Peertechz

LIFE SCIENCES GROUP

Annals of Environmental Science and Toxicology

ISSN: 2641-2969 DOI: https://dx.doi.org/10.17352/aest

Review Article

The Invisible Threat: A Review of Microplastics in Freshwater Systems, Including Their Presence in Water, Sediment, and Aquatic Insects

Richard Olajide Owaseye*

Department of Biology, Federal University of Technology Akure, Nigeria

Received: 22 July, 2025
Accepted: 25 July, 2025
Published: 26 July, 2025

***Corresponding author:** Richard Olajide Owaseye, Department of Biology, Federal University of Technology Akure, Nigeria,
E-mail: owasrichard@gmail.com

Abstract

Plastic particles, often referred to as microplastics, are less than 5 mm in diameter, and have become an inescapable and highly pervasive threat across freshwater environments. Their occurrence in the water, sediments and biological structures in water are a major ecological and biological concern. The current review has conducted a systematic analysis of their sources, spatial distributions, and effects on environment considering especially their occurrence in the water bodies, sediments, and aquatic invertebrates. Routes of entry are urban runoff, wastewater effluent, and agricultural operations and the review discusses the effect of the characteristics of particles on the environment and bioavailability. Considering their importance in food webs and ecosystem activity, aquatic insects are getting more recognition to detect microplastic pollution as bioindicators, which is due to their tendency to ingest and accumulate particles. Existing methods of detection are discussed, as well as limitations in the methods of such a study that cannot make results comparable in different studies. There are also noted gaps in knowledge, the lack of sufficient research in low- and middle-income countries and the need to develop standardized monitoring procedures. To understand the fate and effect of microplastic in freshwater compartments leading to the implementation of effective management strategies is important. Therefore, the review highlights the need for integrated scientific and policy programs aimed at reducing microplastic pollution and maintaining freshwater biodiversity.

Introduction

Microplastic pollution is a recognized environmental problem worldwide due to its non-biodegradability, wide dispersal, and potential damage to the environment [1]. Microplastics are plastic particles with a diameter of below 5 mm [2]. These particles can be primary microplastics, which are purposefully produced on a microscopic scale and used in products, e.g., cosmetics and industrial abrasives, or secondary microplastics, the generation of which is the result of the breakage of larger plastic garbage due to environmental exposure and weathering [3]. Due to their small size, microplastics can enter the fine structure of the ecosystem, and in it, they are easily swallowed not only by the widest range of organisms, but also participate in complex ecological interactions with the rest of the surrounding environment [4]. Whereas microplastic pollution has been highly discussed in marines, there is a growing body of evidence that shows that the same effect is being experienced in the freshwater ecosystems [5]. Freshwater ecosystems include freshwater rivers, lakes, streams, wetlands and reservoirs. The environments maintain the biodiversity, control hydrological processes, and provide water to domestic, agricultural, and industrial use. Without them, it is almost impossible to maintain ecological equilibrium but also to human welfare. Nevertheless, due to poor waste-disposal methods, industrial processes as well as urban runoff, microplastics have become very common in all types of freshwater basins across the globe [6].

Freshwater ecosystems are characterized by water with low salt level and a high level of plant and animal life as well. These systems are dynamic and sensitive to changes in physical, chemical and biological parameters [5]. Microplastics, like other forms of plastic pollution, has the potential to dramatically alter such systems through habitat change, reduced water quality, survival, and reproduction of aquatic life. Microplastics also react with coexisting water-borne toxins, like heavy metal and organic compounds, which tend to increase their levels of toxicity and bioavailability to water organisms [7].

Bioindicator organisms are very often utilized to determine the health of freshwater ecosystems. The monitoring of environmental conditions is done with the use of bioindicators in the form of specific species, which can translate cumulatively the effects of various stressors accumulated over time and help to observe the point of pollution and spatial and temporal trends [8]. The optimum bioindicator is sensitive to environmental factors, has characterised ecological demands and exhibits sampling ease and reliable taxonomic identification. These organisms provide important environmental management and retrieval data as they allow early detection of perturbations of the ecosystem [9]. Some of the highest used bio indicators in freshwater studies include aquatic insects which include, mayflies, stoneflies, caddisflies, midges and dragonflies. They occupy a wide range of trophics in aquatic food webs and are widely distributed in microhabitats thus giving an overall status of the ecosystem's health. Their nature, presence, absence, or abundance can be utilized to ascertain the strength of pollution and the ecological conditions [10].

Aquatic insects are becoming accepted as having a role in microplastic research. Since they feed on such detritus and periphyton, a high number of species experience microplastics through direct consumption or through contaminated foods [11]. The consumed plastics amass in the internal body tissues which may lead to feeding restraint, growth and survival curtailment. Another area of concern is that microplastics can also modify the characteristics of sediments or substrates due to which the habitat suitability can be influenced, the food sources can be reduced, and the number of contaminants is grown. Taken together they have a potential to cause deleterious changes in insect populations and community structure [12]. The surveying of microplastic pollution of freshwater bodies is an urgent but quickly evolving research avenue. The aquatic insects as a source of bioindicators provide a quick and economical bioindicator of the microplastic presence and ecological consequences, especially in areas where there are limited data. The implementation of insects also bridges the gap between laboratory toxicological tests and the in situ environmental monitoring, and thus explains how microplastics impact on the biological communities under natural conditions [11].

Although the issue of microplastic pollution of freshwater ecosystems has gained visibility, there still exists deficiencies of important knowledge on their distributions, their sources, their fates and their biological impacts. Existing evidence is based mainly in developed countries and little is known in areas that have specific environmental, socioeconomic and waste-management regimes [13]. In addition, strict methodological requirements of detection and quantification of microplastics in water bodies and biota are yet to be established and, thus, restrain the variability of research papers [14]. Accordingly, the review is an extensive survey of microplastic pollution in freshwater bodies with a focus on pollution sources, type of plastic, geographical trends, methodologies in detection, and ecological impacts. The aquatic insect's role as bioindicators is detailed highlighting its relevance, merits and demerits. Regarding this, the review isolates conspicuous research needs and knowledge gaps to close the gap in understanding and dealing with microplastic pollution in freshwater systems. The synthesis of the existing evidence presented in the current paper can help to develop perspectives on further discussions of freshwater conservation issues and can be used as a foundation of future research programs and policy making.

Sources and types of microplastics in freshwater systems

Microplastics, with diverse origins, find their way into rivers, lakes and streams through direct and indirect routes [14]. Traditionally, the microplastics are classified according to primary and secondary microplastics (Figure 1). Primary microplastics are properly designed and fabricated in small sizes to serve particular purposes [15]; microbeads of a scrub and toothpaste are examples. Despite the microbead prohibitions that have been adopted in several jurisdictions, there are still microbead remnants in the water bodies [15]. Microfibers are the other type of primary microplastic released during laundry by synthetic fabrics and get through municipal wastewater systems. Treatment centers usually lack the technical capacity to eliminate such tiny fibers and thus the fibers end up getting to waterways. Other origins of primary microplastic are plastic powders used in air-blasting, industrial abrasive and pre-pellets used in production processes before a product is made as such post pellets can be spilled during manufacturing and transports [16]. On the other hand, secondary microplastics are as a result of disintegration of the macroplastics due to physical, chemical, and biological breaking downs [17]. Plastic bags, food packaging, beverage containers, and agricultural films are the most important contributors, which are disposed of and later degraded by exposure to both UV radiation and wind-driven abrasion as well as microbial activity. The end result is microplastics and this is the result of progressive fragmentation. Another couple of major sources are the tire wear particles; wear of tire by friction during transit leads

Figure 1: Schematic flowchart illustrating the sources, types, and entry pathways of microplastics in freshwater systems.

Citation: Owaseye RO. The Invisible Threat: A Review of Microplastics in Freshwater Systems, Including Their Presence in Water, Sediment, and Aquatic Insects Ann Environ Sci Toxicol. 2025;9(1):030-038. Available from: https://dx.doi.org/10.17352/aest.000088

to microscopic debris, which is carried into water bodies via rainfall. These particles are generally made with synthetic rubber and chemical additives hence adding to their complexity in the environment [18].

Two of the main sources through which microplastic enters the freshwater ecosystem are urban runoff and domestic wastewater [19]. Urban environments Streets, roofs, the sides of buildings in a metropolis, are where the anthropogenic debris of trash plastic, plastic fibers and other materials is washed by precipitation into neighboring rivers. Similarly, Microplastics enter the municipal sewer system as wastewaters produced by households during washing, bathing, and cleaning [20]. Although wastewater treatment plants rid a good portion of solid waste materials, a significant percentage of microplastic material, resist the treatment process, thus are present in the treated wastewater, whereby they are deposited in the bodies of water receiving the treated wastewater. Recycling of sewage waste (biosolids) into agricultural applications is another avenue, which results in microplastics being released to the environment particularly after intensive rains aiding the surface run-off technique [18]. Industrial production also contributes significantly to freshwater microplastic emission. Sewers of factories involved in the manufacture of plastics, textiles, packaging and construction industries regularly release effluents containing micro plastics into adjoining waterways and rivers [21]. The combination of industrial waste water being enriched with plastic particles and spillage of polymer resins in the course of transportation and processing increases the total microplastic load. This is also worsened by agricultural means [22]. Polymer-coated fertilisers, plastic mulch films, and drip irrigation pipes are also another form of plastic input in the agricultural landscapes. Microplastic contamination may occur when they wear out or are not handled properly, as a result of leaching and runoffs, particularly during the rainy season [20].

Microplastic contamination through atmospheric deposition has increasingly been regarded as an important source of contamination within the freshwater ecosystem. During wind-disturbance events, fibers, fragments that make up microplastic particles adopt an airborne state over landfills, urban dust, and degraded synthetic goods. These particles are then deposited by atmospheric processes or precipitation and thus explain the presence of microplastic in distant lakes and rivers, far away from any visible pollution source and highlight the long-range spread of contamination. Also, the plastics end up in the environment through human leisure activities in the areas surrounding freshwater bodies [23]. Boating, fishing, picnicking, and camping associated littering usually leaves plastic waste behind [24]. With time, the sun, hydrodynamic force, and biological destruction of such waste leads to the development of microplastics. The extent of such pollution is especially severe in popular tourist destinations where the waste management infrastructures are commonly overwhelmed, which contributes significantly in the accumulation of plastics in the surrounding aquatic bodies of water [25].

In the reclaimed microplastic in freshwater environments, morphologies and polymer composition are heterogeneous. The most common of these shapes are fragments, fibers, beads, films and foams; all shapes influence the behaviour of the particle, and its interactions with organisms and resultant sedimentation patterns [26]. Polyethylene (PE) and polypropylene (PP) are the most commonly reported polymers in modern studies of freshwater ecosystems mostly due to their common use in consumer goods, as well as their low density that enables flotation. Most other polymers (polyethylene terephthalate (PET) - commonly used to make clothing and food packages and polystyrene (PS) - which are often used in disposable packaging) are also very common. Less buoyant is polyvinyl chloride (PVC) which is easily pronounced to be durable and used in construction hence it can be easily found in a sedimentary sample. Both the degradation pathways and the ability of these polymers to adsorb persistent organic pollutants (POPs) and heavy metals and increase their ecological impact are determined by chemical properties of these materials [20].

Distribution and detection of microplastics

Spatial patterns of microplastics in the freshwater ecosystem are characterized by a high level of heterogeneity, and these patterns are modified depending on the range of environmental and anthropogenic factors [21]. These particles are now recorded in all major compartments of freshwater ecosystem; surface water, sediment and water living organisms [22]. The growing body of research that is documenting microplastics in rivers, lakes, estuaries, as well as, in most cases, deep freshwaters highlight the ubiquitous presence of this pollutant. The physical features of microplastic especially the size of the particles, shape of the particle, density and the type in which the polymer is made are decisive in determining their fate as regards their transportation patterns and eventual outcomes in the aquatic systems [23].

The low-density microplastic (polyethylene (PE) or polypropylene (PP)) stays suspended in surface water; that is, it floats because of the buoyancy effect. They are then swept downstream by the currents of water, deposited in the lakes, reservoirs, or other stagnant water bodies. Polymers with higher densities, such as polyvinyl chloride (PVC) and polyethylene terephthalate (PET), on the other hand sink on bed substrates and collect in the river channels or in the lakes [24]. Therefore, primary sinks of microplastic are sediments which may allow their persistent storage and subsequent transfer to the benthic food web.

The distribution of microplastic in space usually depends on the closeness to pollution hotspots [25]. Characteristically high levels are found in urban centres, industrial areas, effluent and agricultural runoffs. Water courses flowing through urban areas or regions with intensive industry are often used as a megaphone and become highways along which microplastics arrive at the downstream environments despite their origin inland. Season also affects abundance of microplastic microplastics: certain weather events (which involve precipitation and floods) tend to move otherwise stationary particles out of terrestrial ecosystems and into the water column [26].

Citation: Owaseye RO. The Invisible Threat: A Review of Microplastics in Freshwater Systems, Including Their Presence in Water, Sediment, and Aquatic Insects Ann Environ Sci Toxicol. 2025;9(1):030-038. Available from: https://dx.doi.org/10.17352/aest.000088

To successfully identify microplastics in fresh waters, a combined approach including sampling, extraction and analytical procedures is required. The sampling programs can be adjusted to a study objective; therefore, the sampled matrix may be water, sediment or biota. Neuston nets or grab samplers are regularly used to sample water, with sediment cores or dredges to sample the surficial and sub-surface materials. Fish or invertebrates as examples of biota can be dissected to check on the presence of microplastic ingestion with the help of gastrointestinal contents [27].

After collection of samples, the obtained samples should be prepared in a manner that will separate the microplastics. A separation based on density which involves immersion in salt solutions like sodium chloride (NaCl) or zinc chloride ($ZnCl_2$) is normally used whereby polymeric particles float while organic and inorganic contaminants settle. There could also be a need to digest biological tissue through enzyme or chemical digestion. Once extracted, visual inspection under a stereomicroscope is usually used to identify a first sample but this procedure is subject to misidentification due to similarity between the microplastic and naturally-occurring micro particles [28].

A certain number of analytical techniques are often used to improve precision. Polymer type can be identified using Fourier-transform infrared spectroscopy (FTIR) and Raman spectroscopy that allow the characterization of molecular signatures. Scanning electron microscopy (SEM) and pyrolysis-gas chromatography-mass spectrometry (Py-GC-MS) further provide more information on particle shape and chemical composition, thus confirming the presence of microplastics and clarifying possible sources and toxicological consequences [29].

A standard workflow of the methodological steps involved in sampling, preparation, detection, and interpretation of microplastic presence in freshwater systems is illustrated in Figure 2.

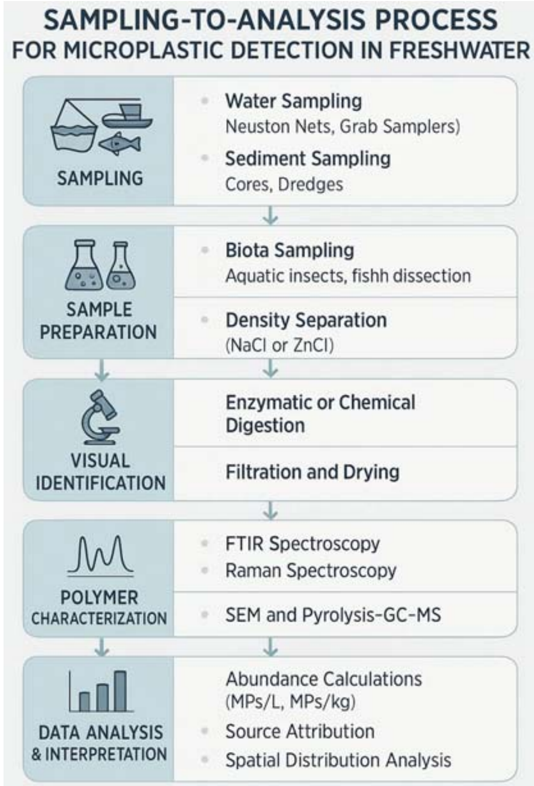

Figure 2: Workflow diagram illustrating the standard sampling-to-analysis process used for microplastic detection in freshwater systems, including water, sediment, and biota.

Microplastics in freshwater compartments

Microplastics have been found everywhere in the various compartments of freshwater ecosystems. It has been found in the water column (Table 1), the sediment layers (Table 2), and aquatic insects (Table 3). The environmental persistence, the character of the ecological interactions and the main exposure pathways of biology pathways are highly dependent on a clear understanding of their appearance and their spatial extent across these compartments. Each compartment is influenced by distinct processes, meaning that they direct the mechanism of behaviour of microplastic, thus, determining its cycling and long-term impacts in freshwater systems.

Microplastics in the water column

In freshwater environments, water column represents the main path through which microplastic contaminants get in and move. The particles with less than 5 mm size are introduced through many and different sources, such as the direct discharge by the industry and municipalities, the stormwater runoff, landfills leachates, and deposition. The problem of microplastic contamination in the water column has been exacerbated due to more and inappropriate use and disposal of plastic materials in the freshwater [32].

Table 1: Microplastics abundance in water samples in some freshwater ecosystem.

Study Location	Abundance (MPs/L)	Polymers Identified	Researcher and Year
Rice field ecosystem Thailand	85.8 items/L	PET, PVA, PPG, PEG, PVME, DEHP	Khamboonruang and Prommi, 2024 [30]
Osun River, Oshogbo, Nigeria	3791–22,079 MPs/L		Idowu, et al. 2024 [31]
Nwangele, Imo State, Nigeria	440–1556 MPs/L	PET, PE, PVC, PP	Ebere, et al. 2019 [32]
Kaduna River, Nigeria	153 MPs/L	PET, PE, PVC, PP, PES	Aliyu, et al. 2023 [33]
Wei River, China	4.67–12.3 MPs/L	PE	Zhao, et al. 2022 [34]

Table 2: Microplastics abundance in sediment of some freshwater ecosystem.

Study Location	Abundance (MPs/L)	Polymers Identified	Researcher and Year
Rice field ecosystem Thailand	0.43 items/g	PET, PVA, PPG, PEG, PVME, DEHP	Khamboonruang and Prommi, 2024 [30]
Osun River, Oshogbo, Nigeria	392–1590 MPs/kg	PET, PE, PVC, PU, EVA, ABS	Idowu, et al. 2024 [31]
Brisbane, Australia	10–520 MPs/Kg	PA, PE, PP, PET	He, et al. 2020 [35]
West River, South China	2560–10,240 MPs/kg	PP, PE, PVC, PET	Huang, et al. 2021 [36]

Citation: Owaseye RO. The Invisible Threat: A Review of Microplastics in Freshwater Systems, Including Their Presence in Water, Sediment, and Aquatic Insects Ann Environ Sci Toxicol. 2025;9(1):030-038. Available from: https://dx.doi.org/10.17352/aest.000088

Table 3: Microplastics abundance in aquatic insects in some freshwater ecosystem.

Study Location	Insect order	Abundance (MPs/L)	Polymers Identified	Researcher and Year
Rice field ecosystem Thailand	Odonata, Ephemeroptera, Hemiptera, Diptera and coleoptera	0.59 ± 0.50 - 17.00 ± 17.00 items/individual	PET, PVA, PPG, PEG, PVME, DEHP	Khamboonruang and Prommi, 2024 [30]
Rice field ecosystem Thailand	Odonata	1.34 ± 1.11	PMMA, PET, PP	Maneechan and Prommi, 2022 [37]
Ogun and Osun river, Nigeria	Odonata, Diptera, Ephemeroptera	43.29 ± 43.29 - 291.76 ± 26.55	ABS, PP, Polyester	Akindele, et al. 2020 [38]
Saynbach stream, Germany	Tricoptera	1.14 - 0.28 microplastics per caddisfly larval case	PE, PP, PVC	(Ehlers, et al. 2019) [39]

Multiple of the physical and chemical properties identify microplastic behavior in the water column. (B) Buoyancy is greatly affected by the density of polymers. Low-density polymers, e.g. polyethylene (PE), and polypropylene (PP), usually become floating around the water surface, aggregating on the surface. Conversely, the polymers with greater density (e.g. polyvinyl chloride (PVC) and polyethylene terephthalate (PET)) are likely to become neutral or to sediment in the lower strata. Secondary processes of particle size, particle shape and biofilms also affect this positioning and persistence within the water column. There is a possibility of changing buoyancy and the sinking of floating particles due to biofouling [31].

Unlike plastic fragments, distribution patterns of microplastic in the water column are hydrodynamically driven, that is, by turbulence and current movement and stratification of water mass. The dynamically moving water in the lotic system is likely to fling particles apart, but lentic systems (lakes and reservoirs) permit stratification of the particles based on density. Such latter environments take a long time to gather the microplastics, particularly, in the areas with no greater outflow or exchange. Also, the thermocline and other stratified layers will trap the contaminants by having temperature differences and restricted mixing [34].

Spatially close human activity is a significant predictor of microplastic concentrations in the water column. The microplastic loads are typically high in the waterways that are adjacent to urban settlements, industrial units, agricultural land, or wastewater treatment systems. Microplastics and other related compounds are dumped to the water column by discharging treated or untreated wastewater. In the situation of rainfall, plastic debris from streets, construction sites and farmlands are washed down by the stormwater runoff to a nearby river or lake. It is also characteristic to seasonal variability and wet seasons are a common cause of greater content of microplastic because of their increased surface runoff and erosion [33,34].

Huge biological interactions with microplastics in the water column occur. These particles are encountered and are often ingested by organisms like zooplankton, insect larvae, mollusks and young fish. Most cases are accidental with microplastics being of a similar size, color, shape, etc., to naturally occurring food sources. Consuming microplastics can either cause a sense of artificially feeling sated, intestinal obstruction, or damage to internal tissues. Also, microplastics are able to serve as carriers of chemical pollution. They will incorporate toxic chemicals like heavy metals, hydrocarbons, and wet persistent organic pollutants (POPs) that may be transmitted to organisms when ingested. Such exchanges arouse an issue of bioaccumulation and trophic transfer via aquatic food webs [40].

Microplastics in sediments

In the fresh water ecosystem, sediments can be seen as major reservoirs/ sinks of microplastics. During the degradation or disposition (suspended in the water column) of the plastic particles, lots of the particles are deposited because of the hydrodynamic forces and association of particles with organic matters and other suspended solid particles. The tendency towards the accumulation of these materials depends on the factors, including the composition of sediments, the velocity of water flow, and the density of microplastic particles. Microplastics are especially likely to settle in areas with low turbulence, such as the bed of a lake or the slow section of a river [31].

Modeling studies currently show that levels of microplastic in sediment frequently surpass levels in the overlying water (effluent) column and the effect is amplified along the mixing zone of wastewater outlets, farmlands that utilize plastic trailers and city drainage points. Morphologies of sediment-encapsulated microplastics are diverse manifesting as fibers of synthetic textiles, pieces of degraded consumer products and films of plastic packaging [35].

The environmental persistence of microplastics and possible interactions with nature is evidenced not only in the long-term immobilization in the sediments but also in the threat to human health. The worms, snails and insect larvae are benthic creatures that are constantly subjected to the sediment particles. Microplastics can be consumed directly during feeding or via contaminated detritus where these organisms have internal abrasions, decreased feed rates, and suffer energy loss. Also, microplastic ability to leach toxic additives or adsorb environmental contaminants further increases the ecological risk it poses on sediment-level life [36].

The other source of microplastic is sediments which act as the secondary sources of microplastics through floods, dredging activities, or bioturbation (disturbing and resuspending bottom layers). These microplastics that have been buried in sediments can consequently be re-exposed to water column, and continuously re-enter exposure pathways in aquatic organisms [41,42].

Microplastics in aquatic insects

Aquatic insects in freshwater habitats are key organisms in the ecology of freshwater ecosystems, as providers and consumers at several trophic levels, as well as in the nutrient cycling, transfer of energy, and the stability of food webs [37]. Aquatic insects show wide biodiversity (Table 4). Over the

Citation: Owaseye RO. The Invisible Threat: A Review of Microplastics in Freshwater Systems, Including Their Presence in Water, Sediment, and Aquatic Insects Ann Environ Sci Toxicol. 2025;9(1):030-038. Available from: https://dx.doi.org/10.17352/aest.000088

Table 4: Biodiversity of aquatic insects.

S/N	Order	Examples	Aquatic stage (excluding egg)	Feeding guilds	Water type (base on water current velocity)
1	Ephemeroptera	Mayflies	Nymphs	Herbivores	Fast flowing
2	Odonata	Dragonflies and damselflies	Nymphs	Predators	Slow flowing and stagnant
3	Plecoptera	Stoneflies	Nymphs	Shredders, scappers	Fast flowing
4	Hemiptera	Water striders, water bugs	All	Herbivores, predators	Slow flowing and stagnant
5	Trichoptera	Caddisflies	Larvae and pupae	Dentritivores	Fast flowing
6	Megaloptera	Dobsonflies	Larvae	Predators	Slow flowing
7	Coleoptera	Water beetles	All	Predators, scavengers	Slow flowing and stagnant
8	Diptera	Midges, mosquitoes	Larvae and pupae	Filter feeders	Slow flowing and stagnant

past decades, they are being studied as possible bioindicator organisms in assessing microplastic pollution due to their widespread nature, ecological importance, and direct exposure to water and sediment sections. The non-biting midge from family Chironomidae, as well as mayfly (Ephemeroptera), caddisfly (Trichoptera), and stonefly (Plecoptera) are of special interest due to the large number of individuals, and evident sensitivity to human interference [43,44].

Microplastic sources of exposure of aquatic insects are varied. The particles either can be ingested directly with the contaminants present in the water column or sediment, or may be ingested indirectly by feeding on microplastic-contaminated detritus or prey invertebrates. Empirical evidence shows that the microplastics has been found in the intestinal contents of larvae most notably those highly benthic fed larvae such as chironomids. During the feeding process such organisms have a habit of swallowing sediment particles hence the chances of getting exposed to microplastic are high. The ingested plastic can also resemble natural matter which in this case is imperfect or murky waters as organic matter as a result resulting in its ingestion [38].

Sublethal and lethal effects are the results of microplastics once in the body. Physically, the particles may cause internal abrasion, digestive blockage and food deprivation due to false sensation of satiety. Phthalates and bisphenol A (BPA) are the chemicals which are related to plastics and can interfere with endocrine and reproductive functions. Ecologically, imperfect insect survival and diminished insect fitness may cascade through the food web, to higher level organisms who depend on insects as staple foods, including fish and amphibian species.

Noteworthy, microplastic transportation also occurs via aquatic insects through predators. Transfer of trophic can cause bioaccumulation and biomagnification of plastic and their concomitant pollutants, and pose a serious ecological and human health concern, particularly in areas where freshwater food serves as a major food base [39].

Aquatic insect orders form their own significant model system to explain spatial and temporal risk of microplastic pollution. Their relative inability to move during larval periods results in them being uniquely responsive to regional concentrations of contaminants and the difference between inter-specific sensitivity can be used to indicate the existence of varying degrees of pollution stress. However, existing studies regarding the presence of microplastics in aquatic insects remain rather limited, especially in the tropical and developing world where biodiversity saturated freshwaters coincide with poorly studied ecosystems [45].

Ecological and biological impacts

Microplastics are an omnipresent pollutant whose ecological and biological consequence in freshwater ecosystems are a serious matter. Their tiny size, stability, and ability to store and carry harmful chemicals allow the microplastics to interact with organisms across trophic levels and cause a range of physiological, reproductive, and ecological imbalances. These impacts of exposure to microplastics are often externalized outside the individual taxa to persist across food webs, thus imparting the ecosystem structure and functioning [46].

The most obvious biological impact of microplastic contamination is probably ingestion. Due to the similarity of the physical attributes between microplastics and natural food such as plankton or detritus, the aquatic life usually confuses plastics as food. Observations in freshwater systems have reported with ingestion by zooplanktons, insects larvae, mollusks, fishes, and amphibians. When ingested, plastics may lead to gastrointestinal blockage, internal body injuries, and poor feeding capability hence energy loss. Overall in fish, the effects of ingestion can be seen in retarded growth, behavioral changes and higher mortality largely when the ingested plastics are either contaminated with toxic additives (e.g., bisphenol A) or have adsorbed pollutants (e.g., pesticides or heavy metals) [31].

Microplastic-related reproductive risks are also equally important. Experimental evidence shows that plastic pieces and the chemicals contained in them such as bisphenol A (BPA) and phthalates have the ability to hurt the hormonal systems of aquatic organisms. These hormone-disrupting chemicals disturb hormone messaging leading to decreased fertility, abnormal development, and biased sex ratios. In large-scale conditions, they lead to the decrease in the population and increase the sensitivity of the species with reproductive disabilities [47].

Microplastics can reorganize community structure and biodiversity, based on an ecological point of view. The sensitivity to pollution will make some species to decline or even become extinct in polluted locations; more tolerant taxa is likely to expand at the expense of the entire ecological balance. The shift in the quantity and nutritional quality of the available food resources as a result of microplastic contamination also disturbs predator-prey relationships: since invertebrates that consume microplastic may provide reduced nutrition to predators of higher trophic levels, this will affect their growth and reproduction ability [31].

Citation: Owaseye RO. The Invisible Threat: A Review of Microplastics in Freshwater Systems, Including Their Presence in Water, Sediment, and Aquatic Insects Ann Environ Sci Toxicol. 2025;9(1):030-038. Available from: https://dx.doi.org/10.17352/aest.000088

Microplastics modify physical and chemical parameters of inhabited places besides their biological consequences. They can alter porosity and oxygen availability in sediments and thus influence microbial activity and nutrient cycling. Biofilms growing on the surface of plastic are often known to harbor injurious pathogens or aggressive species, a fact that presents an emerging biological danger to freshwater ecologies [35].

The fact that microplastics are transferred cross-tropically also means that bioaccumulation and biomagnification need to be addressed. The higher the plastics go in the food system (through insects to fish to birds and mammals) the greater the likelihood of accumulation of plastic particles and other associated toxins that have adverse effects to wildlife and humans with potential harm to human health, particularly in those communities that depend on fresh water resources as drinking water and as a source of food [48].

Conclusion

Microplastics have become an omnipresent and long-term threat to the health of freshwater ecosystems, and as a result, the topic has received increasing scientific attention as it has become evident that the issue has wide-ranging ecological consequences and affects numerous species. The current review is one that reports the widespread dispersion of microplastic pollution between and among water columns, lakes, as well as biotic components of the aquatic insect community. These compartments serve both as microplastic reservoirs and as biotrophic transfer pathways that serve as a conduit to cause vertical particles transport, and consequently between trophic levels, transfer of pollution.

The presence of microplastics in macroinvertebrates also illustrates the extent of ecological disruption that this pollution has created. In addition to the effect of mechanical ingestion, aquatic organisms become subjected to the toxicity of chemicals used in plastic manufacturing as well as chemicals adsorbed on the surface of the plastics due to the ambient media. These contaminants disrupt physiology, reproduction, and development and eventually put the biodiversity as well as the integrity of fresh-water ecosystems at risk.

In spite of the recent breakthroughs made in studying microplastics, huge challenges exist. There is no standardized procedures for sampling and analysis, which impedes the ability to do comparative studies and systematic data compilation. Further, most of the studies are limited to specific areas with most of the water bodies of developing countries poorly captured. Also, the most extended effects of lifelong exposure to microplastics on the individual, population, and ecosystem are poorly characterized.

A multi-pronged approach to addressing the microplastics crisis may include policy change, waste-management improvement, educational engagement, and the devising of alternatives to regular plastics that would be environmentally sound. At the same time, the scientific research needs to extend beyond its boundaries to utilize interdisciplinary tools, which combine ecology, toxicology, chemistry, and socioeconomics to address the gaps in knowledge.

Microplastic pollution in freshwater is an urgent environmental problem that should be prompt, well-coordinated, and globally integrated. By focusing on research, strengthening policy framework and improving the awareness of people, the adverse impact of microplastics can be minimised and the biodiversity and the ecosystem services provided by freshwater systems can be preserved to ensure the prosperity of humans and the environment.

References

1. Andrady AL. The plastic in microplastics: A review. Mar Pollut Bull. 2017;119(1):12–22. Available from: https://doi.org/10.1016/j.marpolbul.2017.01.082
2. Alimi OS, Budarz JF, Hernandez LM, Tufenkji N. Microplastics and nanoplastics in aquatic environments: aggregation, deposition, and enhanced contaminant transport. Environ Sci Technol. 2017;52(4):1704–1724. Available from: https://doi.org/10.1021/acs.est.7b05559
3. Bellasi A, Binda G, Pozzi A, Galafassi S, Volta P, Bettinetti R. Microplastic contamination in freshwater environments: A review, focusing on interactions with sediments and benthic organisms. Environments. 2020;7(4):30. Available from: https://doi.org/10.3390/environments7040030
4. Choy CA, Robison BH, Gagne TO, Erwin B, Firl E, Halden RU, et al. The vertical distribution and biological transport of marine microplastics across the epipelagic and mesopelagic water column. Sci Rep. 2019;9(1). Available from: https://doi.org/10.1038/s41598-019-44117-2
5. Xu S, Ma J, Ji R, Pan K, Miao A. Microplastics in aquatic environments: Occurrence, accumulation, and biological effects. Sci Total Environ. 2019;703:134699. Available from: https://doi.org/10.1016/j.scitotenv.2019.134699
6. Eerkes-Medrano D, Thompson RC, Aldridge DC. Microplastics in freshwater systems: A review of the emerging threats, identification of knowledge gaps and prioritisation of research needs. Water Res. 2015;75:63–82. Available from: https://doi.org/10.1016/j.watres.2015.02.012
7. Castro-Castellon AT, Horton AA, Hughes JM, Rampley C, Jeffers ES, Bussi G, et al. Ecotoxicity of microplastics to freshwater biota: Considering exposure and hazard across trophic levels. Sci Total Environ. 2021;816:151638. Available from: https://doi.org/10.1016/j.scitotenv.2021.151638
8. Baskar K, Gawade S. Aquatic insects and their importance in assessing ecosystem health. MOJ Ecol Environ Sci. 2021;6(4):136–137. Available from: https://doi.org/10.15406/mojes.2021.06.00226
9. Li C, Busquets R, Campos LC. Assessment of microplastics in freshwater systems: A review. Sci Total Environ. 2019;707:135578. Available from: https://doi.org/10.1016/j.scitotenv.2019.135578
10. Rezania S, Park J, Din MFM, Taib SM, Talaiekhozani A, Yadav KK, et al. Microplastics pollution in different aquatic environments and biota: A review of recent studies. Mar Pollut Bull. 2018;133:191–208. Available from: https://doi.org/10.1016/j.marpolbul.2018.05.022
11. Prata JC, Silva C, Serpa D, Soares AM, Gravato C, Silva ALP. Mechanisms influencing the impact of microplastics on freshwater benthic invertebrates: uptake dynamics and adverse effects on Chironomus riparius. SSRN Electron J. 2022. Available from: https://doi.org/10.2139/ssrn.4223058
12. Khedre AM, Ramadan SA, Ashry A, Alaraby M. Assessment of microplastic accumulation in aquatic insects of different feeding guilds collected from wastewater in Sohag Governorate, Egypt. Mar Freshw Res. 2023;74(8):733–745. Available from: https://doi.org/10.1071/mf22257

Citation: Owaseye RO. The Invisible Threat: A Review of Microplastics in Freshwater Systems, Including Their Presence in Water, Sediment, and Aquatic Insects Ann Environ Sci Toxicol. 2025;9(1):030-038. Available from: https://dx.doi.org/10.17352/aest.000088

13. Ramola GC, Rawat N, Singh R, Sajwan AS, Sahu L, Rawat P. Insects as ecological indicators: A review. Int J Environ Climate Change. 2024;14(12):260–279. Available from: https://doi.org/10.9734/ijecc/2024/v14i124623

14. Ehlers S, Manz W, Koop J. Microplastics of different characteristics are incorporated into the larval cases of the freshwater caddisfly Lepidostoma basale. Aquat Biol. 2019;28:67–77. Available from: https://doi.org/10.3354/ab00711

15. Akanyange SN, Zhang Y, Zhao X, Adom-Asamoah G, Ature AA, Anning C, et al. A holistic assessment of microplastic ubiquitousness: Pathway for source identification in the environment. Sustain Prod Consum. 2022;33:113–145. Available from: https://doi.org/10.1016/j.spc.2022.06.020

16. Brehm J, Wilde MV, Reiche L, Leitner L, Petran B, Meinhart M, et al. In-depth characterization revealed polymer type and chemical content specific effects of microplastic on Dreissena bugensis. J Hazard Mater. 2022;437:129351. Available from: https://doi.org/10.1016/j.jhazmat.2022.129351

17. Chen H, Huang D, Zhou W, Deng R, Yin L, Xiao R, et al. Hotspots lurking underwater: Insights into the contamination characteristics, environmental fates and impacts on biogeochemical cycling of microplastics in freshwater sediments. J Hazard Mater. 2024;476:135132. Available from: https://doi.org/10.1016/j.jhazmat.2024.135132

18. Fries E, Dekiff JH, Willmeyer J, Nuelle M, Ebert M, Remy D. Identification of polymer types and additives in marine microplastic particles using pyrolysis-GC/MS and scanning electron microscopy. Environ Sci Process Impacts. 2013;15(10):1949. Available from: https://doi.org/10.1039/c3em00214d

19. Hale RC, Seeley ME, La Guardia MJ, Mai L, Zeng EY. A global perspective on microplastics. J Geophys Res Oceans. 2020;125(1). Available from: https://doi.org/10.1029/2018jc014719

20. Elizalde-Velázquez GA, Gómez-Oliván LM. Microplastics in aquatic environments: A review on occurrence, distribution, toxic effects, and implications for human health. Sci Total Environ. 2021;780:146551. Available from: https://doi.org/10.1016/j.scitotenv.2021.146551

21. Hayes A, Kirkbride KP, Leterme SC. Variation in polymer types and abundance of microplastics from two rivers and beaches in Adelaide, South Australia. Mar Pollut Bull. 2021;172:112842. Available from: https://doi.org/10.1016/j.marpolbul.2021.112842

22. Klein S, Dimzon IK, Eubeler J, Knepper TP. Analysis, occurrence, and degradation of microplastics in the aqueous environment. In: The Handbook of Environmental Chemistry. 2017:51–67. Available from: https://doi.org/10.1007/978-3-319-61615-5_3

23. Rochman CM. Microplastics research—from sink to source. Science. 2018;360(6384):28–29. Available from: https://doi.org/10.1126/science.aar7734

24. Thompson RC. Microplastics in the marine environment: sources, consequences and solutions. In: Springer eBooks. 2015:185–200. Available from: https://doi.org/10.1007/978-3-319-16510-3_7

25. Varsha, Singh SK. Microplastics in freshwater ecosystems: sources, transport and ecotoxicological impacts on aquatic life and human health. Environ Ecol. 2025;43(1A):289–295. Available from: https://doi.org/10.60151/envec/devo7788

26. Yang L, Zhang Y, Kang S, Wang Z, Wu C. Microplastics in freshwater sediment: A review on methods, occurrence, and sources. Sci Total Environ. 2020;754:141948. Available from: https://doi.org/10.1016/j.scitotenv.2020.141948

27. Wang Y, Zhou B, Chen H, Yuan R, Wang F. Distribution, biological effects and biofilms of microplastics in freshwater systems – A review. Chemosphere. 2022;299:134370. Available from: https://doi.org/10.1016/j.chemosphere.2022.134370

28. Tekman MB, Wekerle C, Lorenz C, Primpke S, Hasemann C, Gerdts G, Bergmann M. Tying up loose ends of microplastic pollution in the Arctic: Distribution from the sea surface through the water column to deep-sea sediments at the HAUSGARTEN Observatory. Environ Sci Technol. 2020;54(7):4079–4090. Available from: https://doi.org/10.1021/acs.est.9b06981

29. Yano K, Reyes N, Geronimo F, Jeon, Kim Y, Kim L. A comprehensive review of microplastics: Sources, pathways, and implications. J Wetl Res. 2020;22(2):153–160. Available from: https://doi.org/10.17663/jwr.2020.22.2.153

30. Khamboonruang P, Prommi T. Using aquatic insects as indicators of microplastic pollution in rice field ecosystems. Ecol Montenegrina. 2024;80:106–127. Available from: https://doi.org/10.37828/em.2024.80.10

31. Idowu GA, Oriji AY, Olorunfemi KO, Sunday MO, Sogbanmu TO, Bodunwa OK, et al. Why Nigeria should ban single-use plastics: Excessive microplastic pollution of the water, sediments and fish species in Osun River, Nigeria. J Hazard Mater Adv. 2024;13:100409. Available from: https://doi.org/10.1016/j.hazadv.2024.100409

32. Ebere CE, Wirnkor VA, Verla EV, Ihenetu SC. Macrodebris and microplastics pollution in Nigeria: first report on abundance, distribution and composition. Environ Anal Health Toxicol. 2019;34(4):e2019012. Available from: https://doi.org/10.5620/eaht.e2019012

33. Aliyu AO, Okunola OJ, Awe FE, Musa AA. Assessment of microplastics contamination in river water, bottled water, sachet water and branded table salt samples in Kaduna Metropolis, Nigeria. J Appl Sci Environ Manag. 2023;27(6):1105–1118. Available from: https://doi.org/10.4314/jasem.v27i6.8

34. Zhao H, Li P, He X, Ning J. Microplastics pollution and risk assessment in selected surface waters of the Wei River Plain, China. Expos Health. 2022. Available from: https://link.springer.com/article/10.1007/s12403-022-00522-z

35. He B, Goonetilleke A, Ayoko GA, Rintoul L. Abundance, distribution patterns, and identification of microplastics in Brisbane River sediments, Australia. Sci Total Environ. 2020;700:134467. Available from: https://doi.org/10.1016/j.scitotenv.2019.134467

36. Huang D, Li X, Ouyang Z, Zhao X, Wu R, Zhang C, et al. The occurrence and abundance of microplastics in surface water and sediment of the West River downstream, in the South of China. Sci Total Environ. 2021;756:143857. Available from: https://doi.org/10.1016/j.scitotenv.2020.143857

37. Maneechan W, Prommi TO. Occurrence of microplastics in edible aquatic insect Pantala sp. (Odonata: Libellulidae) from rice fields. PeerJ. 2022;10:e12902. Available from: https://doi.org/10.7717/peerj.12902

38. Akindele EO, Ehlers SM, Koop JHE. Freshwater insects of different feeding guilds ingest microplastics in two Gulf of Guinea tributaries in Nigeria. Environ Sci Pollut Res. 2020;27(26):33373–33379. Available from: https://doi.org/10.1007/s11356-020-08763-8

39. Ehlers S, Manz W, Koop J. Microplastics of different characteristics are incorporated into the larval cases of the freshwater caddisfly Lepidostoma basale. Aquat Biol. 2019;28:67–77. Available from: https://doi.org/10.3354/ab00711

40. Erni-Cassola G, Dolf R, Burkhardt-Holm P. Microplastics in the water column of the Rhine River near Basel: 22 months of sampling. Environ Sci Technol. 2024;58(12):5491–5499. Available from: https://doi.org/10.1021/acs.est.3c08364

41. Dai Z, Zhang H, Zhou Q, Tian Y, Chen T, Tu C, et al. Occurrence of microplastics in the water column and sediment in an inland sea affected by intensive anthropogenic activities. Environ Pollut. 2018;242:1557–1565. Available from: https://doi.org/10.1016/j.envpol.2018.07.131

Citation: Owaseye RO. The Invisible Threat: A Review of Microplastics in Freshwater Systems, Including Their Presence in Water, Sediment, and Aquatic Insects Ann Environ Sci Toxicol. 2025;9(1):030-038. Available from: https://dx.doi.org/10.17352/aest.000088

42. Sajad S, Allam BK, Mushtaq Z, Banerjee S. Microplastic detection and analysis from water and sediment: A review. Macromol Symp. 2023;407(1). Available from: https://doi.org/10.1002/masy.202100367

43. Owaseye RO, Aliyu B, Adu BW. Aquatic insects biodiversity and water quality assessment of Ala Stream located in Roadblock, Akure, Ondo State, Nigeria. Asian J Biol Sci. 2025;18(3):625–632. Available from: https://doi.org/10.3923/ajbs.2025.625.632

44. Adeleke S, Amusan B. Aquatic insects diversity and water quality of a tropical freshwater in Federal University of Education, Ondo, Nigeria. Niger J Entomol. 2024;40(1):126–137. Available from: https://doi.org/10.36108/nje/4202/04.0111

45. Zain NM, Fauzi N, Subki NS, Ghazali ZZ. Occurrence of microplastics in immature aquatic insects of Gua Musang tributaries in Kelantan. IOP Conf Ser Earth Environ Sci. 2022;1102(1):012047. Available from: https://doi.org/10.1088/1755-1315/1102/1/012047

46. Scherer C, Brennholt N, Reifferscheid G, Wagner M. Feeding type and development drive the ingestion of microplastics by freshwater invertebrates. Sci Rep. 2017;7(1). Available from: https://doi.org/10.1038/s41598-017-17191-7

47. Jin M, Liu J, Yu J, Zhou Q, Wu W, Fu L, et al. Current development and future challenges in microplastic detection techniques: A bibliometrics-based analysis and review. Sci Prog. 2022;105(4):003685042211321. Available from: https://doi.org/10.1177/00368504221132151

48. Lambert S, Wagner M. Microplastics are contaminants of emerging concern in freshwater environments: An overview. In: The Handbook of Environmental Chemistry. 2017:1–23. Available from: https://doi.org/10.1007/978-3-319-61615-5_1

Citation: Owaseye RO. The Invisible Threat: A Review of Microplastics in Freshwater Systems, Including Their Presence in Water, Sediment, and Aquatic Insects Ann Environ Sci Toxicol. 2025;9(1):030-038. Available from: https://dx.doi.org/10.17352/aest.000088