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Review

Potential health risks from contaminated fish in Lake Victoria: A 25-year systematic review of pollutants and management challenges

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Highlights

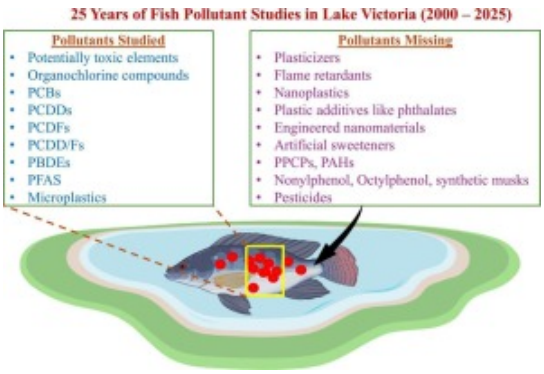
- Mercury levels in silver fish reached 335,000ng/g, exceeding safety limits.
- Liver tissues showed the highest bioaccumulation across all fish species
- Microplastics were detected in up to 75% of fish samples collected.
- PFAS found only in Ugandan fish; no data from Kenya or Tanzania
- Key pollutants exceed WHO/EU limits in artisanal mining regions

Abstract

Lake Victoria is the largest freshwater lake in East Africa, sustaining the livelihoods of over 40 million people. However, its fisheries face increasing threats from contamination by potentially toxic elements (heavy metals), persistent organic pollutants, and emerging contaminants. This systematic review integrates 25years (2000–2025) of research, analyzing primary studies on fish contamination across Uganda, Kenya, and Tanzania. The review assessed the occurrence, bioaccumulation, and toxicology of pollutants, as well as their health implications and management

strategies. Mercury was the dominant pollutant of concern, with concentrations ranging from 3.4ng/g wet weight in Nile tilapia (*Oreochromis niloticus*) to very high values of 335,000ng/g dry weight in silver fish from mining regions, exceeding international safety limits. Other detected contaminants included organochlorine pesticides, polychlorinated biphenyls, endosulfan, polybrominated diphenyl ethers, polychlorinated dibenzo-p-dioxins and furans, *per*- and polyfluoroalkyl substances, and microplastics. Bioaccumulation patterns revealed higher contaminant loads in the liver tissues of all fish, particularly in Nile perch (*Lates niloticus*). The health risks associated with these pollutants include neurotoxicity, carcinogenicity, endocrine disruption, and ecosystem-level impacts. However, significant knowledge gaps remain for newer pollutants, including pharmaceutical and personal care products, plasticizers, and modern pesticides, which have not been assessed in Lake Victoria fish. Furthermore, spatial coverage is uneven, with most islands and some inshore fishing zones lacking data. This review presents the first comprehensive synthesis of fish contamination data in Lake Victoria, providing a foundation for future scientific research, policy, and transboundary management, while also offering a transferable framework for addressing similar pollution challenges in tropical inland waters globally.

Graphical abstract



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Introduction

Freshwater ecosystems, though covering less than 1% of the earth's surface, are vital for global biodiversity and food security (Amatucci et al., 2024; Birnie-Gauvin et al., 2023). Among these, Lake Victoria, the largest freshwater lake in Africa and the largest tropical lake in the world, plays a critical ecological and economic role, supporting over 40 million people across Kenya, Uganda, and Tanzania (Ali et al., 2024; Nyamweya et al., 2023). The lake supports one of the most productive inland fisheries in the world, regional agriculture and trade, and serves as a reservoir for the River Nile (Njiru et al., 2008).

However, Lake Victoria faces increasing environmental pressures due to the combined impacts of rapid urbanization, industrial expansion, and intensified agricultural practices across its basin

(Enalbes et al., 2025; Njagi et al., 2022; Sun and Chen, 2025). Urban centers such as Kisumu (Kenya), Kampala (Uganda), and Mwanza (Tanzania) significantly contribute to the pollution load of Lake Victoria, discharging large volumes of untreated or inadequately treated domestic sewage and industrial effluents directly into the water (Nyamweya et al., 2023; Oyege et al., 2024a). Additionally, the widespread use of agrochemicals, such as pesticides and fertilizers, in farmlands surrounding the lake leads to runoff that enters the lake through rivers and surface drainage (Nakkazi et al., 2024; Nalumenya et al., 2024). These pollutants have accelerated eutrophication of the lake, resulting in algal blooms, oxygen depletion, and the decline of native fish species. Furthermore, contaminated fish undermines market access, especially for export-oriented sectors, as stricter international food safety regulations penalize and exclude non-compliant imports (Visciano, 2024). Locally, declining fish quality affects vendors, disrupts supply chains, and shrinks household income, aggravating economic vulnerability in already marginalized communities.

Several scientific studies have documented the presence of potentially toxic elements (PTEs) commonly known as heavy metals, such as mercury, lead, and cadmium (Mbabazi and Wasswa, 2010; Ngure et al., 2014); persistent organic pollutants (POPs), including polychlorinated biphenyls (PCBs) and dioxins; emerging contaminants such as *per*- and polyfluoroalkyl substances (PFAS), and microplastics in the fish found in the lake (Arinaitwe et al., 2020; Ssebugere et al., 2014a; Wenaty et al., 2019). These pollutants, unfortunately, bioaccumulate in fish tissues, particularly in top predators such as the Nile perch (*Lates niloticus*), thereby posing serious health risks to fish consumers, including neurotoxicity, endocrine disruption, and carcinogenic effects. Beyond human health risks, these contaminants also disrupt aquatic food webs and threaten the sustainability of fisheries industry of Lake Victoria.

Despite the transboundary significance of Lake Victoria and a growing body of environmental research, studies specifically addressing contamination in fish are fragmented and localized. Currently, no harmonized database exists detailing the types, concentrations, and spatial and temporal trends of fish contaminants across Lake Victoria riparian countries. This lack of coordinated monitoring hampers effective risk assessment and evidence-based policymaking.

To address this critical knowledge gap, this systematic review synthesizes peer-reviewed literature published over the past quarter-century (January 2000 to July 2025). The review aims to: identify and categorize major contaminants in fish, including PTEs, POPs, and emerging pollutants; assess spatial and temporal patterns of contamination across Kenyan, Ugandan, and Tanzanian waters; evaluate human health risks associated with dietary exposure to contaminated fish, highlight governance and monitoring gaps, and propose pathways for harmonized regional action. The systematic review is structured in five key sections as follows: (i) contaminant profiles, (ii) bioaccumulation and toxicology, (iii) human health risk assessment, (iv) governance and monitoring challenges, (v) recommendations and future directions. By consolidating existing literature, this work provides a foundation for future research, regional collaboration, and evidence-based policy interventions to safeguard both ecosystem integrity and public health in the Lake Victoria basin.

Section snippets

Methodology

This systematic review was developed using the methodology of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) (Page et al., 2021). …

Scope and trends of research on fish contaminants

A systematic examination of publications from 2000 to 2025 indicates that research on fish contamination in Lake Victoria is limited in both scope and scale. Over the past 25 years, only 22 published studies have directly analyzed pollutants in fish tissues, revealing a significant research gap given the ecological and economic importance of Lake Victoria (Fig. 2). In Fig. 2a, country attribution is based on the location where fish samples were collected, not the nationality or institutional …

Risk assessment

Human health risk assessment follows four linked steps: hazard identification, dose–response assessment, exposure assessment, and risk characterization. We applied this framework to fish consumption in Lake Victoria, following standard practice in environmental health studies (Nag et al., 2022b; USEPA IRIS, 1988, USEPA IRIS, 2001, USEPA IRIS, 2008; EFSA, 2012, 2018, 2020). Unless noted, calculations assume an adult body weight (BW) of 60 kg and a fish ingestion rate (FIR) of 18.36 g/day for the …

Recommendations and future directions

Addressing fish contamination from Lake Victoria requires coordinated action at the regulatory, scientific, and community levels. Based on the scientific evidence reviewed, the following recommendations and research priorities are proposed. We have also proposed a framework (Fig. 6) for future research on fish contaminants in Lake Victoria. …

Conclusions

This systematic review presents the first comprehensive synthesis of 25 years of fish contamination data in Lake Victoria, encompassing potentially toxic elements, persistent organic pollutants, and emerging contaminants, including microplastics and PFAS. Analysis of primary studies revealed significant spatial and temporal gaps, with Uganda accounting for half of the research and an

almost decade-long absence of new research from Tanzania. Concentrations of cadmium and lead exceeded …

CRediT authorship contribution statement

Nelson Mwebesa: Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Ivan Oyege:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Dennis Ssekimpi:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Formal …

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. …

Acknowledgements

BioRender (https://BioRender.com ↗) was used to make the graphical abstract. …

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