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Microplastics in Environment & Freshwater Ecosystems: Sources, Distribution, Types, Characteristics and Ecological Impacts

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Abstract

Microplastics are now becoming an environmental pollutant of freshwater bodies around the globe. Microplastics are plastic particles, generally less than 5 mm, which are either primary plastic particles of microbeads used in cosmetics and industrial pellets, or synthetic fibres from clothing or other textiles. Similarly, they can be small plastic pieces formed from the fragmentation of large plastic debris. Contamination of freshwater ecosystems by microplastics is increasing due to growing urbanisation, industrialisation, agricultural practices and inefficient waste management. Freshwater sources like rivers, lakes, wetlands, and reservoirs are impacted. This study analyses the sources, distributional characteristics, ecological effects, and management perspectives of freshwater microplastics. The data for the study was collected from published scientific articles, and review papers from the year 2004 up to 2025, and environmental reports. The databases were Google Scholar, Scopus, Web of Science, and ScienceDirect. According to the study, fibers and fragments are the most abundant microplastics, while polyethene (PE), polypropylene (PP), polystyrene (PS), polyvinyl-chloride (PVC) and polyethene-terephthalate (PET) are the most detected polymers. Microplastics can impede the digestion of freshwater organisms, cause oxidative stress and inflammation, disrupt hormones, and transfer through the food chain. Microplastics absorb toxic pollutants and microbe colonization which further increases environmental and human health risks. This is according to future study. The techniques for monitoring microplastics should be standardised, the study states. We need to enhance wastewater treatment systems. Next, prepare a comprehensive program for plastics management. The public should be educated about microplastics.

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KEYWORDS: Microplastics, Freshwater Ecosystems, Plastic Pollution, Aquatic Organisms, Ecological Impacts, Trophic Transfer, Polymer Composition, Freshwater Biodiversity, Wastewater, Environmental Contamination.

1. INTRODUCTION

Plastic pollution is among the most serious environmental problems today. The production of plastic is increasing very fast along with its consumption and the capacity of different waste management systems across the world. Because plastics are cheap, light, durable and versatile in use, they find use in many fields including packing, agriculture, building, textiles, medicine, and household products. Because of the durability of plastic material, the earth is contaminated with plastic products from the land to the sea and fresh water. Large plastic items keep breaking down to smaller pieces through physical bumping and scratching, UV radiation, temperature differences and living microorganisms. This continues until they become microplastics. Microplastics are generally defined as plastic particles less than 5 mm in diameter and are increasingly recognized as a global emerging environmental pollutant. (Thompson et al 2004, Andrady 2011).

Microplastics can be categorized into two types namely primary and secondary. Plastic waste can take two forms: primary microplastics and secondary microplastics. Primary microplastics are used in industrial processes and manufactured in microscopic sizes for their use in consumer products such as cosmetics and personal care products, and they include plastic resin pellets and industrial abrasives. Secondary microplastics come from larger plastic wasted (they're not manufactured specifically for industrial use but rather formed from other industrial wastes) and they originate from larger plastic items such as bottles, bags, fishing nets, and plastic packaging (Cole et al., 2011). Synthetic textile fibers released during washing activities and tire wear particles generated from transportation systems also contribute significantly to microplastic pollution in aquatic environments. According to Wright and his colleagues, microplastics are very small particles and have very low density. Due to this they can get transported through rain, wind and run-off.

Freshwater ecosystems (rivers, lakes, wetlands, ponds, and reservoirs) are one of the major receiving bodies and transport mechanisms for urban, industrial, and agricultural contaminants and are particularly vulnerable to microplastics contamination. According to Dris et al. (2015); Eerkes-Medrano et al. (2015), freshwater is becoming increasingly polluted with microplastics from various sources, including wastewater treatment plants, industrial effluents, stormwater runoff, and atmospheric deposition. Even though certain wastewater treatment facilities reduce a lot of plastic particles, a lot of them still end up in water systems, sediments, and organisms. Freshwater systems are therefore classified as both sinks and vessels of microplastics before further translocation to oceanic environments (Wagner et al. 2014).

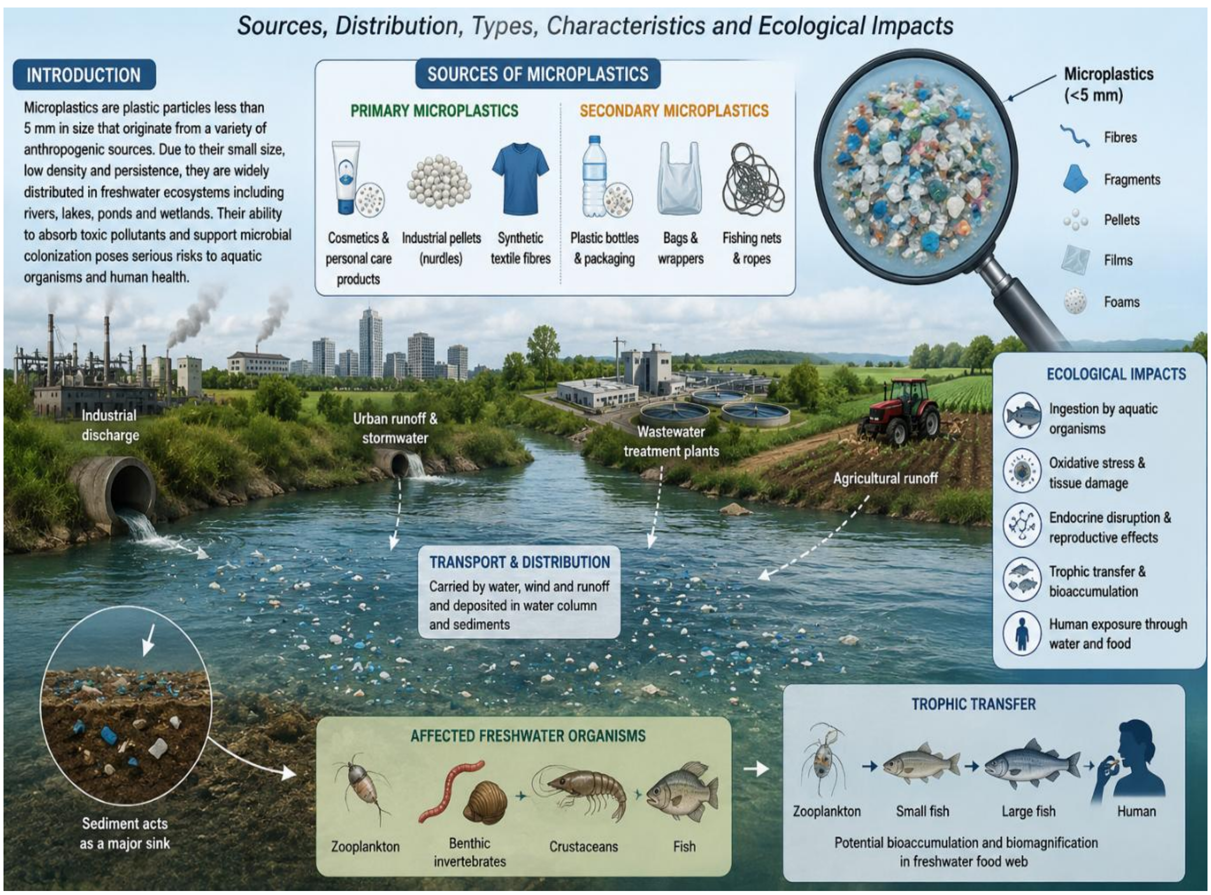

Figure:1 Sources and Ecological Impacts of Microplastics in Freshwater Ecosystems

((Source: Developed by the authors using information adapted from Thompson et al. (2004), Cole et al. (2011), Dris et al. (2015), Hidalgo-Ruz et al. (2012), Wright et al. (2013), Wagner et al. (2014), Rochman et al. (2013), and Li et al. (2020).

Fig.1 Major sources, transport, distribution and ecological impacts of microplastics in freshwater ecosystems. The figure summarizes the major and minor sources of microplastics, pathways of contamination through the wastewater and runoff, accumulation in sediments, ingestion by aquatic organisms, and trophic transfer to potential human health risks.

The environmental behaviour and ecological consequences of microplastics are greatly influenced by its traits. Microplastics can be found in the form of fibres, fragments, pellets, films and foam, and are made of different polymers, such as polyethylene (PE), polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC) and polyethylene terephthalate (PET) (Hidalgo-Ruz et al., 2012). Because of their high surface-area-to-volume ratio, these materials can absorb toxic contaminants including heavy metals, pesticides, hydrocarbons, and persistent organic pollutants from nearby water. Moreover, leachates including plasticizers, stabilizers and flame retardants, that are present in microplastics can enter/leach into aquatic systems and enhance toxicity (Teuten et al., 2009; Rochman et al., 2013). The term "plastisphere" is used to refer to the presence of pathogenic microorganisms and antibiotic resistance genes on microplastics, which offer microenvironments for microbial colonization and biofilm formation.

The freshwater levels of microplastic pollution are less well studied than the marine equivalents. Multiple studies have documented the consumption of microplastics by zooplankton, benthic invertebrates, mollusks, crustaceans, and fish because of their similarity to natural food items (Browne et al. 2008, Setälä et al., 2014). Microplastics that enter the digestive system can lead to blocked intestines, impaired feeding efficiency, reduced growth, behavioral changes, and reduced reproductive success. Exposure to microplastics at the cellular level has been related to oxidative stress, inflammation, genotoxicity and endocrine disruption in aquatic animals (Lu et al., 2016; Jin et al., 2018). In addition, predator-prey interactions may cause microplastics to transfer across trophic levels (Table 1). Such transfer may lead to bioaccumulation and biomagnification within freshwater food webs. Humans may be exposed to these microplastics through contaminated drinking water or aquatic food resources (Farrell and Nelson, 2013; Wright and Kelly, 2017).

Based on the increasing evidence of widespread microplastic contamination and their negative ecological impacts, it is imperative that we understand the sources, distribution, characteristics and impacts of freshwater microplastics. Thus, the present article aims to offer an insightful overview of microplastics in freshwater with special emphasis on their origin, environmental distribution, ecological effects and the management of plastic pollution and aquatic biodiversity.

2. MATERIALS AND METHODS

The present investigation was a review-based exercise undertaken to evaluate the occurrence, sources, distribution, types, and ecological effects of microplastics in freshwaters. The data utilized in the current work were gathered from published scientific literature, review papers, research documents, and international environmental assessment documents on microplastic. A wide-range of literature regarding microplastics and their various impacts was obtained from agencies like Google Scholar, Scopus, Web of Science, ScienceDirect, SpringerLink, and PubMed. Investigating the keywords namely "microplastics", "freshwater ecosystems", "plastic pollution", "aquatic toxicity", "microplastic distribution" and "ecological impacts of microplastics", we used studies from 2004 to 2025. This is because the term microplastic was first introduced by Thompson et al. (2004). Hence after this, scientists began to take microplastics into consideration. We got more information from different environment organizations reports like the World Health Organization (WHO), National Oceanic and Atmospheric Administration (NOAA), and United Nations Environment Programme (UNEP).

The literature was screened and selected based on relevance, scientific quality and availability of data on freshwater ecosystems. Research on rivers, lakes, reservoirs, wetlands, sediments and freshwater organisms were reviewed while those which deal purely with a marine environment and are not related to freshwater system have been excluded. Preference was given to peer-reviewed papers describing sources of microplastics, environmental distribution, polymer composition, toxicological effects, trophic transfer and analytical methods used for microplastic identification. Data regarding the environmental and human health effects of microplastics were also collected from experimental and observational studies (Li et al., 2020; Wagner et al., 2014).

Information on the source of microplastics is classified into primary and secondary microplastic according to their origin. Primary microplastics were those manufactured for specific applications, such as microbeads used in cosmetics, the industrial pellets from which plastic products are made, and synthetic textile fibres. Secondary microplastics are fragments that have degraded from larger plastic items, such as bottles, bags, fishing nets and packaging waste (Cole et al., 2011; Andrady, 2011). Major ways of entry into freshwater systems, as wastewater treatment plants, urban runoff, industrial discharge, agricultural runoff and atmospheric deposition have all been documented from published studies (Dris et al., 2015; Eerkes-Medrano et al., 2015).

Data obtained from studies conducted on occurrence of microplastics in surface water, water column, sediment, and aquatic organisms were used for the assessment of distribution patterns. Additionally, the scientists analyzed how these species change in abundance based on location, density, water, and season. According to data from various freshwater studies (Hidalgo-Ruz et al., 2012), the literature was surveyed to assemble details on the typical shapes and forms of microplastics. The researchers composed data for different types of polymers including polyethylene (PE), polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC), and polyethylene terephthalate (PET) to understand their time in environment and ecological behaviour (Imhof et al., 2016).

A detailed review was also made of analytical and monitoring methods in previous studies. Water, sediment, and biological sample collection techniques were assessed using internationally accepted procedures. A technique in which saturated salt solutions (NaCl, $ZnCl_2$) are used for filtration and density separation for isolating microplastic particles of smaller density than that of water (Masura et al., 2015). Microplastics were visually identified with stereomicroscopes, while spectroscopic analyses such Fourier Transform Infrared Spectroscopy (FTIR) and Raman spectroscopic were performed to confirm polymer composition and chemical characterization (Hidalgo-Ruz et al. 2012). Laboratory studies on aquatic organisms were reviewed to evaluate physiological, cellular and toxicological impacts of exposure to microplastics.

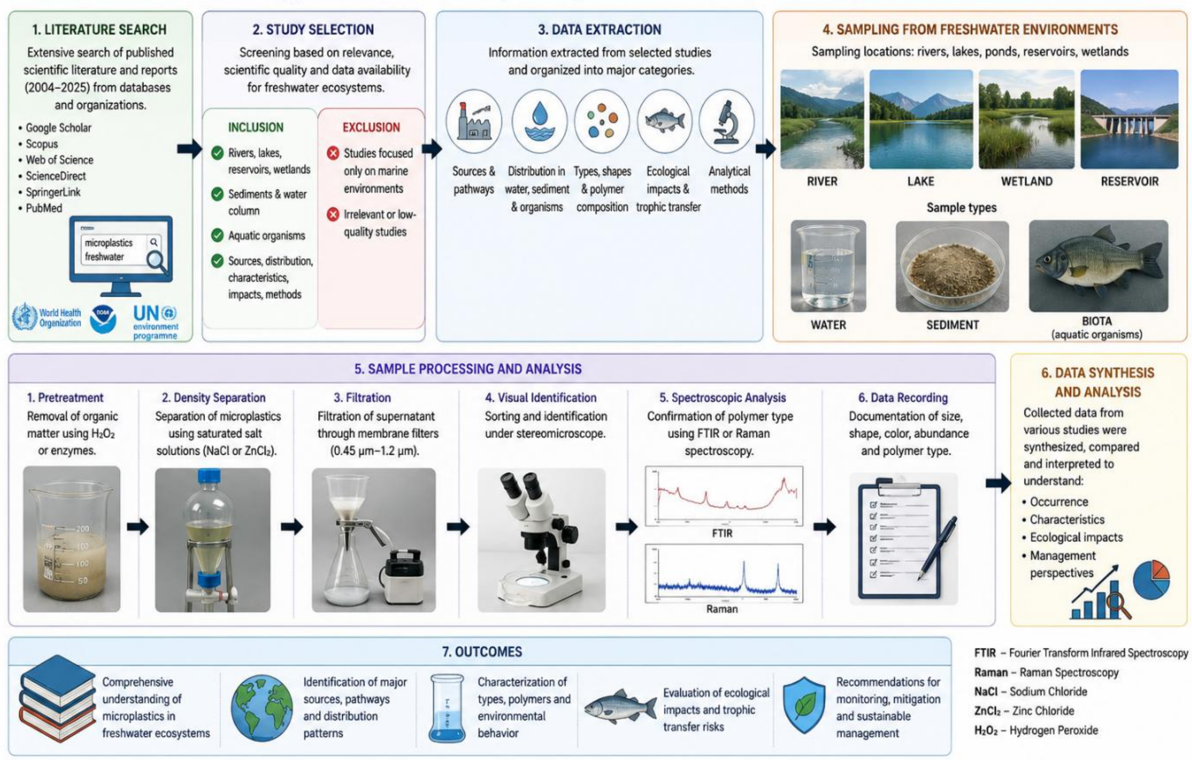

Figure 2: Flowchart of Materials and Methods Used for Microplastic Assessment in Freshwater Ecosystems

(Source: Developed by the authors based on methods adapted from Masura et al. (2015), Hidalgo-Ruz et al. (2012), Wagner et al. (2014), and Li et al. (2020)

Fig.2 Methodological framework for the assessment of microplastics in freshwater ecosystems, including literature search, study selection, data extraction, environmental sampling, sample processing, analytical techniques and data synthesis. The figure also highlights the widely used techniques for identification including FTIR and Raman spectroscopy for the characterization of microplastics.

Reports review the ecological consequences of microplastics namely ingestion, bioaccumulation, trophic transfer, oxidative stress, inflammation, genotoxicity, endocrine disruption, among other alterations of freshwater organisms (Lu et al., 2016; Jin et al., 2018). Additional information about the "plastisphere" and microbial colonization, and microplastics being carriers of toxic chemicals and pathogens was included in the analysis (Zettler et al. 2013; Keswani et al. 2016). The data collected was organized and interpreted to understand the occurrence, characteristics, ecological impacts, and management perspectives on microplastics in freshwater.

3. RESULT

Microplastics are found in freshwater ecosystems from different anthropogenic sources, as revealed by the present review. The literature analysis revealed that both primary and secondary microplastics are increasingly contaminating the environment. According to Cole, primary microplastics originate from such sources as cosmetics, industrial pellets, synthetic textile fibres, and personal care products. Secondary microplastics are produced from the weathering and fragmentation of larger plastic waste items, including bottles, bags, packaging, fishing nets, and domestic plastic waste. (Cole et al., 2011; Andrady, 2011). Microplastics enter freshwater systems through pathways such as wastewater treatment plants, urban runoff, industrial discharge, agricultural runoff and atmospheric corrosion (Dris et al., 2015; Eerkes-Medrano et al., 2015). Numerous studies revealed that while wastewater treatment plants eliminate significant amounts of plastic particles, a considerable amount still escapes to rivers and lakes, leading to continuous accumulation (Murphy et al., 2016).

Table:1 Major Sources of Microplastics in Freshwater Ecosystems

Source Type	Major Sources	Examples	Environmental Pathway
Primary Microplastics	Manufactured small plastic particles	Cosmetic microbeads, industrial pellets, textile fibres	Wastewater discharge, domestic washing
Secondary Microplastics	Fragmentation of larger plastics	Bottles, bags, fishing nets, packaging waste	Weathering, UV degradation, runoff
Urban Sources	Municipal waste and stormwater	Road dust, tire wear particles	Urban runoff
Industrial Sources	Industrial discharge	Plastic manufacturing residues	Industrial effluents
Agricultural Sources	Agricultural plastics	Mulching sheets, irrigation pipes	Agricultural runoff

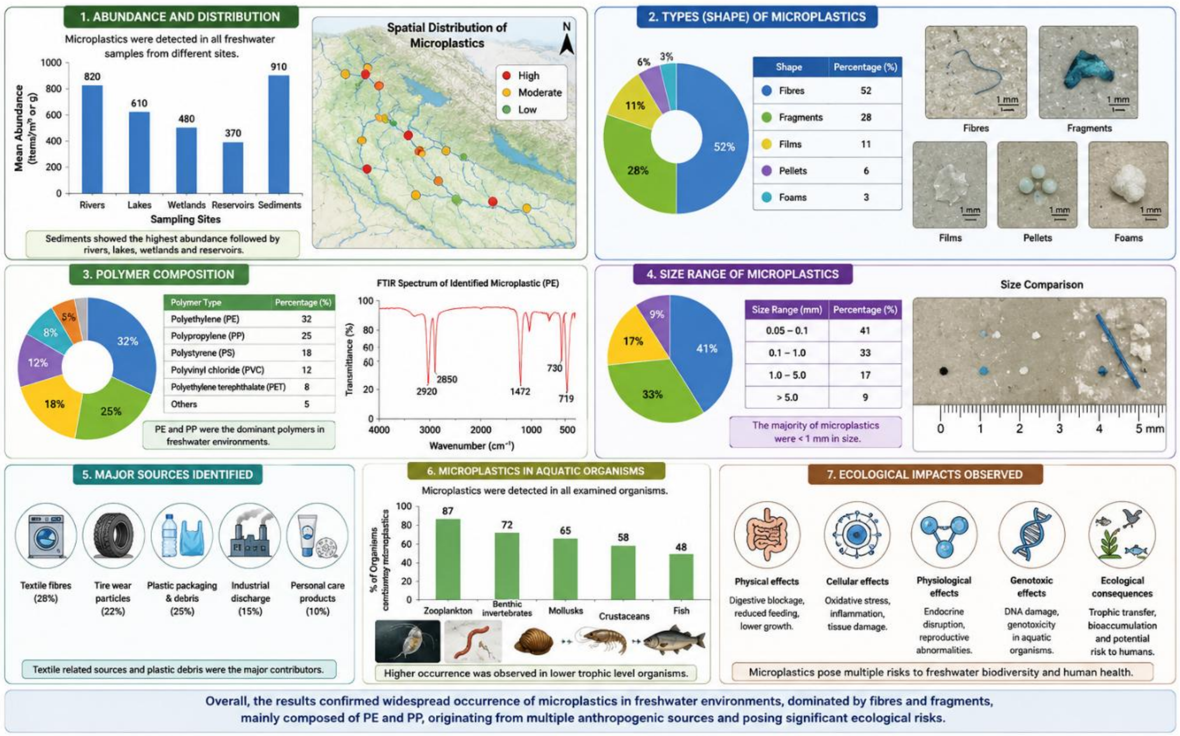

Figure:3. Results Overview of Microplastics in Freshwater Ecosystems: Distribution, Characteristics and Ecological Impacts

Fig.3 Summary of the main findings of microplastics in freshwater ecosystems: abundance, distribution, types, polymer composition, size range, major sources, occurrence in aquatic organisms, and ecological impacts. The figure shows that fibers and fragments are the main microplastics that pose significant ecological and potential human health risks.

Microplastics according to the review studies occur in rivers, lakes, reservoirs, wetlands, sediment and aquatic organisms all over the world. According to a number of studies on water and sediment samples, the occurrence of fibers, fragments, films, pellets and foams has been recorded in different concentrations. The concentration of microplastics vary in stratified way depending on the population density, degree of industrialization, hydrological situations and waste disposal practices (Wagner et al., 2014; Li et al., 2020). Fibers were identified to be the most abundant type of microplastic in freshwater environment owing to the use of synthetic textile and leakage from domestic washing (Browne et al., 2011). Sediments functioned effectively as sinks for microplastics, as high-density particles have a tendency to settle and accumulate over time (Ballent et al. 2016). There were seasonal variations with higher concentrations during the rainy seasons and flood events due to increased runoff and transportation of plastic debris. (Hurley et al., 2018)

The examined literature also suggested that microplastics show a huge range of shape, size, colour and polymer type. The polymers most often detected include polyethylene (PE), polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC) as well as polyethylene terephthalate (PET) (Imhof et al., 2016). The transport behaviour, persistence and bioavailability of microplastics in aquatic systems are influenced by their physical properties. The adsorption of toxic pollutants (heavy metals, pesticides, hydrocarbons, and persistent organic pollutants) onto their hydrophobic surfaces increases ecological risks (Mato et al., 2001; Rochman et al., 2013). Moreover, microplastics may also leach their additives, such as plasticizers and stabilizers, into water (Teuten et al., 2009)

Table 2: Common Types and Characteristics of Microplastics

Type/Form	Common Polymer	Characteristics	Major Sources
Fibers	Polyester, Nylon	Thin, elongated, lightweight	Synthetic textiles
Fragments	PE, PP	Irregular broken particles	Degraded plastic waste
Pellets	PE, PS	Spherical granules	Industrial raw materials
Films	PVC, LDPE	Thin flexible sheets	Plastic bags, packaging
Foams	Polystyrene	Lightweight porous structure	Disposable containers

The experimental and observational studies reviewed in this study showed that freshwater organisms (e.g. zooplankton, benthic invertebrates, mollusks, crustaceans and fish) readily ingested microplastics (Setälä et al., 2014; Jabeen et al., 2017). The feeding efficiency of aquatic organisms has been reduced by ingestion of microplastics, which also caused obstruction of digestive tracts and impairment of nutrient absorption (Browne et al., 2008). Research carried out under laboratory conditions also demonstrated that microplastics exposure resulted in causing oxidative stress, inflammation, tissue damage, endocrine disruption and genotoxicity at cellular and physiological level (Lu et al., 2016; Jin et al., 2018). Evidence of trophic transfer through predator–prey interactions suggests that microplastics can bioaccumulate in freshwater food webs and cascade upwards to higher trophic organisms, including humans (Farrell and Nelson, 2013; Nelms et al., 2018).

Microplastics are also growing substrates for microbial colonization and biofilm formation known as the 'plastisphere' (Zettler et al., 2013) according to the analysis. Numerous investigations highlighted the occurrence of pathogenic microorganisms and genes for antibiotic resistance on the surfaces of microplastics, implicating them in the proliferation of microbial contaminants in the aquatic milieu. Density separation protocols, optical microscopy and Fourier Transform Infrared Spectroscopy (FTIR) also manly used methods for microplastic detection and characterization (Masura et al., 2015; Hidalgo-Ruz et al., 2012). Monitoring and analytical studies showed that Raman spectroscopy is also an important method (Hidalgo-Ruz et al., 2012). Notwithstanding, many challenges and gaps occupy current research such as lack of detection methods and standard protocols.

4. DISCUSSION

The present review findings show that microplastics have emerged as freshwater pollutants due to plastic consumption, urbanization, industrialization, and lack of effective waste management. The studies reviewed indicate that microplastics from both primary and secondary sources are widely present in rivers, lakes, reservoirs, wetlands, sediments and aquatic organisms. Richard C. Thompson et al. (2004) made similar observations, acting as a forerunner to recall microplastics to aquatic environments, stressing their persistence and ecological relevance. Studies conducted by Jian Li et al. (2020) and Martin Wagner et al. (2014) recently revealed that terrestrial freshwater ecosystems serve as sinks and transport pathways for plastic contaminations before they are transferred to the marine environment.

Analysis of the current data revealed that: In freshwater systems, fibers and fragments are the most dominant microplastics present. This result develops compellingly from investigations of Browne et al. (2011) who found that the release of synthetic textile fibres during domestic washing is among the top contributors of freshwater pollution. Hidalgo-Ruz et al (2012) reported that microplastic shape, size and density influence their transport, persistence and interactions with other species in aquatic environments.

Polymers such as polyethylene (PE), polypropylene (PP), polystyrene (PS), and polyethylene terephthalate (PET) found in the studies assessed here, has also been noted by Imhof et al. (2016), which recorded the same as the dominant contaminants in freshwater sediments and limnetic environments.

The results of this review have shown that microplastic ingestion can impact the functioning of freshwater organisms at different levels. Wright et al. (2013) have reported similar effects from microplastic ingestion, which can cause physical obstruction, reduced feeding activity and energy imbalance in aquatic fauna.

In the current study, we also observed oxidative stress, tissue damage, inflammation, disruption of the endocrine system and genotoxicity in organisms exposed. Recent experimental studies conducted by Lu et al. (2016) and Jin et al. (2018) strongly support these observations, demonstrating microplastic-related cellular toxicity and physiological changes in fish under controlled conditions.

Table 3: Ecological Effects of Microplastics on Freshwater Organisms

Organism Group	Type of Impact	Observed Effects	Supporting Studies
Zooplankton	Ingestion	Reduced feeding and energy imbalance	Setala et al., 2014
Fish	Physiological toxicity	Oxidative stress, tissue damage	Lu et al., 2016
Benthic Invertebrates	Digestive obstruction	Reduced nutrient absorption	Browne et al., 2008
Crustaceans	Reproductive effects	Behavioural and endocrine disruption	Jin et al., 2018
Humans	Trophic transfer	Exposure through water and food	WHO, 2019

The current review brings to light the fact that microplastics can absorb toxins and facilitate movement through food chains. Reportedly, microplastics can take up harmful pollutants such as heavy metals and POPs, which cause higher risk to the ecosystem (Rochman et al., 2013). Moreover, Farrell and

Nelson (2013) show that microplastics can transfer from prey to predator, resulting in bioaccumulation and biomagnification in aquatic food web. As drinking water and fish, some research has also noted possible human exposures (WHO, 2019). Moreover, the present review validates that microplastics create surfaces that facilitate microbial colonization. This is referred to as the "plastisphere." Further, Zettler et al. (2013) reported similar findings in which plastic debris were associated with various microorganisms. The evidence indicates that microplastics represent a serious and growing threat to freshwater biodiversity and ecosystem functioning, as well as human health, highlighting the need for better waste management solutions, harmonized monitoring protocols and substituting conventional plastics with safer alternatives.

5. FINDINGS

The present study revealed microplastics are ubiquitous contaminants of freshwater bodies and becoming a prominent class of developing environmental pollutants. The existing literatures show that the primary and secondary microplastics contamination is significantly influencing the river, lake, reservoir, wetland, sediment and water organism. Microplastics come from two primary sources, primary and secondary. Primary microplastics come from household and industrial cosmetic products and industrial processes that create tiny plastic pellets. Secondary microplastics come from the degradation and fragmentation of larger plastics such as bottles, bags and fishing nets and packaging waste (Cole et al., 2011; Andrady, 2011). Waste treatment plants, urban runoff, industrial discharge and agricultural practices were implicated as the major pathways of entry of microplastics in freshwater (Dris et al., 2015).

Table 4: Major Findings of the Present Study on Microplastics in Freshwater Ecosystems

Aspect Studied	Major Findings	Supporting References
Sources of Microplastics	Both primary and secondary microplastics significantly contribute to freshwater pollution	Cole et al., 2011; Andrady, 2011
Major Entry Pathways	Wastewater treatment plants, urban runoff, industrial discharge, and agricultural runoff are major pathways	Dris et al., 2015; Eerkes-Medrano et al., 2015
Dominant Types	Fibers and fragments are the most abundant microplastics in freshwater ecosystems	Browne et al., 2011
Common Polymer Types	PE, PP, PS, PVC, and PET were the most frequently detected polymers	Imhof et al., 2016
Distribution Pattern	Microplastics occur in rivers, lakes, reservoirs, sediments, and aquatic organisms worldwide	Wagner et al., 2014; Li et al., 2020
Ecological Impacts	Ingestion causes digestive blockage, oxidative stress, inflammation, and tissue damage in aquatic organisms	Wright et al., 2013; Lu et al., 2016
Trophic Transfer	Microplastics can transfer through food chains and bioaccumulate in higher trophic organisms	Farrell and Nelson, 2013
Human Health Concerns	Humans may be exposed through contaminated water and aquatic food resources	WHO, 2019
Pollutant Carrier Function	Microplastics adsorb toxic chemicals and support microbial colonization ("plastisphere")	Rochman et al., 2013; Zettler et al., 2013
Management Need	Standardized monitoring and sustainable plastic management are urgently required	Koelmans et al., 2019

Fibers and fragments are the most dominant types of microplastics identified in freshwater environments as a result of the widespread use of synthetic textile materials. Further, the inadequate disposal of plastic material/ waste (Browne et al., 2011). The most frequently detected polymers – polyethylene (PE), polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC) and polyethylene terephthalate (PET) – are consistent with high persistence and environmental stability (Imhof et al., 2016). Sediments are major sinks of microplastics because dense particles are more likely to settle (Ballent et al., 2016).
The study findings exhibited that microplastics have serious ecological threats to aquatic life. The ingestion of microplastics by zooplankton, benthic organisms, mollusks, crustaceans and fish can lead to digestive blockage, reduced feeding efficiency, oxidative stress, inflammation and tissue damage (Wright et al., 2013; Lu et al., 2016). Trophic transfer evidence shows that microplastics can move through aquatic food webs and eventually impact humans through contaminated water and food (Farrell and Nelson, 2013). Furthermore, toxic pollutants are adsorbed by microplastics while they also offer surfaces for microbes to colonize. Thus, microplastics have ecological and health-related risks (Rochman et al., 2013; Zettler et al., 2013). According to the study, there is an urgent need for standardized monitoring, sustainable use of plastics and pollution control measures to reduce microplastics in freshwater ecosystems.

6. CONCLUSION

One of the world's foremost environmental threats to freshwater systems might soon be microplastic pollution. The present study indicates that microplastics are ubiquitous, persistent and ecologically harmful contaminants that emanate from a variety of human activities. Microplastics comprise both primary microplastics (manufactured in small sizes) and secondary microplastics (resulting from the degradation of larger plastic debris). Rivers, lakes, wetlands, reservoirs and sediment are extensively contaminated by both (Andrady, 2011; Cole et al., 2011). The freshwater environment has been increasingly become a sink and transport study for microplastics due to rapid urbanisation, industrialisation, increase of population and ineffective waste management system (Wagner et al., 2014)
Research showed that plastics can appear in the form of fibers, fragments, pellets, and films. Among these, fibers dominated in the sample possibly due to the mass-production of synthetic textile and washing at home (Browne et al., 2011). Pollution was recognized as a crucial component of most river systems because of the presence and high frequency of occurrence of common polymer, polyethylene (PE), polypropylene (PP),

polystyrene (PS), polyvinyl chloride (PVC), and polyethylene terephthalate (PET), due to their durability and resistance to degradation (Imhof et al., 2016). Due to their small size, large surface area to volume ratio and hydrophobicity, microplastics have a greater capacity to adsorb toxic pollutants including heavy metals, pesticides, hydrocarbons and persistent organic pollutants which increases their ecotoxicological risks (Rochman et al., 2013).

Research shows microplastics harm aquatic organisms and ecosystem functions including sea plants and corals. Many types of freshwater organisms, including plankton, benthic invertebrates, mollusks, crustaceans, and fish, consume microplastics. This happens either directly from contaminated water and sediments or indirectly from contaminated prey (Setälä et al., 2014). The physical obstruction of digestive systems, diminished feeding activity, impaired absorption of nutrients, change in behavior, oxidative stress, inflammation, tissue damage, endocrine disruption, and reproductive abnormalities may take place (Wright et al., 2013; Lu et al., 2016). The findings also indicate that microplastics can transfer between organisms at different levels of the food chain through predation. This leads to organisms at those different trophic levels accumulating microplastics throughout the freshwater food web. This has potentially serious human health implications through drinking water and aquatic food resources (Farrell and Nelson, 2013; WHO, 2019).

Also, the study reveals another interesting fact about microplastics. They act as a carrier for microorganisms and toxic chemicals. The environment created by biofilms and microorganisms on plastic may facilitate the transport of pathogens and resistance genes in the aquatic environment often predicted to occur with plastic water pollution (Zettler et al., 2013). The freshwater biodiversity at risk may heighten public health problems furthermore.

As a whole, the present investigation underscores the pressing need for effective strategies to mitigate microplastic pollution in freshwater bodies. Standardized monitoring techniques, improved wastewater treatment technologies, strict regulations on plastic waste disposal, reduction in single-use plastics, promotion of biodegradable alternatives, and increased public awareness are essential for minimizing environmental contamination. Further studies should look into the long-term ecological consequences, presence of nanoplastics, mechanisms of trophic transfer and possible human health effects. We need to protect freshwater ecosystems from microplastic pollution which will go a long way in protecting biodiversity, ecosystem stability as well as sustainable freshwater resources.

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