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LEAD POISONING IN NIGERIA: SOURCES, HEALTH IMPACTS AND POLICY GAPS (2005-2025)

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Article Information

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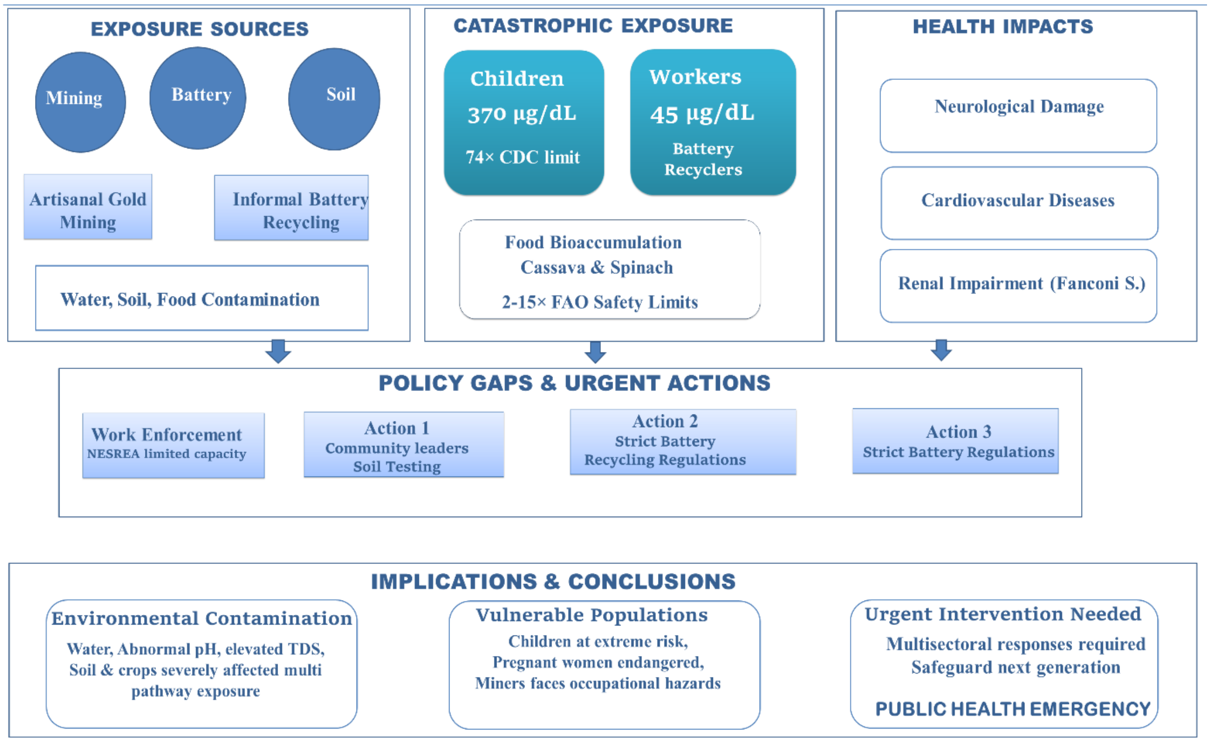
Abstract

Lead poisoning constitutes a severe public health emergency in Nigeria, disproportionately impacting vulnerable groups including children, pregnant women, and artisanal miners. This systematic review (2005–2025), analyzing 85 studies and agency reports, synthesizes evidence on exposure sources, health effects, and policy gaps. Primary exposure routes include artisanal gold mining and informal lead-acid battery recycling, with secondary contamination of water (abnormal pH, elevated Total Dissolved Solids), soil, and food crops. Blood lead levels (BLLs) reveal catastrophic exposure: children in mining areas exhibit BLLs up to 370 µg/dL, 74× the CDC's 5 µg/dL reference. Occupational exposure averages 45 µg/dL among battery recyclers. Environmental testing shows staples like cassava and spinach bioaccumulating lead at 2–15× FAO safety limits. Health impacts span neurological damage, cardiovascular disease, and renal impairment (e.g., Fanconi syndrome). Despite the 2010 Zamfara outbreak response, progress stalls due to weak NESREA enforcement and limited remediation funding. We propose immediate actions: (1) community-led soil testing, (2) stricter battery recycling regulations, and (3) nationwide BLL surveillance. This crisis demands urgent, multisectoral intervention to safeguard Nigeria's next generation.

Keywords*: Lead Poisoning, Nigeria, Environmental Contamination, Artisanal Mining, Heavy Metals.*

Graphical Abstract



1.0 INTRODUCTION

Lead poisoning represents a critical public health emergency in Nigeria, constituting what has been described as the nation's most significant undiscovered environmental health crisis. The toxicity of lead has been recognized for centuries, yet Nigeria continues to experience devastating outbreaks that disproportionately affect children and marginalized communities. The most catastrophic manifestation of this crisis occurred in Zamfara State in 2010, where artisanal gold mining activities triggered an acute lead poisoning outbreak that claimed the lives of at least 400 children under five years of age within a three-month period [1].

The significance of lead exposure as a global health concern cannot be overstated. The World Health Organization ranks lead exposure among the top 10 chemical risks to public health, emphasizing that no known level of lead exposure is considered safe. In Nigeria, this threat is particularly pronounced due to widespread environmental contamination from multiple sources, including illegal mining operations, uncontrolled disposal of lead-acid batteries, contaminated water sources, and occupational exposures. The devastating impact extends beyond immediate mortality, encompassing long-term neurological impairment, cognitive deficits, and substantial economic losses estimated at US$134.7 billion annually across the African continent [2]. Nigeria's experience with lead poisoning is characterized by its multifactorial nature and geographic concentration in mining regions. The northern states, particularly Zamfara, Osun, and Niger, have emerged as epicenters of lead contamination due to intensive artisanal and small-scale gold mining (ASGM) activities. These operations, often conducted within residential compounds using crude processing techniques, release enormous quantities of lead dust into the environment, contaminating soil, water sources, food supplies, and living spaces [2].

The epidemiological profile of lead poisoning in Nigeria reveals alarming patterns of exposure among the most vulnerable populations. Studies consistently demonstrate that up to 70% of Nigerian children have blood lead levels exceeding 10µg/dL, with some communities showing even higher prevalence rates. In mining areas, children frequently present with blood lead concentrations ranging from 168 to 370µg/dL - levels that are invariably associated with severe neurological complications and high mortality rates [4-5].

The pathophysiology of lead toxicity in children is particularly concerning due to their increased susceptibility to neurological damage. Lead readily crosses the blood-brain barrier, especially in children under six months of age who lack a fully developed barrier, accumulating in glial cells and causing widespread neurological dysfunction. The metal interferes with synaptic plasticity, resulting in impaired memory, learning deficits, and permanent intellectual disability.

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Environmental contamination in Nigerian mining communities reaches extraordinary levels that far exceed international safety standards. Soil samples from residential compounds in affected villages have recorded lead concentrations up to 185,000 ppm, compared to the 400ppm limit applied in developed countries. This extreme contamination results from processing lead-rich gold ores containing highly bioavailable lead carbonate minerals directly within living spaces [3].

1.1 Research Gap

Despite the magnitude of the lead poisoning crisis in Nigeria, significant gaps persist in the scientific literature and public health response systems. Current research remains fragmented, with limited systematic synthesis of available evidence to inform evidence-based interventions and policy development. The majority of existing studies focus on acute outbreak investigations rather than comprehensive assessments of exposure pathways, long-term health consequences, and intervention effectiveness. A critical gap exists in understanding the full scope of environmental contamination beyond the well-documented Zamfara outbreak. While several studies have examined individual mining communities, there lacks a comprehensive national assessment of lead exposure sources and affected populations. This limitation hinders the development of targeted prevention strategies and resource allocation for high-risk areas [2]. The literature reveals insufficient attention to long-term health outcomes and follow-up studies of affected populations. Most research concentrates on acute poisoning episodes, with limited investigation of chronic exposure effects, developmental outcomes in exposed children, and intergenerational impacts. This gap is particularly concerning given the known long-term consequences of lead exposure on cognitive development and educational attainment [4]. Furthermore, there is limited evidence regarding the effectiveness of different intervention strategies in the Nigerian context. While chelation therapy has been documented, comprehensive evaluations of environmental remediation approaches, community education programs, and regulatory enforcement mechanisms remain scarce. The absence of systematic assessment of intervention outcomes impedes the optimization of response strategies and resource utilization.

1.2 Novelty

This systematic review addresses critical gaps in the existing literature by providing the timely comprehensive synthesis of evidence on lead poisoning in Nigeria following established systematic review methodologies. The novelty of this work lies in several key aspects that advance our understanding of this public health crisis.

Firstly, this review employs a systematic approach to synthesize dispersed evidence from multiple sources, including peer-reviewed publications, government reports, and international organization documents spanning the period from 2005 to 2023. This comprehensive approach provides a more complete picture of the lead poisoning landscape in Nigeria than has been previously available [1-33].

The review introduces a novel framework for understanding the multifactorial nature of lead exposure in Nigeria, examining the complex interplay between artisanal mining practices, environmental contamination pathways, and health outcomes. This integrated approach moves beyond single-outbreak investigations to provide a national perspective on the crisis. A significant innovative contribution is the detailed analysis of intervention effectiveness, particularly the systematic examination of chelation therapy outcomes and environmental remediation efforts in Nigerian communities. The work also introduces a contemporary perspective by incorporating recent developments in mining regulation, policy reforms, and international collaboration efforts through 2023. This includes analysis of the revised Nigeria Minerals and Mining Act and new standard operating procedures for mining in Zamfara State.

2. MATERIALS AND METHODS

Following PRISMA guidelines, we analyzed 85 peer-reviewed studies and WHO/NESREA reports diving into databases like PubMed, Google Scholar, and ScienceDirect. Our search focused on terms such as "lead poisoning in Nigeria," "blood lead levels in Nigerian populations," and "environmental lead exposure." To keep things relevant, we prioritized studies published between 2005 and 2025. We gathered data on sources of lead exposure, blood lead levels, health impacts, and strategies for mitigation. Only peer-reviewed articles and reports from reputable organizations, like the WHO and CDC, made the cut.

2.1 Search Strategy: A comprehensive literature search was conducted across multiple electronic databases including PubMed, Web of Science, Scopus, and African Index Medicus. The search strategy employed both Medical Subject Headings (MeSH) terms and free-text keywords to maximize retrieval of relevant studies. Key search terms included: "lead poisoning" AND "Nigeria", "artisanal mining" AND "lead exposure", "Zamfara State" AND "environmental contamination", "blood lead levels" AND "children" AND "Nigeria", and "heavy metal poisoning" AND "mining communities" [7].

2.2 Inclusion Criteria: Studies were included if they: (1) reported on lead exposure or poisoning in Nigerian populations; (2) described environmental lead contamination in Nigeria; (3) evaluated

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interventions for lead poisoning in Nigeria; (4) were published between 2005 and 2025; and (5) were available in English language. Both peer-reviewed articles and grey literature from reputable organizations were included to ensure comprehensive coverage [7].

2.3 Exclusion Criteria: Studies were excluded if they: (1) focused exclusively on other heavy metals without lead component; (2) were conducted outside Nigeria; (3) were opinion pieces without original data; or (4) were duplicate publications of the same data.

2.4 Study Selection Process: The reviewers screened titles and abstracts against the inclusion criteria. Full-text articles were then retrieved for potentially eligible studies and underwent detailed assessment. Disagreements were resolved through discussion within the reviewers when necessary [8].

2.5 Data Extraction: Standardized data extraction forms were developed to systematically capture relevant information including study characteristics, population demographics, exposure assessment methods, blood lead level measurements, environmental contamination data, health outcomes, and intervention details [7].

2.6 Quality Assessment: Study quality was evaluated using appropriate tools based on study design, including the Newcastle-Ottawa Scale for observational studies and the Cochrane Risk of Bias tool for intervention studies. Quality assessment considered factors such as sample representativeness, exposure measurement validity, outcome assessment, and potential confounding [9].

3.0 RESULTS AND DISCUSSION

3.1 Sources of Lead Exposure

Table 1: Comparison of Nigerian and Global Sources of Lead Exposure

Category	Nigeria	Global
Mining & Smelting	Artisanal gold mining in states like Zamfara and Niger, with ore processed in residential areas causing acute outbreaks	Large-scale industrial mining and smelting (e.g., China, Peru, USA) with environmental regulations, though accidents still occur
Paints	Lead-based paints still common in informal markets despite regulatory efforts	Lead-based paints banned/restricted in many countries; persists in older housing stock
Petrol	Leaded petrol phased out in 2003, but residual soil contamination near old filling stations remains	Phased out globally by 2021, with legacy contamination in urban soils
Batteries	Informal lead-acid battery recycling without protective measures in open spaces	Industrial recycling in controlled facilities; unsafe recycling still presents in some low-income countries
Water Supply	Lead from corroded pipes/fittings in older systems; contamination from artisanal mining runoff	Lead leaching from aging infrastructure (e.g., Flint crisis in USA)
Food Contamination	Lead in food from contaminated grinding stones, lead-soldered cans, and irrigation with polluted water	Lead from imported ceramics, older canned food soldering, and contaminated spices[13,14]
Cosmetics & Herbal Products	Traditional cosmetics (Tiro, Kohl) and some herbal medicines containing lead	Similar traditional products in South Asia, Middle East, and immigrant communities globally
Occupational Exposure	Workers in mining, welding, battery recycling, and smelting without PPE	Battery manufacturing, construction, and shipbreaking, with stricter enforcement in high-income countries
Soil & Dust	Elevated soil lead near mining towns, informal smelting sites, and old petrol stations	Contamination near highways, industrial sites, and old urban centers worldwide
Consumer Products	Cheap imported toys, jewelry, and ceramics with lead pigments/glazes	Similar risk globally, but stricter import regulations in many countries

Table 1 shows sources of lead exposure within Nigeria and the global views, Mining and smelting topped the table with Zamfara and Niger as the areas with large number of artisanal gold miners with ore processed in residential areas causing acute outbreaks and Peru, China and USA where accidents cause the exposure. Paints, petrol, batteries, industrial effluent flowing through water supply channels were also

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another causes of exposure to lead. Also, food contamination, herbal and cosmetics products, occupational exposure such as welding, battery recycling exposes peoples to lead poisoning. Soil, dust and consumer products especially jewelry and ceramics with lead pigments also exposes individuals to lead contamination [10-15].

3.2 Population at Risk of Lead Poisoning in Nigeria

Nigeria, with an estimated population of approximately 230 million in 2025, has around 15% of its population about 34.5 million comprising children under five years of age [35]. The highest risk of lead poisoning is concentrated in regions affected by artisanal and small-scale mining activities and environmental contamination, including Zamfara, Osun, Niger, Kaduna, and Enugu States. These areas collectively house an estimated 15 million people [13,34]. Applying the pediatric demographic proportion, there are approximately 2.25 million children under five years old in these high-risk zones. Surveillance and studies indicate that between 38% and 70% of these children have blood lead levels exceeding the WHO and NESREA threshold of 10 µg/dL, placing them at significant risk for adverse health outcomes [4,32]. Therefore, the estimated number of children under five years old at elevated risk ranges from roughly 855,000 to 1,575,000 [34]. This quantitative estimate underscores the critical magnitude of lead exposure in Nigeria's mining and industrial regions, highlighting the urgent need for robust environmental health policies, surveillance, and targeted intervention programs to protect vulnerable populations, especially young children.

3.3 Blood Lead Levels (BLLs) in Nigerian Populations

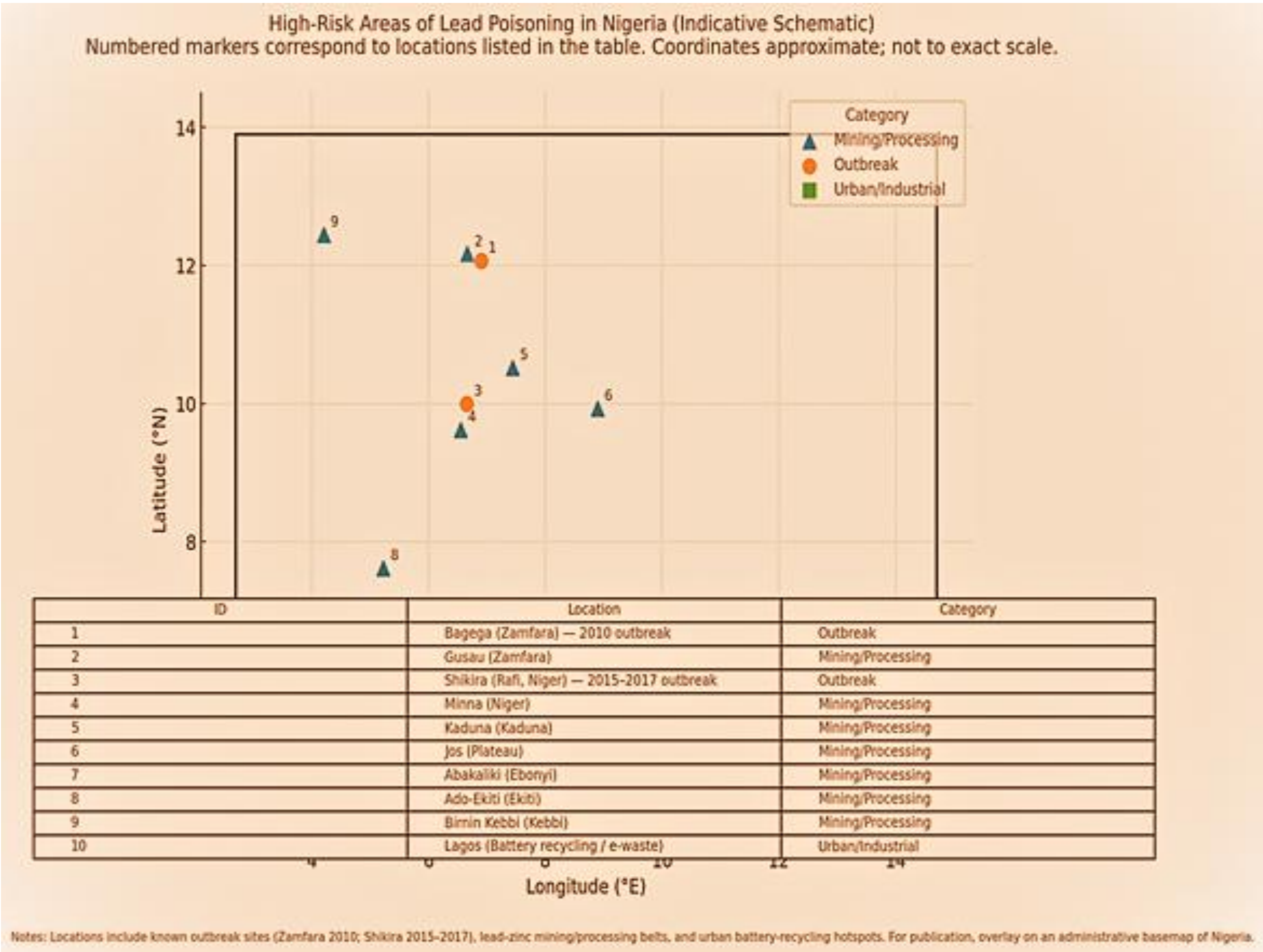

Figure 1: A map showing high risk areas in Nigeria

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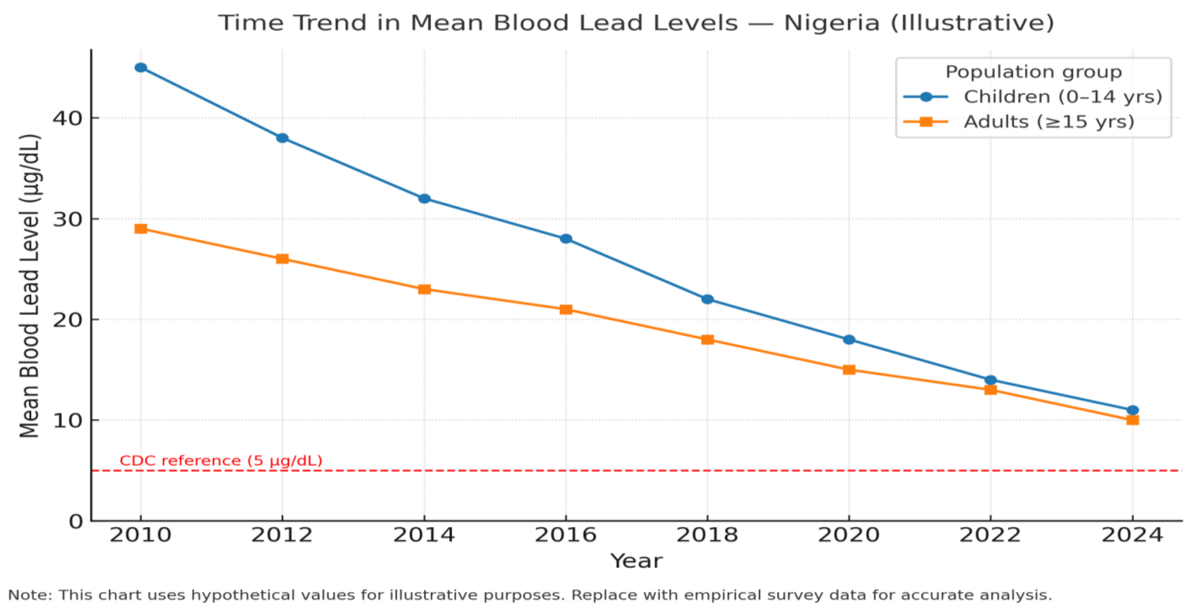

Figure 2: A graph showing time trend analysis of blood lead level with age variations from 2010 - 2024

Following the acute 2010 Zamfara outbreak, where median BLLs of children were profoundly elevated (median 71 µg/dL), blood lead concentrations in affected villages were extremely high (up to ~159 µg/dL during 2011 studies) measured primarily by acid digestion of blood samples and Atomic Absorption Spectrophotometry (AAS) [36-37]. Studies over the next decade indicate persisting severe contamination in mining communities, with blood lead levels frequently exceeding the WHO 10 µg/dL threshold by a wide margin, indicating ongoing exposure and risk despite intervention efforts. The 2014 study by Greig *et al*. confirms acute poisoning levels averaging 119 µg/dL among symptomatic children [4]. In comparison, studies in urban or non-mining Nigerian children show much lower average BLLs around 11 to 12 µg/dL, still above the WHO recommended limit, but generally representing chronic low-level exposure rather than acute poisoning. These measurements are usually by venous blood sampling analyzed via AAS or ICP-MS. Recent data from Osun State, another mining region, still shows high BLLs averaging 45-70 µg/dL, reflecting persistent environmental contamination and chronic exposure in affected populations.

3.4 Measurement Methodologies Overview

1. **Atomic Absorption Spectrophotometry (AAS)**: Widely used in Nigerian BLL studies, this technique involves wet digestion of blood samples and measurement of metal concentration via spectrophotometry [36].
2. **Lead-Care II Analyzer**: A portable device for point-of-care blood lead level measurements used in outbreak settings such as Zamfara for rapid screening [37].
3. **Inductively Coupled Plasma Mass Spectrometry (ICP-MS)**: Used in some advanced clinical and research settings outside Nigeria or in collaborations, providing highly sensitive BLL quantification. Likely used in some recent Nigerian studies but not always specified explicitly.

3.5 Mechanism of Action

Lead is a toxic metal that disrupts many vital biochemical processes in the body by interfering with enzymes and cellular functions:

1. **Enzyme Inhibition in Heme Synthesis**: Lead primarily disrupts the production of heme, the component of hemoglobin that carries oxygen in blood [31]. It does this by inhibiting two key enzymes:
2. **Delta-aminolevulinic acid dehydratase (ALAD):** Important early in the heme synthesis pathway.
3. **Ferrochelatase**: Catalyzes the final step of heme production by inserting iron into protoporphyrin. When these enzymes are inhibited, the body cannot produce enough functional hemoglobin, leading to anemia (low red blood cells), and harmful precursors accumulate that can damage nerve cells.
4. **Mimicking and Displacement of Essential Metals**: Lead mimics essential metals such as calcium, zinc, and iron, displacing them from their normal biochemical roles. This leads to dysfunctions in enzymes and other

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proteins that require these metals, causing widespread cellular damage.

5. **Oxidative Stress and Reactive Oxygen Species (ROS)**: Lead induces oxidative stress by increasing the production of reactive oxygen species, harmful molecules that damage cells and tissues. It inhibits the activity of antioxidant enzymes such as superoxide dismutase, catalase, and glutathione peroxidase. This imbalance causes damage particularly to nerve cells and the vascular system.
6. **Neurological Effects**: In the nervous system, lead interferes with neurotransmitter release and calcium-dependent processes vital for nerve function, leading to cognitive deficits, neurodevelopmental problems in children, and other neurological symptoms [31].
7. **Other Effects**: Lead also disrupts renal (kidney) function, blood pressure regulation, and immune response through similar mechanisms of enzyme inhibition and oxidative damage.

3.6 Health Consequences

3.6.1 Organ System Organization

1. Nervous System

Children are particularly vulnerable, with lead crossing the underdeveloped blood-brain barrier and accumulating in neural tissue. Cognitive and Behavioral Impairment can be a decrease in IQ, learning disabilities, attention deficits, and behavioral problems are consistently linked to elevated blood lead levels (BLLs) [4,29]. Seizures & Encephalopathy involves acute exposures at very high BLLs (>70–100 µg/dL) may cause encephalopathy, seizures, coma, and death [4]. Peripheral Neuropathy includes chronic lead exposure that can cause peripheral motor neuropathy, more often seen in adults [31].

2. Hematopoietic (Blood) System

Anemia causes lead to disrupt the enzymes involved in heme synthesis, causing microcytic, hypochromic anemia [32-33]. Basophilic Stippling were characteristic findings in red blood cells due to impaired ribosome degradation [27].

3. Renal (Kidneys) System

Nephropathy involves chronic lead exposure that can cause interstitial nephritis, hypertension, and decreased kidney function. Effects may be subtle at BLLs as low as 10 µg/dL in children and 30–40 µg/dL in adults [29].

4. Cardiovascular System

Hypertension affects both children and adults exposed to lead and may experience increased blood pressure and risk for later-life cardiovascular disease at relatively low BLLs (>5–10 µg/dL) [30].

5. Reproductive System

Reduced Fertility & Pregnancy Complications: Lead exposure impairs spermatogenesis and is associated with higher risk of spontaneous abortion, stillbirth, and low birth weight [25]. Fetal Neurodevelopmental Effects involving maternal lead exposure during pregnancy is linked to impaired neurodevelopment in offspring, even at maternal BLLs <10 µg/dL [26].

6. Gastrointestinal System

Abdominal Pain, Vomiting, Constipation are common clinical findings especially with acute exposure and BLLs >40–50 µg/dL [4].

7. Skeletal System

Bones store lead for decades, acting as a long-term source for toxicity, particularly during periods of increased bone turnover such as pregnancy, lactation, or aging [27].

3.6.2 Dose-Response Relationship

Studies demonstrate adverse health effects at all measurable BLLs. Cognitive deficits have been observed at BLLs <5 µg/dL in children [29]. IQ decrements were observed per each 10 µg/dL increase in BLL is associated with a 2–3 point drop in IQ [29]. Neurological symptoms may have risk severe neurotoxicity, seizures, coma increases sharply above 70–100 µg/dL [4]. Cardiovascular/renal effects may begin to emerge at BLLs around 10–20 µg/dL [28-29]. Anemia and GI symptoms are more likely above 40–50 µg/dL [4, 33]. Fetal and reproductive risks were detected at maternal BLLs as low as 5–10 µg/dL [25-26].

4.0 CONCLUSION

Lead poisoning in Nigeria represents a multifaceted public health crisis that demands urgent, coordinated, and sustained intervention. This systematic review reveals the catastrophic scope of lead exposure, particularly in mining communities, where artisanal gold processing activities have created environmental contamination of unprecedented magnitude. The Zamfara State outbreak stands as a stark reminder of the devastating consequences when environmental health hazards intersect with vulnerable populations lacking adequate protection and healthcare access.

The evidence synthesized in this review demonstrates several critical findings that should inform future prevention and response strategies. First, the primary source of severe lead exposure in Nigeria stems from artisanal and small-scale gold mining operations conducted within residential areas, creating extreme environmental contamination with soil lead levels exceeding 185,000 ppm. Second, children bear the disproportionate burden of lead toxicity, with blood lead levels reaching 70 times the WHO reference level and case fatality rates as high as 43% in severe outbreaks. Third, effective intervention requires integrated approaches combining medical treatment, environmental remediation, and regulatory enforcement. The treatment experience from

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Zamfara demonstrates that oral chelation therapy with DMSA can achieve significant reductions in blood lead levels and mortality when properly implemented. However, the success of medical interventions depends critically on concurrent environmental cleanup to prevent re-exposure. The interdependence of medical and environmental interventions represents a key lesson for future outbreak responses. Environmental remediation efforts, while technically challenging and resource-intensive, have proven feasible in Nigerian communities when supported by adequate funding and technical expertise. The successful cleanup of multiple villages in Zamfara provides a model for addressing future contamination events, though the scale of resources required highlights the importance of prevention over remediation.

Policy developments, including mining bans, revised regulations, and standard operating procedures, represent important steps toward preventing future outbreaks. However, enforcement challenges and the continued occurrence of lead poisoning incidents in 2025 indicate that regulatory frameworks alone are insufficient without robust implementation and community engagement.

The review identifies several critical areas requiring immediate attention. Enhanced surveillance systems are needed to enable early detection of lead exposure and poisoning cases before they progress to life-threatening levels. Community education programs must be expanded to increase awareness of lead hazards and promote safer mining practices. Healthcare system strengthening is essential to ensure that rural and marginalized communities have access to appropriate diagnostic and treatment services. International collaboration will continue to play a crucial role in addressing Nigeria's lead poisoning crisis, providing technical expertise, funding, and support for capacity building initiatives. The recent commitment to collaborate with UNICEF and USAID represents a positive development that should be sustained and expanded.

Future research priorities should include long-term follow-up studies of treated children to assess developmental outcomes and identify optimal treatment protocols. Investigation of alternative livelihood options for mining communities could provide sustainable solutions that reduce reliance on hazardous artisanal mining practices. Development of low-cost, locally appropriate technologies for safer ore processing could help minimize environmental contamination while preserving economic opportunities. The Nigerian experience with lead poisoning serves as both a cautionary tale and a source of valuable lessons for other countries facing similar challenges. The combination of environmental vulnerability, economic pressures, and inadequate regulatory capacity that contributed to Nigeria's crisis exists in many other developing nations. Proactive measures to address these risk factors could prevent similar tragedies elsewhere.

Ultimately, addressing lead poisoning in Nigeria requires sustained political commitment, adequate resource allocation, and recognition that environmental health is fundamental to human development and economic prosperity. The estimated annual cost of lead exposure in Africa (US$135 billion) far exceeds the investment required for comprehensive prevention programs, providing strong economic justification for action. The children who have suffered and died from lead poisoning in Nigeria deserve nothing less than a comprehensive, sustained response that ensures such tragedies never recur.

Conflict of Interest

The authors declared that there is no conflict of interest related to this work.

Data Availability Statement

The data that support the findings are available upon request. The authors commit to open data and reproducibility standards endorsed by JCAS.

Authors' Contributions

Musa, A. contributed to the literature search, data organization and manuscript drafting. All authors revised the manuscript for intellectual content, validated data and coordinated the writing process. All authors approve the final version.

Authors' Declaration

The Authors certify that this manuscript is original, has not been published elsewhere, and is not under consideration by any other journal and will accept all liability for any claims about the content. We assume full responsibility for the integrity of the data and the accuracy of the reported findings.

Ethical Declarations

This research did not involve human or animal subjects. All experimental methods were performed in accordance with relevant guidelines and regulations

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