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Effects of Microplastics on Fish and in Human Health

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Microplastics (MPs) are regarded as a global issue due to their toxicity effects on fish and humans. Fish is a vital origin of human protein, which is necessary for body growth. Contamination of fish by MPs is a major hazard that requires special focus. After exposure to MPs alone or in combination with other pollutants, fish may experience a variety of health issues. MPs can cause tissue damage, oxidative stress, and changes in immune-related gene expression as well as antioxidant status in fish. After being exposed to MPs, fish suffer from neurotoxicity, growth retardation, and behavioral abnormalities. The consequences of MPs on human health are poorly understood. Due to the abundance of MPs in environment, exposure may occur *via* consumption, inhalation, and skin contact. Humans may experience oxidative stress, cytotoxicity, neurotoxicity, immune system disruption, and transfer of MPs to other tissues after being exposed to them. The toxic effects of MPs in both fish and human are still unknown. This detailed review has the potential to add to existing knowledge about the ecotoxicity effects of MPs in both fish and humans, which will be useful for the forthcoming study.

Keywords: microplastics, toxic effects, fish, contamination, human health risks

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INTRODUCTION

Microplastics (MPs) are a global issue because they are released all over the world (Yu et al., 2018; Alimba and Faggio, 2019). In 2018, global plastics output increased to over 359 million tonnes (Mt), up from 348 Mt in 2017 (PlasticsEurope, 2019). Since the 1950s, when plastic items were widely available, global plastic manufacturing has expanded substantially, from 0.5 Mt/year in 1960 to 348 Mt/year in 2017 (PlasticsEurope, 2018). China is the leading producer of plastics, with 107.7 Mt produced in 2018, accounting for 30% of worldwide plastic production (PlasticsEurope, 2019). Borrelle et al. (2020) projected plastic emissions to 2030 for 173 countries, estimating that plastic emissions to aquatic environment will range between 20 and 53 Mt/year by 2030. Different plastic goods have become commonplace in people's daily lives. Plastics' use has expanded 25-fold in the previous 40 years owing to minimal cost, durability, low weight, and elasticity (Sutherland et al., 2016). Worldwide, plastics are widely utilized in food packaging, building and construction, automobile items, electrical devices, domestic sports and recreational, farming, healthcare, and plastic furnishings (PlasticsEurope, 2019).

MPs are microscopic plastic grains that are said to be common in discarded plastic fragment goods (Thompson et al., 2004). Primary MPs are produced small plastic granules to be used in facial-cleansers and cosmetics, air blasting technology, and vectors for drugs in medicine, while secondary nano plastics are tiny plastic remnants deteriorated from MPs debris (Cole et al., 2011; González-Pleiter et al., 2019). The most prevalent waste materials are brought to the seas by rivers, floods, and winds that pollute the ocean and beaches ecosystem. Discarded fishing craft, plastic bags, food containers, and plastic drinks bottles (water and cold drinks) pollute the water ecosystem (Zhou et al., 2018). Mishandling of enormous anthropogenic activities could introduce many xenobiotic pollutants to water environments around the planet, either deliberately or accidentally (Alimba and Faggio, 2019). MPs are reported to be present at all levels of aquatic environments, posing threat to major biota (Ma et al., 2020; Aragaw, 2021).

MPs have been found in edible fish, according to various research, and as a result of biomagnifications, MPs penetrate human systems (Alfaro-Núñez et al., 2021; Goswami et al., 2020; James et al., 2020). MP-induced impairments in species ranged from minimal biological systems disturbance to substantial unfavorable consequences that resulted in mortality (Mallik et al., 2021). Physiological harm as a result of MPs accumulating within the digestive system; disruption of organisms' energy flow as a result of MPs expelling as pseudofeces; and inner body tissue exposed to MPs after transfer within the body were all designated as harmful by Ma et al. (2020). They also serve as a pathway for organic contaminants and trace metals to reach aquatic habitats (Gholizadeh and Patimar, 2018). MPs can affect predatory behavior in fish and cause misunderstanding between MPs and genuine prey (de Sá et al., 2015), leading to malnutrition and MP storage in key organs such the gills, gut, and stomach (Lu K. et al., 2018; Güven et al., 2017; Greven et al., 2016). MPs were also found in fish muscle/meat, which is mainly consumed by humans (Thiele et al., 2021; Barboza et al., 2020a,b; Akhbarizadeh et al., 2018; Abbasi et al., 2018). Growth retardation, hormone disruption, metabolic perturbation, oxidative stress, immunological and neurotoxicity malfunction, and genotoxicity behavioural alterations are all caused by a buildup of MPs (Güven et al., 2017; Choi et al., 2018).

As fish is a major source of protein for humans, the prevalence and ecotoxicological effects of MPs in fish may influence aquatic food security (Wright and Kelly, 2017; Barboza et al., 2018a). The harmful effects of MPs in fish and humans have been studied in a small number of researches. The goals of this review are to: 1) assess the potentially toxic effects of MPs on fish; 2) determine the impact of MPs on human health, and 3) identify existing knowledge gaps and suggest potential solutions to minimize MPs contamination.

MATERIALS AND METHODS FOR THE DATA COLLECTION AND ANALYSES

Online Study Sites

Data have been collected from many countries around the world. Results from the publications of various scientists and researchers are presented.

Data Collection

The first phase involved the identification of related studies. In order to conduct a systematic literature search, the following specifications were created for the database:

Searching Database

- Scopus, Web of Science, Google Scholar, PubMed, Dimension

Searching Conditions

- Journal articles written in English
- Impact of MPs on fish and human-related journals, book chapters, conference proceedings
- Accessible over the internet (No time limitation)

Searching Strings

The data were tagged with the keywords "*Impacts of microplastics on fish*" "*Effects of microplastics on fish*" "*Toxicity of microplastics on fish*" or "*Adverse impacts of microplastics on fish*" or "*Biomagnification of microplastics on fish*" or "*Impacts of microplastics on human*" or "*Effects of microplastics on human*" or "*Toxicity of microplastics on human*" or "*Adverse impacts of microplastics on human*", etc. A search for "*Impacts of microplastics on fish and human*" in the Dimension database (https://app.dimensions.ai/discover/publication) revealed numerous research papers (**Figures 1A,B**). To gather information on the effects of microplastics in fish and humans, a total of 800 relevant papers were screened. Following the collection of data, two distinct tables were created from these studies.

Research Trends About Effects of MPs in Fish and on Human

MPs pollution is a new environmental concern that poses a risk to fish and human health (Garrido Gamarro et al., 2020; Kutralam-Muniasamy et al., 2020; Huang W. et al., 2021; Aragaw and Mekonnen, 2021). Fish is being contaminated with MPs worldwide and it finds its way to human body through food (Sequeira et al., 2020). Many scientists have recently focused on the effects of MPs in fish and on human health (Chae and An, 2018). Despite the fact that the number of publications is growing, the possible consequences are still largely unknown (Kutralam-Muniasamy et al., 2020). **Figures 1A,B** depicted research patterns, demonstrating how the effect of MPs studies is growing.

Bioavailability of MPs to Fish

MPs are found in practically most of aquatic settings which are the similar size as sediments as well as few planktonic species, subjected them accessible to a variety of aquatic creatures, particularly fish (Pazos et al., 2017; Kumar et al., 2018; Sequeira et al., 2020). The bioavailability of MPs to fish is influenced by a variety of circumstances. Filters and deposit-eating fishes are thought to be more vulnerable to MPs ingestion than predator fishes due to their non-selective feeding behavior (Wesch et al., 2016; Lusher et al., 2020). Mizraji et al. (2017) examined the relationships among tidal fish-eating patterns and the possibility of MPs ingestion and discovered that omnivore fish ingested more MPs than plant-eating and carnivore fish.

MPs particles that resemble natural prey objects seem to be more likely to be ingested by types of fish that are visual eaters. White MPs were ingested more selectively by *Pomatoschistus microps* than black and red particles (de Sa et al., 2015). A suitable form or size could improve the likelihood of MPs being consumed by fish (Auta et al., 2017). Boerger et al. (2010) discovered that the most prevalent size class of MPs swallowed by the Myctophidae in the North Pacific Central Gyre was 1–2.79 mm, which is close to the size category of plankton species, that are the principal food supply for all of these fishes.

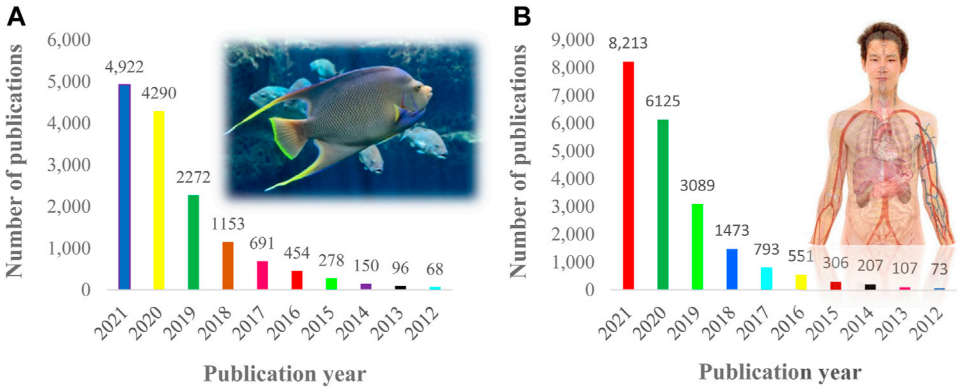

FIGURE 1 | (A) Number of publications on MPs effects in fish **(B)** MPs effect related research trends on human.

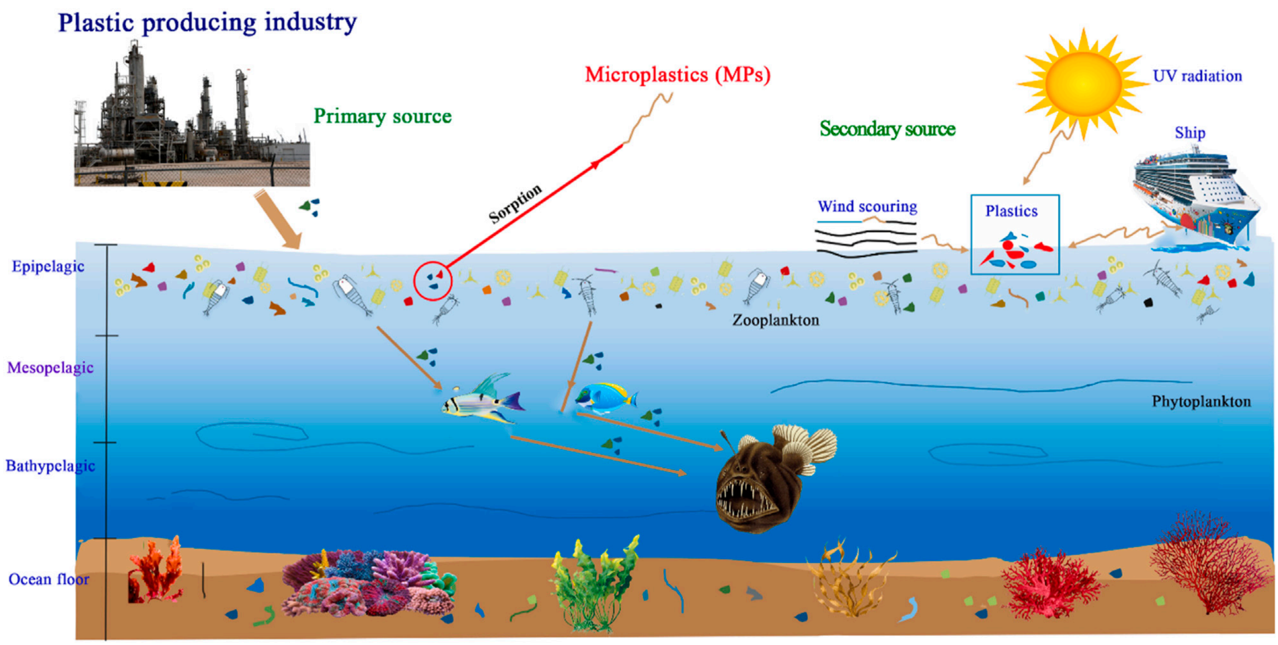

FIGURE 2 | Potential sources and transfer of MPs in fish.

MPs' vertically positioning in the water column is mostly determined by their volume, which may affect the probability of fish encountering MPs in various fish regions (de Sá et al., 2018). Pelagic fishes, for example, seem to be more likely to come across low-density plastics, whereas demersal fish may be more prone to high MPs (Lusher et al., 2013). Moreover, there are many unknowns concerning the fundamental factors that regulate fish choice eating patterns for MPs. The interaction method involving MPs and fish still has to be studied extensively.

Biomagnifications and Trophic Transfer

Biomagnification has been observed in a variety of fish and other species higher up the food chain (**Figure 2**). MPs were found in planktivorous fish, according to Boerger et al. (2010), that biomagnified to bigger predatory feeding on the fish. Biomagnifications have been observed in bluefin tuna, albacore tuna, and swordfish in the Mediterranean Sea (Romeo et al., 2015). MPs were found to be transferred tropically from *Scombrus scombrus* to *Halichoerus grypus*, reported by Nelms et al. (2019). Low density MPs can be expelled as pseudofeces by fish though most of the MPs remain in gastrointestinal tract of fish (Capone et al., 2020; Zhang et al., 2021a; Prata et al., 2022). Biomagnifications from marine species to humans could occur in the same way. Although biomagnification research has been explored, there are few of them. The big facts of biomagnifications and trophic transmission cannot be fully appreciated with these limited investigations. As a result, more research in this area is required.

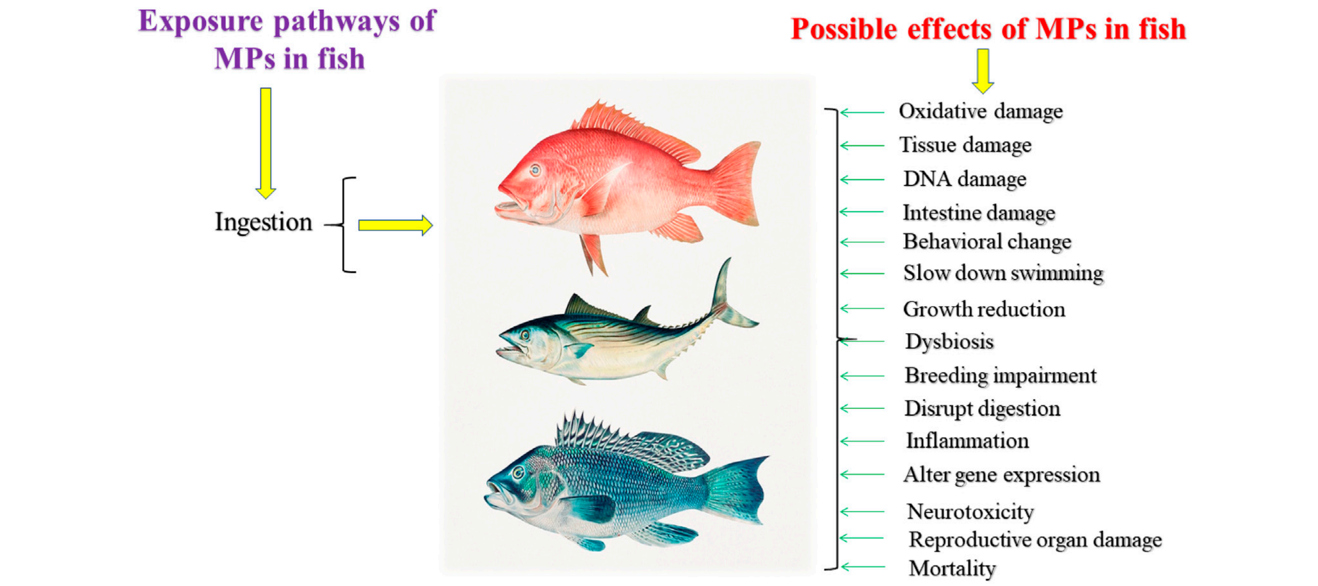

FIGURE 3 | Possible effects of MPs in fish body after ingestion.

How Do Fish React to the Toxicity of Microplastics?

Many researchers have studied the negative consequences of microplastics on species, which can vary from interruption of biological functions to death. MPs poisoning is categorized as follows depending on the nature of MPs after intake:

1) build-up in the gastrointestinal tract, producing physical harm such as blockage and damage;
2) release as pseudofeces, disrupting organisms' energy transfer;
3) transfer inside the body, exposing inner organs and tissues to MPs.

MPs-caused detrimental effects on species were outlined to provide a solid research foundation for sustainable MPs toxicological investigations and to evaluate the potential for huge ecological disruption.

Impacts of MPs, in Fish

MPs exposure has been studied in respect of particular physical or biological reactions. So far, most investigations on the effects of MPs on fish have been undertaken in the laboratory (**Supplementary Table S1**). The fish used in the MPs exposure tests came from a variety of environments, with the bulk coming from the sea. MPs may build up in the gastrointestinal system of fish after consumption, producing obstructions across the digestive tract and limiting feeding owing to appetite (Lusher et al., 2013; Wright et al., 2013). Intake of MPs could also induce anatomical and functional changes in the digestive tracts, causing dietary and development issues in fish (Huang et al., 2022; Jabeen et al., 2018; Borrelle et al., 2017; Peda et al., 2016). Many pieces of research have been carried to demonstrate that MPs pose a threat to fish, with mortality occurring frequently before they reach maturity owing to MPs intake (**Figure 3**). Most of the studies were conducted on *Danio rerio*. Oxidative stress, decreased mobility, gene expression disruption and damage of reproductive organs are the most common effects of MPs in *Danio rerio* (Mu et al., 2021; Zhao et al., 2021; Zhang et al., 2022).

Oryzias melastigma was second most studied fish that subjected to physical impairment due to MPs ingestion (Xia et al., 2022). Growth inhibition, dysbiosis of fish gut, reduction of weight, disturbance of anti-oxidative condition of the liver, damaging reproductive organs and growth retardation are visible effects in *Oryzias melastigma* (Wang et al., 2022; Zhang X. et al., 2021; Feng et al., 2021; Li et al., 2021; Le Bihanic et al., 2020) (**Supplementary Table S1**). *Sparus aurata* is another important consumable fish that affected by MPs ingestion. This fish faced stress, oxidative damage, survival, Behavior changes and damage of immune system's key functions (Espinosa et al., 2017; Pannetier et al., 2020; Jacob et al., 2021; Rios-Fuster et al., 2021; Solomando et al., 2021) (**Supplementary Table S1**).

Microplastics in humans

The presence of MPs in seafood poses a major hazard to human health. Seafood is an essential part of the human diet. MPs contamination of the intestinal system poses a serious risk of spreading to other regions of the body. Endocytosis and persorption are two of the most common methods for MPs to enter the human body (**Figure 4**). Toxicological impacts may reduce fish performance, which is of considerable consideration of humans who eat fish as a major part of their meal, and may have severe impacts on catching fish (Naji et al., 2017; Kor et al., 2020; Kor and Mehdinia, 2020). More examination into these concerns is required, taking into account realistic MP and pollutant levels in the ecosystem (Neves et al., 2015).

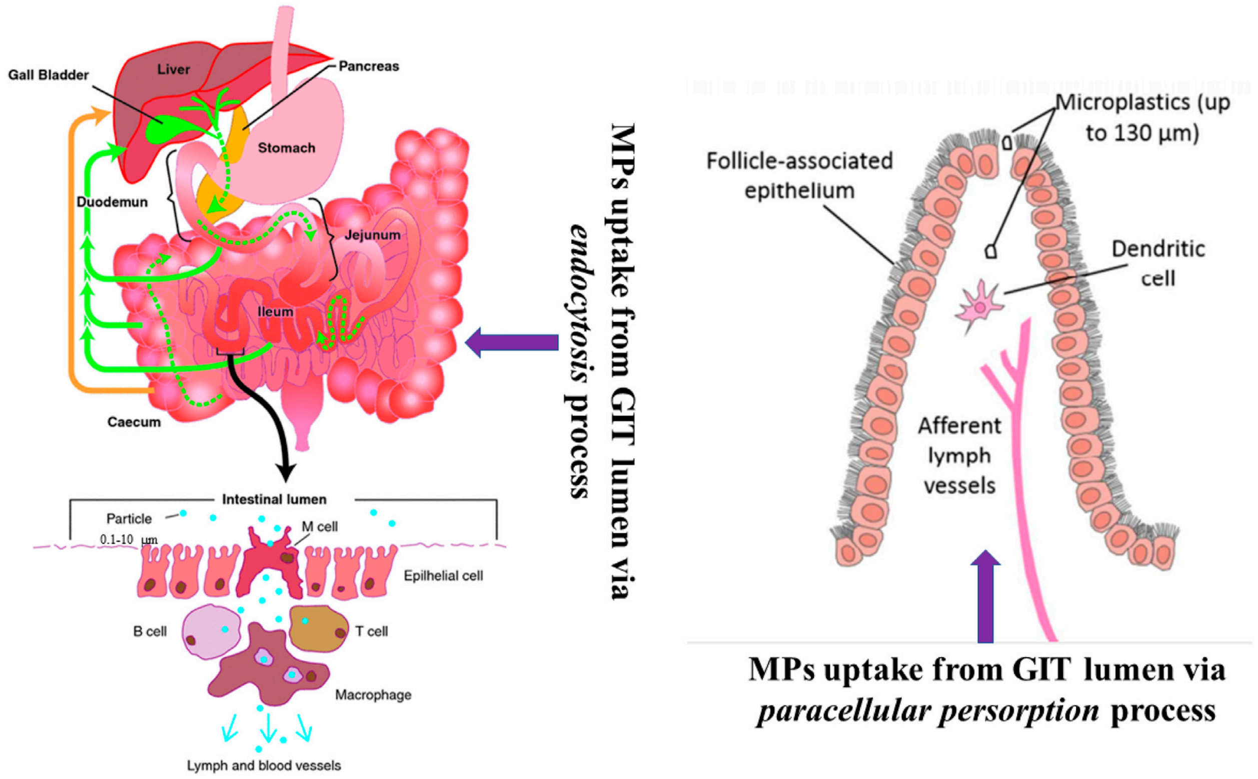

FIGURE 4 | Different process of MPs uptake from gastrointestinal tract (GIT) after exposure (Modified from Galloway, 2015 and Wright and Kelly, 2017).

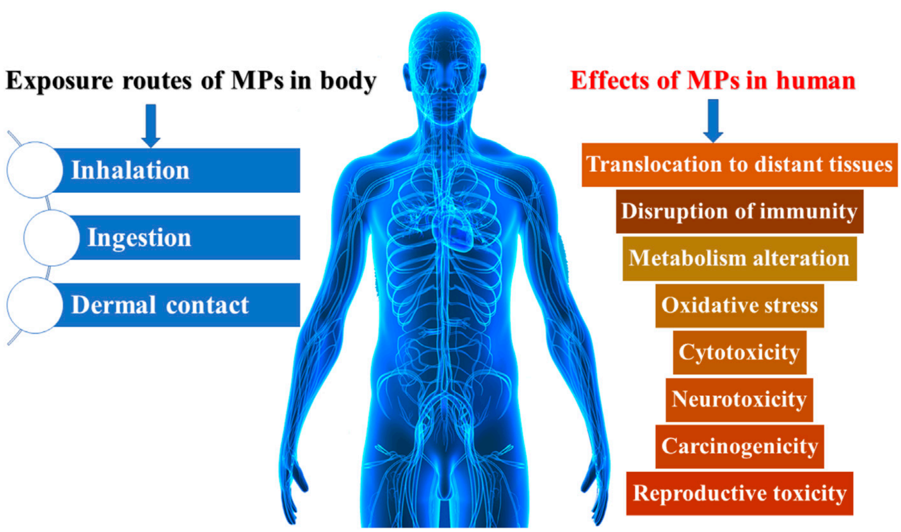

FIGURE 5 | Possible effects of MPs in human body after exposure.

Toxicological Effects in Human Health

Swelling and blockage are caused due to the buildup of MPs and nano plastics in tissues (Wang et al., 2016; Wright et al., 2013). *In vitro* tests revealed that MPs concentrate in the gills, stomachs, and metabolic systems of crabs and cause unfavorable cellular alterations in fish (Karbalaei et al., 2018; Brennecke et al., 2015). Microorganisms and pollutants have also been shown to be transported by them (Manzoor et al., 2020; Wang et al., 2016).

Such negative consequences were mostly determined by the individual's level of exposure and sensitivity (Prata et al., 2020). Exposure to MPs has also been linked to oxidative stress, cytotoxicity, and transfer to other tissues (**Figure 5**) (Galloway, 2015; Schirinzi et al., 2017; Wright and Kelly, 2017; Anbumani and Kakkar, 2018).

MPs are long-lasting in the ecosystem and biological organisms. As a result, the animals are exposed to MPs for an extended period, potentially leading to chronic discomfort, swelling, cell growth, and death, as well as immune cell impairment (Smith et al., 2018). Inflammatory bowel disease was significantly higher in patients with MPs than the healthy people (Yan et al., 2021). PS MPs decreased the growth of Caco-2 cells over time (Wu et al., 2020). The mitochondrial membrane potential was disturbed by PS MPs, according to Wu et al. (2019). MPs may also serve as vectors for a variety of microbes (Kirstein et al., 2016). They can eject compounds from their matrixes or absorb substances from the surrounding (Crawford and Quinn, 2017).

Oxidative Stress and Cytotoxicity

Oxidative stress, consequent inflammatory, and cytotoxic impacts were thought to be the main effects for MPs toxicity in inhalation exposure experiments (**Table 1**). MPs can induce oxidative stress by producing oxidizing substances adsorbing to their surface, as well as reactive oxygen radicals created by the host during the inflammation (Kelly and Fussel, 2012; Valavanidis et al., 2013). Forte et al. (2016) used nanoparticles to stimulate pro-inflammatory replies in A549 lung cells and human gastric cancer cells. Green et al. (1998) found that larger polyethylene particles (0.3–10 m) promote the development of cytokines such as IL-6, IL-1b, and TNF-a, some of which are inflammatory agents.

Due to the polymerization and processing, MPs include reactive oxygen species. Nevertheless, reactions with UV radiation or the existence of reactive metals may cause such free radicals to be greatly amplified. MPs aging also resulted in the formation of free radicals, which oxidized the target tissues (Gewert et al., 2015). Polystyrene nanoparticles link with the surface of the intestinal epithelial, according to Inkielewicz-Stepniak et al. (2018). Nanoplastics caused epithelial cells to oxidize, according to the research (Inkielewicz-Stepniak et al., 2018). Acute toxins and free radicals have been observed to be released by limbs and joint prostheses incorporating MPs in humans because of severe inflammatory reaction. Those oxidants were shown to cause hydrolysis, which led to polymer degradation, breaking, and leaking. This free radical manufacturing process may cause the prosthesis to be rejected by the human organs (Sternschuss et al., 2012).

MPs were found to be cytotoxic as an effect of oxidative damage and inflammation (**Table 1**). MPs can be absorbed by certain cells, such as macrophages, as revealed in animal research and *in vitro* tests (Geiser et al., 2005; Yacobi et al., 2008). MPs interacted easily with intracellular organelles since they were not membrane-bound, posing a risk of damage (Geiser et al., 2005). *In vitro* studies by Furukuma and Fujii, 2016) revealed that MPs particles are cytotoxic. Schirinzi et al. (2017) found that MPs at levels of 0.05–10 mg/L produced reactive oxygen species to high levels, contributing to cytotoxicity in the human brain and epithelial cells in *in vitro* research. Furthermore, *in vitro* contact of macrophages and lung epithelial cells to nano plastics enhanced reactive oxygen radicals, causing unfolded proteins particle agglomeration in the endoplasmic reticulum and cytolysis (Chiu et al., 2015). Thubagere and Reinhard (2010) found that polystyrene particles were cytotoxic to adenomatous cells of the tiny intestine. As a result, individuals exposed to MPs may cause cytotoxicity and oxidative damage. Moreover, no strong cytotoxic effects were found in multiple *in vitro* investigations even at high levels (Magri et al., 2018; Stock et al., 2019; Wu et al., 2019).

Changing the Body's Metabolism and Energy Flow

MPs can either directly influence metabolism by altering metabolic enzymes or circuitously by upsetting the energy equilibrium. By boosting or lowering energy consumption, decreasing nutritional intake, and regulating metabolic enzymes, MPs exhibit metabolic impacts (**Table 1**). Humans, on the other hand, have higher energy requirements and more sophisticated metabolic processes than the creatures studied, which could affect the metabolic impacts (**Table 1**).

Immune System Dysfunction

MPs were reported to cause systemic or local immune responses after exposure, based on their dispersion and human reaction. Environmental exposure to MPs, on the other hand, was enough to impair immune systems in biologically vulnerable individuals, resulting in autoimmune disorders or immunosuppression (**Table 1**) (Prata, 2018; Prata et al., 2020). According to Farhat et al. (2011), chronic damage in cells, the production of immune modulators, and the incorrect stimulation of immune cells may all contribute to MP-induced autoimmune disorders. Antibodies against self-antigens would be produced as an outcome of this chain of events (Farhat et al., 2011). In addition, exposure to MPs has been linked to autoimmune rheumatic illness and systemic lupus erythematosus (Fernandes et al., 2015; Bernatsky et al., 2016). MPs have the potential to alter human immunological function, albeit this has yet to be proven. As a result, more research into the impacts on human immune systems is required.

Translocation of Cells to Other Tissues

MPs may transfer to distal tissues *via* the circulatory system after exposure. Internalization of MPs in the cardiovascular system instigated an inflammatory reaction, blood cell cytotoxicity, vascular swelling, obstructions, and respiratory high blood pressure (**Table 1**) (Wright and Kelly, 2017; Campanale et al., 2020). *In vitro* tests revealed that nanoparticles exposure can cause red blood cell coagulation and endothelium wall adherence (Barshtein et al., 2016). MPs accelerated hemolysis and contributed to the production of histamine, a pro-inflammatory molecule, according to Hwang et al. (2019). The most significant method of MP transfer is enhanced porosity of the epithelial membrane as a result of inflammation (Prata et al., 2020). Wick et al. (2010) revealed that 240 nm nanoparticles may easily pass the placental barrier in a perfusion model of the human placenta. Polystyrene particles were taken up by an *ex vivo* human placental perfusion model, which then

TABLE 1 | Possible lethal effects of micro-and nano plastics on human health.

Toxic effects	Characteristics of Plastic Particles	Particle size	Details	References
Inflammation	Polystyrene particles	202 and 535 nm	* Expression of IL-8 is increased	Deng et al., 2017; Forte et al., 2016; Fuchs et al., 2016; Prietl et al., 2014; Nich and Goodman, 2014; Brown et al., 2011; Green et al., 1998; Devane et al., 1995a,b
	Unaltered/Carboxylated polystyrene nanoparticles	20, 44, 500, and 1000 nm	* Inflammation was induced in human A549 lung cells * Expression of IL-6 and IL-8 is increased	
	Carboxylated and amino-modified polystyrene particles	120 nm	* Multiple human cancers have increased inflammation * Scavenger receptor expression is altered	
	Unaltered polyethylene particles	0–3 µm, 10 µm	* The production of IL-10 was enhanced in M2 cells * TGF (31 (ML) levels have increased, as does energy metabolism (M2)	
	Polyethylene particles from plastic prosthetic implants	0.2 and 10 µm	* Increased IL-6, IL-113, and TNFa production in murine macrophages * TNFct, IL-1, and RANKL expression were all increased	
	Polystyrene MPs particles	5 and 20 µm	* Periprosthetic bone resorption occurred as a result * Induced inflammatory reaction around the implant * The liver is inflamed as a result of the inflammation * Neurotransmission has been harmed as a result of the induction	
Oxidative stress and apoptosis	Amine-modified polystyrene nanoparticles	60 nm	* Mucin has strong interaction and aggregation * Apoptosis was induced in all intestinal epithelial cells	Mahadevan and Valiyaveettil, 2021; Inkielewicz-Stepniak et al., 2018; Liu et al., 2018; Chiu et al., 2015; Ruenraroengsak and Tetley, 2015; Paget et al., 2015; Thubagere and Reinhard, 2010; Xia et al., 2008
	Cationic polystyrene nanoparticles	60 nm	* ROS production and ER stress are both induced * Autophagic cell death in mice macrophages and lung epithelial cells has been induced	
	Unaltered or functionalized polystyrene polyvinyl chloride (PVC) and poly (methyl methacrylate) (PMMA)	20, 40, 50, and 100 nm 120 nm, 140 nm	* Apoptosis was induced in a variety of human cell types * Reduced cell viability due to a decrease in ATP and an increase in ROS levels	
Metabolic homeostasis	Pristine and fluorescent polystyrene MPs	5 µm	* Amino-addition and bile-addition metabolism changes * Induced dysbiosis of the gut microbiota and intestinal barrier failure * Ionic homeostasis and altered ion channel function	Luo et al., 2019a; Jin et al., 2019; McCarthy et al., 2011
	Anionic carboxylated polystyrene nanoparticles	20 nm	* Basolateral K^+ channels that have been activated * Cl^- and HCO_3^- ion outflow is induced	
	Polystyrene nanoparticles	30 nm	* The distribution of cytokinesis-associated proteins and blocked vesicle transit	Stock et al., 2019; Luo et al., 2019a,b; Wang et al., 2020; Deng et al., 2017; Xia et al., 2016; Mahler et al., 2012
	Cationic polystyrene nanoparticles	50 and 200 nm	* Intestinal iron transit and cellular uptake have been disrupted * Hepatic ATP levels are reduced * Deficiency in energy metabolism	
	Pristine polystyrene microparticles	5 and 20 µm	* The metabolic condition is associated with dysbiosis of the gut microbiota and a breakdown of the gut barrier	
	MPs	0.5 and 5 µm	* Increased the chances of metabolic disorders in children	

penetrated the placental barrier without affecting the stability of the explant. Particles were transferred through intracellular and extracellular transporter proteins, as well as diffusion. The results from this study point to the possibility of nanoparticles being transported across the placenta (Wick et al., 2010). Grafmueller et al. (2015) used an *ex vivo* human placental perfusion model to show that polystyrene nanoparticles have a similar capability to breach the placenta barrier.

In vitro tests revealed that when subjected to nano plastics (44 nm), human renal cortical epithelial cells ingested them without cleaning, even after 90 min (Monti et al., 2015). The buildup of particles, on the other hand, caused considerable impairments in renal active operation (Monti et al., 2015). MPs may cause persistent inflammation, impaired organ function, and a higher risk of neoplasia when transferred to distal tissues (Prata et al., 2020). MPs may promote bone loss by stimulating osteoclasts after they reach the bone (Liu et al., 2015; Ormsby et al., 2016). Inconsistencies with the data have been discovered by Braeuning (2019), such as mass disparity of MP tissue burden vs. actual ingestion and the failure to account for MPs' existence in other bodily tissues. As a result, toxicokinetic features of MPs must be considered when evaluating their absorption, dispersion, and effects (Böhmert et al., 2019).

Neurotoxicity

In vivo neurotoxicity has been documented following persistent exposure to particulate matter, particularly MPs, perhaps due to immune cell activation and oxidative stress in the brain (**Table 1**). These events could be the result of direct interaction with teleported particles or the effects of circulating pro-inflammatory cytokines that result in long-term neuronal injury (MohanKumar et al., 2008). MPs have been shown to have an effect on neuronal function and behaviour *in vivo*. Exposure to MPs elevated AChE activity in the brain and altered serum neurotransmitters, according to Deng et al. (2017). Nanoplastics were capable of creating toxicity and impairing metabolic activity in brain cell types in an *in vitro* investigation due to the high level of bioactive chemicals.

Carcinogenicity

For generations, human contact with plastic items has been associated with malignancies. Nevertheless, no conclusive proof has been established until now. According to Prata (2018), prolonged inflammation and irritation caused by MPs consumption may induce cancer by causing DNA damage (**Table 1**). According to Chang (2010), oxidative stress and persistent irritation generated by nano plastics revealed evidence of pro-inflammatory agents, which stimulated vasculature, that led to the creation and development of cancers.

Combine Effects (MPs With Other Pollutants)

Since MPs inclusion in the manufacturing process, they were observed to include a variety of exogenous chemical additions and colors. MPs were frequently detected with persistent organic pollutants (POPs) and phthalates, bisphenol A (BPA), bisphenone, triclosan, organotin, and brominated flame retardants. During the production process of the items, these POPs are applied as additives to plastics (Galloway 2015; EFSA, 2016; Prata et al., 2020). Emollients such as phthalates, for example, are used to soften plastics by lowering the attraction of molecular chains inside the synthetic polymer matrix. BPA is a component monomer in polycarbonate that is used in catering packaging (Cole et al., 2011).

POPs, such as polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs), as well as heavy metals like lead, nickel, cadmium, and zinc, were found in MPs retrieved from various environments (Crawford and Quinn, 2017; Wright and Kelly, 2017). Such chemicals are prone to leaching since no chemical linkages between them and the matrix of MPs (Wright and Kelly, 2017). Structural substances on the surface of MPs were said to travel along the concentration gradient at a consistent rate when they were broken. When MPs come into touch with bodily surfaces and are transported to the deeper tissues, contaminants like these may be produced (Browne et al., 2011). Those chemicals showed the capacity to interact with endogenous hormones even at low doses (Cole et al., 2011).

MPs worked as vectors, delivering germs to target tissues, protecting them from the immune structure, causing pro-inflammatory replies, and potentially facilitating infections (Kirsten et al., 2016). When MPs came into touch with bacteria and chemicals, their large surface area made them vulnerable to becoming vectors (Prata et al., 2020). When compared to the daily consumption of food and dust, MPs may have a minor impact on harmful chemical exposure (Bakir et al., 2014). Numerous MP exposures, on the other hand, could significantly increase their amounts. Monomers, additives, and degradation products carried by MPs, according to Rodrigues et al. (2019), could offer significant human health concerns if transmitted.

Vibrio sp., among the most aggressive bacteria, could populate the surface of MPs, according to Kirsten et al., 2016). MPs, on the other hand, were discovered to affect the variety and activity of the gut microbiome reported by Zhu et al. (2018). Once humans are exposed to a large number of MPs through consumption, such impacts could have serious consequences. According to West-Eberhard (2019), exposure to MPs can affect the gut microbiota, resulting in the rapid growth of opportunistic species, an upsurge in pro-inflammatory responses, and endotoxemia (**Table 1**). The harmful effects of chemicals or microbes adsorbed onto MPs, on the other hand, are greatly reliant on the types and concentrations of swallowed particle, vector particle transportation, release profile, and pollutant lethality in human body cells (Campanale et al., 2020; Prata et al., 2020).

BPA is utilized as an antioxidant and a stabilizer that has the potential to damage the endocrine system (Yamamoto et al., 2001; Halden, 2010). It can move out of polycarbonates and adhere to consumable food, allowing it to be consumed by humans (Calafat et al., 2008). BPA poisoning has been found in tuna fish, pork, and tap water, demonstrating how this toxin can enter highly eaten foods (Colin et al., 2014). BPA levels in the urine of 167 men were shown to be negatively proportionate to serum levels of inhibin B and the estradiol: testosterone ratio, indicating a detrimental effect on hormone levels, according to Meeker et al. (2010). BPA may potentially have a role in the development of overweight by disrupting alpha and beta receptors in fat tissues, changing fat tissue hormone levels, and interacting with the action of lipoprotein lipase, aromatase, and lipogenesis regulators (Vom Saal et al., 2012; Michalowicz, 2014). It has the potential to cause breast and prostate cancer in mammalian species, as well as cancer in humans (Michalowicz, 2014). Many chemical substances found in plastics or firmly attached to MPs, such as leftover low molecular weight styrenes, PAHs, PVC monomer, PCBs, PBDEs, OCPs, and pharmaceutical drugs, which include their metabolites, are toxic to humans, genotoxicity, and hormonal disruptors after being ingested, according to study.

Future Perspectives/Knowledge Gaps

→ The majority of research is done in laboratories, although wild fish must be used in some experiments. The conditions in the lab are very different from those in the real world. Experiment with wild fish to see if there is a difference in the results. A significant future scientific goal should be to increase the number of comparative laboratory-field experiments with parallel exposure in order to evaluate and strengthen our understanding of the real-world impact of MPs.
→ Non-destructive sampling should be maintained. Destructive sampling damages tissue and genetic components in the specimens collected. Destructive sampling makes species-level identification of fish nearly impossible in most circumstances, rendering this methodology inappropriate.
→ MPs' harmful impact on aquatic organisms at various phases of development. Most of the research was carried out in the juvenile stage. Research should be conducted in other stages (e.g., larval, adult stage). MPs exposure must be compared throughout life stages and sexes in order to draw appropriate conclusions about a species' sensitivity. At the moment, findings from a small number of researches imply that younger people and women have a higher inclination to consume more MPs and are more vulnerable to MPs pollution.
→ Proof of the negative effects of MP on individuals, groups, and ecosystems. There are very few negative consequences available. More research is needed to confirm MPs' deleterious impacts. Journals, newspapers, magazines, and different websites are not interested to publish findings if the experiments have no effects on fish and humans. That's why some researchers always try to show negative effects instead of actual findings.
→ Ingestion of MP, internalization and transport potential should be identified. Ingestion routes in the body and how they connect to the gut wall, as well as MPs trophic transfer.
→ MPs' role as vectors for sorbed persistent organic pollutants and metals exposure and bioaccumulation. Many pathogens and contaminants are transported by MPs. It is necessary to define the role of MPs as carriers to identify the ecotoxicological effects of MPs in fish.
→ The influence of related additional compounds on the effects of MPs on aquatic creatures. MPs, in combination with other pollutants, have severe negative effects on organisms, which MPs alone cannot always achieve. It is necessary to determine how much the presence of MPs contributes to fish exposure to these hazardous compounds. Given the importance of fish as a significant source of protein for humans, ongoing research is essential to demonstrate the ecotoxicological effects of MPs on fish at all stages, from individual to community, to experimentally assess the general risks of these emerging pollutants to fish.
→ MPs' specific forms of harmful activity and how they compare to 'typical' oceanic contaminants. Identify the severity of conventional oceanic pollutants and MPs. The toxicity level of MPs in fish is quite necessary to know the extent of MPs' effects in humans.
→ Testing for MP should not be restricted to the gastrointestinal system, but should be done across different tissues and organs as well. The research of tissues of animals used for human sustenance (e.g., fish muscle) is one idea for examining the accumulation of MPs, given their possible role in human healthcare.

CONCLUSION

Plastic is a valuable, useful, and useful material that is used to make up the bulk of the items in daily life; however, in today's world, mismanagement, improper handling, and abuse of plastics have resulted in MPs pollution in every edge of the aquatic environment, from the highest-ranked pelagic layer to seafloor sedimentary rocks. Because MPs are abundant in aquatic ecosystems, fish species have easy access to them. A growing body of research demonstrates that MPs are toxic to a wide range of fish. MPs can collect in the gastrointestinal system of fish after intake and then disperse to other body tissues. MPs can cause a variety of health concerns in fish. Toxic substances and dangerous germs may potentially be transmitted to fish through MPs. Humans eat plastic-tainted fish and are exposed to plastic particles. As a consequence, several chronic illness outbreaks occur, and people suffer the effects. As a result, reducing MPs contamination is critical. Implementing efficient waste management methods, enhancing the shelf life of plastic items, and increasing awareness can substantially limit the input of litter into environments, allowing the aquatic ecosystem to be recovered.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2022.827289/full#supplementary-material

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