Commentary

Sources of Lead Exposure in West Africa

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Abstract: This commentary is an investigation of sources of lead (Pb) exposure in West Africa. Pb is generally acknowledged as one of the most widespread environmental health hazards in West Africa, and there is heightened concern over adverse health effects at various levels of exposure (at doses once considered safe) in the West African region. A literature review for the possible health implications of Pb exposure on human health showed nervous system dysfunction, anemia, and potential cognitive diseases as the major health issues among children, while adults were found to suffer more from cardiovascular dysfunction, neurological decline, and reproductive diseases. Despite a decline in blood lead levels (BLLs), lead exposure continues to be a major public health concern as no level of Pb exposure can be considered safe. Moreover, lowering BLLs entails identifying various lead sources such as gasoline emissions, leaded paint, canned foods, and beverages, as well as plausible biological pathways of lead exposure and response. However, only countries such as Nigeria and Ghana have extensive research available regarding the different sources of Pb exposure. Further, it is not apparent which country is affected the most by Pb exposure. Therefore, this commentary was aimed to explore different literature sources to describe and list the different sources of Pb exposure in 15 West African countries. The findings indicated water, food, and occupational exposure as the major sources of Pb exposure in the region. People with occupations such as e-waste and Pb acid battery recycling, auto mechanics, fuel attending, welding, electronic repairing, farming/spraying, and mining were found to be at immediate risk. Tobacco, spices and paints constituted additional potential sources of exposure. For residents living near landfills or urban area, the major sources of Pb exposure were soil, air, and dust particles. The review revealed a vast research gap on the sources and implications of Pb exposure. Exposure to Pb could further increase due to uncontrolled traffic, urban growth, inadequate urban planning, and the inadequate enforcement of regulations. Therefore, more extensive research on the changing trends of Pb exposure among West African populations is needed.

Keywords: lead exposure; West Africa; environmental exposure; metals

1. Introduction

It is well-documented that excessive exposure to lead (Pb) is harmful to health. Pb exposure can lead to many health effects because of its extensive accumulation in the brain and spinal cord tissues, teeth, bones, skin, and mucosa [1–5]. The toxic effects of Pb are seen in the hematopoietic, neurological, renal, gastrointestinal, cardiovascular, and reproductive systems, the first two being the most frequently and severely affected [6–9].

Many of the historical uses of Pb continue to remain essential reasons for its present elevated exposure risk to humans. Examples include in glazing for pottery, castings, automobile batteries, solder, pipes, paint pigments, and gasoline additives. This exposure is especially pronounced in developing regions such as West Africa.

West Africa is the location of 5% of the world’s population. West Africa’s demographics are disproportionately spread within the region, showing variations in the physical environment and history of human settlement. In the Sahara and Sahel regions of West Africa, which
tend to be arid, only small populations can be sustained. In other areas where the soils are rich and the climate is excellent for crop cultivation, more significant concentrations of people are found [10–12]. This is critical since factors such as population density and soil type can affect exposure risk [13]. For example, Pb exposure in soil that is more sparse can be more easily resuspended and expose populations to chronic levels of atmospheric Pb.

West African cities have become more urban in recent years, with an annual growth rate of roughly 10%; in addition, the annual population growth rate is 2.75%. [14]. The urban population increased by approximately 40% between 1950 and 2019 [15–17]. Urban exposure to Pb is different from rural exposure due to uncontrolled traffic [18,19], urban growth, inadequate urban planning [20], and the insufficient enforcement of regulations [21].

In many areas within West Africa, Pb exposure exceeds the World Health Organization’s (WHO) recommended concentrations of 10 µg/L for drinking water [22] and 0.5 µg/m³ for Pb in air [23].

This level of exposure has put populations living in these regions at risk for health complications. However, the percentage of West Africans who are vulnerable or exposed to Pb is unknown due to the region’s lack of extensive Pb surveillance. The risks associated with Pb exposure are globally well-documented [24], with the health impact in West Africa not being different. Specific data on hospitalizations and loss of GDP due to Pb exposure are unknown, though a study by Attina and colleagues in 2013 [25] estimated that 134 billion dollars had been lost due to childhood Pb exposure in Africa as a whole.

It is critical to understand Pb exposure risk in West Africa, who is being exposed to Pb and how they are exposed, and possible solutions to mitigate exposure risk. Thus, identifying the sources of exposure can provide insight into the factors potentially providing the most risk, help to identify areas needing more research, and open the avenue for solutions for at-risk populations.

2. Findings by Country

The sources of Pb exposure in West Africa are presented below. This commentary was aimed to explore sources of Pb exposure but not explore lithology and how it may affect exposure within different regions. Both the geological background and anthropogenic activities have contributed to Pb levels in all surveyed countries within the region. In addition, other toxic heavy metals (Cd, Cr, As, etc.) are also widely observed in the environment. Previous studies have shown that different metal ions may have different binding effect degrees. Thus, other metal ions may affect sources and toxicity of Pb by combining with it, thus further impacting human health. Therefore, exposure and health risk to individuals and populations must be deduced with caution.

In this paper, factors found to be associated with elevated Pb exposure risk are explored for each of the 15 countries in West Africa. Firstly, countries with limited studies are discussed, followed by countries with a significant amount of studies. A summary of the exposure type found in this study is shown in Figure 1, with Table 1 providing more details by country.

Figure 1. Sources of lead exposure found in this commentary.
Table 1. Exposure type in West African region by country.

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Sources of exposure gathered from articles presented in this commentary.
2.1. Sources of Lead Exposure in Countries with Minimal Studies

2.1.1. Benin

Sources of Pb exposure in Benin are varied; key risk factors for exposure include the water sources of exposed populations, hunting with Pb bullets, food, occupation, and soil. In a study in Allada (a semi-rural area in Benin) examining maternal anemia and offspring neurodevelopment, Bodeau-Livinec and colleagues analyzed blood lead levels (BLLs) in 225 mothers and 685 offspring. The median BLL was 55.1 for mothers and 46.6 µg/L for the offspring. Maternal BLL was mainly correlated with the intake of piped water and animals killed with lead-contaminated bullets, whereas BLL in children was associated with paint chips in their houses and the consumption of animals killed by lead-contaminated bullets [26]. In another study by Ahmadi and colleagues in Allanda, the authors’ findings suggested that bushmeat killed by Pb-contaminated bullets was a significant source of exposure in adults [28], with correlates of exposure in children being rice consumption and paternal occupational exposure [54]. In another study, Pb levels were also found to be high in fish, with the risk being higher for children in an assessment of the daily dose of exposure (DDE) in Ganvié, Benin [55]. The fish Liza Falcipinnis had the highest average Pb contamination, followed by Chrysichthys auratus and Sarotherodon melanotheron. Finally, potential environmental contamination with Pb was demonstrated in a study by Afiavi and colleagues in Cotonou, Benin, which found toxic Pb levels in anti-malarial plants sold in the markets [27]. Specifically, Pb levels were found in the plants Senna Rotundifolia, Pavetta corymbosa, Senna siamea, Dichapetalum madagascariense, and Morinda lucida, with the highest levels in the city of Godomey.

2.1.2. Burkina Faso

Even though there have been very few studies in Burkina Faso, the available literature suggests that exposure to Pb occurs in mines, through water, and food. In a study of a gold mining community of Poura Burkina Faso, Kagambenga and colleagues found the soil and mine-waste samples to be moderately contaminated with Pb, with the source of these heavy metals being sulfides [30]. The authors of another study found elevated Pb levels in irrigation water and lettuce [29].

2.1.3. Cape Verde

Exposure to Pb in Cape Verde likely has several sources; in the published literature, food has been shown to be a significant source of exposure. In a study in Cape Verde, toxic metal contents (including Pb) were examined in 126 samples of cereals; the mean Pb concentration levels in the cereals was 0.03–0.08 mg/kg, with the most elevated levels found in the corn gofio [56].

2.1.4. The Gambia

In a report on Pb in solvent-based paints in The Gambia, results indicated that most sampled solvent-based paints (62%) had Pb concentrations of more than 90 ppm and that 41% of the paints had high Pb concentrations of more than 10,000 ppm. Yellow paints had the highest concentration of Pb, with 90% containing Pb concentrations in excess of 10,000 ppm; for orange paints, 80% contained excess Pb concentrations; and for red paints, 27% contained excess Pb concentrations [31].

2.1.5. Guinea-Bissau

Guinea-Bissau is another country for which data on Pb exposure risk are limited. In a study performed in the Oio and Cacheu regions of Guinea Bissau, concentrating on the characterization of the groundwater supplies, Pb concentrations were only found to be elevated above WHO limits in a sample (concentration = 94.6 µg/L) from the Cacheu region [40]. This elevation was due to the bad condition of the well, which was built by foreign corporations, with the local population having little knowledge or tools to ensure its maintenance.
2.1.6. Ivory Coast  
Food is a route by which Pb exposure occurs in the Ivory Coast. For example, in a study in the Ivory Coast, pineapple juices were shown to be contaminated with Pb [41].

2.1.7. Mali  
Though edible plants are not a significant source of Pb exposure in Mali, drinking water is a potential source of Pb exposure. Medicinal and edible plants were not found to have elevated Pb levels [57], but researchers evaluating the level of contamination in drinking water and its association with health in Pelengana Commune, Mali, found elevated Pb levels [42].

2.1.8. Senegal  
The authors of a study that explored the cause of death of 18 children in a community involved in the recycling of used Pb–acid batteries in the suburbs of Dakar, Senegal, found that the soil and dust were heavily contaminated with Pb [52]. Pb exposure was a factor in the studied disease, but it is hard to make any conclusions about causality due to the study design.

In a study on the health of children living near a landfill, soil and air Pb levels were found to be elevated, with exposed individuals experiencing adverse health outcomes [53]. In a study examining the levels of Pb in Senegalese children and the relationship between Pb levels and markers of oxidative stress and heme biosynthesis in Khombole (a rural area) and Dakar (an urban area), a higher proportion of urban children was shown to elevated Pb exposure. The authors concluded that Pb affects physiological outcomes such as heme biosynthesis and antioxidant/pro-oxidant equilibrium, with Pb exposure sources such as the legacy of leaded-gasoline use being factors of significant concern [58]. It must be noted that leaded gasoline was phased out in Senegal in 2005 but traces may exist in old, inadequately cleaned gas tanks, among other exposure sources.

2.1.9. Guinea, Liberia, Niger, Mauritania, Sierra Leone  
No comprehensive studies on Pb exposure have been conducted in Guinea, Liberia, Niger, Mauritania, and Sierra Leone. More work is needed to explore how people are being exposed in these countries. That said, a study in Niger examining water supplies showed that 6.6% of sampled water exceeded the World Health Organization’s Pb guidance [43].

2.2. Ghana  
In Ghana, exposure to Pb is more elevated in urban than non-urban areas [39]. This is potentially due to migration, industrial activities, and local and imported Pb contamination.

2.2.1. Occupational Pb Exposure in Ghana  
The authors of a study in Accra at Agbogbloshie, a commercial district, who explored the effects of informal e-waste handling on BLLs found that workers involved in e-waste burning were likelier to have the elevated BLLs [37]. Elevated Pb exposure risk due to e-waste processing was confirmed by others [38,39]. A Tema, Ghana, study indicated that the Pb concentration in the soil at a used Pb acid battery recycling facility was significantly elevated, putting children at risk [35].

The authors of study in Kenyasi in the Ahafo region of Ghana who explored BLLs among blood donors in high-risk occupational groups such as auto-mechanics and fuel attendants/drivers found that BLLs were highest among blood donors in high-risk Pb exposure occupations [36]. Airborne Pb was assessed in battery, electronic repair, and welding sources in Kumasi Metropolis, and it was shown that exposure was occurring in these facilities, with exposure being highest during working hours [32]. In a study of farmers and sprayers in Assin South District, Central Region, Ghana, Pb levels were found to be elevated, with effects that were significant enough to be associated with adverse renal
outcomes [60]. Pb exposure was also found to be elevated among mining communities [61]. Mothers in mining communities were also found to transmit Pb to their babies [62].

2.2.2. Community-Based Exposures in Ghana

Water also serves as a source of Pb exposure in Ghana. For example, a study that assessed Pb exposure in tap and surface water, as well as a borehole in the Obuasi Municipality, showed elevated Pb levels [33].

In another study considering metals in shallow groundwater in Anloga community, Volta region, Ghana, Pb levels were found to be elevated in some samples [34]. In a study of metals including Pb in surface water and boreholes in Tinga in the Bole-Bamboi District, Ghana, results indicated that Pb levels were elevated above the WHO recommendations [63]. In an evaluation of surface water and groundwater in Bosomtwe lake in the Ashanti region of Ghana, Pb levels were found to be elevated above the WHO recommendations [64]. Elevated levels of Pb were also found in groundwater in the Atankwidi basin of Ghana [65].

Finally, tobacco use and spices can serve as sources of exposure. A study that explored heavy metals in spices in the Kumasi Metropolis found that Pb levels in Ginger, Black Pepper, and cinnamon were elevated [66]. An analysis of heavy metal contents in tobacco and cigarettes sold in the Wa Municipality of the Upper West Region of Ghana showed that Pb levels were higher than the recommended permissible limits of the WHO [67].

2.3. Nigeria

Nigeria has the most extensive literature on Pb exposure in West Africa, with the country offering critical insight into how exposure occurs in West Africa, e.g., from factors such as occupation, food, soil, and paint.

2.3.1. Occupation

In examining Pb exposure among various artisans such as mechanics, battery chargers, and gasoline station attendants in Abeokuta, Nigeria, Ademuyiwa and colleagues found that Pb exposure was higher in these individuals compared to less-exposed controls, with the effects increasing cardiovascular disease risk [50]. Other studies have shown BLLs to be elevated in mechanics in this area [51]. Gasoline station attendants and automobile mechanics in Nnewi, South-East Nigeria, were also found to have elevated Pb exposure levels, with exposure associated with hematological indices [46].

In another study examining Pb-exposure in occupations such as welding/metalwork, paint/pigment work, radiator repair, battery work, and gasoline work, these workers had significant Pb exposure levels; however, controls were also significantly exposed, with markers of the renal function being higher in the more exposed individuals [20]. Indeed, those occupationally exposed to petrol in Nigeria and other West African countries consistently had higher Pb levels [68].

Research performed in Gwagwalada area comparing occupationally exposed individuals, such as generator mechanics, automobile mechanics, gasoline attendants, and battery chargers, with less-exposed individuals (fulltime students) showed that those who were occupationally exposed had much higher BLLs than the less-exposed individuals, which increased adverse health outcome risk [69].

2.3.2. Community Based Exposures

Research on Pb exposure in the cities of Ibadan, Nnewi, and Port Harcourt showed significant positive associations between BLL and a child’s age ($p = 0.004$), town of residence ($p < 0.001$), the existence of pets in a child’s home ($p = 0.023$), and the amount of time the child played outside ($p < 0.001$) [70].

In an investigation completed in Kaduna, Nigeria, the strongest associations between BLLs and variables of interest were related to whether the family owned a car or they lived in a house on a tarred road [19].
Research in Jos, Nigeria, on factors associated with elevated BLLs included flaking house paint, age of 5 years and under, living near a gasoline seller, male sex, parents’ education, and use of a Pb-ore eye cosmetic [47].

An investigation examining 252 smoked fish prepared near highways indicated that these foods were contaminated with Pb, with food-processing techniques (such as smoking of the fish) accounting for up a seven-fold elevation in fish Pb levels [49].

In a study in the Adudu community examining BLL and exposure pathways in children less than 7 years of age and adults aged 18 and older living near a Pb–zinc mine in Nasawara, Nigeria, it was found that mining communities were exposed to Pb and that 1% of adults had BLLs above 5 µg/dL [71]. That said, results were not as high as had been found in areas such as Abeokuta. In May–June 2010, a Pb poisoning crisis associated with gold ore processing occurred in two villages in Zamfara State, Nigeria, with the odds of childhood Pb poisoning or Pb contamination being three and a half times more elevated in ore-processing villages compared to other towns [72].

2.3.3. Food

In a study assessing the impact of cultural and dietary habits on Pb exposure pathways and estimating the influence of Pb tainted food on children’s BLLs, it was found that cereal grains and legumes were significant sources of exposure [48]. A study among a similar group showed that occupational exposure to Pb was associated with neurotoxicity [73], with some of the health effects limited by ascorbic acid consumption [74].

2.3.4. Soil

Urban Pb levels were assessed in roadside dust particles, surface soils, and rainwater samples from the cities of Awka, Enugu, Onitsha, Aba, Port Harcourt, Nnewi, and Warri in Nigeria. Pb in soils and dust were high, potentially speaking to the legacy of Pb exposure from gasoline, among other exposure sources [44].

Research assessing the levels of Pb in residential topsoil in Lagos and Ibadan showed that Pb concentrations in the soil near residential buildings were more elevated compared to control samples [45].

2.3.5. Water

In a study in the Abakaliki Metropolis, Pb in water was analyzed. There were statistically significant differences ($p = 0.016$) between Pb concentrations in well water and tap water. The most elevated well water Pb level was observed in Azuiyiokwu, while the most elevated level in borehole water was found in Abakaliki [75].

2.3.6. Paint

Paint is also a source of Pb exposure in Nigeria. In a study examining paints produced in Nigeria, the Pb levels in five different colors of paints, each from different manufacturers, were measured. Results indicated that 96% of the paints had Pb levels higher than the recommended levels. The mean Pb levels of paints were between 84.8 and 50,000 ppm, with a median of 15,800 ppm and a mean of 14,500 ppm. The biggest factor determining elevated Pb levels was the color of the paint, with yellow having the highest mean and median concentrations of 42,271 and 40,515 ppm, respectively [21].

2.3.7. Cosmetics

In a study examining the facial cosmetics available in Nigeria, Nnorom and colleagues analyzed the contents of heavy metals such as Pb; data indicated that cosmetics such as Pb-based Kwali eye make-up were a source of elevated Pb exposure among women [76]. Other cosmetics in Nigeria causing elevated Pb exposure include “tiro”, a Nigerian cosmetic and a folk remedy to promote visual development, with reports indicating that some samples contain more than 80% Pb [77].
2.3.8. Medicines

An examination of pediatric syrups in medicine and pharmaceutical shops in Awka, Anambra State Nigeria, revealed that many local and imported syrups had elevated Pb levels [78].

2.4. Comparison of Countries in West Africa

Pb exposure in West Africa is very different from Pb exposure in developed countries. BLLs tend to be higher in studies conducted in West Africa because sources and pathways of exposure are more prevalent and because exposure levels can reach higher concentrations due to a lack of regulations, difficulty in enforcing regulations, and inadequate city planning in urban settings, which allows for various exposure sources and pathways for at-risk populations [79]. The exact differences in BLLs between HIC and LMIC are unclear as most of the data on BLLs in West Africa have been collected in research studies. This is also the case for many LMIC countries.

The sources of Pb exposure across countries explored in this commentary were found to be varied. A constant theme was water and soil as sources of exposure. Exposure from water is especially of concern due to its vital necessity for human function, widespread use, and critical impact on individuals and communities. For soil, its ability to be resuspended in the environment means that in areas with a lot of activity, populations can be consistently exposed to low levels of Pb from the soil.

2.5. Limitations

Ultimately, comparing and contrasting sources of Pb exposure in different West African countries has limitations because specific studies considering all exposure sources have not been conducted in all countries or all regions within countries.

It must be noted that some of the sources of Pb exposure may be related to each other. For instance, Pb-contaminated paint may find its way into the soil, water, or air. The legacy of leaded gasoline may be reflected in the soil, water, and food. Food sources may also be influenced by Pb-contaminated water, soil, and air. Finally, e-waste may be influenced by all the other sources. More studies using radionuclides, isotopic fingerprinting, and in vitro bioaccessibility are needed to offer more insight into sources and exposure/health risks.

3. Conclusions

Pb exposure in West Africa arises from many sources, with exposure potentially putting the health of residents in the region at risk. Therefore, to promote the adequate development and optimal health of the population in the area, the environmental sources of disease must continue to be explored, and more emphasis must be placed on mitigating risk. Environmental surveillance and biomonitoring are needed in West African countries to identify, track, and reduce exposure to Pb. Finally, more surveillance of children’s BLLs are needed to identify and mitigate exposure risk to Pb.

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