Occurrence of Microplastics, Pesticide Residues, and Heavy Metals in Surface Water of Kura Local Government Area, Nigeria

Khadija Sule Kura

Abstract
This study presents a comprehensive review of the occurrence and interactions of microplastics, pesticide residues, and heavy metals in surface waters, with particular focus on identifying knowledge gaps that necessitate investigation in Kura Local Government Area, Nigeria. The review synthesizes findings from global studies demonstrating that microplastics are ubiquitous in aquatic environments, with abundances ranging from 0.2 to 3.8 items per liter, and that these particles function as effective vectors for both heavy metals and pesticides through sorption mechanisms enhanced by plastic aging and biofilm formation. Agricultural watersheds are identified as multi-contaminant hotspots due to the convergence of plastic debris from farming activities, pesticide applications, and metal inputs from fertilizers and amendments, yet integrated assessments examining all three contaminant classes simultaneously remain exceptionally rare. The literature reveals a severe underrepresentation of West African contexts, with no studies comprehensively characterizing microplastic-pesticide-heavy metal co-occurrence in Nigerian surface waters despite intensive irrigation agriculture in regions like Kura along the Watari River. Critical knowledge gaps include the absence of baseline data on multi-contaminant pollution in Nigerian freshwater systems, lack of field validation for contaminant interaction mechanisms under tropical African conditions, and insufficient understanding of seasonal and spatial distribution patterns in agriculturally dominated watersheds. This review establishes the scientific rationale for integrated field investigations in Kura Local Government Area to quantify contaminant occurrence, assess potential interactions, and support evidence-based water quality management for communities dependent on these critical freshwater resources for drinking, sanitation, fishing, and irrigation.

Keywords: Microplastics, pesticide residues, heavy metals, surface water contamination, Kura Local Government Area

1.0 Introduction

Background of the Study

The introduction of complex mixtures of emerging contaminants to freshwater ecosystems turning it into the most characteristic environmental issue of the Anthropocene, strongly diminishing the integrity of aquatic life and people's health everywhere (Teiba et al., 2024). The most worrying pollutants of these include microplastics, pesticide residues, and heavy metals, which can be detected simultaneously in surface water and show symbiosis paper that their individual toxicities are even worsening (Fang et al., 2025). The situation is mostly aggravated by the presence of these substances in the regions with fast agricultural development and urbanization, where inefficient waste management and lack of control of industries lead them to get rid of these substances into the nature (Gani et al., 2024). In this regard, the surface water of Kura Local Government Area in Nigeria serves as the case study that is a representative of such counts of pressure and focus of research on the occurrence and possible interactions of these three types of pollutants.

Plastic microparticles, known to the world as plastic micro units of less than 5 mm, have mainly been dealt with in many aquatic places as a general pollutant (Migwi, Ogunah, & Kiratu, 2020). Their source is quite wide and comprises the direct efflux of primary microplastics in personal care products and abrasives to the fragmentation of larger plastic

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litter through physical, chemical, and biological processes (Gani et al., 2024). After their inclusion in surface waters, the microplastics do not remain the same; due to the small size and the high surface area-to-volume ratio they act as the most suitable vectors for the other environmental contaminants (Naqash et al., 2020). This exceptional vector microbiological effect is the main microplastics, which are sorbed and concentrated both hydrophobic organic compounds, like pesticides, and dissolved metals from the surrounding water (Kinigopoulou et al., 2022) the vector effect is critical. Current findings have shown that this kind of twofold pollution is capable of causing more ecological repercussions than it would be by one pollutant only (Ling et al., 2026; Kumar et al., 2025).

Pesticide residues are a significant type of contaminants identified in agricultural areas such as Kura, as these substances are widely applied to elevate the levels of crop production (Githaiga et al., 2023). These substances, which consist of insecticides, herbicides, and fungicides, are introduced into water bodies via different routes, such as agricultural runoff, atmospheric deposition, and the wrong way of throwing away the containers (Picó et al., 2020). The simultaneous presence of pesticides and microplastics is particularly alarming, as recent findings indicate that microplastics can alter the environmental behavior and bioavailability of these compounds, respectively (Li et al., 2020). As an example, when microplastics are present in the environment, it can have a significant effect on the rate of breakdown of pesticides, which in turn could lead to the long-term movement of those pesticides through the environment (Sarkar et al., 2021).

Heavy metals, such as lead, cadmium, mercury, and chromium, are naturally occurring elements in the Earth's crust but they have been transferred into various environmental components by human activities such as mining, industrial discharge, and agricultural practices (Ahmad et al., 2022). The elevated levels of metals in surface waters not only directly threaten the health of aquatic organisms but can also be passed onto humans after metal accumulation in fish and other organisms through the food chain (Das et al., 2025). The impact of the interaction between microplastics and heavy metals is one of the significant issues in the recent scientific investigations, where researchers disclose that microplastics can indeed transport metals to other locations, affect their chemical form, and hence change their toxicity in waters (Ta & Babel, 2023; Patidar et al., 2023).Furthermore, the sorption capacity of microplastics for heavy metals can be influenced by various factors including the age of the plastic, biofilm formation, and environmental conditions such as pH and salinity (Zhang, Guo, & Wang, 2022).

Surface water along with microplastics, pesticide residues, and heavy metals causes complex pollution problems due to their coexisting that are not fully unveiled yet (Gao et al., 2024). The research has been increasingly proving that these contaminants do not function on their own; instead, they can act together in a way that they increase their mobility, persistence, and toxicity (Fang et al., 2025). A case in point, microplastics may vector both pesticides and heavy metals on their surfaces, thus creating local high contamination patches to be possibly taken up by aquatic organisms (Kumar et al., 2025). The effect of both contaminants together can thus be of the type whereas the sum of the single contaminant effects is not only the total impact (Ling et al., 2026). The apartness of such interactions is essential for the accurate risk assessment and the formulating of the effective management plans.

Kura Local Government Area, based in Kano State of Nigeria, is an excellent model for multi-contaminant pollution investigation. The area is predominantly characterized by farming practices that provide water for yearly crop production via the Watari River, a channel that carries irrigative water (Ahmad et al., 2022). In the area, the agricultural activities include the utilization of the byproducts of the plants such as pesticides to combat pests and diseases and fertilizers that carry heavy metals (Githaiga et al., 2023). On a different note, plastic use in agriculture, like irrigation pipes, mulching films, and fertilizer bags, stands out as a probable source of microplastic pollution, especially through disintegration and improper disposal (Li et al., 2020). Urban and domestic runoff from nearby settlements also medicines and further contaminants to the surface waters (Das et al., 2025).

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Even though the importance of understanding interactions between multiple contaminants in freshwater ecosystems is known for a long time, the knowledge gap still occurs in the surface water of Nigeria regarding the presence and joint effects of microplastics, pesticide residues, and heavy metals (Gani et al., 2024). A majority of the investigations have focused only on the single-class contaminant cases or have been oriented towards different areas of environmental pollution with different pollution conditions and sources (Migwi et al., 2020; Picó et al., 2020). The few studies available from West Africa indicate the necessity for more inclusive assessments that take into account both the simultaneous presence of multiple contaminants and their possible interactions (Teiba et al., 2024).The objective of this work is to offer this missing information. The occurrence and distribution of these three contaminant classes in Kura Local Government Area surface water thus becoming a source of data to make the region's water quality challenges more understandable and influence future assessment and management actions.

The contamination of freshwater sources by microplastics, pesticide residues and heavy metals, which are rapidly increasing, is the most pressing environmental concern, posing risks to ecological health and human well-being especially in developing nations with high levels of agricultural practices. Although, the scope of single contaminant-focusing on a given pollutant in a particular water body, studies is rapidly increasing on the prevalence and distribution of different types of contaminants in freshwater ecosystems, a wide gap between these single-contaminant studies and the reality of mixed contamination, which occur in actual environmental situations, is still evident. This fact is particularly applicable to agriculturally dominant area such as the Kura Local Government Area in Nigeria where the agricultural practices combine with poor waste management strategies and the movement of urban runoff, thus possibly leading to hazardous mixtures of emerging contaminants which were rarely monitored or characterized. Prior studies indicated widespread distribution of microplastics in African freshwaters, with these studies focusing only on eastern and southern African water bodies and neglecting West Africa. While Migwi, Ogunah, & Kiratu (2020) published comprehensive work on microplastic distribution and characteristics in Lake Naivasha, Kenya with useful information regarding shape of particles and spatial variations, their study did not consider other chemical contaminants such as pesticide residues or heavy metals that may coexist with plastic particles. Also, Githaiga et al. (2023) made use of their decade review of contaminants of emerging concern on Kenyan surface waters for the occurrence of microplastics, pharmaceuticals and pesticides, but it was solely a review and did not account for primary experimental evidence from Nigerian surface waters which may be subjected to different practices and pollution sources, with an added factor of agricultural practices (intensive irrigation farming), intensive use of irrigation farming alongside Watari River) of the Northwestern region of Nigeria..

The research investigating the co-occurrence of MP and HM have progressed in Asia and Europe, but is not clear if these finding may apply to the Nigerian setting given different geological contexts, industries, and waste management structures. Kumar et al. (2025) investigated the spatial distribution and controls of MPs and HMs in a lake system in Indian Himalaya and established significant correlation between plastic abundance and HMs concentration; but the study was undertaken in a high-altitude, tourism-affected ecosystem and unlike northern Nigeria that is characterized with lowland, agricultural landscapes. Ta and Babel (2023) investigated the impact of land use and population density on MP contamination with heavy metals in a tropical river, showing urban and agricultural zones with significant influences in contamination, but the study was conducted in Southeast Asia without any consideration of the local pesticides application scheme prevalent in Nigeria agriculture. Patidar et al. (2023) studied MPs as HM vector in fresh water, but without consideration of organic pollutant, such as pesticides which commonly co-contaminate with HMs from agricultural discharge; their study was done in an Indian aquatic ecosystem. Given these limitations, the actual behavior and interaction between the pollutants under local Nigerian environmental conditions (seasonal hydrology, soil types, and cultivation methods) is unknown

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One area even though the importance of microplastics as vectors of organic pollutants such as pesticides are already well established, no empirical research was discovered to this end in the field conditions of arid areas of sub-Saharan Africa, and agriculture. In the Al-Hassa irrigation network (Saudi Arabia), Pic et al. (2020) analysed pharmaceuticals, pesticides, personal care products and microplastics and present significant multi-contaminant data in arid agro-ecosystems; however, the situations thereof significantly differ the conditions under which Kura is located, namely, semi-arid Sudan Savannah area. Sarkar et al. (2021) examined the fate, occurrences, and elimination of microplastics as a heavy metal carrier in natural wastewater treatment wetland systems, which offer mechanistic understanding of the contaminant transportation but not in natural surface waters where agricultural runoffs input directly. Li et al. (2020) studied how people influence the degradation of microplastics by prothioconazole and interact with their heavy metals with microplastics in soil and produced significant results on the chemical reaction, but their studies focused on soil, not in the liquid phase where the contaminants are translocated and available to aquatic organisms.

A recent review has compiled information on combined effects of multiple pollutants with the introduction of the need to have integrated field studies, which would show the complexity of field. The review of Teiba et al. (2024) on the role of marine bacteria in the regulation of the environmental effects of heavy metals, microplastics and pesticides is comprehensive but is more about marine systems and bacterial reactions which do not provide primary data in freshwater systems of agricultural landscapes. Fang et al. (2025) investigated a synthesis of pollution of soil which consisted of heavy metals, microplastics and pesticides and advised the processes of their mechanism and anthropogenic drivers, but their comprehensive research was restricted to the soil systems on the earth without taking the pollution of the surface water presented as another process of transport and exposure to the aquatic life and the human population. Kinigopoulou et al. (2022) offered a survey of microplastics as inorganic and organic contaminant carriers, synthesizing laboratory-based information on the nature of the sorption processes, but their article recognized the absence of field research, which supports the sorption processes under a real-world environment mixed contaminant assemblage. These artificial constructions incessantly refer to the lack of unified field investigation that is available to many geographical entities, namely sub-Saharan Africa, as a distinguishing angle of information that diminishes the establishment of locally practicable water quality ideals and mitigation strategies.

The remaining settings in West Africa which were topographically the same, had not undergone the multi-contamination scenario, which is endemic to highly irrigated agricultural lands. The article of Ahmad et al. (2022) concerning the existence of microplastics and heavy metals in the aquatic and agroecosystems provides the community with useful data on the impact of agrochemicals, yet, the researchers only focused on two types of contaminants, but the use of the agricultural chemicals was observed on the surveyed land. In a study, Das et al. (2025) studied the recent pollution of heavy metals and microplastics of the river systems in Bangladesh and provided an idea of the urban-industrial corridors, but they conducted their research on the river systems in South Asia, and nothing was said about the contamination of the farming areas with pesticides. Gao et al. (2024) assessed nutrients, microplastics, heavy metals, and emerging contaminants in a Chinese wetland and this demonstrates the applicability of a multi-pollutant assessment, albeit with a context of a secluded wetland ecosystem and inverted land use strains to the cultivated landscapes of Kura. The absence of studies which quantify and concurrently quantify microplastics, pesticides residues, and heavy metals in the Nigerian surface waters is the main knowledge gap that will assist in understanding the true pollution burden on the populations which use these waters to drink, clean their hygiene, fish and irrigate their crops.

Specifically, none of the previous research has tried to study in detail the occurrence, distribution and the potential interactions among microplastics, pesticide residues, and the heavy metals in the surfaces of the waters of Kura Local Government Area even though the area is surrounded by a high-density agricultural production and intensive use of

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Watari River to irrigate agricultural plots, and to drink and cook water. The combination of circumstances that is unique to this region such as the extensive use of plastic irrigation pipes and mulch films, the use of various pesticide formulations, vicinity to urban settlements, the semi-arid climate with wet and dry seasons significantly contributes to the development of a contamination situation that cannot be diligently explained by the extrapolation to research carried out in other environmental and socioeconomic settings. In addition to this, nobody is currently investigating the potential of microplastics as a type of vectors to concentrate not only pesticides but also heavy metals in the same environment, and without such scientific foundation, the local people, environmental authorities and policymakers lack such evidence to analyze the risk or develop specific actions to reduce the associated risks. The study therefore is a revolutionary effort being the first of its kind, to provide integrated, empirical data of concomitant, co-occurrence of these three harrowing classes of contaminants in surface water Kura Local Government Area, as such, the creation of a ground level, understanding of multi-pollutant provision, in a region of agricultural importance, within Nigeria, and exceeding the scientific community, in general, in the processes of defining

2.0 Literature Review

2.1 Global Microplastic Occurrence

Microplastics contamination of the aquatic ecosystems has also been reported in various geographical locations which have shown the widespread prevalence of this new category of pollutants. Microplastics, which are generally considered to be plastic waste smaller than 5 mm in diameter, may be produced by both primary and secondary sources through the breaking down of larger, more natural plastic debris during the processes of physical, chemical, and biological weathering (Garbounis, Karasali, and Komilis, 2026). Chen, Cheng, and Zeng (2023) critically examined the incidence of microplastics in water bodies and their toxicity to aquatic organisms, and found that in today's world, these particles are literally found in every water body, both in the remote mountain lakes and the deepest trenches of the ocean, and have been observed to cause both physical harm to the digestive tracts and the aquatic biota The review highlighted that although less focus has been given on freshwater systems compared to marine habitats, they play a vital role in transporting microplastic waste in nature to oceans and act as an important reservoir where organisms are exposed to these pollutants (Chen, Cheng, and Zeng, 2023). Local research has also helped to cognize the patterns of occurrence and features of microplastics in surface water. In this study, Duan et al. (2024) examined the microplastic pollution in the surface waters of the lake and sediment of Lake Chenghai in southwestern China, showing mean abundance of items of 3.8 per liter in the waters and 347 per kilogram in dry weight of sediments with fibers and fragments as the most common morphotypes and polypropylene and polyethylene as the most common poly Their investigation identified great spatial differences in activities related to tourism, agricultural runoff, and wastewater input, which underscores the magnitude of land use on patterns of the microplastic distribution products (Duan et al., 2024). Equally, Rami et al. (2023) have investigated the presence and features of microplastics in the surface water and sediment in the Zayandeh-rud River in Iran and observed an average of 1.2 items per liter in the water and 210 items per kilogram in sediment, with plastic fragments prevailing, polyethylene terephthalate, and polystyrene being the most

2.2.Regional Studies in Developing Countries

Studies in the developing world have already started to record the microplastic pollution, but there are still major geographical gaps, especially in sub-Saharan Africa. Patterson et al. (2020) examined microplastic and heavy metal distributions in an Indian coral reef ecosystem, with microplastic abundances of 0.2-0.8 items/L in seawater, polypropylene and polyethylene as the most common polymers, and having significant correlations between metal concentrations and plastic abundance, indicating that microplastics are vectors of metal transport in marine environments Jeyasanta et al. (2020) also reported the characterization of microplastics in coral reef, seagrass, and nearshore waters of

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Rameswaram Island, India and recorded mean abundance of 0.5 and 85 items per liter in water and sediment, respectively, with fibers constituting more than 60% of the total particles and showed that the pattern of accumulation of micropl Rezaei Kahkha et al. (2025) conducted research about the adsorption of heavy metals on microplastics in drinking water and water systems at Zabol, Iran and found that having aged microplastics in the samples of environmental systems contained much higher levels of adsorbed metals such as lead, cadmium, and arsenic than pristine microplastics, further proving the use of micro African studies are scarce yet are beginning to come out. A systematic review of contaminants of concern in Uganda by Baguma et al. (2023) has reported the presence, source, potential risks and mitigation measures of different types of contaminants in Ugandan water bodies such as microplastics, pesticides and heavy metals. Their literature review has shown that individual contaminant sources are well-researched, but integrated studies that examine different classes of contaminants in one study are extremely scarce, and they found agricultural runoff, urban wastewater, and poor solid waste management to be major sources of contamination in the East African freshwater systems (Baguma et al., 2023). A review of microplastics and chemical contamination of aquaculture ecosystems by Fred-Ahmadu et al. (2024) with specific focus on climate change implications and food safety in Africa found that the fast-growing aquaculture sector in the continent is facing new threats of microplastic contamination that can be aggravated by climate-related changes in pollutant behaviour and bioavailability. These studies in the region highlight the importance of multi-contaminant research in less well-studied areas in Africa, such as in northern Nigeria.

2.3 Microplastic-Heavy Metal Interactions

The contacts between microplastics and heavy metals are currently a topical research area because of the possibility of plastics concentrating toxic metals and changing their environmental behavior and bioavailability. Kumar, Chaudhary, and Bhalla (2024) explored how emerging contaminants occur and how they fate with microplastics, offering an in-depth analysis of current conditions, sources, and effects, and highlighting that the sorption of heavy metals by microplastics takes place through multiple sorption processes such as an electrostatic interaction, a surface complexation, and a hydrophobic partitioning. Liu et al. (2025) revealed the co-occurring presence of microplastics and heavy metals in surface sediments of Dongting Lake, China by revealing significant positive correlations of microplastic abundance and cadmium, lead, and zinc, and integrated ecological risk measures that combined pollution was more threatening than individual agents. Their analysis showed that such characteristics of sediments as organic matter content and particle size distribution determined the strength of microplastic-metal associations where finer sediments exhibit greater retention capacity of contaminated particles (Liu et al., 2025). Mechanisms of these interactions have been clarified by laboratory and field studies. Singh and Yadav (2024) explored the adsorption of heavy metals onto aged microplastics in groundwater at different levels of organic matter in the water, revealing that the weathering processes substantially increase the sorption capacity of the plastics through the increase of surface area, the introduction of oxygen-containing functional groups and the formation of bio films, which help to bind the metals. They found that aged microplastics adsorbed between 2-5 times the amount of lead and cadmium than pristine particles, and dissolved organic matter had complex impacts on metal speciation and bioavailability based on the concentration and composition of particles (Singh and Yadav, 2024). A similar study by Patterson et al. (2020) established that coral reef microplastics systems had high levels of chromium, copper, and zinc and through scanning electron microscopy, surface-level weathering and elemental mapping confirmed that heterogeneous metal distributions in the surfaces of the plastics existed, which is firsthand evidence of microplastics in the environment serving as carriers of metals. These interactions have important ecological implications. Rezaei Kahkha et al. (2025) showed that microplastics in drinking water sources had adsorbed heavy metals which could cause harm to human health when ingested especially when small enough to penetrate through biological membranes. Another effect of the combined effects of microplastics and other metals can be

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synergistic toxicity as microplastics alone have the potential to induce physical damage and provide controlled amounts of the metals to the organism at the same time (Kumar, Chaudhary, and Bhalla, 2024). Jin et al. (2025) performed a survey of developments in the field of microplastic in groundwater, discussing that the subsurface setting poses unusual challenges to comprehend microplastic-metal interactions since the hydrogeology is complex, light does not penetrate easily to degrade plastics, and it is also possible that contaminated groundwater can spread pollutants to drinking water wells. All these studies have demonstrated that microplastics and heavy metals are co-localized in different parts of the environment and their interactions carry significant consequences especially on contaminant transport, bioavailability and toxicity.

2.4 Microplastic-Pesticide Interactions

Microplastics may take up the active ingredient of the pesticides, a new untested issue of multi-contaminant interactions, which may have profound impacts on the environment, particularly in arable lands where both contaminants exist. The study conducted by Fatema and Farenhorst (2022) aimed on comparing micro plastics and sorption of pesticides with charcoal, ash and river sediments. It was revealed that polyethylene, as well as polypropylene, microplastics, were the primary absorbers of high concentrations of herbicides and insecticides, and that the sorption capacities were affected by variables such as the type of plastic used, the hydrophobicity of the pesticide, and the environmental factors such as the pH and ionic strength. The research findings showed that the microplastics tended to interact more with non-ionic than with ionic pesticides and the presence of natural organic matter could either facilitate or inhibit sorption because of competitive interactions and binding routes (Fatema and Farenhorst, 2022). This study showed that plastic components in the watershed system could be the route of pesticides delivery which along with the treated crops include the delivery of pesticides to other locations other than the target fields by the plastic components. This interplay between microplastics and pesticides and how it may impact aquatic life has given rise to the phenomena of the microplastics objecting to the increased toxicity. Garbounis, Karasali, and Komilis (2026) thoroughly examined the source, distribution and risks of microplastics in farm soils, noting that microplastics make it to agricultural systems via sewage sludge application, plastic mulch fragmentation of plastic mulch and irrigation with contaminated water, and accumulate in the areas containing pesticides applied to crops, creating micro-contamination hotspots. The review put forward that the environment of the soil is both the sink for microplastics and the source for those contaminated with pesticides that can migrate to the surface waters through the mechanisms of erosion and runoff, thus bridging the terrestrial and aquatic contamination routes (Garbounis, Karasali, & Komilis, 2026). Fred-Ahmadu et al. (2024) added that climate change could worsen such situations through the rearrangement of the pesticide application pattern, habitating the plastic and objecting the hydrological processes that move the contaminated particles to the water bodies.

The main study proved this theory in the agricultural regions with the following field evidence. Vaid et al. (2022) conducted investigations into the coexistence of microplastics and other pollutants in the Yamuna River, Delhi, with the result of the common presence of microplastics, pesticide residues, and heavy metals in water and sediment samples from this polluted urban river. In particular, their study observed that the sites receiving agricultural runoff featured microplastics of detectable pesticide concentrations, implying that the plastics and seeds transported from the farms into the river system carried the sorbed pesticides (Vaid et al., 2022). In a review on contaminants in Ugandan waters, Baguma et al. (2023) highlighted the fact that agricultural watersheds revealed increased numbers of microplastics that coincided with the frequencies of pesticide detection thereby intensively farmed areas being the major points of multi-contaminant pollution, which calls for integrated monitoring approaches. The results from the mentioned investigations insist on the fact that the double effect of microplastic-pesticide in the environment is of relevance and such should be considered for similar studies in other regions of the world.

2.5 African Perspectives on

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Multiple Contaminants

The contributions from African countries investigate multi-contaminant pollution and offer a minimal extent but a vital framing for the regional challenges, as well as the knowledge gaps involved. The research carried out by Baguma et al. (2023) was the most exhaustive systematic review of the contaminants of concern in Uganda. They creatively linked all the existing studies on the presence, risks caused, and removal technologies of microplastics, pesticides, heavy metals, pharmaceuticals, and other contaminants from Ugandan environmental matrices. A review that they conducted showed that although work on individual contaminants can be found, integrated analyses of multiple classes of contaminants in the same sample are incredibly infrequent, and most studies are based on individual types of contaminants and, therefore, lack important details regarding interplay and compound risks (Baguma et al., 2023). They named agriculture, urbanization, and industrialization as the main sources of contaminant discharges, and they found that absence of monitoring devices and analytic capability in most of the countries in Africa becomes an obstacle in assessing them wholly with regard to pollution.

The topic of Fred-Ahmadu et al. (2024) was limited to the microplastics and chemical pollution in African aquaculture environments, which explored the impacts of climate change on the food safety of the fastest-developing area. Their review pointed to the fact that the African aquaculture systems are more and more vulnerable to microplastic pollution of local waters, and that all the mentioned plastics potentially increase the concentration of pesticides and heavy metals used or entering agricultural zones, which can pose a threat to cultured fish and eventually to human consumers (Fred-Ahmadu et al., 2024). They demanded combined monitoring initiatives that can concurrently measure many classes of contaminants and how climatic changes in terms of temperature, rainfall, and hydrology could lead to changes in contaminant behaviour and bioavailability in tropical African systems. The review further pointed out that food safety inspection founded on individual pollutants might not adequately identify risks in areas where mixtures of several pollutants often occur.

There is also a shortage of West African studies. Fred-Ahmadu et al. (2024) observed that even though Nigeria is the most populous country in Africa and an extensive agricultural country, the published information on microplastic pollutants presence in freshwater systems there is hardly available, and even less information that discusses relations with pesticides or heavy metals. Available literature on other African areas indicate that agricultural watersheds would have been potential hot spots of multi-contaminant pollution, but there is no empirical evidence on Nigerian contexts (Baguma et al., 2023). The presence of this geographical distance is immense since Nigeria agricultural means, such as intensive use of irrigation systems along river patterns like Watari in Kura Local Government Area, usage of various types of pesticides formulae, and high density of plastic materials with the farming system predispose the co-occurrence and interaction of microplastics, pesticide residues, and untyped and unidentified heavy metals.

2.6 Gaps in Knowledge and the Rationale behind the study.

As is seen in the literature review, there are a number of important knowledge gaps to which this study will attempt to fill in. Firstly, although microplastic has been reported globally, with studies in sub-Saharan Africa and especially in West Africa being severely not represented in the scientific literature, this gap has left an enormous geographic location with distinct environmental factors and sources of pollution unexplored (Baguma et al., 2023; Fred-Ahmadu et al., 2024). Second, integrated assessments that evaluate multimedia contaminants, such as microplastic, pesticide residues, and heavy metals, are extremely uncommon, although there is increasing evidence of diverse interactions between these classes and growing evidence of co-occurrence of these and other contaminants in the environment (Kumar, Chaudhary, and Bhalla, 2024; Vaid et al., 2022). Third, agricultural studies established that agricultural practices are a significant source of multi-contaminants pollution, but no research has fully described how the above three classes of contaminants appear in the surface waters of the highly irrigated agriculture landscapes in Nigeria such as Kura

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Local Government Area (Garbounis, Karasali, and Komilis, 2026).
Mechanistic experiments of microplastic-heavy metals and pesticides interaction have developed significantly in the laboratory level, but have not been validated in the field, especially in developing country tropical conditions where environmental conditions, contaminant origins, and exposure interactions are different than in temperate systems where a significant body of research has been performed (Singh and Yadav, 2024; Fatema and Farenhorst, 202 Asian studies reported strong correlations between the microplastic content and the heavy metal levels indicating that a vector effect is active in a real-life context, however, it is still unclear whether the same associations are observed in the Nigerian surface water alongside the various plastic sources, heavy metal sources and environments (Liu et al., 2025; Patterson et al., 2020). Moreover, there is no evidence of microplastics being able to sorb pesticide residues and heavy metals to form complex pollutant mixtures with potentially high toxicity that have been studied in freshwater systems in West Africa.
The need to develop baseline information on the occurrence and distribution of microplastics, pesticide residues and heavy metals in the surface waters of Kura Local Government Area-Nigeria, hence justifies this study. The fact that this research will conduct a concurrent analysis of these three groups of contaminants on the same water samples will be the first to gauge a multi-pollutant contamination investigation in this agricultural landscape, which will enhance the overall scientific knowledge about the emerging contaminant risks in the least-studied parts of Africa. The results will be used in local water management, risk assessment of the communities who rely on these water resources, and form the basis of subsequent studies on the behavior of contaminants, their transport, and the remediation techniques that may be employed to address the problem in freshwater systems in Nigeria.

Findings and Discussion

The overall examination of literature available helps to come up with some crucial results that help formulate the scientific basis and reasoning behind the investigation of the microplastics co-occurrence with pesticide residues and heavy metals on the surface water of Kura Local Government Area, Nigeria. The findings cover the distribution across the globe, the interaction processes of the contaminants, the research gaps in the region and the uniqueness of the agricultural watersheds to be subjected to multi-pollutant contamination.

Ubiquitous Presence and Spatial Variability of Microplastics

The initial significant conclusion drawn based on the literature is that there is a universal level of microplastics in water bodies across the world, and corresponding instances of it have been observed in both remote areas of mountain lakes and in highly densely populated urban rivers (Chen, Cheng, and Zeng, 2023). Asian studies have reported microplastic levels of between 0.2 and 3.8 items per liter in the surface waters with the most common forms and shapes of the microplastic fiber and fragments and the most common polymers detected polyethylene, polypropylene, and polyethylene terephthalate (Duan et al., 2024; Rami et al., 2023). Land use patterns significantly affect the spatial distribution of microplastics, where their concentration of higher levels is always reported in areas receiving agricultural runoff, cities receiving discharges of urban wastewater, and the industrial effluents (Duan et al., 2024). Such spatial inconsistency highlights the need to carry out localized evaluations in areas that have a certain land use profile like the highly agriculturalized Kura Local Government Area, as opposed to making extrapolations to studies done in other environmental settings.

Microplastics as Transporters of Heavy Metals.

The second essential result is that microplastics are effective vectors of heavy metals in water bodies, and many studies provide strong evidence of significant correlations between microplastic amounts and metal levels in waters and sediment layers (Liu et al., 2025; Patterson et al., 2020). The process by which metals sorb onto microplastics takes place in several different ways including electrostatic interactions, surface complexation with functional groups that contain oxygen, as well as partitioning into biofilm layers that form on aged plastic

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surfaces (Kumar, Chaudhary, and Bhalla, 2024). Alterations in the microplastics analyzed in environmental samples indicate that aged microplastics have a higher concentration of adsorbed lead, cadmium and zinc than their pristine counterparts, and studies cite concentrations of adsorbed metal 2-5 times higher on aged microplastics than on pristine microplastics (Singh and Yadav, 2024; Rezaei Kahk The implications of this finding on risk assessment are profound, as it has been shown that microplastics not only do not disappear but also increase and carry toxic metals with them, and they might cause concentrated doses of contaminants to organisms that ingest them (Patterson et al., 2020). Literature also indicates that the environmental factors affecting microplastic-metal interactions include the types of dissolved organic substances, the pH and salinity, the presence or absence of particular peculiarities of the plastics and the metals interacting, and take on complex dynamics that demand site-specific study (Singh and Yadav, 2024).

Microplastic-pesticide Interactions in Agricultural Contexts

The review confirms the active sorption of pesticide residues by microplastics in the agricultural territory, and important implications on the transport of contaminants and bioavailability in nearby water bodies (Fatema and Farenhorst, 2022). Laboratory experiments show that polyethylene and polypropylene microplastics have high sorption affinities of non-ionic pesticides widely used in farming, and that the sorption capacity depends on the hydrophobicity of the pesticides and the type of plastic and environmental factors (Fatema and Farenhorst, 2022). Microplastics that have been found in agricultural watersheds during field studies have also been found with detectable concentrations of pesticides, which are the direct evidence of these interactions in real-world conditions (Vaid et al., 2022). Garbounis, Karasali, and Komilis (2026) thoroughly reported that the agricultural soils are both sinks of microplastics and sources of pesticide-adulterated particles that can be driven to surface waters via erosion and runoff mechanisms, providing a direct relationship between land-based agricultural activities and aquatic contamination. This observation specifically applies to Kura Local Government Area where the intensive irrigation agriculture along the Watari River provides possible routes of transporting contaminated soils and plastics in agricultural lands into surface waters.

Geographical Research Gaps in Africa.

The major contribution to poor representation of African countries, especially the West African countries such as Nigeria, in the international body of research on microplastics and multi-contaminant pollution, is striking (Baguma et al., 2023; Fred-Ahmadu et al., 2024). The systematic review of contaminants in Uganda by Baguma et al. (2023) showed that, although there are individual contaminant studies, an integrated assessment of the presence of multiple classes of pollutants in the same samples is very uncommon on the African continent. In particular, Fred-Ahmadu et al. (2024) observed that Nigeria, though the most populated African country and a significant food producer, has very little published data on the presence of microplastic contamination in freshwater systems, and almost no available research conducted to investigate the relationship between microplastics, pesticides, and heavy metals in Nigerian surface water. This geographical distance is meaningful, as environment, agricultural activities, and source of pollution and waste management systems in African states were significantly different than in Asian, European, and North American regions where the majority of studies have been performed, which restricts the extrapolation of available data to the Nigerian environment (Baguma et al., 2023).

Predominance of Single-Contaminant studies.

The analysis indicates that the comprehensive analyses of microplastics, pesticide residues, and heavy metals have been considered extremely uncommonly (Kumar, Chaudhary, and Bhalla, 2024; Vaid et al., 2022). Although microplastic-heavy metal (Liu et al., 2025; Patterson et al., 2020) and microplastic-pesticide (Fatema and Farenhorst, 2022) interaction with microplastic use have been documented, few studies have examined the use of all three contaminant groups together in the same samples. In one of the rare integrated studies, Vaid et al. (2022) recorded

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microplastics, pesticide residues, and heavy metal in the River Yamuna, India, and showed that agricultural runoff deposited microplastics with pesticides, and higher levels of metals. This observation indicates that multi-contaminant pollution in agricultural watersheds seems especially prone, but no such integrated assessments have been done in farms in Nigeria. Most literature on this topic has focused on single-contaminant methodologies, resulting in a lack of the crucial information regarding the effects of interactions, the cumulative risks, and the actual pollution burden of aquatic environments and human populations in most areas, such as Kura Local Government Area.

Multi-Contaminant Hotspots of Agricultural Watersheds.

Multi-contaminant pollution has repeatedly been found to be a hotspot in agricultural watersheds because of the merging of several sources of contaminants and transport routes to the watersheds (Garbounis, Karasali, and Komilis, 2026; Vaid et al., 2022). Agricultural activities add microplastics due to the fragmentation of the plastic mulch and degradation of irrigation pipes, as well as the use of sewage sludge with plastic particles (Garbounis, Karasali, and Komilis, 2026). Pesticides come in direct contact with crops and flow through water bodies through runoff, spray damage, and drainage (Fatema & Farenhorst, 2022). The heavy metals end up in agricultural watersheds by way of applying fertilizers, atmospheric deposition, and by irrigation using contaminated water (Liu et al., 2025). People combine these sources in agricultural landscapes, which provides an environment among all three types of contaminants, and integrated testing in these environments is infrequent (Vaid et al., 2022). The Local Government Area of Kura and intensive agricultural irrigation activities along the Watari River, mass use of plastic material in farming, use of different pesticide formulations, and possible metal input due to agricultural amendment and upstream sources is a typical example of an agricultural watershed where the multi-contaminant pollution can be anticipated though it has not been studied.

Environmental Conditions that affect Contaminant Interactions.

It is evident in the review that the complex interactions of contaminants are regulated by site-dependent environmental factors that fluctuate seasonally and geographically and, therefore, require site-specific research (Singh and Yadav, 2024; Jin et al., 2025). The sorption and desorption of heavy metals and pesticides on microplastics is greatly affected by factors such as pH, temperature, presence of biofilms, salt content, and content of dissolved organic matter (Kumar, Chaudhary, and Bhalla, 2024). Singh and Yadav (2024) showed that dissolved organic matter may either promote or suppress the sorption of metals onto microplastics, which is complex in predicting contaminant dynamics in natural waters owing to the concentration and composition of the dissolved organic matter. Jin et al. (2025) summarized the studies on microplastic in groundwater systems and emphasized that the conditions in the subsurface, such as light penetration, low microbial activity, and intricate hydrogeology, influence the aging of plastics and their interactions with contaminants differently compared to surface waters. Seasonal changes in rainfall, temperature, and hydrological connectivity between agricultural lands and surface water in tropical areas such as the north of Nigeria are likely to affect contaminant mobilization, transport and interactions, but none of the studies have described such processes in West African settings.

Ecological and Human health Implications.

The literature reports the relevant ecological and human health consequences of the co-occurrence of microplastics, pesticide residues, and heavy metals in surface waters (Chen, Cheng, and Zeng, 2023; Kumar, Chaudhary, and Bhalla, 2024). Exposure to contaminated microplastics could cause physical damage by causing particle ingestion, with contaminated particles toxic, and synergistic exposures leading to greater-than-additive toxicity (Chen, Cheng, and Zeng, 2023). Microplastic contamination has been reported to be transferred along food chains, and there is a possibility of biomagnifying the toxic chemicals that are associated with it in higher trophic levels such as fish that humans consume (Fred-Ahmadu et al., 2024). Rezaei Kahkha et al. (2025) proved that microplastics in drinking water reservoirs are adsorbed with

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heavy metals in levels of human health concerns when ingested, especially when the particles are very small as to translocate across intestinal barriers. The occurrence of various interacting contaminants in agricultural areas where people rely on surface water as a drinking, sanitation, fishing, and irrigation source leads to cumulative exposure pathways, which are not captured by single contaminant risk assessment (Baguma et al., 2023). In the case of Kura Local Government Area where Watari River is a major water resource with a wide range of applications, the entire range of contaminant occurrence must be known to ensure that the health of the population is safeguarded and that there is sustainability in water management.

Multi-Contaminant Methodological Approaches.

The review also reveals methodological strategies that have been successfully used to assess multi-contaminants in different geographical settings which guides the current study. Fourier-transform infrared spectroscopy and Raman spectroscopy have been used to identify and characterize the microplastic morphology, size distribution, and abundance (Duan et al., 2024; Rami et al., 2023). The atomic absorption spectroscopy and inductively coupled plasma mass spectrometry methods have been used to determine heavy metal in water and sediment samples after acid digestion (Liu et al., 2025; Patterson et al., 2020). Following the necessary extraction and cleanup steps, pesticide residues have been determined by gas or liquid chromatography and mass spectrometry (Fatema and Farenhorst, 2022; Vaid et al., 2022). Recent microplastics contaminant vectors studies have used scanning electron microscopy with an energy-dispersive X-ray spectroscopy to visualize surface features and elemental distribution of plastic particles (Patterson et al., 2020). The combination of these methods of analysis makes it possible to fully characterize multi-contaminant pollution and explore the possible links between the abundance of microplastics and the level of sorbed heavy metals and pesticides, which serves as a methodological basis of the study under consideration in Kura Local Government Area.

Conclusion

This extensive literature review has identified that microplastics, pesticide residues, and heavy metals are all important and interacting contaminants in the global freshwater systems, but there are still critical knowledge gaps as to how they interact in West African agricultural watersheds, especially in Nigeria. The review shows conclusively that microplastics are effective vectors of both heavy metals and pesticides, and that aged environmental particles have greater sorption capacities that can concentrate the toxic chemicals and modify their environmental fate, bioavailability and ecological effects. The agricultural areas such as Kura Local Government Area, with intensive irrigation agriculture, the prevalence of plastic in agriculture, frequent pesticide application, and possible metal inputs of various sources are likely hotspots of multi-contaminant pollution that is not fully characterized in the Nigerian context. The acute lack of West African studies in the world literature, coupled with the dominance of single-contaminant methods that do not reflect complex pollutant interactions, highlights the acute need to undertake integrated assessments that can concurrently measure microplastics, pesticides residues, and heavy metals in Nigerian surface waters to provide baseline data, aid risk assessment, and guide evidence-based water quality management decisions by the communities that rely on

Recommendation

On the basis of these results, it is suggested that extensive field studies should be carried out in the surface waters of Kura Local Government Area in order to measure the occurrence, distribution, and possible interactions of microplastics, pesticide residues, and heavy metals by using the accepted analytical techniques such as fourier-transform infrared spectroscopy to identify polymer, atomic absorption spectroscopy or inductively coupled plasma mass spectrometry Future studies should also examine the seasonal changes in the levels of contaminants to capture the effect of hydrological cycles on the mobilization of pollutants in agricultural fields, determine the relationship between microplastics and metals and pesticides using surface characterization methods such as scanning electron microscopy with energy-

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dispersive X-ray spectroscopy, and assess the potential effects of pollutants to humans by exposure assessment taking into consideration Nigeria needs to concentrate on developing multi-class contaminant monitoring programs, establish water quality standards, which take into account interactive effects, and reduce source control mechanisms that address agricultural plastic waste management, safe pesticide use practices, and metal input control in agricultural and urban sources in order to protect freshwater resources and secure human health in agricultural-intensive areas such as Kura Local Government Area.

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