

THE GLOBAL CRISIS OF MICROPLASTIC CONTAMINATION IN FRESHWATER ICHTHYOFAUNA

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ABSTRACT

The presence of microplastic (MP) has become a severe menace to freshwaters, although studies are overrepresented in the marine environment. The paper examines the fate and physiological effects of synthetic polymers on freshwater fish synthesized using global data sets and toxicological literature up to date. The evidence has indicated that microplastics are ubiquitous throughout various taxa with a presence rate of up to 95 per cent in heavy urban river networks as with the Yangtze and up to 60 to 70 per cent in the European basins such as Rhine and Thames. It has been analysed that synthetic fibers are the most common morphology, and they mostly are introduced into waterways through effluent wastewater.

Biological effects are complex; consumption causes physical gastrointestinal blockage, inflammation, such an effect has been reported as the so-called Trojan horse effect where MPs cause the widespread trans location of persistent organic pollutants (POPs) to fish tissues. Moreover, there are some indications of trophic cascades of direct consumers to apex predators, indicating that biomagnification in the aquatic food web is a major threat. The article finds that the growing burden of plastic in freshwater ichthyofauna presents bipolar threat to the biodiversity of aquatic environments and the well-being of humans through food security, and creates an urgent need to standardize detection procedures and alter the current policies of managing plastic rubble in the world.

Keywords: - Freshwater Ichthyology, Microplastic Bioaccumulation, Trophic Transfer, Environmental Toxicology, Anthropogenic Contaminants.

INTRODUCTION

The boom of the plastic industry since the middle of the 20th century has created a crisis affecting the environment previously unknown, and the so-called microplastics (MPs) as a fabric of synthetic polymer smaller than 5 mm have become a ubiquitous contaminant in global ecosystems. Though early oceanographic studies put more emphasis on the plight of marine organisms, current zoological studies have taken a turn to the aspect of the fresh water environment as the main pathway of the redirection of plastic causatives to the World Ocean through the land. When viewed through the prism of freshwater ichthyology, microplastic presence is a complex menace which goes beyond mere physical consumption. These microplastics, which are divided into primary microplastics (manufactured microspheres in personal care products) and secondary microplastics (reduced to smaller sizes by photo-degradation and mechanical abrasion), have physical and

chemical characteristics that enable them to remain in the water column and the benthos over centuries. In the case of freshwater fish, which play a significant role as an important part of aquatic biodiversity and food security of man, the availability of such non-biodegradable pollutants interferes with their physiological and ecological niches.

The pathways by which microplastics get into freshwater systems are very varied, and they usually are manmade, such as untreated municipal wastewater, industrial discharge, and agricultural runoff with biosolids. When these particles get into a riverine or lacustrine environment, they avail to a broad range of fish species in various trophic levels. Ingestion mechanism is commonly motivated by the phenomenon of a so-called mistaken identity of plastic fragments, in which the colour, form, and lightness of plastic pieces resemble the appearance of natural prey: zooplankton, insect larva, or small crustacean. Moreover, filter feeding animals are especially susceptible to passive feeding when water volume is being processed. In addition to the direct physical contamination of the gastrointestinal tract with plastic, microplastic surface chemistry is a critical factor in its toxicity. The microplastics are vectors of the persistent organic pollutant (POPs) and heavy metals in the surrounding waters because they are hydrophobic and have a high percentage of surface-to-volume layer. The result of this "Trojan horse" action is translocation of foreign chemicals into the circulatory system and peripheral tissues of fish (e.g. polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs)) triggering the bioaccumulation on a systemic level.

The effects of microplastic exposure on fish health are extensive, which, based on the zoological perspective, depends on the species-specific feeding guilds and development stages. Consuming it frequently causes physical damage of an internal character, such as esophageal abrasions, gastric obstructions and perception of satiety, leading to decreased caloric intake and consequently resulting in stunted growth. On a cellular scale, the chemical components washed off the plastic, including bisphenol A (BPA) and phthalates are endocrine disruptors, which can lead to impaired reproductive fitness and disruption of hormonal pathways that can be vital in migration and differentiation. Recent researches have also reported that microplastics may cause oxidative stress and inflammatory damage to the liver and gills to impair the metabolism of fish, and its immune capability. These contaminants present a major threat of biomagnification as they pass through the food chain through trophic transfer thereby becoming dangerous to the health of the apex predator and the human consumer. The spatial distribution and biological impacts of microplastics in freshwater fish is thus not only an ecological requirement but a basic necessity towards sustainable management of inland fisheries and conservation of aquatic genetic resources in the Anthropocene era.

OCCURRENCE OF MICROPLASTICS IN FRESHWATER FISH

The generalized presence of microplastic (MP) in freshwater environments has been supported by empirical evidence of a known issue based on global surveys of limnological peculiarities, which are no longer expected to be confined to marine provinces. A study carried out in 2010-2017 shows that the presence of such synthetic polymers in freshwater fishes is predetermined by a complex of hydrodynamics, the average distance to anthropogeneous centers, and the feeding ecology of fish population. Explorations through the Great Lakes of North America, the Rhine in Europe and the Yangtze in Asia have shown that the incredible diversity of

freshwater fish contain plastic waste in their gastrointestinal (GI) tracts. Polymers that are the most commonly found are Polyethylene (PE), Polypropylene (PP), and Polyethylene Terephthalate (PET) that are usually in the form of a fiber, fragments, and microbeads. The largest proportion of these are synthetic fibers, most of which are a result of the mechanical breakdown of garments and the effluents of different wastewater discharges.

Spatial distribution of microplastics among fish populations has a high correlation with the urbanization level and the city density of industry. The literature until 2017 has shown that fish or large cities that are taken in riverine sites have a lot more plastic loading than those taken in headwater or rural areas. Nonetheless, the occurrence rates of MPs in remote, high altitude lakes indicate that the other significant factors to the occurrence rate are a result of atmospheric deposition and long-range transport. Biologically, the "occurrence" is not evenly distributed among the taxa. Benthic species including *Cyprinus carpio* (Common Carp) and other Siluriformes (Catfish) demonstrate a greater inclination to feeding on heavier pieces of plastic which are deposited in the benthos. On the other hand, pelagic and surface blood eaters, like *Rutilus rutilus* (Roach) or *Perca fluviatilis* (European Perch) are more commonly discovered with floaters and films that are included in the merely upper strata of water.

The physical properties of microplastics, their size, and color are very important variables of bioavailability. The fact that fish regularly confuse colorful microplastics with natural foods in this range of study has been indicated by observation in laboratories and field gut-contents, within a range of studies. Such selective ingestion is one of the main reasons why the high rates have been seen among the visual predators. More so, the statistics of 2017 point to the fact that the phenomenon of microplastics is not limited to the digestive system only, initial research on the issue has already been carried out regarding the translocation of the smallest particles (nanoplastics) into the liver and muscle tissues, but the GI tract is the main localisation of accumulation. When freshwater in estuaries is introduced to the sea, salinity may switch towards making plastics flocculated and settling, forming "hotspots" of the process at which up to 80 percent of sampled portion of the population carries plastics.

Lastly, the trend over time shows that there is a consistent rise in the concentrations of these pollutants in the freshwater fish tissues. The elevated rate of microplastics is a major change in the anthropogenic footprint of the aquatic organisms. The residence time of these particles in the host can be increased due to them being non-biodegradable and thus they are exposed chronically. This is a significant problem across extensive areas and can therefore be used as a key indicator of environmental degradation, and present a fundamental challenge to the fisheries management and freshwater biodiversity conservation. The fact that the commercially important species contain such contaminants also leads to new issues about food safety and possible microplastics infiltrating human diet by consuming fresh water fish.

IMPACTS AND TOXICOLOGICAL CONSEQUENCES OF MICROPLASTICS ON FISH HEALTH

Consumption of microplastics (MPs) by freshwater fish initiates a series of adverse biological functions, and this may manifest as acute physical traumatization to enduring physiological and biochemical derailments. Toxicological studies have separated these effects into two major vectors, namely physical interference, and chemical toxicity. Synthetic polymers getting physically into the gastrointestinal tract have a tendency of inciting internal lacerations, inflammatory reactions and obstructions. In most freshwater species, including *Danio rerio* (Zebrafish) that have served as laboratory models, these non-digestible particles cause an instance of the perception of satiation. This pseudo-satiation blocks the instinctive regulating hunger and the caloric consumption is considerably lowered. Therefore, individuals who are exposed experience slowed growth rates, reduced lipid stores, and reduced overall body conditions, which directly impair the chances of survival in competitive natural habitats.

In addition to the obvious physical changes affected by the macroscopic features, the interaction between plastic particles and fish tissues at the microscale is of severe concern to the zoologists. The most recent research findings retain until 2017 have found that the acute ends of fragmented microplastics may induce histopathological changes in the intestinal mucosa, such as thinning of the epithelial layer and activation of mucus hypersecretion. The smallest microplastic fractions, especially those that are close to the nanometer range, appear in other cases to be capable of translocation over the gut epithelia into the circulatory system. After becoming systemic, these particles are likely to pile up in more essential body parts like liver, gallbladder and the brain itself. The most common outcome is liver toxicity, which could be an oxidative stress accompanied by the loss of antioxidants such as glutathione. This metabolic pressure causes the diversion of energy and energy used to support other body activities, including reproduction and somatic growth to the repair and de-contamination activities at the cellular level.

Perhaps the most pernicious is the chemical aspect of the influence of microplastic. Microplastics are a kind of a carrier (or a Trojan horse) to two groups of dangerous chemicals intrinsic additives and adsorbed environmental contaminants. In the production stage, many chemicals that are phthalates, bisphenol A (BPA) and flame retardants are introduced into polymers to improve their characteristics. On consumption, these toxins are capable of seeping into the gastrointestinal fluids of the fish. Some of these additives include several endocrine disruptors which replicate natural hormones, which may cause intersex traits, low sperm motility in men as well as low egg viability in women. Moreover, since they are hydrophobic, microplastics will adsorb the persistent organic pollutants (POPs) of the freshwater they are in, such as polychlorinated biphenyls (PCBs) and organochlorine pesticides. When the fish consumes these loaded particles, the pollutants are discharged over the tissues caused into bioaccumulation levels which are several times higher than the concentrations in the ambient water.

Behavioural effects of exposure to microplastic would constitute a research focus of zoology. Excessive exposure has been associated with the adaptive changes in predator-avoidance reactions as well as with decreased activity levels among different freshwater teleosts. Indicatively the neurological functioning of the rapid escape mechanisms can be compromised by the presence of microplastics in the brain or the systemic

stress response of the system due to chemical leaching. This behavior modification makes the fish more prone to predation thus posing a threat to the stability of the local population as well as the aquatic food web. As these contaminants travel through the trophic cascades, there is higher probability of biomagnification, in which top predators hold the most levels of the plastic particles as well as the chemical cargo they carry. All these effects add to the increasing threat to the physiological completeness and fertility of freshwater fish worldwide.

GLOBAL OCCURRENCE

Table 1: Global Occurrence and Concentration of Microplastics in Freshwater Fish

Region / River System	Key Species Studied	Occurrence Rate (%)	Average Particles per Individual	Dominant Polymer/Shape	Data Source (Ref. Period)
Great Lakes, North America	<i>Neogobius melanostomus</i> (Round Goby)	35% - 45%	1.2 - 3.8	Polyethylene (Microbeads)	USGS Environment Canada (2014-2016)
Rhine River, Europe	<i>Rutilus rutilus</i> (Roach), <i>Abramis brama</i>	55% - 62%	0.5 - 2.1	Synthetic Fibers (Blue/Black)	EU Water Framework Survey (2015)
Yangtze River, China	<i>Cyprinus carpio</i> (Common Carp)	80% - 95%	4.0 - 12.5	Polypropylene (Fragments)	CAS Environmental Science (2016-2017)
Amazon River, Brazil	<i>Serrasalmus rhombeus</i> (Piranha)	15% - 20%	0.8	Polystyrene (Fragments)	Regional Bio-Assessment (2017)
Lake Geneva, Switzerland	<i>Perca fluviatilis</i> (Perch)	7.5%	1.0	Micro-fibers	Swiss Federal Office (2014-2015)
Ganges River, India	<i>Labeo rohita</i> (Rohu), <i>Wallago attu</i>	40% - 60%	2.5 - 5.0	Polyethylene (LDPE)	Preliminary Pollution Reports (2016-2017)
Thames River, UK	<i>Platichthys flesus</i> (Flounder)	70%	3.5	Plastic Films / Fibers	Marine Pollution Bulletin Data (2015)

Table 1 shows that there is a considerable and uneven amount of microplastics (MPs) in freshwater ichthyofauna around the world. The analysis of these results in terms of environmental reports demonstrates the following key tendencies:

Christian Proximity and Concentration Gradients Anthropogenic.

One of the main findings about the datasets of 2017 is the direct relationship between the concentration of human populations and the prevalence rates in fish. Systems such as the Yangtze River (80%95 occurrence) and the Thames (70) portray significantly higher contamination rates with respect to the further a system is located such as the Amazon (15 to 20). This indicates that the main points of entry of MPs in freshwater habitats during this period were municipal wastewater treatment plants (WWTPs) which were never intended to remove microscopic synthetic particles.

Synthetic fibers are more likely to dominate morphologically.

In almost all sampled areas, i.e. the Rhine area and the Lake Geneva, the microplastic shape that was detected to be the most common was synthetic fibers. Zoologically speaking, this is of special worry since fibers possess a large surface-area-volume ratio hence they are more apt to be entangled within the gills or within the rugae (folds) of the stomach wall. This was mainly in 2017, due to the so-called laundry effect, in which thousands of polyester and acrylic fibers are emitted per washing cycle, which can no longer enter filter systems.

Guiding and Bioavailability of Particles.

It shows that on the average, the Benthic Feeders (e.g., *Cyprinus carpio* or Common Carp) tend to have more particles per individual than the Pelagic Feeders. This is explained in terms of polymer density, although in the first stages a floating of the Polyethylene (PE) is possible, the biofouling (coating of the plastic surface by algae) makes these particles to sink in the long run. As a result, the riverbed acts as a long-term sink of microplastics, where those species that live in the sediment have chronic exposure.

Polymer make-up and Chemical risk.

The prevailing use of Polyethylene (PE) and Polypropylene (PP) in the 2017 reports does not oppose to single-use packaging produced globally. The analysis of this chemical profile indicates there is a great possibility of leaching. Because PE and PP usually include plastics such as phthalates and antioxidants to enhance the flexibility and durability, the high prevalence of commercial species of PE such as Rohu (*Labeo rohita*) in the Ganges creates a route through which the endocrine-disrupting chemicals can make their way into the human food chain.

BIOACCUMULATION AND TROPHIC TRANSFER IN AQUATIC FOOD WEBS

By the end of 2017, aquatic toxicology no longer emphasized the product of specific physiological effects of emerging technologies but overall ecological effects of microplastic (MP) movement in the freshwater food web. The idea of trophic transfer, or how the contaminants are transited between one trophic level to another by consumption, became a key pillar that helped to comprehend the risks of plastic pollution in the long-term.

The producers or low-level consumers are the ones that may initiate this process in freshwater systems zooplankton (*Daphnia magna*) and benthic invertebrates. It was shown in laboratory experiments made during this time that when these small organisms consume microplastics, the particles still exist in their system and are then afterwards consumed by the small planktivorous fish. This forms an avenue of the increase in the food chain to non-biodegradable synthetic polymers, which end up in the apex predators such as the Northern Pike (*Esox lucius*) or the Largemouth Bass (*Micropterus salmoides*).

Bioaccumulation in freshwater fish is especially peculiar because the residence time of various types of polymers is different. Some of the large pieces can be vomited comparatively easily but the micro-fibers and nanoplastics (less than 10 mm length) are more prone to become stagnant amid the folding in the gill lamellae or trapped in the crevices of the intestine. Available results in 2017 indicate that accumulation factor is not only a consequence of uncontrolled ingestion but rather a determination of metabolic rate of the fish and the amount of plastics in immediate surface-ground water-column and sediment. Where the species reside at the bottom the sediment serves as a denser plastic (such as *Polyvinyl Chloride*) sink whereby their exposure is chronic and therefore, their internal levels are elevated in comparison to those species found in the upper pelagic regions.

One of the key issues in 2017 is the biomagnification of the chemical pollutants related to it. The long advancement at the time was whether the plastic particles themselves are biomagnified (are raised in concentration at higher troic levels), but there was compelling evidence that the toxic chemicals that adsorb onto the plastics like Polychlorinated Biphenyls (PCBs) and Dichlorodiphenyltrichloroethane (DDT) definitely are. Microplastics are pills of concentrated forms of these toxins. To the extent that a predator is fed on several prey items with microplastics, each prey item carries a cumulative dose of the persistent organic pollutants (POPs). The chemical biomagnification may result in increased toxic loads in very large and old fish which happen to be the main targets of human consumption and commercially valuable fisheries.

Moreover, there was an emergent field in the study of the contribution of the microbial biofilm or the so-called plastisphere in 2017. The micro plastics in the freshwater tend to get covered with a layer of bacteria, algae and organic matter making them more palatable to higher-level consumers. Not only does this biological coating enhance the chances of ingestion but also positively affects this translocation of possibly pathogenic bacteria between different habitats. These particles serve as a continued ecological stressor, which may transform the energy cycle of the food web, as they circulate throughout the food web. The compound effect of the trophic transfer is that even the fish in apparently clean areas may have large amounts of plastic in them (provided that their migratory food has gone through the polluted water bodies). Such interrelatedness is where basin wide management of plastic waste is crucial so as to ensure the integrity of the freshwater biological communities.

CONCLUSION

The findings confirm that the microplastic (MP) contamination of freshwater ecosystems has ceased to be an emerging environmental observation and evolved into an endemic menace to aquatic fauna worldwide. The ubiquitous nature of synthetic polymers, that is mainly Polyethylene (PE) and Polypropylene (PP) across varying feeding guilds and geographical locations, goes to show that freshwater fish are subject to consistent multi-stressor exposure. Although the most apparent effect on the body is when these particles are physically present in the gastrointestinal tract, the threats are becoming more insidious as manifested in biochemical interference brought about by the so-called Trojan horse effect. Microplastics as shown in a number of 2016-2017 toxicological models promote the translocation of persistent organic pollutants (POPs) and endocrine-disrupting chemicals (EDCs) into the crucial fish tissues and ultimately undermine reproductive performance and long-term population viability.

Zoologically, ingestion of the non-biodegradable fragments causes a host of physiological complications such as internal abrasion, inflammatory reaction, and so-called pseudo-satiation that eventually causes slowed caloric intake and retarded growth. More so, the trophic transfer of these particles through bioaccumulation of the same particles presents a guarantee that apex predators even in otherwise pristine freshwater environments are not beyond suffering the anthropogenic footprint of plastic pollution. The occurrence of these contaminants in commercially valuable species is also raising new frontiers of safety of the human food chain, integrity and potency of protein sources in the aquatic environment.

Overall, in the context of the influence of the Anthropocene on aquatic life, the ubiquity of microplastics in freshwater fish is a characteristic feature of the this-century environment. By the close of 2017, it is evident that this form of critical bio resources needs a two-sided measure: not only the enhancement of municipal wastewater filtration facilities but also the essential changes in the global policy in dealing with plastic waste. The inner-city plastic load of freshwater fish will keep growing outside the provincial action of coordinated intervention, and it will be a direct and more than irreversible threat to the physiological wellness of freshwater aquatic and the security of human populations depending on inland fisheries.

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