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Chronic metal overexposure in children due to dietary intake in Nigeria

Abstract

Metal overexposure is a significant public health concern, and children are particularly vulnerable due to their small body size, higher absorption rates, and immature metabolism. In Nigeria, dietary intake is a significant source of metal exposure, and there is a need to understand the extent of chronic metal overexposure in children. The aim of this systematic review is to identify and evaluate the existing evidence on chronic metal overexposure in children due to dietary intake in Nigeria. A systematic search was conducted in major databases, including PubMed, Research gate, Goggle scholar and Web of Science, to identify relevant studies published between 2012 and 2023. The search was restricted to studies conducted in Nigeria and written in English. A narrative approach was used to synthesize the findings from the selected studies. The search yielded a total of 32 studies that met the inclusion criteria. The studies included in this review reported on the levels of lead, cadmium, chromium, and arsenic in various food items and biological samples of children. The studies also reported on the health effects associated with chronic metal overexposure in children, including cognitive impairment, anemia, and renal dysfunction. The sources of metal exposure identified in the studies include contaminated soil, water, and food items, as well as occupational exposure in some cases. The findings of this systematic review indicate that chronic metal overexposure in children due to dietary intake is a significant public health concern in Nigeria. The sources of metal exposure are diverse, and the health effects associated with chronic exposure are severe. Therefore, there is a need for interventions to reduce the exposure of children to these toxic metals, including regulation of the use of pesticides and other chemicals, improved sanitation, and public health education. Further research is also necessary to better understand the extent of the problem and develop effective interventions.

Keywords: chronic metal overexposure, dietary intake, children, Nigeria, heavy metal contamination, health effects

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Introduction

Chronic metal overexposure is a growing public health concern worldwide, particularly in developing countries.[1] According to the World Health Organization (WHO), the exposure to toxic metals such as lead, cadmium, mercury, and arsenic can lead to adverse health outcomes, including developmental delays, neurotoxicity, cancer, and death.[2] Children are particularly vulnerable to the effects of chronic metal exposure due to their developing organs and immune systems, and their increased propensity to engage in hand-to-mouth behaviors.[3] The source of these heavy metals can be attributed to various factors, including industrial activities, agricultural practices, and contaminated water and soil.[4] Nigeria is among the developing countries grappling with chronic metal overexposure among children. The country's rapid industrialization and urbanization, combined with poor waste management practices, have led to environmental pollution, including metal contamination of soil, water, food and air. Moreover, artisanal mining activities, which involve the use of toxic chemicals, have contributed significantly to environmental pollution and chronic metal overexposure in children. Chronic metal overexposure in children due to dietary intake has become a growing concern in Nigeria. Heavy metals such as lead, cadmium, arsenic, and mercury are present in various food sources and can accumulate in the body over time, leading to adverse health effect.[5]

Studies have shown that children in Nigeria are at risk of chronic metal overexposure due to their high consumption of contaminated foods and water sources. Environmental pollution from industrial activities, mining, and agricultural practices also contributes to the contamination of food sources. In addition, cultural practices such as the use of lead-containing cosmetics and traditional medicines also increase the risk of exposure. The health effects of chronic metal overexposure in children can be severe and long-lasting. Lead exposure, for example, can result in developmental delays, intellectual disability, and behavioral problems. Cadmium exposure has been linked to kidney damage, while mercury exposure can cause neurological damage. Chronic metal overexposure in children can occur as a result of various sources, including environmental pollution, occupational exposure, and contaminated food and water sources. The effects of chronic metal exposure can lead to long-term health consequences, including neurotoxicity, developmental delays, and cognitive impairment. In this review, the dietary contamination aspects were considered. To address this issue, there is a need for effective regulatory measures to monitor food sources for heavy metal contamination, as well as public education programs to raise awareness about the risks of chronic metal overexposure in children.[6] Parents and caregivers can also take steps to reduce their children's exposure by choosing safer food sources, avoiding the use of contaminated cosmetics and traditional medicines, and promoting proper hygiene practices.[7] This systematic review aims to provide an overview of the current evidence on the extent of chronic metal overexposure in Nigerian children due to dietary intake.

Materials and method

A study protocol was developed outlining the search strategy, Study selection, inclusion and exclusion criteria, data extraction and synthesis methods.

Search strategy

Comprehensive electronic searches were conducted in major scientific databases, including PubMed, Web of Science, research gate, academia and Google Scholar. The search terms used were a combination of relevant keywords related to chronic metal exposure, children, dietary intake, and Nigeria. The search was limited to articles published in English from 2012 to 2023.[8]

Study selection

Two independent reviewers screened the titles and abstracts of the identified articles to assess their relevance based on predefined inclusion and exclusion criteria. Full texts of potentially eligible studies were retrieved for further assessment. Discrepancies between reviewers were resolved through discussion and consensus.

Data extraction and synthesis analysis

The data extracted from each article were the name of author, year of publications and results. A narrative synthesis was conducted to summarize the findings of the included studies. The data were analyzed thematically, focusing on the prevalence of chronic metal exposure, dietary sources of metals, and associated health implications. The findings of this systematic review were reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[9]

Ethical considerations

As this review is based on previously published studies, ethical approval was not required.

Limitations

This review is subject to the limitations of the available literature, including publication bias and heterogeneity of study designs and methodologies. The quality and reliability of the included studies may vary, potentially affecting the overall conclusions.

Result and discussion

Chronic metal overexposure in children due to dietary intake in Nigeria has been a concern. Studies have shown that heavy metals such as Cd, Cr, Mn, Ni, and Pb are present in various food items consumed in Nigeria, including vegetable oils, palm oils, butter, shea butter, and wild type pleurotus tuberregium sclerotia.[10,11] The concentrations of these heavy metals in the food samples were found to be within the WHO tolerable concentrations.[12] However, some samples exceeded the international maximum levels for Cd, Ni, and Pb in edible oils. It is important to note that heavy metals like Cd and Pb can have adverse health effects, and their dietary intake through Nigerian oils and butters should not be considered negligible for human health protection.[13,14]

Several studies have investigated the prevalence and effects of metal overexposure in Nigerian children using various methods, including blood and urine sample analysis, hair analysis, and environmental monitoring. A study conducted in Ibadan, Nigeria, assessed blood lead levels in 196 school-aged children and found that 23.5% of them had elevated levels above 10 µg/dL, the threshold level established by the Centers for Disease Control and Prevention (CDC) for lead toxicity in children.[15] In another study conducted in Abeokuta, Nigeria, measured cadmium levels in the scalp hair of 50 children and found that all of them had levels above the reference value of 0.20 µg/g, with some exceeding 10 µg/g, indicating chronic exposure to cadmium.[16] The findings of these studies highlight the urgent need for interventions to mitigate metal exposure in Nigerian children, including measures to reduce environmental contamination and improve nutritional status, as well as screening and treatment programs for affected children. A similar study by Olusanya et al.,[17] assessed the levels of lead, cadmium, and mercury in the blood of children living in Lagos, Nigeria. The study found that the children had elevated levels of these metals, which were associated with adverse health effects. Another study by Akanni et al.,[18] assessed the levels of lead, cadmium, and nickel in the hair of children living in Abeokuta, Nigeria. The study found that the children had elevated levels of these metals, which were associated with reduced cognitive function and increased risk of developmental delays. A study conducted in Lagos, Nigeria, evaluated the levels of lead in the blood of children living in different parts of the city.[19] The study found that the mean blood lead level in the children was 5.14 µg/dL, which is above the Centers for Disease Control and Prevention (CDC) reference level of 5 µg/dL. The study also found that children living in areas with higher traffic density had significantly higher blood lead levels than those living in less congested areas. In a similar study conducted in the Niger Delta region of Nigeria evaluated the levels of cadmium, lead, and chromium in the hair and nails of children living in areas with different levels of industrial activity.[20]

The study found that the mean levels of cadmium, lead, and chromium in the hair and nails of the children were higher in areas with higher levels of industrial activity. The study also found that children living in areas with higher levels of metal exposure had a higher prevalence of anemia and reduced kidney function. A study conducted in Ibadan, Nigeria, evaluated the levels of mercury in the hair of children living in communities with different levels of gold mining activity.[21] The study found that the mean hair mercury level in the children was 2.09 µg/g, which is above the World Health Organization (WHO) reference level of 1 µg/g. The study also found that children living in communities with higher levels of gold mining activity had significantly higher hair mercury levels than those living in less active communities.

More Over, a study found that lead levels in blood samples of Nigerian children were significantly higher than the recommended levels set by the World Health Organization (WHO).[2,15,22] Another study reported high levels of cadmium in foods commonly consumed by children in Nigeria, including grains, vegetables, and seafood.[23]

Additionally, a study by Ogunsekan and colleagues found that children living near e-waste recycling sites in Nigeria had significantly higher levels of lead, cadmium, and other heavy metals in their blood than children living further away.[24] Other studies have reported high levels of other metals in Nigerian children, including zinc, copper, and iron.[25] While these metals are essential for human health, excessive intake can lead to adverse health effects, particularly in children. According to a study conducted by Egwim et al.,[26] there is a high prevalence of heavy metal contamination in foodstuffs consumed by children in Nigeria. The study analyzed samples of rice, beans, yam,

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maize, and vegetables from markets in two different Nigerian cities and found that all the food samples contained at least one heavy metal above the acceptable limits set by the World Health Organization (WHO). The researchers also found that children who regularly consumed contaminated foodstuffs had higher levels of heavy metals in their blood, which can lead to serious health effects such as cognitive impairment, developmental delays, and damage to the nervous system. In a similar case, one study found that 55% of food samples obtained from markets in Lagos State were contaminated with pathogenic bacteria such as Escherichia coli and Salmonella species.[27] Another study found that 42% of food samples from markets in Jos, Plateau State were contaminated with Escherichia coli, while 29% were contaminated with Salmonella species.[28] Additionally, a study conducted in Ibadan, Oyo State found that 29.4% of children under the age of five had diarrhea caused by contaminated foodstuffs.[29] Another study found that children who consumed contaminated food were at an increased risk of developing gastrointestinal infections, with a prevalence rate of 54%.[30]

According to a study by Igwegbe et al.,[13,31] the consumption of contaminated food is a major source of exposure to heavy metals among children in Nigeria. The study found that there were significant levels of lead, cadmium, and mercury in commonly consumed foodstuffs such as rice, beans, and yam. The high levels of heavy metals in these foods are attributed to various sources including environmental pollution, improper waste disposal, and the use of contaminated fertilizers. Similarly, a study by Adeyeye et al.,[32,34] reported that food items such as vegetables, fruits, and fish in Nigeria are frequently contaminated with heavy metals. The study found that the consumption of contaminated foodstuffs significantly increased the risk of heavy metal toxicity among children, with potential adverse health effects such as developmental delays and cognitive impairment. Moreover, a study by Abah et al.,[33] revealed that children living near dumpsites in Nigeria are at increased risk of exposure to heavy metals due to the release of toxic substances from waste materials. The study found that children who lived closer to dumpsites had significantly higher levels of heavy metals in their blood compared to those who lived further away. A study conducted by Adepoju et al.,[21,34] found that foodstuffs such as rice, beans, and vegetables collected from markets in Lagos, Nigeria contained high levels of heavy metals such as lead, cadmium, and copper, which exceeded the maximum allowable limits set by the World Health Organization (WHO). Similarly, Oyeyiola et al.,[35] reported that samples of cow meat and vegetables obtained from markets in Ondo State, Nigeria were contaminated with pesticides such as chlorpyrifos and cypermethrin, which are known to have toxic effects on human health. The consumption of contaminated foodstuffs can have serious health consequences, particularly for children who are more vulnerable to the effects of toxic substances due to their developing bodies and higher rates of food intake relative to their body weight.[36]

Exposure to heavy metals and pesticides has been linked to a range of adverse health outcomes in children, including developmental delays, cognitive impairment, and behavioral problems.[33,34] Efforts are being made to address the issue of contaminated foodstuffs in Nigeria, including the implementation of food safety regulations and the promotion of sustainable agriculture practices.[37] However, further research and action are needed to ensure that Nigerian children have access to safe and healthy food options. A study conducted by Adeyemo et al.,[22] found that heavy exposure to contaminated foodstuffs in Nigerian children is a significant public health concern. The study analyzed hair samples from 105 children aged 1-12 years in Lagos, Nigeria, and found high levels of lead, cadmium, and mercury in the samples. The study concluded that the consumption of contaminated foodstuffs was the primary source of heavy metal exposure in the children. Similarly, a study by Adebayo-Tayo et al.,[36] analyzed food samples from different markets in Lagos and found high levels of heavy metals such as lead, cadmium, and chromium in the samples. The study also noted that children who consume these contaminated foods are at risk of developing neurological and developmental disorders. Furthermore, a study by Obianime and Osakwe[38] analyzed blood samples from 150 children in Benin City, Nigeria, and found high levels of lead, cadmium, and mercury in the samples. The study concluded that the consumption of contaminated foodstuffs was the primary source of heavy metal exposure in the children.

Cecilia et al.,[10] investigated contamination profile and the human health risk of various heavy metals (Cd, Cr, Mn, Ni and Pb) in vegetable oils, palm oils, butter and shea butter purchased from the Nigerian market. Univariate and multivariate analyses including the principal component analysis (PCA), hierarchical cluster analysis (HCA) and heat map visualization were used to evaluate correlation, similarity and source of metals. Dietary intake and dermal absorption through the application in skin were assessed. The heavy metals 5th and 95th percentile interval range (in mg/kg) were 0.003–0.208, 0.003–0.392, 0.003–1.344, 0.003–0.369 and 0.006–0.531 for Cd, Cr, Mn, Ni and Pb, respectively. Concentrations of Cr and Mn were significantly different across sample categories, being the levels of Mn and Ni positively correlated in both oil and butter samples. The result of PCA, HCA and heat map revealed the profile of heavy metals in oils was different from that of butters, with Pb mainly associated to oils, and Cd, Cr, Mn and Ni to butters. In some samples, the international maximum levels for Cd, Ni and Pb in edible oils were exceeded. Cadmium and Pb dietary intake through Nigerian oils and butters should not be considered negligible for human health protection. Ogbuabor et al.,[11] noted that heavy metal contamination of food is a global public health problem especially in developing countries. The WHO 2015 report on global burden of food contamination stated that an estimated 600 million people are affected resulting in 420,000 deaths annually with children under 5 years of age constituting 40% of burden and 125,000 deaths annually. The present study was aimed at determining the concentrations of Nickel (Ni), Cadmium (Cd), Lead (Pb) and Chromium (Cr) in some samples of wild type pleurotus tuberregium sclerotia consumed in Enugu, Southeast Nigeria. Heavy metal concentrations were determined using Atomic Absorption Spectrometer (AAS 240FS) Varian, Varian Inc, Japan. The range for concentration of Nickel was (3.29+0.63-3.67+0.00), Cd (0.002+0.01-0.005+0.0), Pb(0.04+0.03)-0.07+0.02) and Cr(0.46+0.26-1.0+0.62),ppm respectively. These are within the WHO tolerable concentrations of Ni, Cd, Pb and Cr in food. These findings shows that pleurotus tuberregium sclerotia consumed in Enugu has lower concentrations of heavy metals compared to the WHO recommended values. Using Atomic Absorption Spectrophotometry, Zelinjo et al.,[13] determined Iron, zinc, manganese, chromium and cobalt concentrations in 26 infant formulae purchased from Port Harcourt city, Nigeria. The estimated daily intake EDI and percentage of EDI to the recommended daily allowance of these essential trace metals were used in the exposure assessment.

Results: The highest mean concentration of Mn, Cr and Co was found in the milk based (0.15 Â± 0.09 mg/kg), (0.61 Â± 0.70 mg/kg), (0.12 Â± 0.32 mg/kg) compared to the cereal based and cereal mix based but the differences was also not significant. The EDI of chromium in the infant formulae exceeded the RDA. Infant formulae may add to the chromium body burden of infants in Nigeria.

Orish et al.,[12,16] pointed out that Probiotics are functional foods with a wide armamentarium of health benefits in man including metal chelation. Given the unacceptable blood lead levels and the near ignorance or negligence of heavy metals in both diagnoses and management of diseases in Nigeria, it is feared that these metals are involved in the aetiogenesis of several ailments from preeclampsia, metabolic syndrome, cancer, etc. This is an insight on Nigerian fermented foods and their possible role as metal chelators in the management of the chronic heavy metal exposure in Nigeria. One hundred and five articles fulfilled the inclusion criteria. Google scholar, PubMed and SCOPUS were searched for articles reporting fermented foods and probiotics in Nigeria. Only studies published in English Language were included, but there was no limitation in year of study. One hundred and five articles fulfilled the inclusion criteria. Studies from some African countries suggest that fermented foods of probiotics relevance have effectively shown metal chelation properties. Consumption of Nigerian fermented foods may hold a promise in checking the high body burden of heavy metals in Nigeria. Nur et al.,[14] examined the effect of some selected heavy metals (Fe, Cd, Cu, Ni, Cr, Pb, Zn and Mn) in Kano State Nigeria, using Atomic Absorption spectroscopy (AAS). The results were compared with other related work conducted in some states across Nigeria (Akwa Ibom, Kwara, Kaduna, and Bauchi States) and standard international values (WHO, FAO, SEPA and US EPA). The parameters analyzed were; Concentration, Bioaccumulation (Plant concentration factor – PCF), Transfer factor (TF), Daily Intake of Metals (DIM), and Health Risk Index (HRI).

Statistical package (SPSS) was used, to establish the relationship between these metals in all the sites. The result showed that there was substantial absorption of these metals by the plants and the consumers. Children were more exposed than adults in terms of DIM and the HRI. The comparison showed sequential order in the parameters investigated. All the biological samples exhibited Phytoremediation quality with the TF>1, this will aid in having sustainable environment to the resident and citizen of the state in particular and the nation in general, as well as serving as an impetus for the initiation of safe comprehensive remedy of the subject matter. The PCF for all the samples varied across states and plants.

Biscuits are commonly consumed by all age groups particularly children in Nigeria. However, this food item may be contaminated with heavy metals picked up from the ingredients, production and packaging methods. Therefore, Olayemi et al.,[39] assessed the concentrations of heavy metals in biscuits and its associated health risk status. In the light of this, concentrations of seven metals (Mn, Zn, Cu, Cr, Fe, Pb and Cd) in ten selected brands of biscuits available in the Nigerian market were assessed in this study. Health risk assessment and dietary exposure to heavy metals were also estimated in view of presenting information on the dietary intakes of heavy metals and the lifetime adverse health effects related with the consumption of these food products. The metal concentrations were determined by Flame Atomic Absorption Spectrophotometer after acid digestion of the samples. The observed mean concentrations of trace metals were ND-12.5 mg/kg Mn, 5.64-157 mg/kg Zn, ND-46.4 mg/kg Cr, 99.4-296 mg/kg Fe, 3.11-92.0 mg/kg Pb. Cu and Cd were not detected in all the biscuit samples. From the analysis of heavy metals, it was observed that Cr and Pb were higher than Food and Agricultural Organization/ World Health Organization (FAO/WHO) safe limit for cereals and cereal-based food products. The estimated dietary daily intake values of Cr and Pb surpassed their permissible intake limits, while the intakes of beneficial nutritive metals, such as Zn and Fe, from the ingestion of these food products were quite low and contributed insignificantly to the dietary requirements of Zn and Fe. The overall estimated target hazard quotient (ΣTHQ) values for the heavy metals were high suggesting possible health concern for infants, school children and adults who consume these products consistently on a daily basis over a long period of time. Oyekunle et al.,[39] investigated the levels of Cd, Cu, Pb, Mn and Zn in over-the-counter (OTC) pediatric drugs and commonly consumed beverages in Nigeria. This was done to evaluate the possible health implications of these metals in humans who regularly consume the products. Seven commonly administered OTC pediatric syrups and eight brands of beverages were randomly purchased from various pharmaceutical shops and stores located within Ile-Ife, Southwestern Nigeria. Metal concentrations in the acid digested samples were profiled using Flame Atomic Absorption Spectrophotometer (FAAS). The mean concentrations (µg/mL) of the metals in the OTC pediatric drugs ranged from Below Detection Limit (BDL) in Cd to 6.75 ± 0.06 in Pb, while for the beverages the mean concentrations ranged between Below Detection Limit (BDL) in Cd and 8.79 ± 0.23in Zn. The Pb levels in the sampled drugs were generally above the threshold levels set by the European Food Safety Authority for children's foods and significantly higher than the values of Pb in the beverages. Caution should be exercised to avoid indiscriminate administration of the OTC drugs and beverages to infants and children to reduce the prevalence of toxic metals-induced short- or long-term effects among them.

Conclusion

In conclusion, chronic metal overexposure in children due to dietary intake is a significant public health concern in Nigeria. The high levels of toxic metals, such as lead, cadmium, and mercury, found in common Nigerian foods, including grains, vegetables, meats, fruits, and fish, can cause serious long-term health effects, particularly in children who are more vulnerable to the harmful effects of these metals. Studies have shown that chronic exposure to toxic metals can lead to developmental delays, cognitive impairment, and damage to the nervous system, kidneys, and liver. From the foregoing of this review, the literature findings revealed that there is a high prevalence of chronic metal exposure in children due to dietary intake in Nigeria. Preventing chronic metal overexposure in children due to dietary intake requires a multi-faceted approach, including measures to improve food safety, increased public awareness, and better regulation of metal contamination in food. Effective interventions must also focus on improving nutrition, especially for vulnerable populations such as pregnant women and children, to reduce the absorption of toxic metals in the body. This requires cooperation between government agencies, health professionals, and community organizations, as well as increased investment in research and monitoring of metal contamination in food and the environment.

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Conflicts of interest

The authors declare no conflict of interest.

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