



Review article

Public health and economic burden of heavy metals in Ethiopia: Review

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ABSTRACT

Heavy metals pose a significant threat to public health and economic stability in Ethiopia, contaminating various environmental media, including water, soil, and air. This paper aimed to provide an overview of the public health and economic burden of heavy metals in Ethiopia. Exposure to heavy metals such as lead, mercury, cadmium, and arsenic has been linked to numerous adverse health effects, including neurological disorders, renal failure, cardiovascular diseases, and cancer. In Ethiopia, populations are particularly vulnerable to heavy metal exposure due to various factors, such as artisanal mining, industrial activities, agricultural practices, and inadequate waste management systems. The economic burden of heavy metal contamination manifests through increased healthcare costs, loss of productivity, and environmental remediation expenses. Furthermore, the impact extends to sectors such as agriculture and tourism, affecting national development goals and exacerbating poverty levels. Efforts to mitigate the public health and economic burdens of heavy metals in Ethiopia require multidisciplinary approaches, including policy interventions, regulatory enforcement, public awareness campaigns, and investment in sustainable development practices. Strengthening monitoring systems, implementing pollution control measures, and promoting research on alternative technologies for waste management are essential steps toward addressing this pressing issue. In conclusion, addressing the public health and economic challenges posed by heavy metal contamination in Ethiopia necessitates concerted efforts from the government, industry, academia, and civil society to safeguard human health, preserve the environment, and promote sustainable development.

1. Introduction

Heavy metals present a grave threat to public health and economic stability worldwide, particularly in regions like Ethiopia [1]. As industrialization accelerates and urbanization expands, heavy metal pollution becomes increasingly concerning due to its detrimental effects on human health, ecosystems, and economic progress [2]. Heavy metals harm public health and economies globally, worsened by industrial operations, mining, agriculture, and improper waste disposal [3]. Exposure to heavy metals like lead, mercury, cadmium, and arsenic is linked to neurological disorders, respiratory problems, cardiovascular diseases, cancers, and poses risks to ecosystems and biodiversity [4].

African nations, including Ethiopia, grapple with heavy metal pollution due to rapid industrialization and inadequate environmental regulations, worsened by urbanization in informal settlements lacking proper sanitation and waste management [5]. Additionally, artisanal and small-scale mining activities significantly contribute to heavy metal contamination in water bodies and soils

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across the continent, disproportionately affecting vulnerable populations living in poverty [6].

In Ethiopia, the substantial public health and economic implications of heavy metals are evident, with research indicating widespread contamination of water sources, agricultural lands, and urban areas [7]. Communities relying on contaminated water face increased risks of heavy metal poisoning, leading to chronic health issues and higher healthcare costs [8]. Furthermore, agricultural productivity suffers as heavy metal accumulation in soils reduces fertility and crop yields, posing threats to food security and livelihood [9]. Studies conducted in Ethiopia reveal alarming levels of heavy metal contamination across various environmental matrices, particularly in urban and industrial areas [10]. Additionally, research highlights the bioaccumulation of heavy metals in food chains, posing risks to both human consumers and livestock alike [11]. Severe heavy metal contamination in Ethiopia includes lead over 100 mg/kg in Addis Ababa soil, mercury at 1.5 µg/L near the Legedembi gold mine, and high cadmium and arsenic in vegetables, highlighting the need for policy reforms, technological innovations, awareness campaigns, and community engagement for sustainable development. Therefore, this paper was aimed to review the public health and economic burden of heavy metals in Ethiopia.

2. Review methodology

In this review of the literature, I employed diverse approaches. I consulted respected journals sourced from Scopus, Web of Science, and PubMed databases. The selection criteria predominantly targeted articles released post-2019, while omitting pertinent data and books. So, the review materials were chosen spanning the years, guided by indexes and respective protocols. In total, 32 articles (30.4 %), 37 articles (35 %), 34 articles (32 %), 25 articles (23 %), and 37 articles (35 %) were sourced from WoS, Scopus, PubMed, All, and other databases, respectively. The year wise analysis indicates that the majority of articles were published between 2019 and 2023. The majority of the reviewed papers concluded that varying types of heavy metals significantly impact the public health and economy of the world encompassing Ethiopia.

3. Overview of heavy metals contamination

Heavy metal contamination poses a global concern with significant implications for both the environment and public health [12]. Metals such as lead, cadmium, mercury, arsenic, and chromium, although naturally occurring, enter ecosystems through industrial activities, mining operations, and agricultural practices [3,13]. Released metals accumulate in soil, water, and food chains, posing serious health risks such as neurological disorders, organ damage, and cancer, underscoring the need for global intervention [14].

In Africa, heavy metal contamination poses particular challenges due to factors like rapid industrialization, inadequate waste management, and weak regulatory frameworks [15]. Many African nations wrestle with pollution stemming from mining, industrial emissions, and improper disposal of electronic waste [16]. Agricultural practices worsen the issue by introducing contaminated water and fertilizers, leading to metal accumulation in soil and crops [17]. This disproportionately affects vulnerable communities lacking access to clean water and adequate healthcare. In Ethiopia, heavy metal contamination is increasing due to urbanization, industrial growth, and inadequate environmental regulations [18]. Industries such as mining, manufacturing, and agriculture release heavy metals into the environment, contaminating soil, water, and air [19]. Informal recycling and inadequate waste management in Ethiopia, especially near industrial and mining areas, heighten exposure risks, with soil lead levels in Addis Ababa exceeding 100 mg/kg and mercury levels in nearby water bodies at 1.5 µg/L, comparable to contamination in China's industrial regions and Brazil's Amazon Basin, and similar cadmium and arsenic levels in vegetables as found in Bangladesh, all linked to non-communicable diseases and severe health issues, underscoring urgent global concerns for public and environmental health [20].

4. Heavy metal sources and exposure pathways

Heavy metals, naturally occurring elements found in the Earth's crust, have become concerning due to heightened human activities such as industrial processes, mining, agriculture, and urbanization [21]. These activities contribute to heavy metal pollution through various pathways, including emissions, effluents, and improper waste disposal, with common heavy metals such as lead, mercury, cadmium, chromium, and arsenic being associated [22]. Urbanization, transportation activities, and improper waste disposal significantly contribute to heavy metal pollution in urban environments, particularly through vehicle emissions, industrial activities, and landfill leachate [23,24]. Inhalation of airborne particles containing heavy metals is a significant exposure pathway, particularly in industrial and urban areas with high levels of air pollution [25]. In Ethiopia, rapid industrialization, mining activities, and agricultural practices contribute to heavy metal contamination in soil, water, and air [26]. Additionally, artisanal and small-scale mining, often informal and unregulated, pose significant environmental risks by releasing heavy metals such as mercury and lead into water bodies and soil [27]. Efforts to combat heavy metal pollution involve research, monitoring, regulation, cleaner production, and public awareness, with international collaboration essential for capacity-building and sustainable development in Ethiopia and Africa.

5. Public health impacts of heavy metals

Heavy metal contamination in Africa, especially Ethiopia, has severe public health implications, with metals like lead, mercury, cadmium, and arsenic released through industrial processes, mining, agriculture, and improper waste disposal [28,29]. These metals pose health risks through water contamination, with industrial activities and mining in Ethiopia notably contributing to pollution near mining sites (Table 1). Furthermore, heavy metals can infiltrate soil and crops, contaminating food sources, especially in agricultural regions using contaminated water for irrigation [30]. Chronic heavy metal exposure is linked to neurological disorders, kidney

damage, respiratory and cardiovascular issues, developmental delays, and cancers, especially for those near industrial or mining areas [4]. Children are particularly vulnerable due to their developing physiology and behaviors such as hand-to-mouth contact, potentially leading to developmental delays and cognitive impairments [31]. Heavy metal pollution also adversely affects ecosystems and wildlife, disrupting aquatic life and biodiversity [2]. These health impacts impose significant economic burdens on affected communities and healthcare systems, especially in low-resource settings.

6. Environmental impacts of heavy metals

Africa's vast mineral wealth fuels extensive mining activities, often conducted without rigorous environmental safeguards [32]. This results in the release of toxic heavy metals such as mercury, lead, and cadmium into the environment, contaminating soil, water, and ecosystems (Table 1). Industrial processes such as manufacturing and metal processing contribute further to heavy metal pollution through improper waste disposal practices [33]. Additionally, the growing issue of electronic waste exacerbates contamination, as discarded devices leach heavy metals into the environment, impacting air, soil, and water quality [34]. Heavy metals reduce biodiversity, impair soil fertility, and degrade water quality, with Ethiopia facing significant pollution from gold and tantalum mining, requiring a multifaceted approach to protect vulnerable populations and ecosystems [35]. Industrial practices, such as manufacturing and tanning, degrade the environment by discharging untreated heavy metal effluents [36,37]. Moreover, agricultural activities worsen the issue, as metal-containing pesticides and fertilizers contaminate soil, affecting crop growth and food safety [9,38]. Heavy metal pollution in Africa, including Ethiopia, harms biodiversity and human health, with aquatic ecosystems suffering and communities facing neurological and respiratory issues from contaminated food and water [39].

7. Risk assessment and management

Managing heavy metal risks in Africa, especially Ethiopia, is complex, involving scientific, regulatory, socio-economic, and political factors, with lead, mercury, cadmium, chromium, and arsenic threatening health, ecosystems, and agriculture [62]. These metals infiltrate the environment through human activities like mining, industrial processes, agriculture, and inadequate waste disposal. In Africa, rapid industrialization, informal mining, and weak environmental regulations exacerbate soil, water, and air pollution with heavy metals, leading to severe health issues such as neurological disorders, organ damage, and cancer, especially affecting vulnerable groups like children and pregnant women who are more susceptible to their toxic effects [63]. The accumulation of heavy metals in soil

Table 1
Public health and environmental impacts of heavy metal (short summary).

Heavy metals	Public health impacts	Environmental impacts	Ref.
Lead (Pb)	Lead poisoning can cause developmental delays, learning difficulties, neurological and kidney damage, and reproductive issues, particularly affecting children and pregnant women.	Heavy metals accumulate in soil and water, hindering plant growth, causing reproductive issues in wildlife, and leading to neurological, kidney, and cardiovascular problems in humans.	[40–42]
Mercury (Hg)	Mercury exposure leads to neurological and kidney damage, respiratory issues, and developmental delays in children, with methylmercury in tainted fish being especially toxic.	Mercury bioaccumulates in aquatic food chains, harming human neurological health and causing reproductive issues in wildlife.	[43–45]
Cadmium (Cd)	Cadmium exposure can damage the kidneys, lungs, and bones, and increase the risk of cancers such as lung and prostate cancer.	Cadmium accumulates in soil and water, harming plants, wildlife, and human health, with links to kidney damage, lung cancer, and bone diseases.	[46,47]
Arsenic (As)	Arsenic exposure can result in skin lesions, cardiovascular disease, neurological effects, developmental delays in children, and an increased risk of certain cancers such as skin, lung, bladder, and liver cancer.	Heavy metals pollute water sources, harm plant growth, and cause health issues like skin lesions, cardiovascular diseases, and cancers in humans.	[48,49]
Chromium (Cr)	Hexavalent chromium (Cr(VI)) causes lung cancer and other health issues, while trivalent chromium (Cr(III)) can induce skin irritation and allergic reactions.	Hexavalent chromium is a carcinogen that contaminates soil and water, affects plant and aquatic life, and poses health risks to humans through the food chain.	[50,51]
Nickel (Ni)	Nickel exposure can trigger skin allergies, dermatitis, respiratory issues if inhaled, and potentially increase the risk of lung cancer.	Impairing plant growth and reducing crop yields, heavy metals are toxic to aquatic organisms, disrupting aquatic ecosystems and are linked to respiratory issues and lung cancer in humans.	[52,53]
Copper (Cu)	While essential at low levels, excess copper exposure can cause gastrointestinal issues, liver and kidney damage, and neurological symptoms such as headaches and confusion.	Excessive copper in water harms aquatic life, accumulates in soil affecting microbial communities and plant growth, and can cause gastrointestinal issues and liver damage in humans.	[54,55]
Zinc (Zn)	Zinc, essential in moderation, can cause gastrointestinal problems such as vomiting and diarrhea in excess, and in severe cases, may lead to neurological symptoms and copper deficiency.	High levels of zinc are toxic to aquatic organisms, disrupting ecosystems and accumulating in soil, affecting quality and plant growth, while excessive intake in humans causes gastrointestinal issues and hampers copper absorption.	[56,57]
Beryllium (Be)	Beryllium exposure causes chronic beryllium disease, leading to coughing, shortness of breath, fatigue, and skin sensitization with allergic reactions.	–	[58,59]
Thallium (Tl)	Thallium exposure can cause gastrointestinal issues, neurological symptoms, hair loss, and severe damage to the nervous system, kidneys, and heart.	–	[60,61]

and water disrupts ecosystems, imperils biodiversity, and compromises food security by reducing crop yields [64]. Numerous African nations require stronger regulations to manage heavy metal pollution, emphasizing the urgent need for enhanced environmental oversight and stricter enforcement [65]. Interdisciplinary collaboration among scientists, policymakers, and stakeholders is essential for assessing contamination sources, exposure routes, and prioritizing actions for pollution prevention and public health [65].

In Ethiopia, addressing heavy metal contamination is vital for food safety and public health, with soil testing, better waste management, and sustainable mining regulations crucial for mitigating risks and promoting sustainable development [66]. Regional and international collaboration is essential for tackling cross-border heavy metal pollution, with African countries benefiting from partnerships with global organizations, research institutions, and donors for expertise, funding, and best practices [67]. Applying Integrating Human Health and Ecological Risk Assessment (HHERA) principles to heavy metal exposure involves identifying contaminants, assessing risks, quantifying exposure through soil, water, and food, and implementing regulatory and remediation measures to protect health and the environment.

8. Public awareness and education

Public awareness and education about heavy metals in Africa, including Ethiopia, are crucial due to their impact on health, the environment, and economic development, with pollutants like lead, mercury, cadmium, arsenic, and chromium stemming from industrial, mining, agricultural, and household sources [68]. Raising awareness about the dangers of heavy metals is crucial, as these substances can accumulate in the body, leading to long-term health issues such as neurological disorders, kidney damage, respiratory problems, and cancer. Public health campaigns, educational resources, and community outreach efforts can empower people to understand these risks and take protective measures [69]. Soil and water contamination can disrupt ecosystems, harm aquatic life, and contaminate food crops, ultimately impacting food security [39]. Raising awareness of heavy metal pollution can mobilize communities to support sustainable practices and push for stricter regulations on emissions and waste disposal [70]. Public education should highlight common sources of heavy metal contamination, such as industrial emissions, mining, improper waste disposal, and contaminated agricultural inputs [71]. Communities can use waste management, cleaner production, and awareness campaigns to push governments for stronger enforcement against polluting industries [72]. Raising public awareness about international agreements and conventions on heavy metal pollution, while building local capacity and investing in affordable technologies, can empower communities to effectively address contamination [73]. Public awareness and education efforts should prioritize community engagement and participation to ensure inclusivity and sustainability [74,75]. Involving local communities, empowering grassroots organizations, and fostering partnerships across sectors can enhance intervention effectiveness and promote local ownership of environmental initiatives [76]. In Ethiopia, tackling heavy metal pollution needs a multi-sectoral approach involving government, NGOs, academia, businesses, and local communities [77]. Raising awareness, improving education, enforcing regulations, and encouraging community involvement can help Ethiopia and other African nations mitigate heavy metal contamination and protect public health.

9. Economic burdens of heavy metals

In rapidly industrializing African countries like Ethiopia, weak environmental regulations worsen the economic impact of heavy metals, with global costs exceeding \$9 billion annually [78]. Exposure to heavy metals can lead to a wide range of health problems, including neurological disorders, developmental delays in children, respiratory issues, and various cancers [4]. Treating these health issues can impose substantial costs on healthcare systems, including expenses for hospitalization, medication, and long-term care [79]. Heavy metal exposure can impair cognitive function, reduce work capacity, and lead to absenteeism due to illness [80,81]. In agricultural settings, heavy metal contamination of soil and water can reduce crop yields and livestock productivity (Table 2), further impacting economic output [71]. Cleaning up contaminated sites and mitigating the effects of heavy metal pollution requires substantial financial resources [82]. Soil and water remediation, pollution control, and related costs impact tourism, agriculture, and

Table 2
Economic burdens of heavy metals (short summary).

Heavy metals	Economic burdens of heavy metals	Ref.
Pb	Pb, found in old paint, pipes, batteries, and industrial emissions, causes neurological damage in children, leading to learning disabilities and behavioral issues.	[85, 86]
Hg	Hg from power plants, mining, and industry accumulates in fish, posing health risks and leading to neurological and developmental issues.	[87, 88]
Cd	Cd from mining, smelting, and industry contaminates soil and water, potentially causing kidney damage, lung cancer, and bone disease.	[89, 90]
As	As, naturally found and released by mining and industry, poses risks like skin lesions, cancer, and cardiovascular diseases.	[91, 92]
Cr	Cr, used in steel production and leather tanning, contaminates soil and water, with some forms causing lung cancer and skin irritation.	[93, 94]
Ni	Ni from industrial emissions, mining, and metal processing can contaminate soil and water, leading to lung cancer and allergic reactions.	[95]
Cu	Cu, used in wiring and plumbing, can leach from mining and industry, with excessive exposure causing liver and kidney damage.	[96, 97]

industry [83]. Enforcing heavy metal regulations demands resources for monitoring and legal action, exacerbating social inequalities and requiring extra economic investment for affected communities [84]. Overall, the economic burdens of heavy metal pollution in African countries like Ethiopia are substantial and multifaceted, encompassing healthcare costs, lost productivity, environmental remediation, impacts on tourism and agriculture, legal and regulatory expenses, and social costs (Table 2).

10. Research and innovation

Research and innovation on heavy metal contamination in Africa, including Ethiopia, are crucial for tackling environmental and public health challenges [1]. Research often begins by assessing heavy metal levels in soil, water, air, and biota to identify contamination sources and pathways [98]. In Ethiopia, for instance, researchers have conducted studies to assess heavy metal contamination in soils due to mining activities and industrial pollution [99]. Innovation is key to developing technologies for remediating heavy metal contamination, with researchers in Africa, including Ethiopia, exploring methods like phytoremediation, bioremediation, chemical immobilization, and advanced filtration systems [100]. Research findings often inform policy formulation and regulation aimed at mitigating heavy metal pollution [101]. Ethiopia is working to strengthen regulations and enforcement to control industrial emissions, regulate mining, and improve waste management [102]. Capacity building initiatives are essential for enhancing local expertise in monitoring, assessing, and managing heavy metal pollution [103]. Collaborative research, training workshops, and academic partnerships build capacity for researchers, policymakers, and environmental practitioners in Africa, including Ethiopia [104]. Community-based participatory research approaches empower communities to take ownership of environmental health issues and advocate for sustainable solutions [105]. Researchers are using nanotechnology and sustainable methods to address heavy metal pollution in Africa, promoting collaboration and knowledge exchange [106]. African researchers are innovating with nanotechnology and sustainable methods to remediate heavy metal pollution, fostering collaboration and best practice development [106].

11. Remediation strategies

11.1. Worldwide strategies

Managing global heavy metal pollution requires coordinated efforts across sectors, including environmental protection, public health, industry, and policy-making. Governments must enforce strict regulations, emphasize pollution prevention, and invest in research on remediation technologies [107]. Comprehensive monitoring, awareness campaigns, international collaboration, and capacity building in developing countries are essential [108]. Encouraging corporate responsibility and adopting an integrated approach are also crucial to mitigating global heavy metal pollution [38].

11.2. Africa-specific strategies

Heavy metals in Africa pose unique challenges due to socio-economic, environmental, and geopolitical factors. Tailored strategies, including assessment, technology utilization, capacity building, and regulation enforcement, are essential [109]. Community engagement, innovative remediation technologies, cross-sector collaboration, and integration into sustainable development are essential for effective environmental management [110].

11.3. Ethiopia-specific strategies

Managing heavy metals in Ethiopia, like elsewhere, demands a multifaceted approach involving regulations, technology, awareness, and global collaboration, including strengthening environmental laws and enforcing regulations on emissions, waste, and mining [111]. Furthermore, it involves establishing monitoring systems for heavy metal levels, investing in training programs for government and industry personnel, and partnering with international organizations for technical support [112]. Educating communities on heavy metal risks, promoting public pollution monitoring, sustainable agriculture, and cleaner industry practices are crucial in managing heavy metals [113]. Implementing waste management systems for industrial waste containing heavy metals and supporting cleaner technologies in manufacturing processes are essential steps toward reducing environmental contamination [114]. Efforts to manage heavy metals entail enhancing mining regulations, implementing rehabilitation programs, securing international funding and technical support, participating in regional initiatives, investing in research, and fostering interdisciplinary collaborations for effective management in Ethiopia and beyond [78].

11.4. Research gaps and future line of works

Despite global studies on heavy metal impacts, comprehensive assessments integrating data from diverse regions, including Ethiopia, are lacking. Conduct meta-analyses to synthesize global data and identify gaps. Collaborate to initiate multi-country studies in Africa, focusing on Ethiopia's heavy metal pollution. Conduct surveys to map contamination, investigate exposure pathways, assess health effects, and quantify economic costs, implementing interventions to evaluate effectiveness and inform policy decisions.

12. Summary and conclusions

The heavy metal contamination in Ethiopia poses a significant threat to public health and economic stability, as toxins such as lead, mercury, cadmium, and arsenic infiltrate the environment through industrial emissions, farming practices, and improper waste disposal, contaminating water, soil, and crops. Exposure to heavy metals causes severe health issues such as neurological disorders, respiratory illnesses, and increased cancer risks, especially affecting vulnerable groups like children and pregnant women with limited healthcare access. Additionally, the economic impact includes strains on healthcare systems, decreased productivity, and expensive environmental cleanup efforts. Combining expertise from public health, environmental science, economics, and policy-making can improve the effectiveness of mitigation strategies. Addressing heavy metal contamination in Ethiopia necessitates urgent national and international intervention, including stringent emission regulations, enhanced waste management practices, and protection of food and water resources, alongside increased monitoring, improved healthcare access, and heightened public awareness. Investing in research and innovation for efficient pollution detection and mitigation is crucial, requiring collaboration among government, academia, industries, and civil society to pool resources and expertise.

13. Recommendation

Addressing heavy metal contamination in Ethiopia necessitates a comprehensive approach that includes researching contamination sources, enforcing strict regulations, enhancing detection capabilities, raising public awareness, strengthening healthcare facilities, investing in innovative technologies, seeking partnerships for support, and establishing long-term monitoring programs. Implementing these measures can help Ethiopia mitigate the health and economic impacts of heavy metal contamination, ensuring a healthier and more sustainable future.

Data availability statement

Data sharing is not applicable to this article, as no new data was analyzed in this study.

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Yohannes Gelaye: Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization.

Declaration of competing interest

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