Physiological Effects of Microplastic on Marine Organisms

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Abstract

The beginning of the 20th century was an era of the rise of the plastic industries, with the rapid manufacturing of plastic-based products. However, the 21st century has brought the need to confront its consequences. Improper management, a lack of awareness about its negative effects, and the irresponsible use and disposal of plastic products have turned our planet into a "plastic planet." Microplastics are small plastic pieces less than five millimetres long which form from a variety of sources including larger plastic pieces that have broken apart, resin pellets used for plastic manufacturing, or in the form of microbeads. This waste material significantly proves to be a great threat for human and animal health. Plastic or Microplastic has polluted the marine environment significantly. The ever-increasing amount of microplastics in the sea has resulted in considerable interest in their implications for oceanic animals. This review aims to illustrate and explain how these plastic particles affect marine life, particularly at the organ and cellular level. The incorporation of these microplastics into the tissues of marine organisms has been forecasted to result in structural damage to multiple organs, the inefficiency of the feeding activity, and the malfunctioning of the digestive system, among other depressing scenarios. According to reports, microplastics cause inflammation, impair the immune system, induce stress through their presence in cells, and disrupt ecosystems, causing organisms to struggle to cope with environmental changes. Not only that, microplastics may also disturb vital activities including metabolism, reproduction, and fluid regulation, hence affecting their survival and reproductive success rate. The focus of this review is summarizing the current state of knowledge on microplastics and physiological processes in other organisms which may have implications in the broader context of marine life. It stresses the importance of prevention of further microplastic pollution and measures to address its health risks to marine organisms and their ecosystem.

Key words : Microplastics , Physiology effect , Biomagnification , Bioaccumulation

Introduction

Plastic is a synthetic or semisynthetic polymer, is durable, cost-effective, easy to model and has dominance on the market within a very limited time. Plastic products are made from essential polymer mixed with Chemicals to improve their performance functional and chemical. Due to the presence of large chemical structures, it is hard to degrade into matter. The improper disposal of the plastic from dumping yards, sewage, and Industrial waste ends up in seas, oceans or aquatic bodies where it is not easy to degrade. A significant portion of ocean plastic pollution originates from human activities, particularly during travel to beaches and rivers, it takes hundreds - thousands of years to break down. It is reported that in 2024 Global plastic production was of 220 million tons, and worldwide plastic production is reached to 413.8 million metric tons by 1950 - 2023 (Statista Research Department,2024). Plastic fragments less than 5 mm in length are known as microplastics (Arthur et al., 2009).

The marine ecosystem is badly impacted by the pollutants which are due to human activities, it poses threats to our health and global ecological structures. When humans consume the fishes and marine organisms it causes health issues and also raises environmental concerns. Microplastic is of critical concern as an emerging contaminant (Choi et al., 2023; Hader et al., 2020). These microplastics enter the marine and freshwater through domestic sewage and industrial eluents. The tiny plastic fragments get into the aquatic system by wind forces, like landfills and urban areas. Marine and commercial fishing is associated with poor waste management. Microplastics can move distant and get widespread by the side of coastlines because of their miniature size, low density, and longevity (Shim et al., 2018). The small plastics such as microplastics are consumed by Zooplankton, crustaceans, Mollusca, fish and birds which depend on fish (Kibria, 2023; McCormick et al., 2020). These ways the microplastics get into the food web like human food webs (de de de Souza Machado et al.,2018). There are different types of microplastics connected with origin, physical attributes and composition. Microplastics are broadly classified into 2 groups in the literature that is primary and secondary microplastics. Microplastics of primary type are a result of the emission of particles speeded during industrial manufacturing and plastic dust discharge from plastic items. The 2nd type is secondary microplastics which are bigger in size such as films, fibres, and fragments, which is the outcome of the breakdown of big plastic debris which is due to environmental factors (Laskar and Kumar, 2019). Plastic junk in the environment is distinguished into different categories that cover macroplastics, mesoplastics, microplastics and nano-plastics. Plastic examples are polyvinyl chloride (PVC), polyethylene terephthalate (PET), polyamide (PA), polystyrene (PS), propylene (PP), and polyethene (PE) (Gallo et al., 2018). These tiny plastics have the capacity to absorb and stockpile the pollutants which come from the environment such as organic contaminants and heavy metals. MP’s can be carriers and sources for chemical additives like flame retardants and plasticizers. They are usually resistant to chemical reactions, but they might undergo photochemical deterioration when exposed to Ultraviolet light, following higher rates of fragmentation. The Microplastic's hydrophobic nature shows the interaction with marine habitats and organisms and it affects the distribution, uptake, and toxicity in marine species because of its unique properties as environmental pollutants.

The fishes maintain the health and the balance of marine ecosystems and are the integral components of food webs, in the trophic levels, and behaving as prey and predators, humans get immunity as the fish which humans eat has a lot of persistent contaminants by eating contaminated fish. These tiny pieces enter into the tissues of fishes through the ingestion of plastics. The zooplankton which eats the plastics thinks that it is its prey in water because the size of the plastics is mirrored to its prey. Microplastics enter into the gills of marine organisms in respiration via passive filtrations. The ingestion of these miniature plastics depends on the diet, habitat, species and the pollution level in their environment.

The uptake of MP's leads to toxic effects such as oxidative stress, inflammation, growth inhibition, alternation of target organs, histopathological alteration of target ions, metabolic interference, and hepatotoxicity. Heavy metals, antibiotics, organic compounds, and polycyclic aromatic hydrocarbons cause synergistic toxicity in marine organisms such as fishes and others. Reproduction in fishes is affected by microplastics and it is a growing concern. Microplastics affect the endocrine systems of fishes as plasticizers such as phthalates and bisphenol analogues and notable endocrine disrupts as they leach into the environment from these tiny fragments of fishes (Chen et al., 2021; van der Veen and de Boer, 2012; Zhang et al., 2021). These chemicals cause imbalances in hormones, low fertility rates, altered growth in progeny, or sex ratios. Microplastics show effects on female reproductive systems by inducing hormonal imbalance, and oxidative stress. Apoptosis and it can cause effects on fertilization, gonadal morphology, steroidogenesis and the function of the HPG axis (Hypothalamic pituitary gonadal i.e., maintaining the balance of reproductive hormones, and microplastics can disrupt the HPG axis and the delay of ovarian development. In addition, the CNS is affected by microplastics which results in a change of reproductive behavior. This paper attempts to tell about the relation between plastic and its health effects on marine organisms as it is an emerging threat to the water ecosystem and how it acts as the substrate for microbial growth which leads to pathogen spread and also the invasion by alien species.

Studying the physiological impacts on marine life is important to understand the health, adaptability, and sustainability of marine ecosystems in the face of changes induced by nature and human popularity (Hochachka & Somero, 2002). Understanding physiological responses to (Pörtner & Farrell, 2008) stressors helps identify which species may adapt or thrive under changing conditions. Insights into genetic and phenotypic plasticity guide conservation (Reusch, 2014) strategies and ecosystem management. Studying the physiological impacts on marine life bridges ecological understanding and practical applications, enabling us to safeguard marine biodiversity and the benefits it provides to humanity (Calow, 1991). Marine organisms play key roles in maintaining ecosystem balance, such as nutrient cycling, oxygen production, and carbon sequestration (Hoegh-Guldberg et al., 2007). Physiological changes in key species like corals, fish, or plankton can indicate broader environmental changes and ecosystem disruptions. Global warming affects metabolic rates, reproduction, and species distributions (Somero, 2010). Ocean acidification impacts calcifying organisms, such as corals and shellfish, altering their growth and survival (Kroeker et al., 2013). Physiological change in commercially important species can affect fisheries, aquaculture, and global food security.

(Cheung et al., 2010) Coral reef degradation, linked to physiological stress, impacts tourism and coastal protection (Hughes et al., 2003). Tracking bioaccumulation and biomagnification of toxins aids in understanding food web implications (Booth & Zeller, 2005). Knowledge of species' physiological limits underpins marine conservation strategies, such as creating marine protected areas or restoring degraded habitats (Roberts et al., 2001). Research informs breeding and reintroduction programs for endangered species (Hutchings, 2000). Marine life often faces multiple simultaneous stressors like temperature changes, pollution, and hypoxia. Understanding their combined physiological impacts is critical for holistic management strategies (Breitburg et al., 2018). It is a cornerstone for addressing contemporary environmental challenges and ensuring the sustainability of marine ecosystems (Pörtner, 2012).

1. Routes of Exposure in Marine Organisms

Physical contact with microplastics can cause physical harm to marine organisms such as entanglement, su ocation and injuries. The plastic particles can get entangled in appendages, gills, or other body parts, leading to injuries, reduced mobility, and increased susceptibility to infections (Barnes et al., 2009; Derraik, 2002). The report stated that more than hundreds of organisms got entangled and 580 species were affected (Cózar et al., 2014). For example, microplastics can adhere to coral surfaces, potentially causing stress and impairing their ability to feed and reproduce in marine animals (Galloway & Lewis, 2016), including sea turtles and whales, can become entangled in discarded fishing nets and other plastic waste, resulting in severe injuries or death, getting trapped into the net and unable to consume prey leading to starvation (Lusher et al., 2013) and death. The presence of plastics can disrupt natural behaviour, such as feeding and migration, and is threatening marine life (Rochman et al., 2013). Dermal exposure refers to the direct contact of microplastic with the external surfaces of marine organisms, including skin, scales, shells, or other body parts. This exposure is studied less than ingestion or trophic transfer but still has a significant impact on marine life (Sherrington & Macfadyen, 2014). The accumulation of microplastics on the skin or exoskeletons of marine organisms can interfere with normal physiological functions (Wright et al., 2013). Chemicals and toxins released from microplastics can be absorbed through the skin, potentially affecting species in their physical features and in rare cases, it has the potential to mutate the genome (Galloway & Lewis, 2016.)

The marine organisms often mistake microplastics for food and ingest them directly or indirectly. Marine organisms vary in size and their food consumption, from zooplankton to small fishes to large whales. Organisms directly consume microplastic as food and large organisms denoting Predators consume their prey containing microplastic, facilitating trophic transfer (Barnes et al., 2009; Cózar et al., 2014), namely zooplankton ingests microplastics, which are then consumed by larger organisms, including fish and whales. Ingesting plastics can cause physical harm, such as digestive tract blockages, and circulation of toxic substances into the organism's system. The blockages of the digestive tract lead to starvation and death of the organisms (Derraik, 2002). For instance, a study found that plastic debris in aquatic habitats can transfer hazardous chemicals to fish, leading to adverse effects

(Lusher et al., 2013) The major reason for some marine organisms get entangled or ingest microplastics is because of the formation of biofilm on the microplastic surface, the development of biofilm begins when microorganisms of marine ecosystems attach to the surface of the microplastic resulting in an extracellular polymeric matrix. The biofilm traps nutrients and chemicals in its matrix misleading the organisms as food (Galloway & Lewis, 2016). This direct and indirect transfer of microplastic has affected the food chain badly, A recent study shows traces of microplastics in humans as well, marine organisms that consume microplastics and have those chemical toxins are transferred to humans by consuming them which is dangerous to humans as well (Rochman et al., 2013). The studies also reveal that aquatic plants also uptake microplastics present within the soil matrix (Sherrington & Macfadyen, 2014). The number of marine species reported to interact and get badly affected by plastic and this count increases over time more than thousands of organisms get affected. Previous reports showed that by ingestion 220 species were contaminated, these organisms include marine mammals, fish, invertebrates and fish-eating birds (Wright et al., 2013).

Microplastic moves through the marine food web via trophic transfer (Galloway et al., 2017). When predators consume prey containing microplastics, these particles accumulate in the predator's body which is said to be trophic transfer. This trophic transfer can lead to bioaccumulation, where concentrations of plastics and associated toxic substances increase in the food chain (Wright et al., 2013). A report highlighted that microplastics can act as vectors for major ocean pollutants, facilitating their transfer through marine food webs (Cole et al., 2011). Studies have shown that microplastics are present across all five main trophic levels in aquatic food webs, indicating widespread exposure in marine ecosystems (Setälä et al., 2014). Bioaccumulation and biomagnification are the two critical concepts used in ecological risk assessment to determine the extent of pollutant transfer within food webs. The concept of bioaccumulation and biomagnification refers to dissolved chemical contamination present in marine ecosystems. Bioaccumulation following with trophic transfer of a contaminant may result in the biomagnification of these contaminants at higher trophic levels (Rochman et al., 2013). Biomagnification across a food web can thus be defined as the increase in the concentration of a contaminant (i.e. MPs or additives) in one organism compared to the concentration in its prey. several studies reported high variability in bioaccumulation depending on the taxonomic group and geographical origin of the organisms.

2. Physiological Impacts of Microplastics on Marine Organisms

2.1 Blockages and Obstruction of Digestive Tract:

A wide range of marine organisms including fishes and crustaceans can easily consume microplastics mistaken for food due to these ingested particles, physical blockages are created in the digestive system troubling digestion, reducing feeding efficiency and leading to malnutrition or death (Wright et al., 2013). Microplastics can disturb the gut microbiota, further compromising digestive health and damage may lead to decreased energy levels (Smith et al., 2020). For example, sea turtles consume plastic bags resembling to jellyfish, resulting in fatal blocks (Shaver et al., 2017). Ingested microplastics can damage the gut lining, impairing nutrient absorption and metabolic processes (Browne et al., 2008). Organisms like mussels, clams and oysters are filter feeders, face a lot of peril and are particularly vulnerable, as their feeding mechanisms accidentally trap microplastics along the food particles (Gregory, 2009). It must be noted that the intestinal epithelium is completely exacerbated due to the presence of toxicity and the energy metabolism of the organism negatively impacts its growth, reproduction, and whatever chance of survival there is left (Rios et al., 2019). This has also been supported by several studies related to marine worms, in which it was shown that microplastics affected digestion, among other issues, and impaired energy assimilation (VanCauwenberghe et al., 2015). A case study on blue mussels (Mytilus torculas) in the Baltic Sea collected 500 mussel samples to study the impact of microplastics and nearly 75% with the microplastic logged in their gut lining were found. Not only blockages but more than a 30% reduction in nutrient absorption is seen, resulting in decreased growth rate, reproductive ine ciency and mortality increase in experimental conditions simulating their natural habitat (Lusher et al., 2017). In the same way study on Japanese Lanternfish (Myctophidae) in the Pacific Ocean, a key prey species for larger marine predators, Researchers found that nearly 80% had consumed microplastics and identified over 300 particles per fish in the digestive tracts (Choy et al., 2019). The blockages caused extended hunger periods and made the fish vulnerable to predators (Choy et al., 2019). Over a year-long observation, the population of lanternfish in microplastic-rich zones dropped by 15%, affecting predators like tuna and dolphins (Choy et al., 2019).

2.2 Inflammation and Immune Activation:

Microplastics when inhaled or consumed trigger the immune system and in response, the body attempts to eliminate these foreign particles leading to inflammation and immune system activation, potentially causing tissue damage and increasing susceptibility to diseases due to its ongoing presence causing several micro lesions, the response generally cause reactive oxygen stress (ROS) or oxidative stress in organisms (Rist et al., 2017; Avio et al., 2017).

Oysters show an increase of reactive oxygen at the cellular level which results in consequences such as stress. Stress on micro levels is fine but when it accumulates it inflicts damage on the cellular structure, nervous system and eventually the whole organism (PaulPont et al., 2016). Relative ROS studies show Oxidative Stress in Bivalves (Tegillarca granulosa) when Exposure to PS-MP microparticles and BPA led to significant physiological changes in clams, including alterations in hematic parameters and immune system responses (Cappello et al., 2017). Oxidative Stress in Crustacean's fluorescent PS microparticle exposure caused a significant increase in catalase activity in both crustaceans at almost all tested concentrations. The increased catalase activity indicates that MPs can induce oxidative stress (Zhu et al., 2020). Oxidative Stress in Crustaceans Short-term exposure to nanoparticles reduced antioxidant enzyme activity, highlighting oxidative stress. Long-term exposure increased lipid peroxidation, further confirming oxidative stress (Lusher et al., 2017).

2.3 Chronic Immune Suppression and Disease Susceptibility:

Chronic exposure may suppress the immune function, making marine organisms more vulnerable to infections and diseases. This immunosuppression can have cascading effects on population health and ecosystem stability. There is a clear correlation in the research that has been done that chronic exposure to microplastics in crustaceans and other fish has lowered their chances of developing high-grade pathogens etc. which will have a negative effect on the food web, for instance, one such research revealed (Yang et al. (2022)the microbiomes of crustaceans and bacteria got disrupted as well as viruses and other parasites have a field day within this vacuum of disruptions. A study carried out on Pacific Oysters in Aquaculture Farms analysed the immune response of Pacific oysters exposed to microplastics and found that prolonged exposure triggered a 40% increase in oxidative stress markers, Cellular damage was also observed in the oysters' hemocytes, which are critical for immune defence. As a result, the oysters were 60% more susceptible to infections from the Vibrio bacteria, a common marine pathogen. Certain research has shown that chronic immune suppression increases disease susceptibility in various marine organisms. In bivalves such as *Tegillarca granosa*, exposure to polystyrene MPs (PS-MPs) and bisphenol A (BPA) significantly suppresses immune-related genes, including those in the NF-κB signalling pathway (e.g., TRAF6, MAP3K7). This suppression leads to reduced hematic cell populations, altered cell-type composition, and diminished phagocytic activity, compromising the clams' ability to defend against pathogens(Tang et al., 2019). Crustaceans like striped barnacles (*Amphibalanu amphitrite*) and brine shrimp (*Artemia franciscana*) exposed exhibit accumulation in their intestines, resulting in oxidative stress marked by increased catalase (CAT) activity, this oxidative stress can impair immune functions and make these organisms more vulnerable to infections, and altered swimming behaviour and disrupted neurotoxicity markers further weaken their survival capabilities (Wang et al., 2021). In fish such as zebrafish, prolonged exposure causes intestinal dysbiosis and exacerbates inflammation, weakening the gut's immunological barrier and increasing susceptibility to diseases (Hou et al., 2020). Mussels (*Mytilus galloprovincialis*) exposed to amino-modified PS MPs show decreased hemocyte functionality and altered lysozyme activity, indicating a compromised immune response (Moore et al., 2022). These chronic immune impairments reduce the overall resilience of marine populations, making them more prone to infections and environmental stressors. Overall, MPs-induced immune suppression disrupts essential defence mechanisms in marine organisms, heightening their vulnerability to diseases and reducing population stability.

2.4 Reproductive health impact on hormonal level and fertility:

Exposure to chemicals associated with microplastics, such as bisphenol A (BPA) and phthalates, mimic natural hormones and can disrupt endocrine function in marine organisms and can alter an organism's hormone level or even alter how hormones are regulated and are also linked to reduced fertility and lower reproductive success in marine species. Studies indicate that microplastics can impair gamete quality, and embryonic and larval development, causing hormonal disruption, energy allocation shift, and threatening population sustainability (Lusher et al., 2017). For example, in the case of sea urchins and crustaceans, microplastics caused a decrease in eggs. For instance, research on oysters has shown that microplastic exposure results in decreased sperm motility and egg production, leading to lower fertilization success and compromised larval development (Green et al., 2019). The impact on the reproductive might be the major reason for the decrease in the population of the affected organisms and in the future lead to their annihilation of them from the earth, and these changes affect the long-term evolution of species affected as well as the stability of ecosystems. It can help in understanding the more complicated ways in which microplastics influence marine life. Case studies were carried out which show that when Zebrafish (Danio rerio) were exposed to polystyrene microplastics exhibited a 45% decrease in egg fertilization rates. Male zebrafish also showed reduced sperm motility. Embryos from exposed pairs displayed spinal deformities and lower survival rates, indicating the transgenerational effects of microplastic pollution (Hou et al., 2020). And the other study shows Coral Reefs of the Great Barrier Reef Microplastic particles were found embedded in coral polyps, interfering with gametogenesis. Corals showed a 50% reduction in spawning success, which is compounded by environmental stressors like warming waters and threatening reef stability (Moore et al., 2022). Overall, the presence of microplastics in marine ecosystems stances a substantial threat to the reproductive health of marine organisms, with potential long-term consequences for biodiversity and ecosystem stability.

2.5 Changes in Sensory Systems and Eating Habits Alter from Microplastics Exposure:

The organisms of marine ecosystems rely on their sensory organs like eyes, ears, nose, lateral lining system and vibrissae to detect food, predators, mates and navigate (Cunningham et al., 2020). Sensory signals are essential for habitat selection and migration. Alterations in sensory perception can lead to habitat mismatches, exposing organisms to suboptimal or hazardous environments (Akoueson et al., 2021). And the microplastic interferes both physically and chemically with the sensory system. Physically it may block sensory organs or pathways. For instance, particles lodged in the gills of fish or the feeding appendages of crustaceans can obstruct sensory reception, leading to reduced environmental awareness (Cole et al., 2011), whereas the chemicals of microplastic disrupt chemosensory functions, weakening the ability to detect food or avoid predators (Rochman et al., 2013). Neurotoxic effects or endocrine disruption may cause problems in neural development and hormone regulation leading to alteration in sensory processing and behaviour. For instance, in European Sea Bass and Polystyrene Beads, an experiment shows, sea bass (Dicentrarchus labrax) exposed to water containing microplastics exhibited altered feeding behaviour (Rochman et al., 2013). The fish mistook floating microplastic beads for prey, consuming fewer actual prey items. This reduced their caloric intake by 30%, leading to slower growth (Akoueson et al., 2021), and Hermit Crabs in Coastal Ecosystems when exposed to microplastic-laden environments showed impaired ability to locate suitable shells, which are essential for protection. This behavioural change increased their mortality rate due to predation (Cunningham et al., 2020). Research repeatedly pointed out that microplastics negatively impact organisms and humans throughout their lifespans and shift their course in life. The course change mainly involves the loss of basic sight and an organic, foul odour. Such ailments directly affect marine ecosystems and biodiversity (Rochman et al., 2013).

2.6 Neurotoxicity

Microplastics can trigger neurotoxicity in fish by interfering with enzymes that are critical for nerve function. Research has shown that microplastics can suppress various neurotransmitters, including dopamine, melatonin, vasopressin, serotonin, and oxytocin (Cole et al., 2011). Acetylcholinesterase is often used as a marker of neurotoxicity because it provides insight into potential disruptions in cholinergic signalling pathways. This enzyme deactivates acetylcholine, which is essential for cholinergic junctions and synaptic transmission (Wright & Kelly, 2017). In European seabass, exposure to microplastics decreases acetylcholinesterase activity and increases lipid peroxidation in the brain

(Pedà et al., 2016). Studies have shown that exposing Nile tilapia to MPs for 14 days inhibited Acetylcholinesterase activity, potentially affecting other biochemical responses and leading to neurotoxicity (Cunningham et al., 2020). Accumulated acetylcholine in synapses due to reduced Acetylcholinesterase activity further exacerbates this issue. The inhibition of Acetylcholinesterase is a significant mechanism underlying MPs-induced neurotoxicity. Disruption of nerve signalling can result in motor dysfunction, including muscle weakness, tremors, and coordination issues Multiple studies have documented Acetylcholinesterase inhibition in various fish species after MP exposure, including.

Common carp zebrafish larvae; juvenile common goby (Pomatoschistus microps); African catfish Amazonian cichlid (Symphysodon aequifasciatus) and goldfish. Such inhibition disrupts neurotransmission, motor functions, and behavioural patterns (Cole et al., 2011; Pedà et al., 2016).

2.7 Immunotoxicity

The intestinal immune system includes myeloid, innate lymphoid, and T cells. This system is continuously exposed to various pollutants, including microplastics, which disrupt the functionality (Smith et al., 2018). Numerous studies highlight the detrimental effects of MPs on fish immune systems. For example, exposure for 21 days has been shown to impair intestinal immune cells in zebrafish, leading to an increased abundance of harmful bacteria and potential health issues (Jovanović et al., 2020). Similarly, 30-day exposure to polyethene (PE) MPs at concentrations disrupted the complement system and enzyme activities related to immunity in the plasma of common carp (Xie et al., 2021). Furthermore, phagocytic capacity and respiratory burst of head kidney leukocytes were impaired after exposure to polyvinyl chloride (PVC) MPs for 21 days (Liu et al., 2019). Genes like interferon-induced transmembrane protein and leukotriene B4 receptor were downregulated in the liver of zebrafish following exposure to high concentrations for 20 days (Zhao et al., 2020) MP exposure can also induce neutrophil extracellular trap release, primary granule degranulation, and oxidative damage in cells, collectively impacting fish immunity (Huang et al., 2021). Fish possess an innate immune system that complements their adaptive immunity to defend against foreign toxins. However, MPs can interfere with these defence mechanisms. For example, a study on Crucian carp exposed to MPs at a concentration for over two weeks reported a reduction in IgM levels (Zhang et al., 2019). Lysozymes, crucial components of fish innate immunity that break down bacterial cell walls, are also affected by MPs (Li et al., 2021). The presence of MPs has been shown to alter lysozyme levels in fish. Moreover, exposure to MPs caused significant reductions in lysozyme and immunoglobulin levels in common carp (Yuan et al., 2020). This decline in immunoglobulins could be due to reduced numbers of mature B lymphocytes, their impaired ability to produce immunoglobulins, or diminished production of immunoglobulin (Liu et al., 2019). MPs can lower neutrophil counts in Nile tilapia, aligning with broader findings on MPs' immunotoxin effects in various organisms (Zhao et al., 2020). Cholinesterase inhibition also contributes to reduced immunoglobulin levels in fishes (Zhang et al., 2019). These effects may stem from impaired nutrient absorption and disrupted energy allocation caused by MPs. MPs are recognized as foreign substances that can either trigger immune responses or suppress immune function by inducing immunotoxicity However, other environmental stressors and confounding factors may also influence immune responses, complicating the isolation of MPs' specific effects (Smith et al., 2018). Therefore, while MPs have the potential to impact immune function, the conflicting findings underscore the complexity of their effects and highlight the need for further research to elucidate the mechanisms behind these impacts and their interactions with other environmental fact (Li et al., 2021).

3. Toxicological Effects of Microplastics

Microplastics come from the breakdown of big plastic items into small-sized particles with a diameter between one micrometre to 5mm (Moore, 2008) because of their small size, it is a great threat to the marine organisms which mistake it for their food. Microplastics can be a vector for the introduction of toxic compounds in marine organisms (Brennecke et al., 2016; Wang et al., 2016). The toxicological effects of microplastics are complicated as they carry harmful chemical additives, heavy metals and persistent organic pollutants. When the plastic is uptake by marine life it also ingests the toxic chemicals present in the plastic fragments and it is released into their body creating various health problems such as carcinogenicity, neurotoxicity and disruption of the endocrine system(Zhao, Z., et al., 2019).

3.1 TOXICITY

3.1.1 Chemical Additives: A variety of chemicals are added to improve performance and functionality, which can pose great risks for organisms in marine water bodies. Phthalates (2ethylhexyl) are the most common add-ons used as plasticizers that leach into the environment's surroundings called as endocrine disruptors and are linked with the toxicity of reproductive and developmental defects in marine living organisms such as sea turtles (Zhao, Z., et al., 2019). Bisphenol a polycarbonate plastic and epoxy resin-making component, makes disruptions of endocrine in the organisms of marine habitats. This gets accumulated in the organism’s tissues called bioaccumulation leads to biomagnification passes in the food chain (Zhao, Z., et al., 2019). Polybrominated diphenyl ethers are mixed to decrease the flammability and become a risk to organisms such as species like mussels and oysters, the toxic substance enters their system while they filter the water (Liu, Y., et al., 2018).

3.1.2 Absorption of Pollutants: Microplastics absorb a variety of contaminants, pollutants and toxic metals from marine environments because they have a large surface area to volume ratio and high affinity for heavy metals like Cadmium, mercury and lead which are found in coastal water areas. (Naqash et al., 2020, Rodrigues et al., 2019)These pollutants get attached and end up inside the marine animal body and lead to potentially toxic effects internally like weakened immunity, oxidative stress, and impaired growth (Teuten, E. L., et al., 2009). Microplastic's ability to absorb persistent organic pollutants like DDT, dioxins, and polychlorinated biphenyls which are cancer-causing and cause toxicity in the body.

3.1.3 Leaching of Toxic Substances And Bioaccumulation:

Microplastics have harmful chemicals that leach into the water surrounding water such substances are pollutants and additives. It leads to Bioaccumulation causes damage to marine life because of its toxicity. Like herring and bass when eaten they suffer from an imbalance in hormones and develop disorders. Invertebrates like barnacles, corals, and polyps are affected by disruption of cellular function, which decreases growth and increases mortality, bioaccumulation leads to neurological disorders, the little expectancy of life, and failure of the reproductive system (Browne, M. A., et al., 2013).

3.1.4 Longterm Toxic Effects: The toxic effects of Microplastics make them permanent for longer periods affecting from the cellular level to the entire living population of marine. Carcinogenicity, and neurotoxicity, which make important ecological shifts and loss of biodiversity (Browne, M. A., et al., 2013). The long-term effects cause the stability and sustainability of populations and biodiversity in marine water (Zhao, Z., et al., 2019). Recent reports have said that in 2050 there will be many more microplastics than fish in the world's oceans (World Economic Forum, 2016).

4. Conclusion

The impact of microplastics on marine organisms and ecosystems is a significant environmental issue that requires immediate attention. This review highlights the numerous ways in which microplastics penetrate marine ecosystems, including direct ingestion and physical harm, as well as the release of toxic substances. These factors can cause physiological disruptions that impair essential processes such as digestion, immune function, reproduction, and sensory function in marine organisms. As a result, survival rates and biodiversity are diminished. Marine organisms mistakenly ingest microplastics thinking they are food, they can experience physical blockages and malnutrition. This disruption of gut microbiota can lead to reduced growth, energy imbalances, and increased vulnerability to environmental stressors.

Microplastics can absorb and release harmful chemicals, increasing their toxicity. These particles serve as carriers for pollutants, enhancing the risk of bioaccumulation and biomagnification in marine food webs. As these contaminants are transferred to humans through seafood consumption, they pose significant health risks, connecting the marine microplastic crisis to global food security and public health issues.

The ecological consequences are equally alarming, as microplastics disrupt ecosystem services essential for nutrient cycling, oxygen production, and carbon sequestration. The effects on keystone species like fish, corals, and zooplankton destabilize marine habitats, threatening biodiversity and ecosystem resilience. The reproductive and hormonal disruptions observed in various marine organisms highlight the potential for long-term population declines, which could lead to irreversible ecological damage and economic losses in industries such as fisheries and tourism.

Mitigating the impacts of microplastics requires a multifaceted approach. Preventative measures, including improved waste management, reduction in plastic production, and public awareness campaigns, are essential to curtail the influx of microplastics into aquatic environments. Concurrently, research must continue to unravel the complexities of microplastic interactions with marine organisms, ecosystems, and human health to inform effective policies and conservation strategies. International collaboration and legislative action are critical to reducing plastic pollution at its source and safeguarding marine ecosystems from further degradation.

In conclusion, microplastics represent an escalating threat to marine life and global ecological balance, bridging the realms of environmental and human health crises. Addressing this challenge is not only crucial for protecting marine biodiversity but also imperative for ensuring the sustainability of the ocean's resources and the services it provides to humanity. Our collective actions today will determine the health of marine ecosystems for generations to come.

Fig: Plastic Pollution on the Beaches

Fig: Microplastic in the Ocean

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