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Review

Assessing the Effects of Microplastics on Freshwater Fish

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Abstract: Microplastics are formed through the breakdown of engineering products in consumer goods and large plastic products. These anthropogenic pollutants accumulate globally in both marine and freshwater ecosystems. Nowadays, people use personal care products a lot, and microplastics formed through the decomposition of the packaging of these products spread to the land and water ecosystems, and many living things come into contact with them. Studies have made the presence of microplastics in body parts such as the gastrointestinal tract and stomach, especially in marine and freshwater fish. It can cause physical harm in fish such as internal organ and tissue damage, immune system damage, accumulation, obstruction and damage in the gastrointestinal tract. Increasing evidence shows that a wide range of fish species are susceptible to microplastic ingestion. Already to many criteria such as overfishing, habitat loss, and the increasing number of invasive fish, the negative effects of microplastics will cause fish populations to decrease and some species to become extinct. It is known that plastic pollution, especially about increasing plastic production, poses a great threat to humans, aquatic creatures, and the global environment. Therefore, to draw attention to the danger of microplastics, in this study, the conducted research was examined, the effects of microplastics were reviewed, and the study results were evaluated. In this study, all articles searching microplastics and the amount of microplastics in freshwater fish were systematically examined. 25 studies were found that included the criteria we were looking for, and in these studies, the presence of microplastics was detected in a total of 100 fish species.

Keywords: Environmental pollution; Freshwater fish; FTIR; Microplastics.

1. Introduction

Microplastics are classified as primary or secondary and are less than 5 mm in size. When microplastics originate from industrial processes, they are termed primary microplastics; whereas, if they result from the environmental breakdown of larger plastics owing to thermal, mechanical stimuli or photo-oxidative, they are referred to as secondary microplastics (GESAMP, 2016). Microbeads, airborne pellets, and microfibers found in textiles constitute primary microplastics (Barnes et al., 2009). On the other hand, secondary microplastics encompass plastic debris and waste originating from the photochemical and biodegradation duration of larger plastics, like discarded fishing nets (Boucher and Friot, 2020).

The purpose of this study is to understand the adverse effects of microplastic pollution on fish, to summarize the existing research, and to guide future studies on this topic.

1.1. Classification of microplastics

Many parameters such as the sources, type, shape, wear condition, color of the materials from which they are produced are used to classify microplastics. The classification of microplastics is shown in Figure 1, divided into 5 main classes (Yurtsever, 2015).

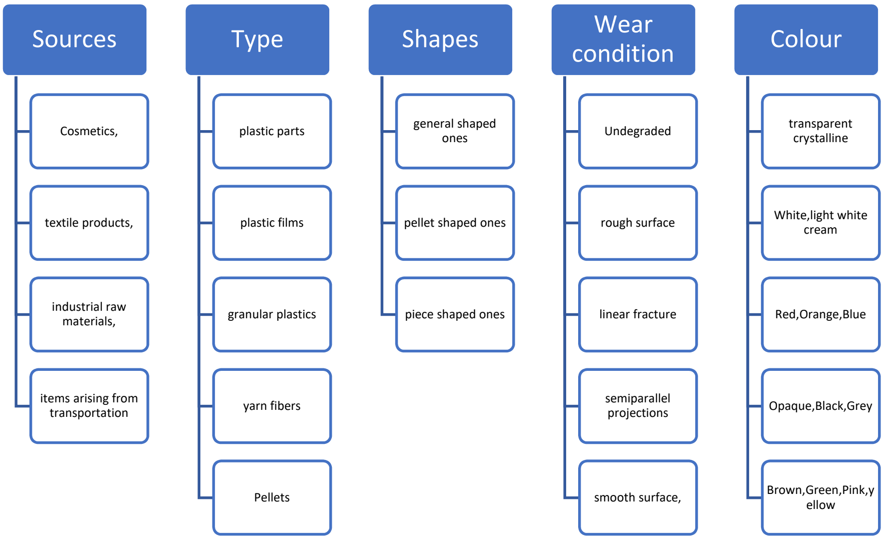

Figure 1. Classification of microplastics.

1.2. Physicochemical features of microplastics

Microplastics exhibit various physicochemical properties, encompassing characteristic features such as hydrophobic surfaces, buoyancy, pollutant transport, UV photo-oxidative degradation, thermo-oxidative characteristics, and biodegradation and/or thermal degradation properties (Hidallgo-Rulz et al., 2012; Wrıght et al., 2013).

1.3. Microplastic polymers

Widely encountered microplastics, constituting approximately 90% of global plastic production, include polystyrene (PS), polyethylene (PE), polyvinyl chloride (PVC), polypropylene (PP), and polyethylene terephthalate (PET) (Venghaus, 2017).

1.4. Microplastic forms

Microplastics can be found in many different forms in environmental environments. Although it is commonly rectangular, tablet-like, spherical, cylindrical and disk-shaped, it is mostly seen in spherical and oval shapes with rounded ends (Abu-Hillal and Al-Najar, 2009; Esmeray and Armutçu, 2020). Most shapes of microplastics exhibit variations according as the type of degradation process and the duration of their presence in the around (Doylle et al., 2011).

1.5. Sources of microplastic

1.5.1. Primer sources of microplastic

Major primary sources of microplastics encompass microbeads found in specific personal care and cosmetic products, microplastics originating from consumer use, some medical applications, drilling fluids used for gas and oil exploration, preproduction plastics, industrial abrasives, residues and waste transferred to the environment throughout plastic recycling and industrial processes (Cole et al., 2011; Yurtsever, 2015; Duis and Coors, 2016; Aslan, 2018).

1.5.2. Seconder sources of microplastic

Secondary microplastics arise from the breakdown of plastic materials used in household kitchens and exteriors, losses during waste collection from recycling facilities, and the release of plastic materials into the environment during natural disasters. Additionally, synthetic polymer particles used for plastic mulching, soil improvement, and compost additives, textile materials produced from synthetic polymers used in clothing, and materials lost or discarded on fishing and comercial vessels also contribute to the formation of secondary microplastics (Cole et al., 2011; Yurtsever, 2015; Duis and Coors, 2016; Aslan, 2018).

1.6. Toxic effects of microplastics

Plastic wastes, owing to their durability and extended lifespan, can persist in the environment for an extended period when discarded. (Rochman et al., 2013). Additionally, microplastics have the capacity to absorb toxic organic chemicals and heavy metals, including antibiotics and pesticides. (Rochman et al., 2013). In plastic production, heavy metals such as lead, copper, and hazardous substances like bisphenol A are utilized, and the small particles resulting from the breakdown of these plastics also contain the same hazardous substances (Brenecke et al., 2016; Koelmanns et al., 2016). Microplastics can accumulate inorganic, organic, and toxic substances from water on their surfaces, transferring them to the surfaces of living organisms (Brennecke et al., 2016; Koelmans et al., 2016).

1.7. Effects of microplastics on fish

The contamination of fishes by microplastics is a concerning danger, particularly since fishes is a crucial source of human protein essential for body development. If fish are exposed to microplastics or microplastics together with other pollutants, it can cause various health problems. These problems include oxidative stress, damage to internal organs and tissues, alterations in antioxidant levels, changes in immune-related gene expression, accumulation in the gastrointestinal tract causing physical harm like clogging and damage, and effects such as the secretion of pseudofeces disrupting the organism's energy transfer (Bhuyan, 2022).

Even when not ingested, microplastics can adversely affect fish and their behavior. If microplastics adhere to the fish body, it can change behavior and lead to respiratory stress, as it affects vital activities such as oxygen consumption-ion regulation (Wats et al., 2016; Abdell-Tawwab et al., 2019). Movement disorders might significantly effect fish as both predators and prey, influencing their survival or growth rate, potentially causing declines in populations (Little and Finger, 1990).

Furthermore, there is evidence of microplastic ingestion by more than 150 species of fish and various other organisms, with the inclusion of mammals, small fish, plankton and seabirds. These occurrences have been reported in both marine systems and freshwater (Jabeen et al., 2017).

1.8. Effect of microplastics on human health

Microplastics can pass to humans directly orally (consumption of drinking water, seafood and other foodstuffs), dermally or through inhalation (Brate et al., 2016), or by penetrating injured skin, although the probability seems low (Lehner and Weder, 2019).

It has been revealed that American adults and children may be exposed to 81,000-123,000 microplastics per year on average (Cox et al., 2019).

Additionally, microplastics may cause mutations in human chromosomes, potentially leading to infertility, obesity, and also cancer (Kumar et al., 2021).

Microplastics were found in the analysis of fecal samples taken from individuals with a diet rich in aquatic products in different geographical regions (Liebmann et al., 2018).

Another potential effect of microplastics is their accumulation on the skin, which can lead to dermal problems (Cox et al., 2019). There is a significant concern about the possibility of microplastics entering the human body through the consumption of fish, which holds a crucial place in the human food chain.

2. Materials and Methods

2.1. Literature review

In this research, a systematic examination of articles related to microplastics and the quantity of microplastics in freshwater fish was conducted. The documents were systematically reviewed using Web of Science (https://webofknowledge.com) until May 1, 2023, employing subject headings and the following terms Search Sequence; ("Microplastic" or "microplastics") and (microplastic; freshwater fish or microplastic Freshwater fish) and (effects of microplastics on fish) and (effects of microplastics on human health).

From the articles obtained as a result of the search, articles containing results suitable for our study were taken.

2.2. Quality evaluation and data extraction

The review of articles adhered to predetermined criteria. Initially, by scrutinizing the titles and abstracts, relevant studies addressing the research question were identified. Subsequently, the materials and methods of each document were assessed to extract specific parameters: water source, microplastics analysis device, freshwater fish species, and the organ from which microplastics were extracted. The evaluation included fish species, the type, and form of microplastics extracted for each species, as summarized in Table 1. Articles investigating the laboratory exposure of fish to microplastics were excluded, focusing solely on studies that selected freshwater fish species as samples and reported the presence of microplastics. Information extracted from each selected document encompassed the first author's name, publication year, study location, the number of samples studied, microplastic shape, and polymers. Additionally, articles reporting the sampling of various fish species were treated as separate entries.

Table 1. Analysis of the data.

Author (row) (Year)	Water resource	Country	Analysis M.	Body part	Fish Species	Eating habits	Number of Sample	Microplastic polymers	Microplastic Shapes
Pattira Kasamesiri (2020) (1)	River	Thailand	M	GIT	*Labiobarbus siamensis*	Detritivore	15	PE, PA	Fiber, rod, pellet, fragment
Pattira Kasamesiri (2020) (2)	River	Thailand	M	GIT	*Puntioplites proctozystron*	Omnivore	6	PE, PA	Fiber, rod, pellet, fragment
Pattira Kasamesiri (2020) (3)	River	Thailand	M	GIT	*Cyclochelichthy repasson*	Omnivore	15	PE, PA	Fiber, rod, pellet, fragment
Pattira Kasamesiri (2020) (4)	River	Thailand	M	GIT	*Henicorhynchus siamensis*	Omnivore	27	PE, PA	Fiber, rod, pellet, fragment
Pattira Kasamesiri (2020) (5)	River	Thailand	M	GIT	*Labeo chrysophekadion*	Detritivore	14	PE, PA	Fiber, rod, pellet, fragment
Pattira Kasamesiri (2020) (6)	River	Thailand	M	GIT	*Mystus bocourti*	Carnivore	20	PE, PA	Fiber, rod, pellet, fragment
Pattira Kasamesiri (2020) (7)	River	Thailand	M	GIT	*Hemibagrus spilopterus*	Carnivore	6	PE, PA	Fiber, rod, pellet, fragment
Pattira Kasamesiri (2020) (8)	River	Thailand	M	GIT	*Laides longibarbis*	Detritivore	4	PE, PA	Fiber, rod, pellet, fragment
Angela CurteanBănăduc (2023) (1)	River	Romania	M	GIT	*Chondrostoma nasus*	Carnivore	12	-	Particles, fragment
Natalia Kuśmierek (2020) (1)	River	Poland	M	GIT	*Gobio gobio*	Carnivore	202	-	Particles, fragment
Natalia Kuśmierek (2020) (2)	River	Poland	M	GIT	*Rutilus rutilus*	Omnivore	187	-	Particles, fragment
Nicholas Koutsikos (2023) (1)	River	Greece	F	GIT	*Squalius vardarensis*	-	32	PE, PVA, PP, PVC	Fiber, fragment
Dalya Saad (2022) (1)	River	South Africa	R	GIT	*Cyprinus carpio*	Omnivore	26	LDPE, HDPE, PP, PET, PTFE	Fragment, pellet, fiber, foam
Parvin Fahmida (2021) (1)	Chan, Lake, River	Bangladesh	F	GIT	*Labeo calbasu*	Omnivore	3	PE. PPC, EVA	Fiber, fragment, foam, filament
Parvin Fahmida (2021) (2)	Chan, Lake, River	Bangladesh	F	GIT	*Cirrhinus reba*	Omnivore	3	PE. PPC, EVA	Fiber, fragment, foam, filament
Parvin Fahmida (2021) (3)	Chan, Lake, River	Bangladesh	F	GIT	*Awaous grammepomus*	Omnivore	2	PE. PPC, EVA	Fiber, fragment, foam, filament
Parvin Fahmida (2021) (4)	Chan, Lake, River	Bangladesh	F	GIT	*Mystus vittatus*	Omnivore	3	PE. PPC, EVA	Fiber, fragment, foam, filament
Parvin Fahmida (2021) (5)	Chan, Lake, River	Bangladesh	F	GIT	*Silonia silondia*	Carnivore	3	PE. PPC, EVA	Fiber, fragment, foam, filament
Parvin Fahmida (2021) (6)	Chan, Lake, River	Bangladesh	F	GIT	*Anabas testudineus*	Omnivore	6	PE. PPC, EVA	Fiber, fragment, foam, filament
Parvin Fahmida (2021) (7)	Chan, Lake, River	Bangladesh	F	GIT	*Mastacembelus armatus*	Omnivore	4	PE. PPC, EVA	Fiber, fragment, foam, filament
Parvin Fahmida (2021) (8)	Chan, Lake, River	Bangladesh	F	GIT	*Nandus meni*	Omnivore	3	PE. PPC, EVA	Fiber, fragment, foam, filament
Parvin Fahmida (2021) (9)	Chan, Lake, River	Bangladesh		GIT	*Labeo bata*	Herbivore	3	PE. PPC, EVA	Fiber, fragment, foam, filament

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Parvin Fahmida (2021) (10)	Chan, Lake, River	Bangladesh	F	GIT	*Puntius sophore*	Omnivore	2	PE. PPC, EVA	Fiber, fragment, foam, filament
Parvin Fahmida (2021) (11)	Chan, Lake, River	Bangladesh	F	GIT	*Cyprinus carpio*	Omnivore	2	PE. PPC, EVA	Fiber, fragment, foam, filament
Parvin Fahmida (2021) (12)	Chan, Lake, River	Bangladesh	F	GIT	*Labeo rohita*	Herbivore	3	PE, PPC, EVA	Fiber, fragment, foam, filament
Parvin Fahmida (2021) (13)	Chan, Lake, River	Bangladesh	F	GIT	*Ompok bimaculatus*	Omnivore	3	PE, PPC, EVA	Fiber, fragment, foam, filament
Parvin Fahmida (2021) (14)	Chan, Lake, River	Bangladesh	F	GIT	*Eutropiichthys vacha*	Carnivore	2	PE. PPC, EVA	Fiber, fragment, foam, filament
Parvin Fahmida (2021) (15)	Chan, Lake, River	Bangladesh	F	GIT	*Oreochromis mossambiscus*	Omnivore	3	PE. PPC, EVA	Fiber, fragment, foam, filament
Muhammed Atamanalp (2022) (1)	River	Turkey	ATR-F	GIT	*Squalius cephalus*	Omnivore	29	PE, PES, PP, PLA, CEL	Fiber, fragment, pellet
Muhammed Atamanalp (2022) (2)	River	Turkey	ATR-F	GIT	*Cyprinus carpio*	Omnivore	25	PE, PES, PP, PLA, CEL	Fiber, fragment, pellet
Muhammed Atamanalp (2022) (3)	River	Italy	ATR-F	GIT	*Alburnus mossulensis*	Omnivore	24	PE, PES, PP, PLA, CEL	Fiber, fragment, pellet
Alessandra Cera (2022) (1)	River	Italy	R	GIT	*Atherina boyeri*	-	36	-	-
Alessandra Cera (2022) (2)	River	China	R	GIT	*Coregonus lavaretus*	-	20	-	-
Xia Xu (2021) (1)	Lake	China	F	GIT	*Crucian*	-	-	PES, PP, PVC, PA, PE, PET	Fiber, fragment, film
Xia Xu (2021) (2)	Lake	China	F	GIT	*Catfish*	-	-	PES, PP, PVC, PA, PE, PET	Fiber, fragment, film
Xia Xu (2021) (3)	Lake	China	F	GIT	*Culter alburnus*	Omnivore	-	PES, PP, PVC, PA, PE, PET	Fiber, fragment, film
Xia Xu (2021) (4)	Lake	China	F	GIT	*Culter dabryi*	-	-	PES, PP, PVC, PA, PE, PET	Fiber, fragment, film
Xia Xu (2021) (5)	Lake	China	F	GIT	*Silver carp*	-	-	PES, PP, PVC, PA, PE, PET	Fiber, fragment, film
Xia Xu (2021) (6)	Lake	China	F	GIT	*Hemiculter leucisculus*	-	-	PES, PP, PVC, PA, PE, PET	Fiber, fragment, film
Xia Xu (2021) (7)	Lake	China	F	GIT	*Mongolian culter*	-	-	PES, PP, PVC, PA, PE, PET	Fiber, fragment, film
Xia Xu (2021) (8)	Lake	China	F	GIT	*Carp*	-	-	PES, PP, PVC, PA, PE, PET	Fiber, fragment, film
Xia Xu (2021) (9)	Lake	China	F	GIT	*Bigmouth grenadier anchovy*	-	-	PES, PP, PVC, PA, PE, PET	Fiber, fragment, film
Xia Xu (2021) (10)	Lake	China	F	GIT	*Pomfret*	-	-	PES, PP, PVC, PA, PE, PET	Fiber, fragment, film
Xia Xu (2021) (11)	Lake	China	F	GIT	*Siniperca chuatsi*	-	-	PES, PP, PVC, PA, PE, PET	Fiber, fragment, film
Xia Xu (2021) (12)	Lake	China	F	GIT	*Pampus argenteus*	Omnivore	-	PES, PP, PVC, PA, PE, PET	Fiber, fragment, film
Xia Xu (2021) (13)	Lake	China	F	GIT	*Xenocypris argentea*	-	-	PES, PP, PVC, PA, PE, PET	Fiber, fragment, film
Xia Xu (2021) (14)	Lake	China	F	GIT	*Cultrichthys erythropterus*	-	-	PES, PP, PVC, PA, PE, PET	Fiber, fragment, film
Xia Xu (2021) (15)	Lake	Canada	F	GIT	*Paracanthobrama guichenoti Bleeker*		-	PES, PP, PVC, PA, PE, PET	Fiber, fragment, film
Keenan Munno (2021) (1)	Lake, River	Canada	F+R	GIT	*Ameiurus nebulosus*	-	18	PE, PET, PP	Fiber, fragment,
Keenan Munno (2021) (2)	Lake, River	Canada	F+R	GIT	*Catostomus commersonii*	Omnivore	33	PE, PET, PP	Fiber, fragment,
Keenan Munno (2021) (3)	Lake, River	Canada	F+R	GIT	*Perca flavescens*	-	22	PE, PET, PP	Fiber, fragment,
Keenan Munno (2021) (4)	Lake, River	Canada	F+R	GIT	*Neogobius melanostomus*	Carnivore	84	PE, PET, PP	Fiber, fragment,
Keenan Munno (2021) (5)	Lake, River	Canada	F+R	GIT	*Notropis atherinoides*	Omnivore	4	PE, PET, PP	Fiber, fragment,
Keenan Munno (2021) (6)	Lake, River	Canada	F+R	GIT	*Luxilus cornutus*	-	62	PE, PET, PP	Fiber, fragment,
Keenan Munno (2021) (7)	Lake, River	Canada	F+R	GIT	*Notropis hudsonius*	Omnivore	8	PE, PET, PP	Fiber, fragment,
Keenan Munno (2021) (8)	Lake, River	Canada	F+R	GIT	*Pimephales promelas*	Omnivore	49	PE, PET, PP	Fiber, fragment,
Keenan Munno (2021) (9)	Lake, River	Canada	F+R	GIT	*Catostomus catostomus*	Omnivore	22	PE, PET, PP	Fiber, fragment,
Keenan Munno (2021) (10)	Lake, River	Canada	F+R	GIT	*Coregonus clupeaformis*	-	30	PE, PET, PP	Fiber, fragment,
Keenan Munno (2021) (11)	Lake, River	Canada	F+R	GIT	*Prosopium cylindraceum*	-	10	PE, PET, PP	Fiber, fragment,
Keenan Munno (2021) (12)	Lake, River	Canada	F+R	GIT	*Coregonus spp*	-	36	PE, PET, PP	Fiber, fragment,
Keenan Munno (2021) (13)	Lake, River	England	F+R	GIT	*Salvelinus namaycush*	-	3	PE, PET, PP	Fiber, fragment,
AR McGoran (2018) (1)	River	England	F	G	*Osmerus eperlanus*	Carnivore	10	PET, PES, PE	-
AR McGoran (2018) (2)	River	United Kingdom	F	G	*Platichthys flesus*	Carnivore	66	PET, PES, PE	-
Alice A. Horton (2018) (3)	River	Belgium	R	GİT	*Rutilus rutilus*	Omnivore	64	PE, PES, PP	Fiber, fragment, film

Bart Slootmaekers (2019) (1)	River	China	R	GİT	*Gobio gobio*	Carnivore	-	-	-
Bowen Li (2020) (1)	River	China	M	G	*Hemiculter leucisculus*	-	32	-	Fiber, pellet
Fangzhu Wu (2020) (1)	Bay	China	F	G, S	*Konosirus punctatus*	-	10	CEL, PA, PE, PP, PET, ABS	Fiber, pellet
Fangzhu Wu (2020) (2)	Bay	Portugal	F	G, S	*Larimichthys crocea*	Carnivore	10	CEL, PA, PE, PP, PET, ABS	Fiber, pellet
Filipa Bessa Estu (2018) (1)	Estu	Portugal	F	GIT	*Platichthys flesus*	Carnivore	40	PE, PP, PES, PAN, PVC, RAYON	Fiber, fragment
Filipa Bessa Estu (2018) (2)	Estu	China	F	GIT	*Dicentrarchus labrax*	Carnivore	40	PE, PP, PES, PAN, PVC, RAYON	Fiber, fragment
Hing Sang Chan (2019) (1)	River	China	F	S	*Evynnis cardinalis*	-	9	-	Fiber, fragment
Hing Sang Chan (2019) (2)	River	China	F	S	*Lutjanus stellatus*	Carnivore	26	-	Fiber, fragment
Hing Sang Chan (2019) (3)	River	China	F	S	*Repomucenus richardsonii*	-	13	-	Fiber, fragment
Xiong Xiong (2018) (1)	Lake	China	R	G, S	*Gymnocypris przewalskii*	-	10	PP, PE, PET, PS	Sheet, fragment, foam, fiber
Ke Zheng (2019) (1)	River	China	F	GIT	*Hypophthalmichthys molitrix*	Algivore	20	PE, PE-PP, PET	Fragment, fiber, sphere
Ke Zheng (2019) (2)	River	China	F	GIT	*Ctenopharyngodon idella*	Herbivore	8	PE, PE-PP, PET	Fragment, fiber, film, sphere
Ke Zheng (2019) (3)	River	China	F	GIT	*Megalobrama hoffmanni*	-	44	PE, PE-PP, PET	Fragment, fiber, film, sphere
Ke Zheng (2019) (4)	River	China	F	GIT	*Squaliobarbus curriculus*	#DEĞER!	52	PE, PE-PP, PET	Fragment, fiber, film, sphere
Ke Zheng (2019) (5)	River	China	F	GIT	*Cirrhinus molitorella*	Herbivore	41	PE, PE-PP, PET	Fragment, fiber, film, sphere
Ke Zheng (2019) (6)	River	China	F	GIT	*Cyprinus carpio*	Omnivore	19	PE, PE-PP, PET	Fragment, fiber
Ke Zheng (2019) (7)	River	China	F	GIT	*Carassius gibelio*	Omnivore	39	PE, PE-PP, PET	Fragment, fiber, film, sphere
Ke Zheng (2019) (8)	River	China	F	GIT	*Coptodon zillii*	Omnivore	44	PE, PE-PP, PET	Fragment, fiber, film, sphere
Ke Zheng (2019) (9)	River	China	F	GIT	*Channa maculata*	Carnivore	12	PE, PE-PP, PET	Fiber
Khalida Jabeen (2017) (1)	Lake	China	F+M	G	*Carassius auratus*	Omnivore	30	PET, PES, SELOFAN	Fiber, pellet
Khalida Jabeen (2017) (2)	Lake	China	F+M	G	*Hemiculter bleekeri*	Planktivore	30	PET, PES, SELOFAN	Fiber
Khalida Jabeen (2017) (3)	Lake	China	F+M	G	*Cyprinus carpio*	Omnivore	30	PET, PES, SELOFAN	Fiber
Khalida Jabeen (2017) (4)	Lake	China	F+M	G	*Megalobrama amblycephala*	Herbivore	30	PET, PES, SELOFAN	Fiber, fragment
Khalida Jabeen (2017) (5)	Lake	China	F+M	G	*Pseudorasbora parva*	Omnivore	30	PET, PES, SELOFAN	Fiber, fragment
Khalida Jabeen (2017) (6)	Lake	Canada	F+M	G	*Hypophthalmichthys molitrix*	Algivore	30	PET, PES, SELOFAN	Fiber, fragment, pellet
Samantha Campbell (2017) (1)	Creek	Canada	M	GIT	*Notropis atherinoides*	Omnivore	75	-	Fiber, fragment, beads
Samantha Campbell (2017) (2)	Creek	Canada	M	GIT	*Esox lucius*	Carnivore	30	-	Fiber, fragment, beads
Samantha Campbell (2017) (3)	Creek	Canada	M	GIT	*Catostomus commersonii*	Omnivore	32	-	Fiber, fragment, beads
Samantha Campbell (2017) (4)	Creek	South Africa	M	GIT	*Eucalia inconstans*	-	10	-	Fiber, fragment, beads
Trishan Naidoo (2020) (1)	Man.	South Africa	F	W	*Oreochromis mossambicus*	Herbivore	58	PES, NYLON, PVC, PP, PE, RAYON	Fiber, fragment
Trishan Naidoo (2020) (2)	Man.	South Africa	F	W	*Ambassis dussumieri*	-	29	PES, NYLON, PVC, PP, PE, RAYON	Fiber, fragment
Trishan Naidoo (2020) (3)	Man.	South Africa	F	W	*Terapon jarbua*	Omnivore	29	PES, NYLON, PVC, PP, PE, RAYON	Fiber, fragment
Trishan Naidoo (2020) (4)	Man.	China	F	W	*Mugil sp*	Omnivore	58	PES, NYLON, PVC, PP, PE, RAYON	Fiber, fragment
Wenke Yuan (2019) (1)	Lake	Argentina	R	GIT	*Carassius auratus*	Omnivore	11	PE, PP, PVC, NYLON	Fiber, film, pellet, fragment
Martín CM Blettler (2019) (1)	River	South America	F	GIT	*Prochilodus lineatus*	Omnivore	21	HDPE, LPDE, PP, PS, EPS	Fiber, film
Marcelo C. Andrade (2019) (1)	River	South America	F	W	*Pristobrycon cf. Scapularis*	Carnivore	14	PVC, PP, PA, PMMA, PET-PA, PET, RAYON	Fragment, film
Marcelo C. Andrade (2019) (2)	River	South America	F	W	*Pristobrycon eigenmanni*	Carnivore	6	PVC, PP, PA, PMMA, PET-PA, PET, RAYON	Fragment, film
Marcelo C. Andrade (2019) (3)	River	South America	F	W	*Pygocentrus nattereri*	Carnivore	4	PVC, PP, PA, PMMA, PET-PA, PET, RAYON	Fragment, film
Marcelo C. Andrade (2019) (4)	River	South America	F	W	*Serrasalmus manueli*	Carnivore	7	PVC, PP, PA, PMMA, PET-PA, PET, RAYON	Fragment, film
Marcelo C. Andrade (2019) (5)	River	South America	F	W	*Serrasalmus rhombeus*	Carnivore	9	PVC, PP, PA, PMMA, PET-PA, PET, RAYON	Fragment, film
Marcelo C. Andrade (2019) (6)	River	South America	F	W	*Metynnis guaporensis*	Herbivore	11	PVC, PP, PA, PMMA, PET-PA, PET, RAYON	Fragment, film
Marcelo C. Andrade (2019) (7)	River	South America	F	W	*Myloplus rubripinnis*	Herbivore	15	PVC, PP, PA, PMMA, PET-PA, PET, RAYON	Fragment, film
Marcelo C. Andrade (2019) (8)	River	South America	F	W	*Myloplus schomburgkii*	Herbivore	6	PVC, PP, PVC,	Fragment, film

								PP, PA, PMMA, PET-PA, PET, RAYON	
Marcelo C. Andrade (2019) (9)	River	South America	F	W	*Acnodon normani*	Omnivore	4	PVC, PP, PA, PMMA, PET-PA, PET, RAYON	Fragment, film
Marcelo C. Andrade (2019) (10)	River	South America	F	W	*Myloplus rhomboidalis*	Omnivore	1	PVC, PP, PA, PMMA, PET-PA, PET, RAYON	Fragment, film
Marcelo C. Andrade (2019) (11)	River	South America	F	W	*Ossubtus xinguense*	Omnivore	19	PVC, PP, PA, PMMA, PET-PA, PET, RAYON	Fragment, film
Marcelo C. Andrade (2019) (12)	River	South America	F	W	*Tometes ancylorhynchus*	Omnivore	5	PVC, PP, PA, PMMA, PET-PA, PET, RAYON	Fragment, film
Marcelo C. Andrade (2019) (13)	River		F	W	*Tometes kranponhah*	Omnivore	63	PVC, PP, PA, PMMA, PET-PA, PET, RAYON	Fragment, film

Water Resource; Chan: Channel; Estu: Estuary; Wet: Wetland; Farm: Farmalnd; Man: Mangrove

Body Part; GIT: Gastrointestinal track; G: Gut (or intestine and stomach); S: Stomach; W: Whole

Analysis M; M: Microscope; F: FTIR; R: Raman

Microplastic polymers; PE: Polyethylene; PA: Polyamide; PVA: Polyvinyl Alcohol; PP: Polypropylene; PVC: Polyvinyl Chloride; PET: Polyethylene Terephthalate; PMMA: Polymethyl Methacrylate; PAN: Polyacrylonitrile; PS: Polystyrene; PES: Polyester; LDPE: Low-Density Polyethylene; HDPE: High-Density Polyethylene; EVA: Ethylene Vinyl Acetate; PLA: Polylactic Acid; PA: Polyamide (Nylon); ABS: Acrylonitrile Butadiene Styrene; PTFE: Polytetrafluoroethylene; PPC: Polypropylene Block Copolymer; Cel: Cellulose

2.3. Literature review and features of the studies

The initial step involved selecting an appropriate search engine for document retrieval. Subsequently, a primary screening was carried out based on the titles and abstracts of the studies, adhering to predetermined criteria. Microplastic-related information was then extracted from the articles, encompassing the first author's name, publication year, fish species, the number of samples, and body parts examined. Articles lacking relevant data were excluded, and the remaining data on each topic were analyzed based on the chosen parameters for further examination.

3. Results

In our study, 25 studies were found that included the criteria we were looking for, and in these studies, the presence of microplastics was detected in a total of 100 fish species.

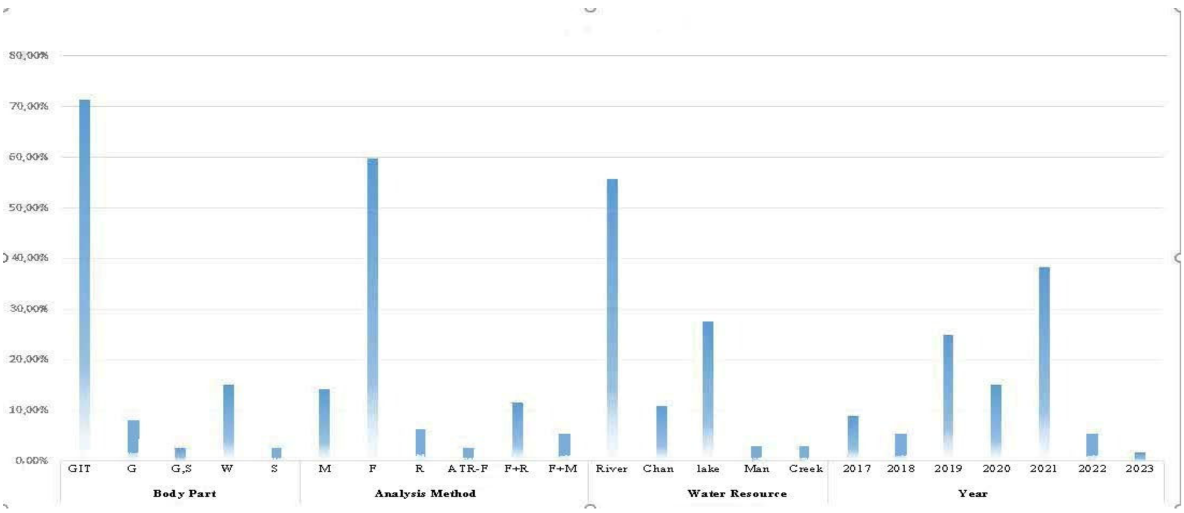

Figure 2. Ratio graph of studies according to body part, analysis method, water source, year.

Among the 25 articles examined according to Figure 2, most studies were on rivers. On the other hand, in the majority of studies, fish gastrointestinal system was used to measure the number of microplastics, and FTIR was used to measure microplastic characterization.

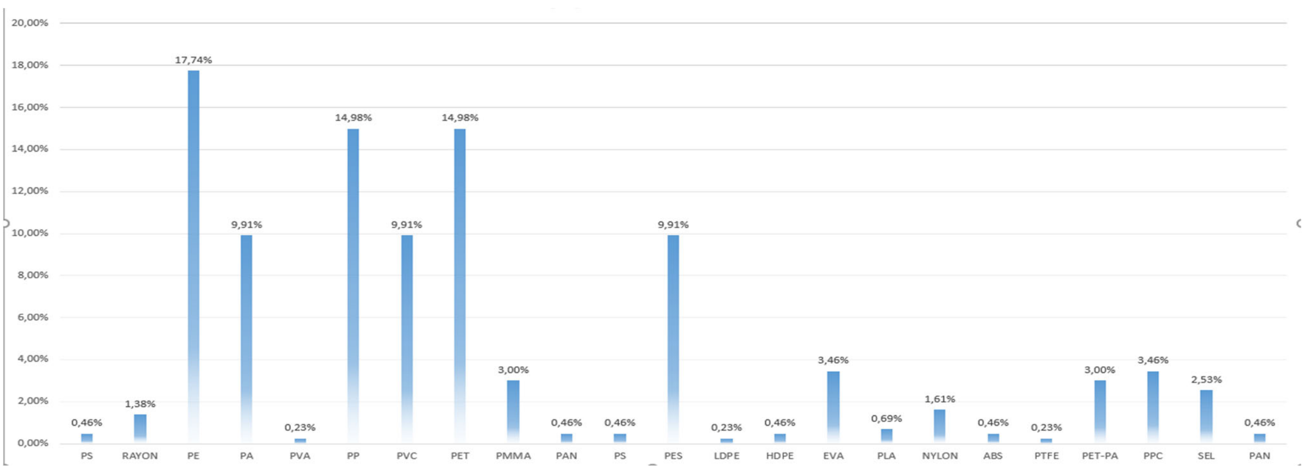

Figure 3. Distribution plot of polymer diversity.

When the studies conducted according to Figure 3 are examined; The highest percentage of microplastic in fish belongs to polyethylene (PE) with (17.74%), this rate is followed by polypropylene (PP) and polyethylene aphthalate with 14.98%, and the lowest percentage of microplastic is polyvinyl chloride (PVA) with (0.23). It has been observed that it belongs to polytetrafluoroethylene (PTFE) and low-density polyethylene (LDPE) polymer types.

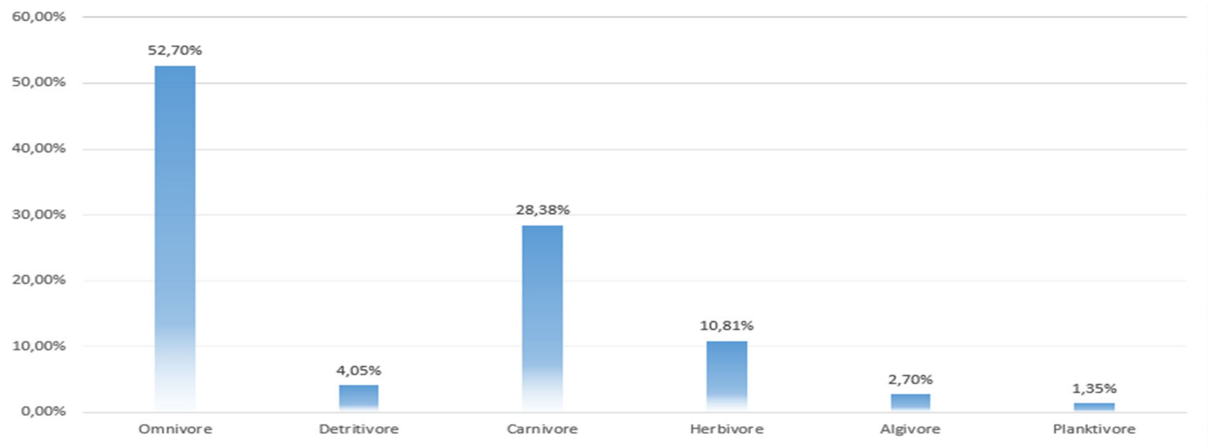

Figure 4. Nutrition habit distribution graph.

When the studies reviewed according to Figure 4 are examined; The fish in which microplastics were detected had the highest omnivorous diet with a rate of 52.70%, followed by the Carnivore diet with a rate of (28.38%), and the lowest diet was a planktivore diet with a rate of (1.35%) It has been observed that.

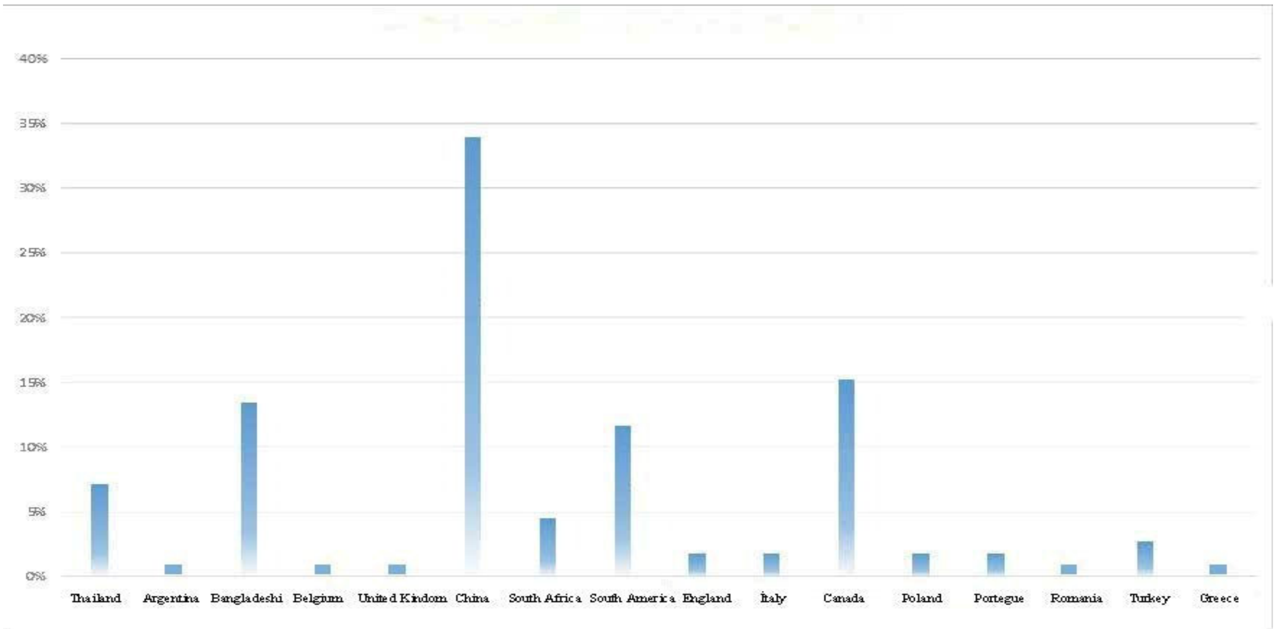

Figure 5. Distribution graph of studies by countries.

When the studies carried out according to Figure 5 are examined; When the distribution analysis was made by country, it was seen that China ranked first, followed by Canada and then Bangladesh.

4. Discussion

Examining many studies conducted in different countries, the presence of microplastics in fish has been proven. Globally, an average of 19-21 million tonnes of plastic entered wastewater ecosystems in 2016, and this amount is predicted to more than double by 2030 (Borrela et al., 2020). Plastic products have increased 25 times in the last 40 years, being preferred by people due to their low price, durability, low weight and flexibility (Sutherland et al., 2016). Plastics are widely used worldwide in food packaging, construction, automobile products, electrical appliances, in-home sports and entertainment, farming, healthcare, and plastic furniture (PlastiksEurope, 2019). Population growth accelerates waste production, which leads to serious environmental problems such as increased plastic pollution, especially in freshwater systems (Blettler et al., 2019).

Microplastics can directly and indirectly affect the lives of aquatic creatures. With the widespread use of plastic waste and the decomposition of old plastics, the presence of microplastics in global waters will continue to increase.

When the studies were examined, it was seen that there was much more research on marine microplastic pollution than on freshwater microplastic pollution, this is because the marine ecosystem is seen as the final pool of microplastics. In addition, the number of species in freshwater fish is less than in the sea, and since people prefer to consume fish living in the sea, studies may have focused on this aspect.

Indeed, the quantity of microplastics found in river fish is influenced by various factors, including the geographic region, level of urbanization, proximity to urban areas, sample size, and the size of the river (Pegado et al., 2018; Slootmaekers et al., 2019). Moreover, variations in the types of microplastics detected in fish from different water sources are attributed to the utilization and discharge of distinct plastics in different regions (Zheng et al., 2019).

Polyethylene, polypropylene, polyester, and polystyrene, which are among the most widely produced polymers globally (PlasticsEurope., 2019), are frequently identified in the gastrointestinal systems of fish (Rummel et al., 2016; Tanaka and Takada, 2016). Fish can ingest microplastics directly through the mixing of these particles with their natural prey items, or indirectly by consuming other organisms that already contain microplastics (Romeo et al., 2015; Batel et al., 2016). When the studies are examined; The highest percentage of microplastic in fish belongs to polyethylene (PE) (17.74%), followed by polypropylene (PP) and polyethylene aphthalate with 14.98%. It was observed that the lowest percentages of microplastics belonged to polyvinyl chloride (PVA), polytetrafluorethylene (PTFE) and low-density polyethylene (LDPE) polymer types, with a ratio of (0.23). The presence of polyethylene in the gastrointestinal systems of fish is linked to its widespread use in fishing gear such as nets, traps, and hooks, as well as its common utilization in food packaging and supplies (Xiong et al., 2018; Kasamesiri and Thaimuangpho, 2020). According to research, another reason why some microplastics are more plenty is that they break down faster. Scientists have reported that PP breaks more easily than PE and PVC, thus producing more microplastics (Xiong et al., 2018).

When the research are examined; It has been observed that most of the studies were made out in China. The reasons for this are; Considering that the country with the largest share in plastic production at the world level is China; The fact that China, the center of the industry, is facing serious pressure in terms of international microplastic pollution may have caused it to do more work in this field to agree with its international commitments and environmental responsibilities.

5.Suggestions

The practice of effective waste management methods, extending the shelf life of plastic products and raising awareness can significantly limit the entry of garbage into the environment, allowing the recovery of the aquatic ecosystem.

Indeed, removing microplastics from habitats is challenging due to their small size. Even if the entry of plastics into the water system is halted, the quantity of microplastics may still rise as larger plastics break down in the environment. Therefore, adopting fundamental measurements followed by reducing plastic input is considered the most effective approach.

Upgrading wastewater treatment facilities to effectively remove microplastics and implementing regulations and limits on the use of plastic fishing gear, along with exploring alternatives made from different materials, can contribute significantly to reducing the introduction of microplastics into water bodies and subsequently impacting aquatic organisms.

Conflicts of Interests

Authors declare that there is no conflict of interests

Financial Disclosure

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Statement contribution of the authors

Conception/Design of Study BA, AP; Data Acquisition BA, AP; Data Analysis/Interpretation BA, AP; Drafting Manuscript BA, AP; Critical Revision of Manuscript BA, AP; Final Approval and Accountability BA, AP; Material and Technical Support BA, AP; Supervision BA, AP

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