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Microplastics in the Global Seas and Their Impacts on Fish: Implications for Human Health

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Abstract:
Microplastic pollution is a global issue due to its impacts on fish and humans. They could have detrimental impacts on aquatic life, environmental functions, and human health. In addition to highlighting their effects on fish and prawns, this research looks at the distribution and consequences of microplastics in the maritime environment. The Southern Atlantic has a high concentration of microplastics, mostly from land-based activities that may be connected to the Southern African coast. Physiological, behavioral, and reproductive abnormalities in marine fish have all been connected to the growing buildup of microplastics in marine environments. These effects significantly negatively influence the sustainability of fish populations, the general health of our seas, and the balance of aquatic ecosystems. Microplastics in fish raise questions about human exposure to these pollutants because fish are a crucial component of the human diet.

Keywords: Microplastic, Fish, Global Seas, Environmental pollution, Marine ecosystems

INTRODUCTION

Microplastics are small plastic particles becoming increasingly prevalent in the aquatic environment (Mariano et al., 2021). Over the years, the accumulation of microplastics has been detected in urban atmospheres and remote and pristine environments (Chen et al., 2020). This shows that microplastic suspension, deposition, and aeolian transport are major environmental transport pathways (Bianco and Passananti, 2020). There are five categories of plastic waste based on its size: megaplastics (>50 cm), macroplastics (5–50 cm), mesoplastics (0.5–5 cm), microplastics (1 µm–5 mm), and nanoplastics (<1 µm) (Bianco and Passananti, 2020). Microplastic pollution in the aquatic environment has garnered considerable attention from the research community and authorities lately, primarily due to its ability to persist in the environment and its possible adverse effects on human, animal, and environmental health (Wu et al., 2019). Studies have focused on different environmental compartments, such as soil, vegetation, bodies of water (fresh and marine), and the atmosphere (Chen et al., 2020; Unsworth et al., 2021; Yang et al., 2021). Among these, microplastic pollution in the aquatic environment is highly significant as water covers about 71% of the earth, and more so, aquatic organisms have their intrinsic and socioeconomic values (Arias-Arévalo et al., 2017). Also, microplastic pollution has detrimental effects on the food chain in the marine ecosystem (Paul and Isaac, 2023). However, the interactions among microplastic, the food chain, and the marine ecosystem are complex as one is highly connected to others in various ways, such as transport (Nava and Leoni, 2021).

One of the challenging areas involved in research on microplastics is their transport (Huang et al., 2021). The transport of microplastics is more complicated due to chemical interdependence and dynamic environmental mobility (Bianco and Passananti, 2020). In the meantime, microplastics have also emerged as an important issue in environmental sciences (Yakovenko et al., 2020). Microplastics may negatively affect aquatic organisms, ecosystem services, and human health. In fish, research has indicated that these tiny plastic particles can disrupt the feeding habits of young fish, resulting in diminished growth and survival rates (Uy and Johnson, 2022). Microplastic consumption also reduced shrimps' feeding rates and energy reserves (Saborowski et al., 2022). In humans, plastic particles reportedly present in human blood demonstrate that microplastics can enter the blood through absorption, inhalation, or ingestion (Bhat et al., 2023). Industrial compounds like bisphenol-A (BPA) and phthalate (DEHP), which are recognised for their deleterious effects, such as endocrine disruption, are specifically used in the production of plastics (Zhang et al., 2018).

One of the most worrying concerns human activities brings is the pervasive presence of plastic garbage in many world ecosystems. More precisely, micro-sized plastic particles are everywhere and pose a serious risk to human health and the environment (Vighi et al., 2021). Prioritising research efforts to understand the effects of microplastics' existence is essential, given the limited knowledge of their effects, as many research efforts have focused on their occurrence and abundance. Therefore, this study examines the distribution and effects of microplastics in the marine environment and further highlights their impacts on fish and shrimps. This study is expected to inform scientists, policymakers, and the public about the magnitude and extent of plastic pollution, contributing to a better understanding of the implications on the environment and human health.

SOURCES, DISTRIBUTION, AND FATE OF MICROPLASTICS IN THE MARINE ENVIRONMENT

There are two main sources of microplastics: primary and secondary (Figure 1). Primary sources are the intentional use of microplastics in products such as cosmetics, while secondary sources are the fragmentation of larger plastic debris (Martinho et al., 2022).

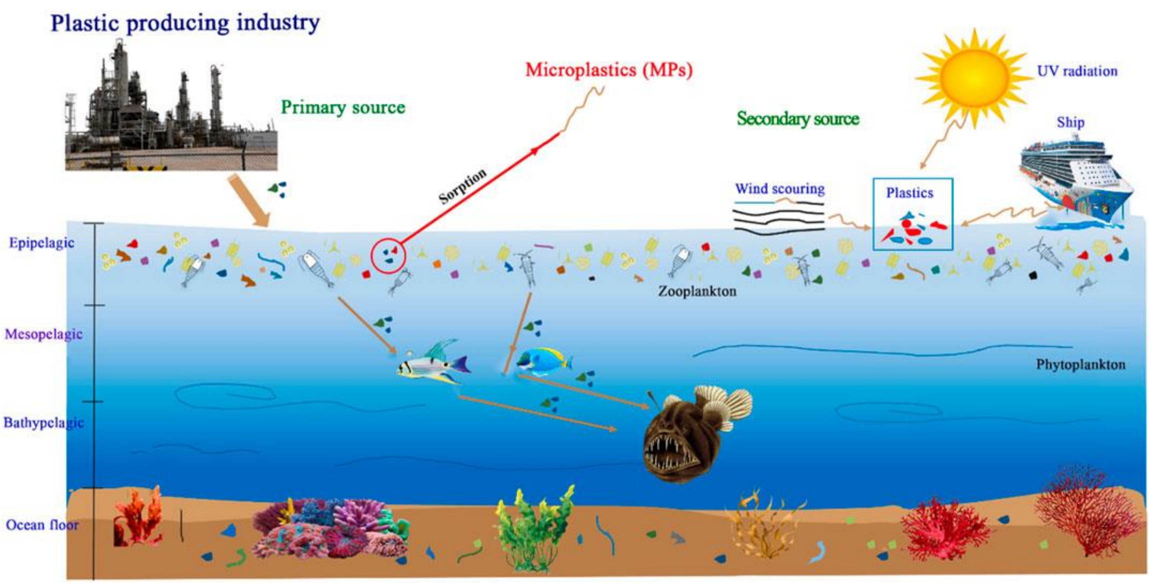

Figure 1. Potential sources and transfer of microplastics in fish
[Figure and caption from Bhuyan, (2022), with permission].

In the marine environment, microplastic pollution originates from various sources and can generally be divided into inland-based, sea-based, and air-based sources (Yang et al., 2021). Many microplastics (80% of marine debris) come from terrestrial sources washing into the marine environment (Coyle et al., 2020). In the terrestrial environment, microplastics have three major sources: inputs from agricultural practices, the influence of runoff, and domestic activities such as tourism (Martinho et al., 2022). Many microplastics (80% of marine debris) come from terrestrial sources washing into the marine environment (Coyle et al., 2020). Irrespective of its primary or secondary origin, it is widely acknowledged that the marine ecosystem accommodates around 92% of the world's plastic waste (Eriksen et al., 2014). Additionally, scientific evidence indicates that microplastics have been observed in seawater at a concentration of 102,000 particles per cubic meter (Prata et al., 2019).

Moreover, several sources, including coastal tourism, recreational and commercial fishing, maritime boats, and marine businesses, directly contribute to increased marine plastics (Bhuyan, 2022). Unfortunately, tourism and recreational activities are linked to the detrimental impact caused by the increased number of plastics dumped along beaches and coastal resorts (Derraik, 2002). This seriously threatens aquatic life and the general food chain from the marine habitat (Paul and Isaac, 2023).

Marine habitats exhibit a wide distribution of microplastics documented along shorelines extending from the poles to the equator (Strafella et al., 2020; Tajwar et al., 2022). Extensive distribution of microplastic particles has been observed in Africa, Asia, Southeast Asia, India, South Africa, North America, and Europe (Auta et al., 2017). Most marine plastic debris floats on the surface of the seas and coastal regions and is deposited in sediments (Figure 1). Since certain microplastics are less dense than seawater and float on the ocean surface, and since converging sea currents concentrate and store debris for a long period, microplastics continue to build up in the global ocean circulation (Reddy et al., 2006; Goldstein et al., 2013; Cózar et al., 2014). Typically, any debris in a body of water will ultimately find its way into the ocean. Over time, microplastics move and spread throughout the ocean with the help of. water and wind, gradually becoming as widespread as they are today (Isobe et al., 2014; Issac and Kandasubramanian, 2021). Thus, they spread in numerous regions, including major ocean gyres like the Pacific Ocean (Law and Thompson, 2014), the Atlantic Ocean (Cózar et al., 2017), and the Indian Ocean (Reddy et al., 2006), as well as the polar regions, equatorial areas, densely populated regions, remote islands, and even the deep sea.

THE BIOGEOCHEMICAL PROCESS OF MICROPLASTICS IN THE MARINE ENVIRONMENT

The concept of the plastic cycle involves a continuous and intricate transfer of plastic materials across a wide range of environments, with potential effects on living organisms, including humans (Bianco and Passananti, 2020).

On the other hand, three potential pathways are included in the metabolic cycle of microplastics by which waste and chemicals connected to microplastics enter and span the environment. These methods entail breaking up bigger plastic debris into tiny pieces, releasing plastic-related chemicals into the environment, and moving plastic via ocean currents (Bhuyan, 2022).

Birarda et al., (2021) further buttressed the details of the methods through which microplastic might enter the biogeochemical cycles. The first method involves shredding big plastic garbage into tiny microplastics eaten by marine organisms. There is thus a movement of plastics up the food chain. Microplastics build up in tissues and organs and affect species that consume them. The second pathway involves releasing chemicals associated with plastics into the environment.

These chemicals can originate from various sources, including plastic manufacturing, as in the case of plastics and primary microplastics, leaching from plastic products either due to high temperatures or the end of the product life cycle, and the breakdown of plastics in the environment by both biotic and abiotic components.

Once in the environment, they can enter the food chain and accumulate in organisms, and potentially pose risks to wildlife and humans. The third route involves the physical transportation of plastics through ocean currents. Initially, most marine plastics are found in the upper portion of the water column (Birarda et al., 2021), and they can be transported by currents, eventually accumulating in specific regions like ocean gyres (Galgani and Loiselle, 2021).

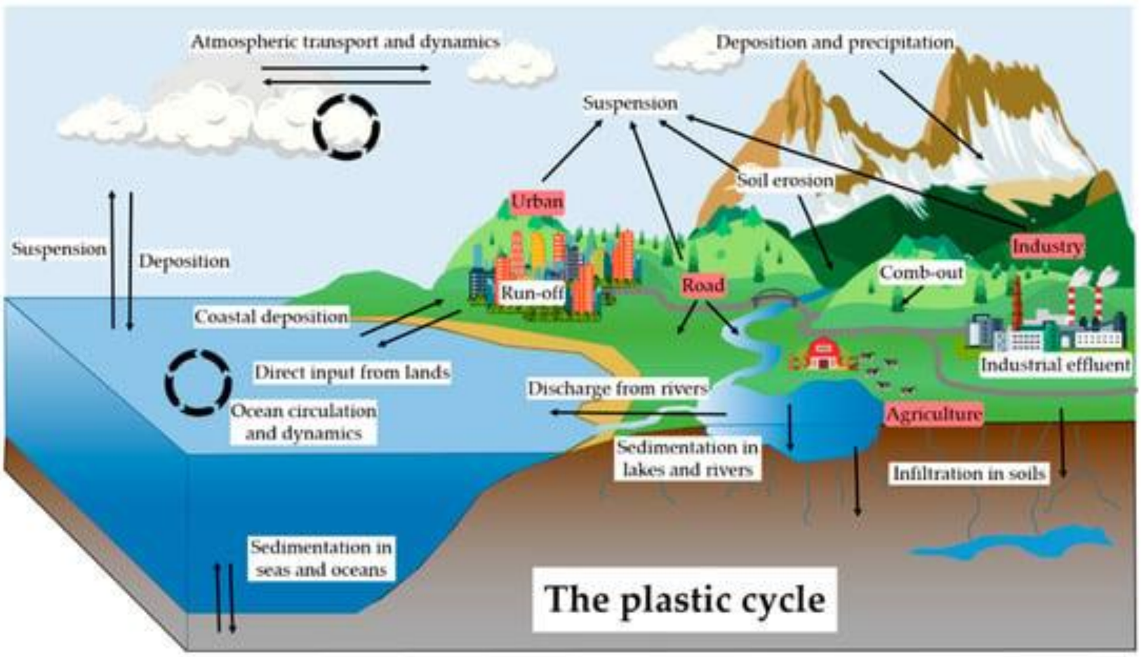

Figure 2: Conceptual model of the biogeochemical cycle of plastic. Red boxes represent sources, and white boxes represent transport factors and mechanisms. Arrows represent transport pathways

(Figure and caption from Bianco and Passananti, 2020, with permission).

ENVIRONMENTAL CONCENTRATIONS OF MICROPLASTICS IN GLOBAL SEAS

Microplastics have been discovered in every ocean region (Figure 3) and have converged in zones of accumulation in subtropical gyres, including gyres in the Southern Hemisphere where the density of coastal population is much lower than in the Northern Hemisphere, showing that microplastic pollution has spread throughout all oceans (Chen et al., 2020).

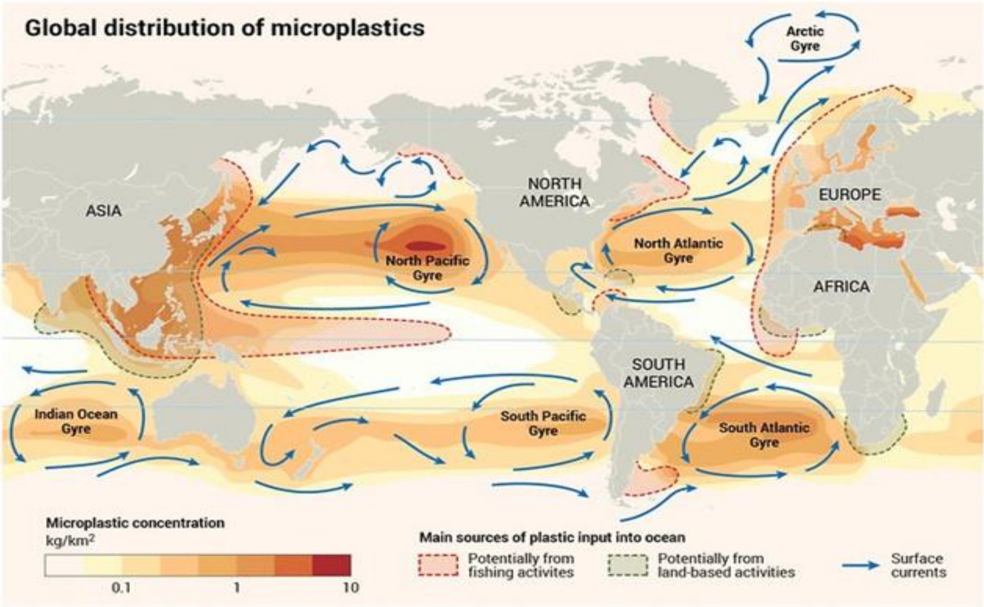

Figure 3: Global distribution of microplastics in the Oceans.
Source: GRID-Arendal, 2023. Creator credit: Riccardo Pravettoni and Philippe Rekacewicz.
Available at https://www.grida.no/resources/13339.

Globally, the distribution of microplastics shows that the highest concentrations are observed along the North coast of Libya, Egypt, Turkey, and the Northeast Pacific basin. The concentration reached 10 kg/km^2, suggesting the exposure of marine animals, including fish microplastic toxicity. Also, significant microplastic concentration is observed in the Southern Atlantic, majorly from land-based activities potentially from the Southern African coast.

It suggests that marine microplastic dispersion can be influenced by the currents moving along the coasts, with fishing and land-based activities as potential sources. Furthermore, the high plastic manufacturing and waste creation in the northern Pacific Ocean may be related to the high microplastic concentration recorded in the region (Jambeck et al., 2015; Chen et al., 2020).

TOXICITY OR IMPACT OF MICROPLASTICS ON THE MARINE FISH

Concern has been raised about the possible impacts of plastic on marine life, especially fish. Due to their hazardous effects on both people and fish, microplastics are viewed as a global problem (Bhuyan, 2022). The increased concentration of microplastic is significant to fish health and results in various effects such as reduced swimming, reduced growth, DNA damage, tissue damage, oxidative damage, behavioural change, dysbiosis, inflammation, reproductive impairment, neurotoxicity, altered gene expression, breeding impairment, disrupted digestion, and mortality (Bhuyan, 2022). Findings indicated that fish exposed to microplastics exhibited a remarkable two-fold increase in brain Acetylcholinesterase (AChE) activity and heightened (Lipid Peroxidation) LPO levels in the brain and muscle tissues (Barboza et al., 2020). Further analysis using in vitro methods demonstrated the concentration of microplastics in crabs' gills, stomachs, and metabolic systems, leading to unfavourable cellular alterations (Bhuyan, 2022).

Fish and other aquatic species may die due to a buildup of plastic garbage in aquatic habitats because it can reduce oxygen levels and increase nutrient loading (Issac and Kandasubramanian, 2021). Additionally, fish can consume plastic trash, resulting in physical harm and the buildup of toxins associated with plastic in their systems (Bhuyan, 2022). Researchers have examined how plastic can affect benthic foraminiferal organisms, an important part of marine ecosystems. They found that chemicals connected to plastic and plastic litter can interact with biogeochemical cycles and harm ecosystems (Galgani and Loiselle, 2021). Foraminifera developed on plastic remnants displayed signs of oxidative stress and protein aggregation, whereas calcareous foraminifera can integrate bis-(2-ethylhexyl) phthalate (DEHP) into their cytoplasm. Additionally, microplastic debris was discovered in the foraminifera's cytoplasm and agglutinated shell (Galgani and Loiselle, 2021). These results imply that microplastics may negatively impact foraminifera's ability to store biogenic carbon, ultimately impacting fish and the rest of the food chain (Bouchet et al., 2023).

The consumption of microplastics by fish can lead to various harmful effects like physical injury, changes in lipid processing, and oxidative stress (Bardoza et al., 2020). From laboratory studies carried out initially, it appears that both nano-plastics and microplastics pose risks detrimental to many species of fish, even major damage physically (Bardoza et al., 2020). The uptake by a fish of smaller plastic particles causes a range of problems such as reduced appetite, abnormal behaviour, poor growth rates and changes in stored fats which harm health levels over time, including increased oxidative stress levels. This could be made worse by bioaccumulation within key tissues across multiple generations - plus entering humans inadvertently by eating affected species, posing significant human health risks (Bardoza et al., 2020). Therefore, any negative impacts felt spread widely from just one group of animals impacting wider aquatic nature chains triggering delayed growths, poor behavioural patterns, and low intake, adding more strain physically at the molecular level, and negatively impacting carbohydrate metabolism (Hamed et al., 2021). Our current understanding regarding this new ecological threat only covers response to around 30% of species affected. Thus, more data is required to fully comprehend microplastics' impact on marine life (Capó et al., 2021; Hamed et al., 2021; Solomando et al., 2021).

Different studies have reported significant changes in fish physiology, development, behaviour, and survival due to microplastic pollution (Hamed et al., 2021; Uy and Johnson, 2021; Tongo and Erhunmwunse, 2022). In Blue discus (*Symphysodon aequifasciatus*), microplastics reduced growth and caused neurotransmitter changes (Huang et al., 2022). In Gilthead bream (*Sparus aurata*), microplastics caused oxidative damage, while antioxidant enzymes were stimulated in the liver and plasma (Solomando et al., 2021). Microplastics also increased antioxidant defences and resulted in oxidative damage and behavioural changes in Gilthead bream (Capó et al., 2021; Nanninga et al., 2021; Rios-Fuster et al., 2021). In other studies, *Oreochromis niloticus* has experienced significant hepatocyte deformation, and degenerative liver tissue, while oxidative stress and intestinal microbiota dysbiosis have been observed in *Lates calcarifer* due to microplastic consumption (Solomando et al., 2020; Hamed et al., 2021; Xie et al., 2021). These have implications for human health through the consumption of these fish.

COUNTERMEASURES TO COMBAT MICROPLASTIC POLLUTION IN THE MARINE ENVIRONMENT

One way to effectively address microplastic pollution is by reducing plastic production by using biodegradable materials and promoting reusable products while limiting single-use plastics consumption. However, more research into sources that causes dispersion as well as impacts should be conducted with standardised techniques for sample collection across different surfaces such as sediment or water bodies (Brodhagen et al., 2017).

To translate knowledge about combating marine-based microplastics into action should holistically involve governance strategies that include effective plastic waste management policies enforcement along with establishing regulations on manufacturers who overtly use or produce non-degradable materials posing a risk to the marine life cycle; public awareness programs such as educational schemes or informative communication disguised as service announcements support this holistic approach by raising interest among those who never thought about this subject before (such as students who can learn at school or internet users reached via social media) (Gago et al., 2019).

One of the most effective measures to combat microplastic pollution is to reduce plastic production. This can be achieved by incorporating biodegradable materials, advocating for the use of reusable products, and minimising the consumption of single-use plastics (Brodhagen et al., 2017). Furthermore, a comprehensive understanding of microplastics' sources, dispersion, and impacts necessitates additional research. Notably, standardised field techniques for collecting microplastic samples from sediment, sand, and surface water have been established, and ongoing research is dedicated to examining microplastics' health and environmental implications (Gago et al., 2019; Onyena et al., 2021).

CONCLUSIONS AND FUTURE DIRECTIONS

The oceans being invaded by microplastics pose high threats not just to marine life but also to affecting human well-being directly. The northern coasts of Libya merged with Egypt and Turkey alone contribute to some significant concentrations of these microscopic plastic particles within their waters across the Northeast Pacific basin, where records reveal up to 10 kg/km^2 concentration. For marine animals like fish, this signifies exposure levels that exceed healthy proportions leading towards toxic outcomes risking their population considerably - including highly worrying trends surfacing in Southern Atlantic areas where land-based activities around Southern African coasts account for significant amounts observed there.

A rising volume rate surrounding microplastic accumulation is linked predominantly to various adverse effects, negatively transmitting physiological disturbances among fish behaviorally and adversely impacting reproductive functions disturbing ecosystem balances carrying oversized implications wider threatening oceanic health overall along with direct implications over human health challenges. Therefore, global actions are now critical to tackling this growing pollution problem, thereby preventing further threats towards ecological sustainability.

One way to effectively address microplastic pollution is by reducing plastic production by using biodegradable materials and promoting reusable products while limiting single-use plastics consumption. However, more research into sources that causes dispersion as well as impacts should be conducted with standardised techniques for sample collection across different water bodies.

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