on the Zamfara historical outbreak of lead poisoning. In 2015, similar situation occurred in Niger state because of unsafe mining practices. More than 2500 community members were exposed and about 30 children died. Safer mining pilot programs have had considerable success in reducing lead contamination in Niger state and lessons learnt from Zamfara crisis.

The Context, Drivers, and Consequences of illegal mining in Nigeria has been adequately described. Illegal mining in Northern Nigeria has two worrying trends: exchange of illegally mined gold for weapons, and the use of women and girls in these activities. Spread of illegal mining across these areas is due to the rise in the world market price of gold since 2009. Young girls between 12 and 15 years old are used in the mining fields as laborers by illegal miners contrary to the law (minimum age in 1973 and No. 182 of 1999 on child labour). The gendered dimension of illegal mining in Northern Nigeria may be fueled by a volatile security context characterized by ungoverned spaces where state authorities are weak or absent, escalating security crisis including Boko Haram insurgency, conflicts between sedentary farmers and nomadic herdsmen, and rural banditry, causing displacement and social dislocation. High level of unemployment and poverty, particularly among the youth, limited income-generating opportunities, promoted illegal mining activities for survival by over two million people, including women and girls. Environmental Emergency Response Mission in 2010, the Joint UNEP/OCHA Environment Unit (JEU) led a sampling and analysis mission to investigate the lead pollution emergency in 5 communities in Zamfara State. Drinking water from wells did not meet WHO and Nigerian standards (10 μg/l). Water in ponds and boreholes was highly contaminated (up to 200 μg/l). In some villages, the soil was highly polluted with lead sometimes as high as 60,000 ppm, compared to the US standard is 400 parts per million (ppm). Since young children readily ingest soil as part of normal hand-to-mouth behaviour, such high concentrations expose children to potentially harmful levels of lead. Further study of food pathways (livestock, crops) should be undertaken as livestock drink from contaminated ponds, and crops are grown in contaminated soil.

Preliminary remediation procedures have been described. Remediation procedures should include topsoil removal and replacement, which is an expensive procedure. Treatment of children, enlightenment on safe method of mining, protective storage, closing of toxic wells, creation of gold processing zones, and proper monitoring of artisan miners as ways to prevent the plaque from reoccurring. Occupational Knowledge International (OK) is a US based NGO that builds capacity in developing countries to identify, monitor, and mitigate environmental and occupational exposures to hazardous materials to protect public health and the environment. A pilot programme introduced to reduce lead poisoning in Nigerian gold mining communities in partnership with Doctors Without Borders/Médecins San Frontières (MSF) has yielded positive result. They introduced wet spray misting in mine processing activities to crush and grind gold ore. Miners were provided information and tools to reduce their exposures to lead and silica dust; and were motivated to take measures to reduce exposures, by investing time and money to implement these measures. The intervention was successful in reducing health risks significantly and protect children from lead poisoning. The conclusion was that significant reductions in respirable silica and lead exposures are feasible in low-resource, small-scale mining communities.

Government and Stakeholders’ Strategic Plan have been described. The major challenge identified in preventing lead poisoning from re-occurring is behavioral change by the artisanal and small-scale miners (ASM). The country needs to move from providing remediation to building a realistic and sustainable national plan for the mining environments. Some proffered intervention strategies to address the dangers for women, girls and minors in gold and arms smuggling, include establishment of governmental presence and control in ungoverned areas that serve as smuggling routes. Intensive and extensive awareness creation and community engagement on the consequences
of the use of women and minors in illegal mining is another important element in interventions. The government needs to prosecute illegal miners for mining and use of minors as labor.

Recommendations from environmental emergency response mission: \(^{56}\) include drinking water from boreholes as a safe alternative for people in the villages because lead is very immobile in soil and leaching of lead into ground water is not expected to be a problem. In cases where lead concentrations in wells were significantly (2-3 times) higher than the WHO guideline, closing the well as a remedial measure should be done after the installation of an alternative drinking water supply system like boreholes. Measures should be taken to prevent further ore processing activities from taking place at sensitive sites. Walls should be constructed to prevent the possible run-off of potentially lead-contaminated soil into these sources of drinking water. Preliminary remediation procedures have been described.\(^{58,59}\) Government and Stakeholders Strategic Plan have been described.\(^{48,49,58}\)

6. Lead in Gasoline
The incorporation of tetra ethyl lead as an additive to gasoline to improve octane rating has generated much controversy since its inception in 1921\(^{60}\). A balance of technological improvement with environmental sustainability, is needed given the well-established deleterious effects of lead on humans, especially children. When leaded fuel is burned, the particles from the exhaust are released into the air, where they can be inhaled or settle into the soil. Leaded gasoline is the greatest single source of human exposure to lead and the elimination is identified as a priority, because of its harmful lead content and the triggering effect the elimination would have on pollution. The use of unleaded gasoline is a prerequisite to introducing automobile catalytic converters which, in turn, can help reduce pollutants by as much as 90 percent.\(^{61}\)

After considerable inertia, Nigeria achieved a complete phase-out of leaded gasoline around 2004 with measurable benefits.\(^{64}\) In a study by Ojo et al,\(^{62}\) in 2010 on 62 Nigerian females who are occupationally exposed to vehicular pollution. In that study the mean lead levels in the blood determined using ICP-OES was 6.81 ± 2.61 µg/dL, which is within the currently accepted "No Action" level of 10 µg/dL, significantly lower levels (12.0 ± 6.0 µg/dL) than measured in the 1990s by same researchers. Jimoda et al\(^{63}\) in 2014 published the lead levels of gasoline and diesel samples from states in Southwestern Nigeria: 0.491-1.903mg/L for gasoline; and 2.301-10.97mg/L for diesel. Levels in gasoline were below the Department of Petroleum Resources (DPR) Nigeria limit of 3.37mg/L. The researchers concluded that the percentage lead contributions from gasoline and diesel fuel consumption were minimal due to various fuel-level regulations that have been established over the years.

7.0 Lead in Paint
Heavy metals such as lead, cadmium, arsenic are constituents of pigments added to paint formulations to increase brightness and longevity. Paints and coatings play an indispensable role in household appliances, buildings, cars, ships, airplanes, computers, furniture, and circuit boards. The American Academy of Pediatrics states that the “source of most lead poisoning in children now is dust and chips from deteriorating lead paint on interior surfaces”.\(^{64}\) Prior to 1955, white color house could contain up to 50% lead, reduced to 0-06% by 1978.\(^{65}\) The old and decaying homes are an ongoing danger: 70% of homes built prior to 1960 contain lead paint\(^{65}\) and approximately 25% of US homes with one or more children under the age of six contain exposed lead.\(^{64}\) Deteriorating or renovation projects can release the lead in paint into the surrounding air, where it can be absorbed during respiration or settle into the soil.
7.1 Lead from Paints—Nigeria scenario
The World Health Organisation (WHO) calls lead from paint “a major flashpoint” for children’s potential lead poisoning and says, “Since the phase-out of leaded petrol, lead from paint is one of the largest sources of exposure to lead in children”. Lead paints for home use continue to be widely produced, sold, and used in developing countries despite the ban by most highly industrial countries more than 40 years ago. Adebamowo et al\(^{66}\) in 2007, Apanpa-Qasim et al\(^{67}\) in 2016 and Sustainable Research and Action for Environmental development (SRADev Nigeria) in partnership with IPEN in 2009\(^{65}\) reported values much higher than the legally permitted and safe limits.

In 2016, SRADev Nigeria analyzed 18 different brands of paints produced by 16 manufacturers at an accredited laboratory in the USA for their lead content, based on dry weight of the paint. They found 40 out of 54 (74%) contained concentrations above 90ppm; and 29 paints (54%) contained dangerously high lead above 10,000ppm, while 14 out of 54 (26%) contained below 90ppm. A summary of the findings is presented in Table 3. They found paints with no meaningful information about lead content or the hazards; warning symbols on the cans indicated the flammability but no warnings on the effect on children and pregnant women.\(^{68}\)

<table>
<thead>
<tr>
<th>Author</th>
<th>Design</th>
<th>Settings</th>
<th>Sample tested</th>
<th>Metals Tested</th>
<th>Measurements</th>
<th>Remarks by researchers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adebamowo et al(^{66}) 2007</td>
<td>Paints manufactured in Nigeria in 2006</td>
<td>Paints from different manufacturers</td>
<td>Paints</td>
<td>Lead</td>
<td>96% of the paints had higher than recommended level of lead. Ranged from 848 to 50,000 ppm.</td>
<td>Enforce regulations leading to the elimination of lead based domestic paint.</td>
</tr>
<tr>
<td>Apanpa-Qasim et al(^{67}) 2016</td>
<td>174 paint samples marketed in Lagos and Ibadan 5 colours</td>
<td>All samples registered/not registered Standards Organization of Nigeria (SON)</td>
<td>Paints</td>
<td>Cadmium, Lead</td>
<td>98–1999 μg/g (Cadmium), 170–3231 μg/g. (Lead)</td>
<td>All the samples were above the permissible limits of 90 ppm of the US Consumer Product Safety Commission and 100 ppm limit of the European Union (EU) for Pb and Cd in paint.</td>
</tr>
</tbody>
</table>

7.2 Conclusions
The researchers concluded that solvent-based paints for home use with high concentrations of lead are widely available in Nigeria and the technology to produce paints without added lead exists in Nigeria. This provides a strong justification to adopt and enforce a regulation that will ban the manufacture, import, export, distribution, sale and use of paints with total lead concentrations greater than 90ppm. Studies by SRADev in 2017 and Apanpa-Qasin in 2016 observed no progress since the study by Adebawowo in 2007 to conform to best safety standards and eliminate lead in paint in Nigeria.

7.3 Recommendations
SRADev Nigeria and IPEN propose recommendations:\(^{65}\) highlighting the roles of Government and agencies like Standard Organization of Nigeria (SON), Paint Industry, Individual, Household and Institutional Consumers, Organizations and Professional Groups, Civil Society and NGOs, and other Stakeholders. There is need to raise awareness on the known dangers inherent in lead exposure to
women and children from paints, and how to mitigate exposure. Campaigns that will empower consumers’ right to know the lead content of paints they purchase should be encouraged.

8.0 Lead in “Tiro” a Nigerian eye cosmetic

“Tiro” also known as “tozali” and “Kwali” in Nigeria, is like Kohl ‘Surma,’” and “Kojal” used in the Middle East, India, and Pakistan. It is a fine powder applied to the dermal surface of the eyelid for improving attractiveness, aesthetics and promoting visual development. Tiro has been used to ward off “the evil eye”, to relieve eyestrain, pain, or soreness; to prevent infection of the umbilical stump or circumcision wound, and to prevent sun glare.

Healy et al. in a review of lead-containing traditional medicines in Nigeria, describe an eye cosmetic made of powdered mixture from ground lead ore and carbon. It is typically applied with a finger three to four times per day from about 4 months of age, regardless of gender, around the eyes like eyeliner until a dark stain is formed. Pfitzner’s et al documented two types of ‘tiro’ eye cosmetics: the paste and the powdered types. The pastes are lead free but more costly. Two powdered samples contained 43.8 and 68.8% lead respectively, while the range of lead levels in six of the paste type was 0.01 – 0.24%. Pfitzner recommended that since lead-free alternatives are available, educating the public regarding these materials could be done without disrupting an important custom to this religious group.

8.1 Studies on “Tiro”

A male infant of Nigerian descent aged 6 months in Boston, Massachusetts was found to have elevated blood level (BLL) attributed to application of “tiro eye cosmetic, lead content was 82.6%.” A single application of 10mg of tiro would deliver 8mg of lead to the infant’s eyelids. The most likely routes of exposure were eyelid-hand-mouth, absorption from the conjunctival surfaces and ingested tears. Analysis by the U.S Geological Survey, using scanning electron microscopy, showed that the sample contained lead sulfide, known as galena. Capillary blood testing performed by the physician indicated a blood lead level (BLL) of 13μg/dl, more than twice the CDC’s reference value of 5μg/dl. Lead-based paint from old buildings is a notable source of lead exposure in the United States, however, non-paint sources are increasingly being identified. These non-paint exposures include take-home exposure from workplace exposures contaminating homes or vehicles, and use of imported products such as spices, food, candy, cosmetics, health remedies, ceramics or pottery, and jewelry. Cases of lead poisoning in children from eye cosmetic and folk remedy have been reported in the United Kingdom.

Pfitzner et a investigated the prevalence and risks of elevated blood levels in young, urban children in Jos, Nigeria. Seventy percent of the children evaluated had blood levels higher than 10μg/dl, while 18% had blood lead levels >20 μg/dL. Mean blood lead levels were 15.2 ± 1.4 μg/dL; median blood lead concentration was 12.0 (range 1- > 60 μg/dL). Both male and female children used eye cosmetics, but the practice was significantly more among Muslims than Christians (80% vs 15%, p<0.0001). Exposure is thought to be due to children rubbing their eyes, placing hands in their mouths, and ingesting the lead rather than direct conjunctival absorption. The importance of eye cosmetic in lead poisoning in children has been confirmed by CDC. Other causes include living near a battery smelter. Lead ore (galena) is sold for crushing into a fine powder and used as an eye cosmetic. It is not imported, but sold locally by traditional vendors, hence not easily regulated.

8.2 Conclusion and Recommendations on Lead in “Tiro”

Tiro is a potential source of lead exposure among not only homeland Nigerians and Africans but also those in diaspora, Asians, and Middle Eastern populations. Public health educational campaigns can help identify and prevent further cases. Obstetricians, pediatricians, midwives, and allied health-
care professional should discuss this potential risk factor during prenatal and early childhood medical visits by families which these cultural practices apply. The Nigeria Centre for Disease Control is working with the vendors of tiro for safer alternatives. There is also a need to launch a national public health awareness campaign.

9.0 Lead in Food, Food wares, and Dietary supplements
Lead occurs in foods because of its presence in the environment. It can settle on or be absorbed by plants grown for fruits or vegetables or used as ingredients in food, including dietary supplements. Lead on the plants cannot be completely removed by washing or by other food processing. It may be ingested and absorbed by the animals and passed to humans when eaten. Lead can enter, through manufacturing processes such as contamination of water used in food production. Lead in pottery and other food contact surfaces leach into food or drinks prepared, served, or stored. Lead was most found in baby food types such as fruit juices: Grape (89%), mixed fruit (67%), apple (55%), and pear (45%); root vegetables like sweet potatoes (86%) and carrots (43%) and cookies like arrowroot cookies (64%) and teething biscuits (47%).

9.1 Interim Reference Level
The FDA assesses whether the amount of lead in a food product is high enough to be of concern by calculating a maximum daily intake of lead from food, called the Interim Reference Level (IRL). In determining the IRL, the FDA considers the amount of food consumed daily, and other factors, that would result in blood lead levels of 5µg/dL, at which the CDC recommends clinical monitoring of lead exposure in children. The FDA calculated the current IRL at 3 µg per day for children and 12.5 µg per day for adults. These levels allow for differences across human populations and are set nearly ten-times less than the actual amount of lead intake from food that would be required to reach the CDC’s blood reference level. The adult level is particularly important for women of childbearing age, to protect against fetal exposure in those unaware that they are pregnant, and infant’s exposure during nursing.

9.2 Lead in food—scenario in Nigeria
Adekunle and Akinyemi examined the levels of 252 indigenously processed smoked fish foods prepared and sold on the highways in Abeokuta via atomic absorption spectrometry. A fraction of the sample was investigated for the effect of atmospheric exposure while the remaining for the impact of processing technique on the fish metal levels. Quantitative evaluation of the vehicular traffic density per hour (VTD/h) of the near-by highway to each market was conducted. Results indicate contamination of these fish foods by lead with mean values varying from 8∙0+/−0∙8 to 12∙5+/−1∙6mg/kg. The food processing technique accounted for up to seven times increase in fish lead levels and the average VTD/h ranged from 1510+/−198 to 1752+/−344. Results also indicate a certain degree of relationship between the vehicular traffic and the lead levels. Positive correlation coefficient (r) ranged from 0∙336 to 0∙867. The investigated systems conjoin to give fish lead contents more than thirty folds above the stipulated safety standard for lead in fish foods. The researchers concluded that this connotes a potential threat to the health, security, and safety of such items to the consumer.

The middle belt region of Nigeria is regarded as the food basket of the nation, responsible for the cultivation of most food crops including vegetables consumed in the country. A comprehensive health risk assessment of agricultural soils in this region is urgently needed, to assess the level of soil pollution by Pb due to mining activities.

Orisakwe et al assessed the potential hazard of heavy metal exposure including lead in vegetable samples (tomatoes, red pepper, brown beans, lettuce, cabbage, Irish potatoes, onions, green beans, and carrot), soil samples, irrigation water and sediment samples collected from the Dilimi River,
Bukuru and Barkin Ladi communities in north central Nigeria using atomic absorption spectroscopy. The lead levels found in soil samples, ranged from 9.19-36.042 mg/kg, exceeding safety standards. Values in vegetables range from 0.5-2.4 mg/kg (Dilimi River), 0.3-1.7 mg/kg (Barkin Ladi) and 1.46-1.89 mg/kg (Bukuru), above the maximum permissible limit recommended by WHO/FAO. At least 75% of the calculated estimated daily intakes of Pb from different vegetable samples were also higher than the permissible tolerable daily intakes PTDI (0.0035 mg/kg day⁻¹) of Pb in both adults and children. Target hazard quotient THQ values >1 was also observed in children. High lead (Pb) levels were identified in some traditional alcoholic and non-alcoholic drinks such as Kunnu and Zobo. The researchers concluded that there is a health risk from consumption of vegetables in these mining communities.

Canned food, and dried fish have been shown to be lead-contaminated. Portions of unused canned foods like tomato paste, canned beef, sardines, and baked beans are stored in the fridge in the cans for days/weeks before use. Malnutrition may contribute to lead intoxication: deficiencies of both calcium and iron enhance lead absorption. The diet in Nigeria is generally deficient in calcium, and children may preferentially absorb another divalent cation like lead in lieu of calcium. Prenatal vitamins supplements over many months was found to constitute a significant source of toxic element exposure to the mother and offspring. Several samples exceeded known standards for gestational toxic element exposure. Paediatric medication syrups have been found to be another source of lead exposure in children.

9.3 Conclusion and recommendation on Lead in food, food wares and dietary supplement
Further research is needed to identify the food items with high levels of lead such as root plants like yam tubers, potatoes (sweet and Irish), coco-yams, cassava and carrots, heavily consumed as staples in Nigeria. Ripening agents which contain lead have been featured in the discourse on “Pesticides”. Food is an indispensable requirement of man and known environmental factors that poison our food must be taken into consideration for any meaningful intervention to reduce the lead burden of women and children. Public enlightenment is required to know measures to reduce consumption of lead in food. Very critical is the formulation of a Food Policy to govern every aspect of the food chain.

10.0 Lead in Toys
The chewing and swallowing of toys by children is common path for lead and cadmium exposure. Incidence of lead poisoning in children led to the first public study to ascertain the presence of lead in PVC by Arizona Health Department in 1995. An interim enforcement policy for children’s metal jewelry containing lead was published by US Consumer Product Safety Commission (CPSC) in 2005. Concern over lead paint in toys prompted several states to act in recent years. Jewelry sold in vending machines and chain stores has been identified as a potential source of lead exposure. The US Consumer Product Safety Commission (CPSC) put into effect a new enforcement policy providing clear guidance to manufacturers, importers, and retailers as to how toys will be tested for lead and what limits will be deemed acceptable. The maximum soluble migrated levels of lead in toys are listed in Table 4. Recalls of Chinese-made toys occur frequency in the US.

<table>
<thead>
<tr>
<th>Standard</th>
<th>Antimony</th>
<th>Arsenic</th>
<th>Barium</th>
<th>Cadmium</th>
<th>Chromium</th>
<th>Lead</th>
<th>Mercury</th>
<th>Selenium</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>60</td>
<td>25</td>
<td>1000</td>
<td>75</td>
<td>60</td>
<td>90</td>
<td>60</td>
<td>500</td>
</tr>
<tr>
<td>EU</td>
<td>60</td>
<td>25</td>
<td>1000</td>
<td>75</td>
<td>60</td>
<td>90</td>
<td>60</td>
<td>500</td>
</tr>
<tr>
<td>ISO</td>
<td>60</td>
<td>25</td>
<td>1000</td>
<td>75</td>
<td>60</td>
<td>90</td>
<td>60</td>
<td>500</td>
</tr>
<tr>
<td>Canada</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
<td>-</td>
<td>90</td>
<td>10</td>
<td>1000</td>
<td></td>
</tr>
</tbody>
</table>
10.1 The Nigerian scenario
Sindiku and Osibanjo\textsuperscript{95} analyzed the heavy metal contents of children’s toys manufactured from different countries on sale in Nigeria. They found high levels of metals compared with the elemental concentration threshold limit concentration (TTLC) of 90, 75 and 60 mg/kg for Lead, Cadmium and Chromium respectively. The levels were 28.5 to 12600 mg/kg lead; 0.15-9.55 mg/kg Cadmium; 1.30-394.50 mg/kg Chromium; and 5.9-1911 mg/kg Nickel. These toys are hazardous and therefore not safe for children.

Omolaoye et al\textsuperscript{96} analyzed some toys randomly selected from shops at Zaria, Kano and Kaduna. Seventy-five percent of the toy samples tested positive for PVC and 17% show high concentration (above US FDA limit) of Lead, Cadmium, Chromium, and other metals determined, which poses a threat to children. Non-PVC toys contain heavy metals with concentration less than that of PVC toys.

Igweze et al\textsuperscript{97} assessed the level of three toxic metals in thirty toy samples from stores in Port Harcourt and they were found to contain Lead (4.16 - 9.747), Cadmium 1.942-6.50) and Arsenic 1.459-6.318 mg/kg). The highest lead samples were found in ‘toy’ donkey 9.747 mg/kg, toy balls 6.50 mg/kg, and toy rabbit 6.318 mg/kg respectively, while the lowest levels were detected in Teddy bear 4.16 mg/kg, toy bird 1.942 mg/kg and Fischer pince rattle 1.459 mg/kg. The oral and dermal exposure risk assessment showed no significant non-carcinogenic and carcinogen health risks of public health concern.

10.2 Conclusion and recommendations
Toys are a big business and both the imported and locally manufactured tainted with lead can be an issue. The lead can be both in the paint and in the plastic itself; sucking or chewing on the toy or getting lead on the hands can be enough to poison a child. Old toys are also a risk, especially if they have peeling paint. Hence, children should play with age-appropriate toys to prevent swallowing. Kids should not play with old toys if it is not certain they are lead-free. Hence used toys such as those purchased at garage sales or thrift stores should be avoided. The safest choices for toys are unpainted wood, stuffed animals, and books. What is required is the formulation and enforcement of a national policy to protect the children from toxic toys. There is need for public enlightenment on the possibility of toxic chemicals migrating from toys like ‘teething rings,’ crayons, molding clays, and putty, building blocks. These children whose hands are hardly washed are given food items to handle at home, day care centres and nursery schools. Some consumer products that could be vehicles of toxic metals like lead are children’s jewelry, childcare products, couches, beds, chairs, dining tables, chests, curtains, dressers, and pianos. There must be tighter controls on manufacturing, and enforcement of regulations to govern the content of toxic metals in children’s products. There is need for greater public enlightenment on the possible presence of toxic metals in toys and how to mitigate exposure in children. Some steps to reduce lead intake include removal of shoes before entering the house, frequent hand washing in children and washing of toys, pacifiers, and bottles regularly.

11. Pica in Nigeria
Pica is the eating of non-nutritive substances on a persistent basis for at least one month, prevalent among young children and pregnant women. Commonly ingested substances include soil, clay, ice, starch, baking powders, chalk, and paint.\textsuperscript{98} Aminu et al\textsuperscript{99} studied the prevalence of pica among 442 women attending antenatal clinic in a tertiary facility in Bauchi, Nigeria and found it in 38.9% of the women. Among those positive for pica, 18.77% ate ice; 14.77% sand; 7.39% soil; 1.73% ashes; 1.75% chalk, 0.57% soap; and 55.11% other substances. Blood lead levels were not assessed in the women, but it is expected that lead levels would be high because of the items ingested.
Brice Vofo et al\textsuperscript{98} assessed the prevalence of the consumption of Calabar chalk among pregnant women and umbilical cord blood lead levels in two hospitals in Cameroon. Calabar chalk made from clay is a lead-laden pica with levels of up to 40mg/kg mostly consumed by pregnant women for morning sickness. Cameroon is a border country which share border and similar culture as the Calabar community in Nigeria. The prevalence of Calabar chalk consumption was 43.33\% and the overall umbilical cord blood lead levels were extremely high in both consumers and non-consumers. Health education and chelation therapy was recommended. However, chelation therapy is contraindicated in pregnancy and recommended for pregnant women only when the woman’s life is in danger\textsuperscript{100–103} because of the potential harm to the fetus and the increased risk of pregnancy complications.

12.0 Miscellaneous studies on lead (Pb) levels in Nigeria

Several studies were conducted in Nigeria on lead levels in various samples such as the blood of children, pregnant and non-pregnant women, breast milk, dust in residential homes, and scalp hair.

12.1 Some studies were conducted on lead levels in blood among children. Table 5 presents the results of blood lead levels in children.

<table>
<thead>
<tr>
<th>Study</th>
<th>Setting</th>
<th>Geometric mean</th>
<th>Range</th>
<th>Prevalence of BLL $\geq 10 \mu g/dL$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pfitzner et al\textsuperscript{102} 2000</td>
<td>Jos Urban</td>
<td>15.2 $\mu g/dL$</td>
<td>1.0 - 60.0</td>
<td>70.0</td>
</tr>
<tr>
<td>Wright et al\textsuperscript{105} 2005</td>
<td>Jos Urban</td>
<td>11.2 $\mu g/dL$</td>
<td>NA</td>
<td>55.0</td>
</tr>
<tr>
<td>Dooyema et al\textsuperscript{106} 2012</td>
<td>Northwestern Nigeria Rural</td>
<td>Village A 153.3</td>
<td>Village A: 55.9 - 331.0 Village B: 36.5 - 445.0</td>
<td>97*</td>
</tr>
<tr>
<td>Keating et al\textsuperscript{107} 2011</td>
<td>Jos Urban</td>
<td>11.1</td>
<td>0.0 - 43.0</td>
<td>44.7</td>
</tr>
<tr>
<td>Nriagu et al\textsuperscript{108} 2008</td>
<td>Ibadan, Nnewi, Port Harcourt</td>
<td>8.9 ± 4.8 $\mu g/dL$</td>
<td>8.3 ± 3.5, 4.7 ± 2.2</td>
<td>1.52</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>University of Nigeria, Teaching Hospital, Enugu</td>
<td>9.6 $\mu g/dL$ (Male) 6.3 $\mu g/dL$ (Female)</td>
<td>0.3 - 17.7</td>
<td>33.3</td>
</tr>
</tbody>
</table>

* Gold ore was processed inside two-thirds of the family compounds.

Fetuses may be exposed to lead throughout pregnancy given that lead can easily cross the placental barrier. In a study at Federal Medical Center, Owerri, Imo State, by Njoku et al\textsuperscript{110} 78\%-9\% of Nigerian pregnant women had a BLLs $\geq 10 \mu g/dL$ (range: 0.5 - 448 $\mu g/dL$).\textsuperscript{110} Another study by Adekunle et al\textsuperscript{111} assessed lead in blood (BLL) and urine (ULL) of some non-occupationally exposed, nonsmoking 214 pregnant Nigerian women, and resident in Lagos with control consisting of 113 nonpregnant women. The mean BLL and ULL ($\mu g/dL$) for pregnant women (59.5±2.1; 29.4±1.1) were significantly (p<0.01) higher than the values obtained for nonpregnant women (27.7±1.1; 9.2±0.6). Blood lead level found in women in the first, second, and third trimesters were 57.2±2.3, 61.6±2.2, and 63.1±1.8, respectively. Urinary lead level could not serve to predict BLL due to weak correlations ($r = -0.06$ to +0.15; p>0.10). Another study by Ugwuja et al\textsuperscript{112} among pregnant women in Abakaliki showed that 88.5 \% of the women had a mean ± SD blood Pb of 40.0 ± 16.5 $\mu g/dL$. Furthermore, because breastfeeding constitutes a potential source of exposure if the mother has a high body burden of lead, Vander Jagt et al\textsuperscript{113} conducted a study of the breast milk of 34 Fulani women in Plateau state. Forty-four percent of the specimens contained measurable lead (limit of detection, 4.6 microg/dL). The median lead concentration of milk specimens was 6.7 microg/dL (range, < 4.6-130
Given the mean weight of the (4.6 kg) and assuming each infant consumed 0.7 L/day of milk, the average lead intake of these exclusively breastfed infants was 9.9 microg/kg/day, a value which is twice the daily permissible intake (DPI) of 5.0 microg/g/day set by the WHO in 1972. These data indicate that some exclusively breastfed Fulani infants in the Jos Plateau are at risk of injury from lead derived from their mothers' milk.

12.2 Lead Dust in Residential Homes and Environmental/Industrial Pollution

In Nigeria, aerosolization of lead, through dust or automotive exhaust, represents another source of exposure. Children living in ground floor apartments had higher blood lead levels than those living in upper floor apartments suggesting particulate transmission, either by direct tracking of contaminated soil into the dwelling or through roadside dust from vehicular and pedestrian traffic. Ndukua et al.\textsuperscript{114} assessed Lead (Pb) in roadside surface soils, from dust particles and rainwater samples from the urban cities of Enugu, Awka, Onitsha, Nnewi, Aba, Portharcourt and Warri in South East Nigeria in 2007 and 2008. Samples were collected during the dry season, while rainwater samples were collected during the early rain (April–June), mid rain (July–August) and late rain seasons (September–October) for the two years. Soil samples were collected from traffic congested roads, dust was collected by tying a plastic basin on a pole 1.5 m above ground level and leaving it for 45 days. Rain samples were collected from three equidistant points. The highest soil Pb of 120.00 ± 0.00 and 80.36 ± 0.00 mg/kg were reported in Onitsha for 2007 and 2008, respectively. Nnewi showed 33.40 ± 0.01 and 4,238.29 ± 0.00 mg/kg for 2007 and 2008. Aba had 22.56 ± 0.01 and 21.28 ± 0.00 mg/kg for 2007 and 2008. Dust Pb ranged from 0.13–0.49 mg/kg and 0.15–0.47 mg/kg for 2007 and 2008, respectively. Rain samples had the least Pb concentration, ranging from 0.103 ± 0.000 to 0.163 ± 0.046 mg/L.

Nnorom et al.\textsuperscript{115} conducted a multielement analyses of human scalp hair samples from three distant towns in South East Nigeria. The locations of study were Aba and Onitsha—industrial areas and Isuochi, a rural small unindustrialized town. About 89% of the population had Pb levels >30 \(\mu\)g/g, indicative of occupational/environmental exposure, while about 20% had Pb levels >110 \(\mu\)g/g which is considered dangerous. Female hair samples in Aba and Onitsha had higher levels of all the metals than samples in Isuochi. The very high lead levels were attributed to occupational exposures in an industrialized area.

Taiwo et al.\textsuperscript{116} studied health risks associated with road dusts in major traffic hotspots in Abeokuta metropolis, Ogun State, South West Nigeria. Lead concentrations of road dusts (paved = 31.8 ± 33.6mg kg\(^{-1}\), unpaved = 50.8 ± 48.9mg kg\(^{-1}\)) were also statistically higher \((p<0.05)\) than those of control samples \((6.33 ± 3.36 \text{ mg kg}^{-1})\). Urban areas in sub-Saharan countries are very dusty given the low proportion of paved road and the high traffic density reported lead dust concentrations were ≥7000 \(\mu\)g/dl in Lagos.\textsuperscript{117} In Nigeria, many women of childbearing age work as traffic control officers putting them and their families especially the children at risk of lead poisoning from “take home” lead on their body and breast milk.\textsuperscript{117}

13.0 Prevention of Lead exposure

The most effective strategy for keeping blood concentration of lead low is prevention of exposure.\textsuperscript{118} This includes ensuring that industries that generate significant levels of lead emissions and employees follow safety guidelines for limiting exposure.\textsuperscript{119} Identification of lead contamination sources, followed by removal or avoidance, constitutes the ideal solution to reduce exposure to heavy metal.\textsuperscript{119}

Intervention needs to be divided between education, community/government involvement, and treatment through chelation. Education as a primary, preventive public health measure would be the easiest to implement and the least likely to cause political resistance. Families, service providers,
advocates, and public officials need to be educated on primary prevention of lead exposure in homes, schools, daycare centre, and other facilities occupied by children to eliminate the hazards before exposure. Dangerous practices must be discontinued, and environmental sources removed. Lead screening is not available to these children at present; therefore, education is pivotal.

Prenatal vitamins supplements were found to constitute a significant source of toxic element exposure to the mother and offspring. With several samples exceeding known standards for gestational toxic element exposure, guidelines for routine monitoring and reporting are required. In keeping with recommendations from the International Federation of Obstetrics and Gynecology, stringent industry regulation would be welcomed to protect expectant mothers and their vulnerable offspring. Paediatric medication syrups have been found to be another source of Lead exposure in children, hence, should be censored. Exclusive breast feeding of babies would help to eliminate toxic exposure to lead from water used for mixing infant formula. Government agencies such as National Environmental Standards and Regulations Enforcement Agency (NESREA), the National Agency for Food and Drug Administration and Control (NAFDAC), and Standard Organization of Nigeria (SON) must use evidence based targeted strategies to update and improve their surveillance capabilities taking cues from the approaches from developed nations. Unregulated waste disposal practices must be discontinued. Public enlightenment activities about the sources and breast cancer risk potential of lead would help to discontinue the use of lead-laden eye cosmetics, pica and Ayurvedic products. It is not necessary to advise pregnant women in Nigeria not to eat fish or shrimps although these are proven sources of lead and mercury poisoning. Since fish and shrimps are important sources of animal proteins for pregnant and nursing mothers, emphasis should be placed on reducing environmental sources of lead which contaminates sea food.

Children are especially vulnerable to lead toxicity due to their physiology, predisposition to exposure through hand to mouth behaviours and inhalation, hence there is no known safe blood lead levels in them. The potential of lead as a risk factor for breast cancer was not factored into the toxicokinetics of lead when the permissible level was initially calibrated. The recently discovered breast cancer risk factor now reinforces the zero tolerance for lead exposure hence, the ideal acceptable level should be zero µg/dL. Nigeria has every known risk factor for lead exposure implying that important efforts should be directed towards reinforcement of known prevention programmes and through research studies to identify hitherto unknown exposure sources. Individuals are advised to take responsibility of their well-being by testing their drinking water sources periodically.

13.1 Policy implications
Since malnutrition and infectious diseases represent the most significant health problems for children in developing countries like Nigeria environmental hazards are understudied. Furthermore, environmental hazards are often invisible and their symptomatology non-specific, hence, they are ignored. Children in developing countries may not reach their intellectual potential due to the presence of lead, resulting in a ‘dumbing down’ of the population. With the grave potential of later development of breast cancer, toxics like lead should no longer be acceptable. There is need for Heavy Metals Regulations in Nigeria so that current and future generations are not affected by environmental hazard like breast cancer. Further work is necessary to better identify occult sources of lead exposure in Nigeria and to develop methods to decrease the lead burden currently imposed on young children.

In 2007, Ogunseitan and Smith calculated the cost of environmental lead (Pb) poisoning in Nigeria by conducting a meta-analysis of measured blood lead levels (BLL) and used published Relative Risk values for disease categories to estimate the proportion of overall disease burden attributable to Pb. They modeled the health costs of Pb exposure and compared this to the cost of banning Pb. They estimate that Pb exposure accounts for 7-25% of the disease burden among Nigerian children costing...
the health and education sectors $0.38 - 1.15 billion year\(^1\) for every 1\(\mu g/dL\) increase in BLL. In comparison, they estimate that a Pb abatement program in Nigeria will cost $0.076 - 0.23 billion year. If a Pb phase-out program is instituted now to lower the national BLL to 1 \(\mu g/dL\) by 2020, a savings of $2.7-8.0 billion would be realized.

13.2 WHO Efforts\(^{121}\)
World Health Organization identified lead as 1 of 10 chemicals of major public health concern, needing action by member states to protect the health of workers, children, and women of reproductive age. World Health Organization made available through its website a range of information on lead, including information for policymakers, technical guidance, and advocacy materials. The phasing out of lead paint by 2020 is one of the priority actions for governments included in the WHO Road map to enhance health sector engagement in the Strategic Approach to International Chemicals Management towards the 2020 goal beyond approved by the Seventieth World Health Assembly in decision WHO 70.

The Global Alliance to Eliminate Lead Paint is an important means of contributing to the implementation of the strategic Approach to International Chemicals Management (SAICM), which both concern the phasing out of lead paint. WHO is also a partner in a project funded by the Global Environment facility that aims to support at least 40 countries in enacting legally binding controls on lead paint. There is an Interim Guidelines and Standards for Environmental Pollution Control in Nigeria\(^{122}\) issued by the Federal Environmental Protection Agency (FEPA). These guidelines and standards relate to six areas of environmental pollution control: Effluent limitations, Water quality for industrial water uses at point of in-take, Industrial emission limitations, Noise exposure limitations, Management of solid and hazardous wastes, and Pollution abatement in industries.

14. Conclusion
Primary prevention is the most effective way to prevent lead exposures in young children; however, blood screening tests and secondary prevention remain a proven and essential safety net for children exposed to lead. Monitoring of the integrity of surface waters is significant to be assured of the sustainability of desired eco-system functions of aquatic environments. More attention should be given to the monitoring of toxic heavy metals due to inherent bioaccumulation and biomagnification potentials. The main anthropogenic sources of heavy metals contamination of water, sediment and aquatic animals are industrial activities, mining and disposal of untreated and partially treated effluent containing toxic metals. Thorough and geographically widespread studies need to be carried out to find the true incidence of lead poisoning in Nigeria. Known effective public health measures including the elimination of residential lead paint, control of emission from formal and informal ore processing and metal recycling and increased availability of lead safe cosmetics and traditional medicines should be undertaken.

List of Acronyms
ANSI = American National Standards Institute
ICP-OES = Inductively Coupled Plasma Optical Emission Spectrometry
ISO = International Organization for Standardization
NSF = National Science Foundation

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