

Review Article

Lead contamination in Cameroon: A scoping review of food-related occurrences, exposures, and risks

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Abstract

Lead poisoning remains a significant public health concern in low- and middle-income countries, particularly among children, for whom no level of exposure is considered safe. This scoping review examines potential sources, occurrences, exposure pathways, and associated health risks of lead contamination in Cameroon. A systematic search of Web of Science, Google Scholar, MedLine, and PubMed, using "lead," "lead occurrence," "lead exposure," and "Cameroon" as primary keywords, identified 16 relevant studies. Key sources of environmental lead included mining activities, informal recycling of lead-acid batteries, contaminated water sources, aluminum cookware, certain foodstuffs, and the ingestion of "Calaba" chalk. Reported mean lead concentrations ranged from 280 to 12270 mg/kg in soil and up to 8.87 mg/L in water. Food items such as condiments, vegetables, and fish showed levels between 0.019 and 3.61 mg/kg, while poultry feed contained up to 3229 µg/kg. Blood lead levels in children and pregnant women ranged from 8 to 31.19 µg/dL, which exceeded recommended safety thresholds. Overall, 95% of reported lead levels across all sample types exceeded permissible limits. These findings highlight widespread environmental lead contamination in Cameroon and underscore the urgent need for further research and public health interventions.

Keywords: Blood lead levels, Cameroon, Dietary exposure, Heavy metals, Lead poisoning.

Introduction

Heavy metal contamination in Cameroon represents a significant environmental and public health challenge, primarily due to anthropogenic activities such as mining, vehicular emissions, and agricultural practices (Ngole-Jeme, 2016; Suh et al., 2025). Research has documented elevated levels of metals such as lead (Pb), mercury (Hg), cadmium (Cd), chromium (Cr), and arsenic (As) in soils, sediments,

and foodstuffs across various regions of Cameroon (Mandeng et al., 2019; Suh et al., 2025). For example, studies have shown that soils along unpaved roads in urban areas like Kumba contain high concentrations of Pb, Cd, and Cr due to vehicular emissions, posing moderate to high health risks, especially to populations exposed through incidental soil ingestion and food contamination near these roads (Ngole-Jeme, 2016). Additionally, artisanal gold mining areas such as Ngoura exhibit extreme

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<https://doi.org/10.30466/fsp.2025.56535.1016>

Received: 12 September 2025

Accepted: 10 October 2025

Available online: 15 November 2025

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mercury contamination from mining wastes, exacerbating ecological and human health risks (Tchoukeu et al., 2025). Agricultural activities contribute to metal accumulation through the indiscriminate use of fertilizers and pesticides that introduce Pb, Hg, Zn, and other metals into soils, potentially contaminating crops and water sources (Suh et al., 2025). Lead contamination poses a major environmental and public health challenge in Cameroon, with lead (Pb) recognized as one of the most pressing health hazards affecting the population (Weidenhamer et al., 2014; Monebenimp et al., 2017; Tchana et al., 2018).

Lead poisoning remains a significant public health concern worldwide, with particularly severe impacts in sub-Saharan Africa (SSA). Globally, an estimated 900,000 deaths were attributed to lead exposure in 2019, with 21.68 million disability-adjusted life years (DALYs) lost (Zhou et al., 2022). The economic cost of lead exposure was estimated at US\$6.0 trillion in 2019, equivalent to 6.9% of global gross domestic product (Larsen & Sánchez, 2023). In SSA, lead exposure accounted for about 63.07%, 66.39%, and 54.3% of DALYs caused by idiopathic developmental intellectual disability in all ages, women of childbearing age, and children < 5 years, respectively (Bede-Ojimadu et al., 2018). Additionally, over 55 million children have blood lead levels (BLLs) exceeding 10 µg/dL, twice the World Health Organization's risk threshold (Muhavani & Mangwiro, 2017). A systematic review found that the weighted mean blood lead level in SSA children under 6 years was 13.1 µg/dL (Ngueta & Ndjaboue, 2013). Although lead exposure has been reported in all age categories, children and pregnant women are the most susceptible group to the health effects of lead (Bede-Ojimadu et al., 2018). In Cameroon, common exposure pathways include lead in settled dust from lead-based paint, soil ingested during normal hand-to-mouth behavior among children, mostly ingested food or water contaminated by lead, informal recycling operations of lead-acid batteries, cosmetics, and electronic waste (e-waste). Yet, studies on lead occurrences and exposures are limited.

Lead poisoning is often clinically silent, with nonspecific symptoms that can include gastrointestinal disturbances (such as anorexia,

recurrent abdominal pain, constipation, and vomiting), behavioral issues (including apathy, irritability, or hyperactivity), attention and sleep disorders, delayed psychomotor development, and pallor associated with anemia (Pearce, 2007). Low and Middle-Income Countries, including some African countries, have a greater burden of lead-related mortality (Brown et al., 2022). This review discusses the potential sources, occurrences, exposures, and associated health risks of lead in Cameroon.

Materials and Methods

Increasing A scoping review was conducted in accordance with PRISMA guidelines to identify peer-reviewed studies reporting on lead occurrence and exposure in Cameroon. Four major scientific databases, Web of Science, Google Scholar, MedLine, and PubMed, were systematically searched for relevant literature.

Search strategy

The search strategy aimed to capture studies published between 2000 and 2024, using a combination of the following primary keywords: "lead," "lead occurrence," "lead exposure," and "Cameroon." The search targeted studies that reported the presence of lead in environmental media (soil, water, food) and biological samples (blood), as well as those assessing lead exposure levels in the Cameroonian population.

Inclusion and exclusion criteria

To ensure relevance and quality, studies were included based on predefined eligibility criteria. Specifically, articles were selected if they focused on lead occurrence or exposure within the context of Cameroon, were published in either English or French, and presented original research data. Only studies published between 2000 and 2024 were considered for inclusion. Conversely, studies were excluded if they did not pertain directly to lead contamination or exposure in Cameroon, lacked original data (e.g., review articles, editorials, or opinion pieces, or newspaper articles), or were published in languages other than English or French.

Screening and selection process

All records retrieved from the database search were first sorted manually where duplicates were identified and removed. The remaining articles were screened. Initially, titles and abstracts were reviewed to assess their relevance based on the inclusion criteria. Studies that passed this stage were then subjected to full-text evaluation to confirm their eligibility. Only those that met all inclusion criteria were retained for the final analysis. This systematic approach ensured that only pertinent studies were included in the review.

Data extraction and language considerations

Data were extracted from all included studies, including those published in French. Given the bilingual proficiency of the research team (fluent in both English and French), French-language articles were carefully reviewed, and relevant information was translated and reported in English.

Additional data consideration

In addition to lead-specific data, information on the presence of other heavy metals, particularly in vegetables commonly consumed in Cameroon, was also extracted and analyzed when available.

Results

A total of sixteen studies were included in this study (Fig. 1). The majority of the studies analyzed a set of heavy metals: Hg, As, Cadmium (Cd), Pb, Copper (Cu), Chromium (Cr), Zinc (Zn), Nickel (Ni) and Cobalt (Co) in various matrices: soil, water, lead-based paints, food, vegetables and blood samples. These studies were carried out between 2006 and 2022 in the East, West, South-West, North-West, Adamawa, Littoral, and Centre regions of Cameroon (Fig. 2). Two studies assessed lead content in green leafy vegetables in Cameroon, and the studied vegetables were made up of: waterleaf (*Talinum triangulare*), bitterleaf (*Vernonia amygdalina*), eggplant (*Solanum macrocarpon*), okra (*Abelmoschus esculentum*), pumpkin (*Telfaria occidentalis*), green (*Amaranthus hybridus*), cocoyam leaf (*Colocasia esculentum*), scent leaf (*Ocimum gratissimum*), and cassava leaf (*Manihot esculentum*).

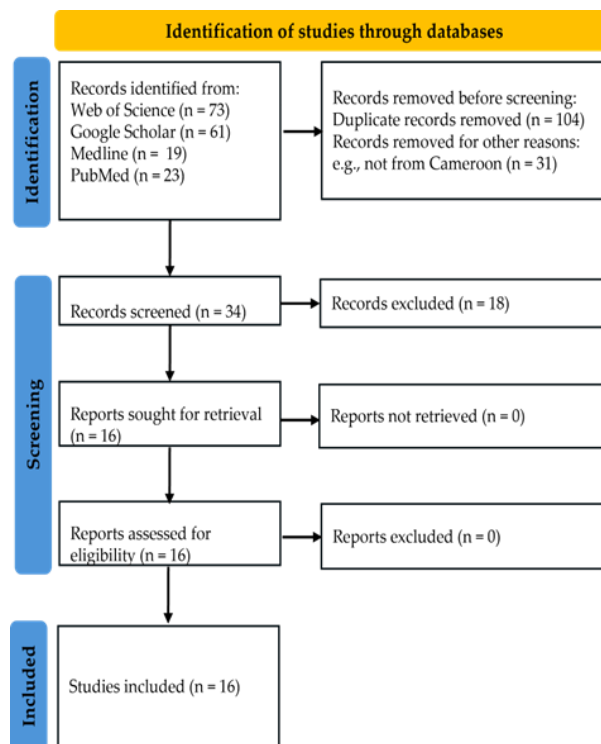


Figure 1. Flow diagram of the literature search and study selection process.

Lead occurrence/exposure in/through contaminated soil

Two of the 16 studies reported on lead levels in soil from the Littoral and East regions of Cameroon. In 2017, investigations were conducted to assess the ecological risks and human health implications associated with heavy metal contamination in surface soils at e-waste recycling sites in Douala, Littoral region of Cameroon, specifically in the Makea, Ngodi, and New Bell areas. It was revealed that the level of lead in soil from the e-waste recycling sites in all samples (Makea: 290 ± 40 ; Ngodi: 310 ± 30 ; and New Bell: 280 ± 40 mg/kg) exceeded the recommended permissible levels of 80 mg/kg units fixed by the Environmental Protection Ministry of China (Ouabo et al., 2019). Another study highlighted the source of heavy metal concentration in the soils of the Pawara Gold Mining area, the East region of Cameroon. From the three mining sites investigated, labeled as A (soil on which mining had been done and abandoned and later being used for agriculture), B (major mining site), and C (major agricultural site, no mining ever), levels of heavy metals in sampled soils were high, with lead levels

being highest on site B with a concentration of 1227 mg/Kg. Indeed, this was not strange when considering that Site B was the site of major mining operations, where mining was done by the Chinese using heavy machinery, whereas Sites A and C are

places where agricultural activities are done. The levels of lead in the soils of the three sites were above the world reference value of 25 mg/kg (Fodoué et al., 2022).

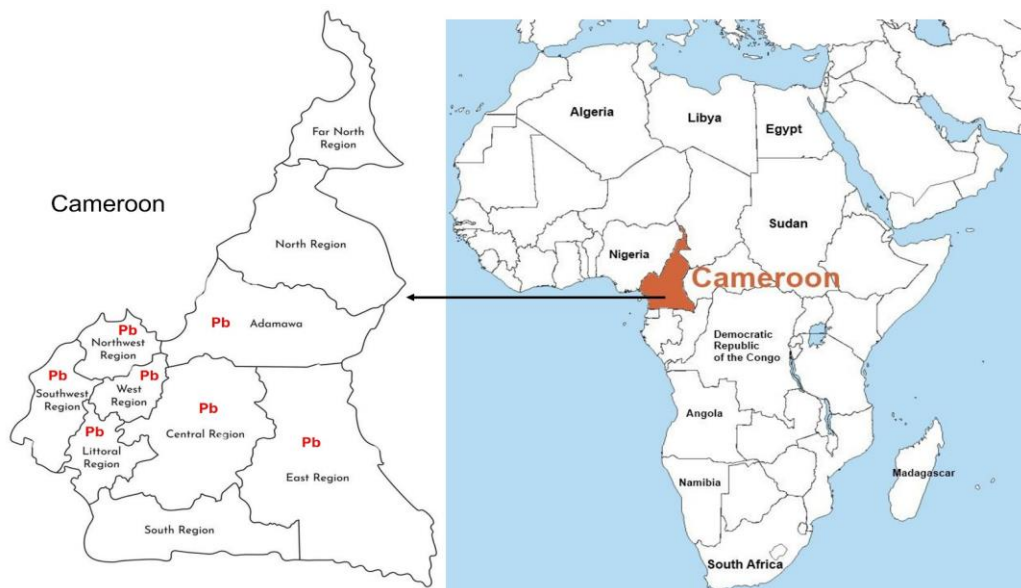


Figure 2. Geographic distribution of Pb concentration studies conducted in Cameroon (2000–2024): Studies conducted across the East, West, South-West, North-West, Adamawa, Littoral, and Centre regions.

Lead occurrence/exposure in/through contaminated water

A study conducted in Batouri, Eastern Cameroon, assessed the impact of gold mining activities on surface water quality. Water samples were collected from five distinct locations, and concentrations of heavy metals were analyzed. Among the metals examined, lead levels ranged from 1.51 to 3.58 mg/L, significantly exceeding the World Health Organization (WHO)'s recommended maximum limit of 0.01 mg/L (Mambou et al., 2021).

In Yaoundé, Centre region of Cameroon, water samples were collected from 15 alternative water supply sources across several locations, including Nsimeyong (Damas); the southern periphery of Nsimeyong (from a flowing tap and a well adjacent to a marsh); Akomnyada in Mbalmayo (Nyong River); and Nkolbisson (Mefou River) water treatment plants. Levels of lead (1.22 - 8.87 mg/L) in all the samples (Brenda Agnes et al., 2021) exceeded

the maximum permissible level (0.01 mg/l) fixed by WHO (WHO, 2011).

In the South West Region of Cameroon, 40 water samples were collected from surface and groundwater on the South-Western flank of Mount Cameroon. Among the constituents of soluble agrochemical residues, heavy metals, including lead, were measured. As a result, only lead was out of range, 95% of its values exceeding the permissible limits during the wet (not detectable - 0.065 mg/L) and dry (0.001 - 0.052 mg/L) seasons (Neh et al., 2023). Additionally, in 2019, the quality of groundwater in Douala, Littoral region, was assessed in the Tongo-Bassa watershed, which is one of the largest watershed basins in the city of Douala. The studied water samples included hand-dug wells, spring waters, and boreholes. Lead levels in the samples ranged from 0.098 to 11.46 µg/L, with the highest concentration of lead of 11.46 µg/L found in W12, which was a hand-dug well, and this might be a consequence of contamination of fuel from motorcycle garages found around the well (Boum-

Nkot et al., 2023). This concentration was above the WHO standard of 10 µg/L, while the levels of the other heavy metals in the analyzed samples were less than this standard (WHO, 2011).

Lead occurrence and exposure in or through lead-based paints

In 2017, the Center for Research and Education for Development conducted a study revealing that 47% of lead-based paints sampled contained total lead levels exceeding 90 mg/kg, which is the regulatory standard established in countries such as India, the Philippines, and the United States. Moreover, 15% of the paints sold on the market contained lead levels exceeding 10,000 mg/kg, with the highest concentration (220,000 mg/kg) found in an orange anticorrosion paint from the Smalto brand, commonly used in construction. Lead content above 10,000 mg/kg was observed in yellow (42%), red (14%), orange (33%), and green (12%) colored paints. Additionally, some imported and locally manufactured paint brands were found to have false labels indicating incorrect lead content (CREPD, 2017).

Lead occurrence/exposure in/through dietary exposure

A dietary exposure assessment to trace elements was conducted in Yaoundé using a pooled total diet sample, representing 96.5% of the inhabitants' typical diet, prepared as consumed prior to analysis. The food groups containing the most lead on average were "condiments, salt and flavourings" (3.61 mg/kg), followed by "tubers and starches" (0.042 mg/kg) and "fish" (0.036 mg/kg), indicating a possible risk related to lead exposure (Gimou et al., 2014). On the other hand, 26 samples of aluminum cookware and utensils, including three cooking ladles, were collected from local artisans in four regions in Cameroon known for cookware production: Kumba in the South West region, Douala in the Littoral region, Ngaoundéré in the Adamawa region, and Yaoundé in the Centre region. Source materials for this cookware included scrap metal such as engine parts, radiators, cans, and construction materials. Although the lead content in this cookware was relatively low, the potential exposure to lead was estimated to be 260 µg/serving, with a median estimated lead content/

serving based on 2 hours of boiling extraction of 97 µg (Weidenhamer et al., 2014). These values exceeded the Provisional Total Tolerable Intake Levels (PTTIL) for lead established by the U.S. Food and Drug Administration (FDA): 6 µg/day for young children and 75 µg/day for adults (FDA, 1993). Moreover, it was estimated that 1 serving of food from the analyzed cookware would exceed California's Maximum Allowable Dose Level (MADL) of 0.5 µg /day for lead (California OEHHA, 2013). Additionally, dietary exposure of people in Yaoundé to heavy metals in table-ready food, water, and soft drink samples has been reported. Samples from street restaurants were the most tainted with heavy metals. Lead was detected in 93% of the studied samples (0.019-1.77 mg/kg), exceeding its corresponding provisional tolerable daily intake (PTDI) of 3.6 µg/kg.bw.d established by the Joint FAO (Food and Agriculture Organization)/WHO (World Health Organization) Expert Committee, with a high average daily intake of 0.96 mg/day, especially through tap water (Tchana et al., 2018). In Santa, the North West Region of Cameroon, heavy metal concentrations were assessed in cultivated cabbage and carrots. Among the heavy metal concentrations, lead levels were 1.36 mg/kg and 1.31 mg/kg in the cabbage and carrot, respectively, being above the WHO/FAO permissible limits for human consumption of 0.30 mg/kg (Fonge et al., 2021). Heavy metals were also assessed in poultry feeds from the Centre, Littoral, and Western Regions of Cameroon in 2019. Six local broiler feeds, six local layer feeds, and three imported layer feeds were randomly collected from each region. As a result, lead showed the highest average content in the bulk layer feed from the Littoral (995.8 ± 0.4 µg/kg), followed by the one from the West (503 ± 209.3 µg/kg). The highest lead levels were found in the imported layer feeds (3229.8 ± 3 µg/kg). All the lead content in the analyzed samples was above the permissible limits of 10µg/kg as recommended by WHO (Keutchatang et al., 2023).

Lead residues in green leafy vegetables

In Cameroon, some common leafy vegetables include: pumpkin leaves (*Telferia occidentalis*), waterleaf (*Talinum triangulare*), bitter Leaf (*Vernonia amygdalina*), eggplant (*Solanum macrocarpon*), and green leaf (*Amaranthus viridis*).

These vegetables can exhibit differential uptake of lead (Orisakwe et al., 2012). In 2022, Djouego et al. analyzed the heavy metal content (Pb, Cd, Hg, Cu, As, Zn, Ni) of waterleaf (*Talinum triangulare*), bitter leaf (*Vernonia amygdalina*), and eggplant (*Solanum macrocarpon*). In all the samples collected during the rainy season, the concentrations of lead were 0.47, 0.34, and 0.36 mg/kg, respectively, exceeding the permissible levels set by FAO (0.3 mg/kg). In comparison, the levels during the dry season were 0.26, 0.13, and 0.21 mg/kg, respectively (Djouego et al., 2024). In 2022, a health risk assessment of selected toxic heavy metals in commonly consumed vegetables (okra, pumpkin, green cocoyam leaf, bitterleaf, scent leaves, cassava leaf, and waterleaf) was conducted in Mamfe, a town in the Southwest

region of Cameroon. The mean values of Pb for bitterleaf (3.62 ± 1.01 mg/kg), eggplant (4.68 ± 2.8 mg/kg), waterleaf (5.08 ± 1.08 mg/kg), pumpkin (8.31 ± 1.3 mg/kg), cocoyam leaf (10.18 ± 3.18 mg/kg) and green (10.73 ± 1.01 mg/kg), were above the safe limit recommended by FAO (0.3 mg/kg). Nevertheless, cocoyam leaf recorded the highest content levels for Pb (none detectable or less than the limit of detection, <LOD) - 103.16 mg/kg). Additionally, the pollution index (PI) values for lead in all samples exceeded six, indicating a very high level of contamination. Furthermore, the lead Hazard Index (HI) values were greater than one, suggesting a significant potential health risk associated with consuming these vegetables (Agbor et al., 2024).

Table 1. Summary of key characteristics of the 16 studies included in this review: sample size, sample type, and reported lead levels

Location	Number of samples	Description of sample	Detected lead levels			Reference
			Mean ± SD	Range	Unit	
<i>Litoral Region of Cameroon</i>						
Douala (Makea, Ngodi, and New Bell)	30 (10/site)	Surface soil samples collected at a depth of 0 - 20 cm	290 ±40 310 ±30 280 ±40 respectively	210 -340 260 -370 230 -340 respectively	mg/kg	Ouabo et al. (2019)
Douala	21	Hand digs wells, spring waters, and boreholes.	2.13 ± 2.59	98 x 10 ⁻⁵ – 0.01146	mg/L	Boum-Nkot et al. (2023)
Douala-Bassa Industrial Zone	3 /season	<i>Talinum fruticosum</i> (L.) Juss., <i>Vernonia amygdalina</i> Delile, <i>Solanum macrocarpon</i> L.	NA	0.13 -0.47	mg/kg	Djouego et al. (2024)
<i>Centre Region of Cameroon</i>						
Yaoundé (Nsimeyong)	57 (3/site)	Water processing plant (Nyong and Mefou rivers), alternative water supply sources, tap water and well.	NA	<LOD - 8.87	mg/L	Brenda Agnes et al. (2021)
Yaounde	64 pooled samples	Preparation of samples as consumed before analysis	0.93	0.05 –3.61	mg/kg	Gimou et al. (2014)
Yaounde	150	Table-ready food, water and soft drink samples	NA	0.019 -1.77	mg/kg	Tchana et al. (2018)
Yaounde	147	Children aged 12 months to 6 years	8	<LOD – 25.1	µg/dl	Monebenimp et al. (2017)
<i>East Region of Cameroon</i>						
East region (Pawara)	24 (6/site)	Soil samples collected at a depth of 20 cm	NA	4265 - 12274	mg/kg	Fodoué et al. (2022)
East region (Batouri)	5	Water samples 30 cm below the surface between 10 a.m. and 2 p.m.	2.202 ± 64	1.51 - 3.58	mg/l	Mambou et al. (2021)

Table 1. Continued

South West Region of Cameroon						
South Western Flank of Mount Cameroon	40	Surface and groundwater water, 20/ season (dry and wet)	0.02144 ± 0.015 0.034 ± 0.017 respectively	0.001 - 0.052 0.00 - 0.065 respectively	mg/l	Neh et al. (2023)
Mamfe	111	Edible vegetables (okra, pumpkin, Green, cocoyam leaf, bitter leaf, scent leaves, cassava leaf, waterleaf) grown on agricultural soils	NA	<LOD -103.16	mg/kg	Agbor et al. (2024)
North West Region of Cameroon						
Santa	8	Cultivated cabbage and carrot in 4 villages, 1:1/ site	NA	1.31 -1.36	mg/kg	Fonge et al. (2021)
Combined Littoral and Centre Regions of Cameroon						
Stores and markets in Douala and Yaoundé	65	Oil paint pots, decorative enameled	NA	< 60 – 220.000	mg/kg	CREPD (2017)
Combined Centre and South West Regions of Cameroon						
Yaoundé and Buea	300	Pregnant women aged 15 to 42 years who consumed Calabar chalk and who did not consume Calabar chalk	31.19 ± 18.55 25.33 ± 17.95, respectively	9 -92	µg/dl	Vofo et al. (2019)
Combined Centre, Littoral, and West Regions of Cameroon						
Centre, Littoral, West	3 /season	<i>Talinum fruticosum</i> (L.) Juss., <i>Vernonia amygdalina</i> Delile, <i>Solanum macrocarpon</i> L.	NA	0.13 -0.47	mg/kg	Djouego et al. (2024)
Combined South West, Littoral, Adamawa, and Centre Regions of Cameroon						
Kumba, Douala, Ngaoundéré, Yaoundé	29	Cookware samples and 3 cooking ladles	336	<15 -850	mg/kg	Weidenhamer et al. (2014)

LOD: limit of detection; NA: not applicable

Blood lead levels

The level of lead in the venous blood is the definitive biomarker of exposure and risk on which management decisions are routinely based. In 2017, the first report on lead poisoning in children was published amongst children in Yaoundé (Monebenimp et al., 2017). The blood lead levels of 147 children aged 12 months to 6 years were analyzed, and 88% of the children had lead levels greater than 5 µg/dL, which is the threshold set by the United States Centers for Disease Control and Prevention (US CDC) and WHO, with an arithmetic mean of 8.7 µg/dL in Yaoundé (Monebenimp et al., 2017). Additionally, the BLLs in the umbilical cord of

some pregnant women in Yaoundé Central and Buea Regional Hospitals were assessed. The lead levels ranged from 9 µg/dL to 92 µg/dL. Among individuals who consumed "calabar chalk", a lead-contaminated pica commonly ingested by pregnant women with lead concentrations reaching up to 40 mg/kg, the mean umbilical BLLs were elevated (31.19 ± 18.55 µg/dL). Nevertheless, lead levels in the umbilical blood of women who did not consume calabar chalk (25.33 ± 17.95 µg/dL) were still above the US CDC threshold (5 µg/dL), suggesting the existence of other sources of lead exposure in the environment of these women (Vofo et al., 2019). **Table 1** presents a summary of major findings about the studies being reviewed in this article.

Discussion

The level of lead in soil samples from Douala and the Pawara Gold Mining area was above the permissible limit levels (80 mg/kg). In Douala, the hazard Index (HI) for children decreased across the sites in the order of Ngodi > Makea > New Bell, meanwhile it was increasing for adults across the sites in the order of New Bell < Makea < Ngodi (Fodoué et al., 2022). The hazard quotient results revealed that adults and children living near e-waste recycling sites were at risk of lead toxicity through the ingestion and inhalation pathways. Elevated lead levels at the e-waste site could have resulted from the burning of e-waste, such as refrigerators, computers, cables, batteries, and air conditioners, among others. Open dumping and dismantling were the most common methods of handling e-waste in recycling sites in Douala (Fosuh-Mensah et al., 2017). This may be partly attributed to weak laws and regulations against the open burning and dismantling of e-waste, as well as the absence of an effective e-waste management system. Elevated mean lead levels in soils can eventually enter the human body, for example, through uptake by crops and subsequent dietary exposure, leading to toxic effects on multiple systems, including the central and peripheral nervous systems, the genitourinary system, and the reproductive system (Harrington et al., 2023). For the Pawara Gold mining area in East Cameroon, the high enrichment factor values for lead in the studied mining sites show anthropogenic influence through soil ploughing and excavation by farmers and miners (Ona et al., 2006). Indeed, these activities have the potential to increase soil porosity and enhance the mobility of lead in the soil, increasing also the contact probability with local people, especially children and local farmers (Fodoué et al., 2022).

Water contamination by lead has been observed in the cities of Batouri, Yaoundé (Damas), South-West, and Douala. The lead content in the samples (surface and ground water, dug well, borehole) exceeded the WHO recommendations (0.01 mg/kg) (WHO, 2011). Water is central to agriculture, animal and human life, and good management of its resources is necessary to the well-being of local communities. The presence of lead in water samples could be due to either the excavation activities of miners resulting

in leaching metal from waste dumps, or from exhaust pipes of heavy trucks, and mining machinery, or to the weathering of minerals containing lead, in particular lead sulfides, such as galena (PbS) (Aranguren et al., 2008). On another hand, tap home water revealed that the processed water could have been contaminated with high concentrations of lead, as it was conveyed to the quarters for use. Indeed, Damas is a new layout where cocoa farmers use a lot of herbicides and pesticides in their plantations (Brenda Agnes et al., 2021). The heavy metals present in those pesticides leach into the different water bodies in the quarter, which further will accumulate in the human body system when the inhabitants consume such water, and induce various toxic effects. The presence of lead in the consumed water is evidence that the inhabitants of Damas are running the potential risk of classical signs of lead poisoning in a community under lead exposure (Sallsten et al., 2016). Additionally, the contamination of the water samples collected from the surface and groundwater on the south-western flank of Mount Cameroon suggested possible contamination of the water sources by the application of agrochemicals in the agro-industrial areas, having a notable impact on water resources. Moreover, the higher concentration of lead (1.146 µg/dL) in groundwater in Douala was suspected to be associated with occasional contamination of the well by fuel from nearby motorcycle garages (Neh et al., 2023; Boum-Nkot et al., 2023).

Lead found in the common lead-based paints used in Cameroon did not respect the regulatory standard of > 90 mg/kg as fixed in the USA or even India. Therefore, it constitutes a critical source of exposure to lead poisoning among the population, with the painters being the first victims. Regarding young children who have the hand-to-mouth habit (pica), they are likely to eat chipped paint. Moreover, lead affects children's brain development and their measurable intelligence quotient (IQ). According to the WHO, childhood lead exposure is estimated to contribute to 600,000 new cases of children with intellectual disabilities every year (CREPD, 2017).

Ingestion is part of the main route of exposure to toxins. Lead poisoning through food consumption has been evaluated in frequently eaten vegetables and table-ready food of Cameroonians, including

poultry feeds (Tchana et al., 2018; Fonge et al., 2021). All the food samples were found to have lead content above the permissible limits, and the lead Hazard Index (HI) level > 1 indicated a potential high health risk, especially for vegetables (uncooked ones and table-ready foods) (Agbor et al., 2024). Nevertheless, the findings from the above-cited studies in Cameroon were lower than those reported by (Adedokun et al., 2016) and (Kalagbor et al., 2014) in Nigeria. Adedokun et al. (Adedokun et al., 2016) investigated six heavy metals (Pb, Cr, Zn, Cd, Ni, and Cu) accumulation in five leafy vegetables, namely: fluted pumpkin, waterleaf, scent leaves, plumed cockscomb (*Celosia argentea*), and slender amaranth. As a result, only lead levels (0.34 - 5.44 mg/kg), in all the vegetables, were above the permissible levels, with a range of daily intake of metals for Pb (0.046 - 0.182 mg/kg) exceeding the recommended dose of 0.00 mg/day/person, but was below the upper tolerable daily intake level of 0.240 mg/day/person, as established by the Institute of Medicine for people between the ages of 19 to 70 years (Adedokun et al., 2016; FDA, 2001). Additionally, Kalagbor et al. evaluated the metal content of some vegetables, which showed concentrations of lead (6.25 - 8 mg/kg) above the permissible levels; with lead levels being 7 mg/kg, 6.75 mg/kg, and 6.25 mg/kg in bitterleaf, fluted pumpkin, and waterleaf, respectively (Kalagbor et al., 2014). These vegetables are planted and grown sometimes either on contaminated soils that contain large amounts of agrochemical residues, or near polluted streams with industrial wastes, or even in swampy ("marecages") areas, especially the waterleaf plant (*Talinum triangulare*). Moreover, the water used to irrigate the plants can contain pollutants coming from the nearby factories or contaminated sites (Oluwole et al., 2013). These vegetables can exhibit differential uptake of Lead. Indeed, it is assumed that the accumulation of heavy metals in vegetables may be due to foliar uptake from the atmosphere and root uptake from soil, especially for leafy vegetables (Xu et al., 2022). Once bioaccumulated in these leafy vegetables, lead is then difficult to remove and is therefore of major concern. Also, the use of locally made pots that leach some amount of lead during cooking, the acidity of the food being prepared in those pots, in addition to the quality of water used for cooking, are some

factors that increase the amount of lead and other heavy metals in the food at the end of the cooking process (Weidenhamer et al., 2014). The contaminated poultry feed represents a potential source of cross-contamination for poultry and consumer populations, as it could be transferred to the products of chicken, such as the tissues and eggs (Canadian Food Inspection Agency, CFIA, 2017).

The level of lead concentration in the blood samples of children and umbilical cords of pregnant women was greater than 5 µg/dL, which is the threshold established by WHO (Swaringen et al., 2022). Calaba chalk, a natural non-food substance, was the main source suspected to be associated with high blood lead levels. Calabar chalk is widely consumed by women for various reasons, with a mean lead concentration of approximately 40 mg/kg (Dean et al., 2004). The body stores the absorbed lead in bones as lead-phosphate complexes, and permanent exposure easily causes tissue accumulation to toxic levels because lead is poorly excreted by the kidney (Kumar et al., 2020). Therefore, pregnancy remobilizes the stored lead from the skeletal tissues to the bloodstream. Thus, the fetus is exposed to lead that is consumed during pregnancy and that is remobilized from the skeletal tissues (Vofo et al., 2019). In young children, the most worrying effect of lead poisoning is the reduction in cognitive and sensorimotor performance, with long-lasting effects that persist in adulthood (Swaringen et al., 2022). At low concentrations, growth, weight, and sexual development disorders in young children occur. From 1.2 µg/dL, an IQ point is lost, and between 0 and 10 µg/dL, a total drop of 6 to 7 points is expected (EFSA, 2010). Beyond this, each increase of 10 µg/dL in BLLs in children leads to a drop of 1 to 3 points (Anonymous, 2019). In pregnant women, lead increase the risk of pregnancy-related hypertension and can induce (Haut Conseil de la santé publique, 2014): abortion or premature birth with sufficient evidence if blood lead level is greater than 25 µg/dL and limited below; intrauterine growth retardation and low birth weight if blood lead level is less than 5 µg/dL; and cognitive disorders in children even when blood lead levels are below 5 µg/dL.

Overall, there is a lack of comprehensive studies on lead in Cameroon, with the few existing ones primarily concentrating on occurrence data, and

most limited to the Eastern (Bertoua), Littoral (Douala), and Centre (Yaounde) regions. There is a need for further research on lead occurrence across different regions of Cameroon, especially in areas with significant mining activities (Kamga et al., 2018). Future studies should focus on exposure through various pathways and health risk assessments. Studies on exposure and health, particularly among vulnerable subpopulations such as children and pregnant women, are also encouraged.

Conclusion

Cameroonians, particularly vulnerable groups such as pregnant women, their unborn babies, and children under five, are exposed to Pb through multiple sources across all regions. These sources include Pb-contaminated soil (notably in gold mining areas in the East), Pb-contaminated water (partly due to anthropogenic activities and inadequate e-waste management, especially in Douala), Pb-contaminated food, lead-based paints (especially during painting without proper protection), poultry products from birds fed with Pb-contaminated feed, and consumption of “Calabar chalk.” In all exposure media, lead levels exceeded the respective permissible limits for soil, water, food, and paint. Additionally, elevated lead concentrations have been detected in blood samples, with levels in umbilical cords and children surpassing thresholds established by the US CDC, suggesting potentially underreported health risks. This review provides strong evidence of the extent of lead exposure among Cameroonians. It underscores the urgent need for more occurrence and biomonitoring studies and regulatory measures to protect public health.

Conflicts of interest

The authors declare no conflict of interest.

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