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*Review*

# Tiny Particles, Big Problems: The Threat of Microplastics to Marine Life and Human Health

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**Abstract:** Microplastics, primarily derived from plastic waste, are pervasive environmental pollutants found across aquatic and terrestrial ecosystems. This review investigates microplastics' presence, distribution, and impacts in marine ecosystems, with a particular focus on fish species. Research indicates that microplastics are present in various anatomical parts of fish, including the gastrointestinal tracts and gills, with significant implications for marine biodiversity and human health through seafood consumption. The review also highlights the sources of microplastics, such as synthetic textiles, packaging, and personal care products, and explores the pathways through which these particles enter marine environments. Advanced detection techniques have identified microplastics in human tissues, underscoring the urgency of addressing this environmental threat. Comprehensive strategies are essential to mitigate microplastic pollution and protect both marine life and human health.

**Keywords:** microplastics; fish species; marine environment; sources; human health

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## 1. Introduction

Microplastics infiltrate water, air, and soil worldwide. Scientists have provided various insights into their harmful impacts, yet a clear understanding of the extent of their damage to human and animal health remains elusive [1,2]. Nonetheless, there is a consensus that microplastics significantly harm marine ecosystems and are recognised as hazardous pollutants [3]. The primary contributor to microplastic pollution in oceans is the fragmentation of plastic debris originating from waste that enters the ocean from various sources [4].

### *1.1. Sources of Microplastics*

The world is full of plastics, which generate microplastics and nanoplates that are available everywhere, such as water, air, and soil. They have become significant environmental pollutants, posing risks to wildlife and human health. In the following, we will discuss the sources of microplastics and nanoplastics.

The release of tiny synthetic particles or fibres from clothing, textiles, or other synthetic materials into the environment is often very small and can easily become airborne or wash into water systems [5,6]. Similarly, plastic packaging in modern consumer goods contributes to microplastic pollution during both opening and disposal processes [7]. Personal care and cosmetic products, especially prevalent in densely populated urban areas, are also implicated as sources of environmental contamination by microplastics [8,9]. Also, the wear and tear of tyres release microplastics into the environment, a factor often overlooked but significant in exacerbating contamination [10]. Commercial fishing activities inadvertently generate microplastics through processes like netting and gear abrasion [11,12]. Even seemingly harmless items like toy building bricks can be unsuspected reservoirs of microplastics and nanoplastics, posing risks to children who are more susceptible to exposure [13]. Furthermore, industrial activities such as the deterioration of building materials [14] and the transformation of plastic furniture by fire contribute to microplastic and nanoplastic pollution [15]. Advancements in technology, such as Raman imaging, have facilitated the detection and characterisation of these tiny particles across various matrices, such as kitchen blenders [16], smartphones [17], printed toner powders [18], chopping boards [19], cut Polyvinyl Chloride (PVC) pipes [20], non-stick cookware [21], kitchen sponges [22], burned disposable gloves [23], PPE masks [24], rubber bands [25], and haemodialysis waters [26]. Recently, microplastics have also been found in bottled drinking water [27,28] as well as cookware [29]. Details are given in Figure 1.

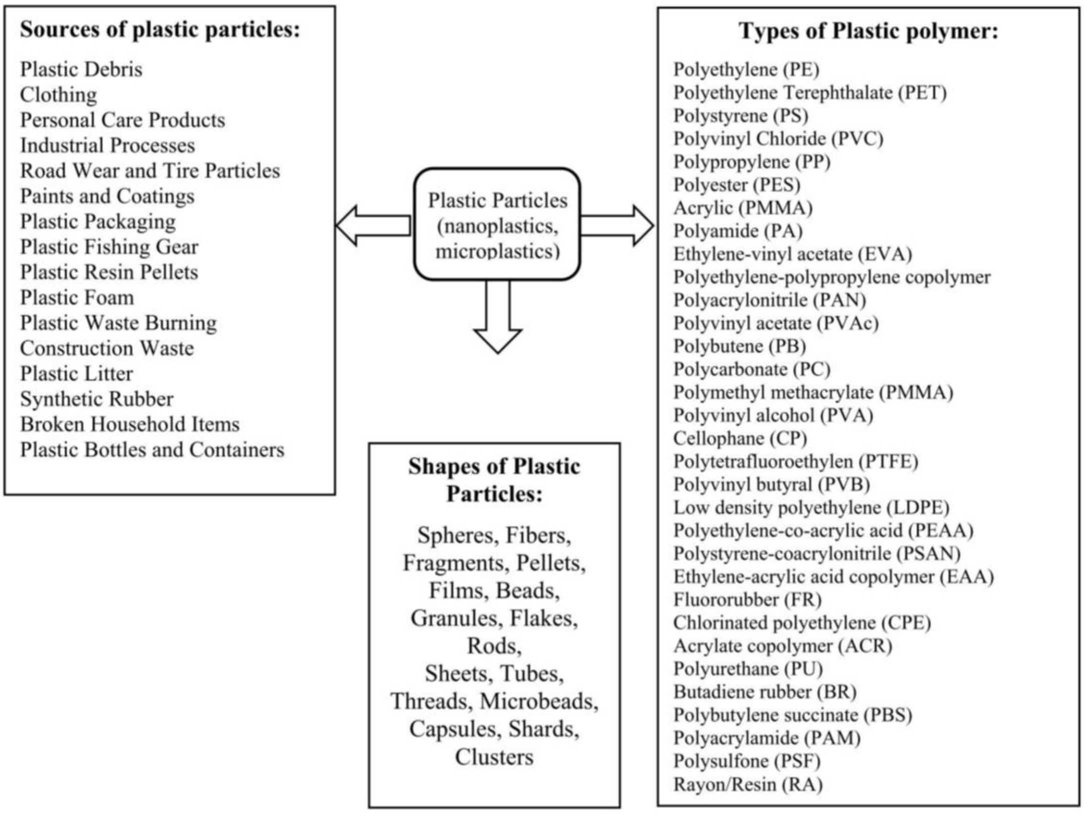


**Figure 1.** Sources of plastic particles, its types and shapes.

### *1.2. Microplastics in Fish Species*

Over the years, researchers have shown that microplastics are found in different fish species, and the details of this literature are discussed below.

In 2016, it was seen that Mussels from China's coastline contained microplastics, with higher levels in wild mussels and those from areas with intensive human activities, primarily fibres and fragments, with a significant proportion smaller than 250 µm, suggesting that mussels could be used as a bio-indicator of microplastic pollution [30]. Also, microplastics were found in 77% of Japanese anchovy in Tokyo Bay, with an average of 2.3 pieces per fish, mostly polyethylene and polypropylene fragments, with some microbeads and a size range of 150 µm to 1000 µm, indicating that microplastics have penetrated the marine ecosystem [31].

In 2017, it was observed that adult grass shrimp exposed to microplastics of various sizes and shapes experienced acute toxicity, with mortality rates ranging from 0% to 55%, and that the shape and size of the particles significantly influenced ingestion and residence time in the gut and gills, with fibres causing significantly higher mortality [32]. Also, only 1 out of 400 North Sea fish (0.25%) had ingested microplastics, with two particles found in a single Sprat, and the particles were identified as polymethylmethacrylate [33]. Moreover, microplastics were found in the livers of the European anchovy, European pilchard, and Atlantic herring, with 80% of anchovy livers containing large microplastics (124–438 µm) [34].

In 2018, it was found that the windward beaches along Trindade Island's eastern coast exhibited a notable concentration of debris, primarily consisting of small plastic fragments. Furthermore, this debris already engaged with the island's wildlife, including seabirds and endangered land-dwelling crabs, adversely affecting these populations [35]. Later, microplastics and other debris were found in all seawater and mussel samples from U.K. coastal waters and supermarkets, with higher levels in pre-cooked supermarket mussels, presenting a route for human exposure [36]. Also, microplastics were found in various tissues of fish and a crustacean from five sites of the Musa Estuary and the Persian Gulf, with a total of 828 microplastics detected, mainly fibrous fragments of various colour and sizes, and some suspected to be paint fragments, raising concerns about the potential transfer of synthetic materials into humans [37]. Moreover, fish from the Persian Gulf contained microplastics and metals, with concentrations increasing with fish size [38]. In addition, microplastics were found in 26 individual fish from 26 species along the Saudi Arabian coast of the Red Sea. Most microplastics were films (61.5%) and fishing thread (38.5%), made of polypropylene and polyethylene [39]. Also, only 2.1% of 292 planktivorous fish (6 individuals) in the Southeastern Pacific coast had microplastics in their digestive tract. It was found that the microplastics were degraded fragments and threads, 1.1–4.9 mm long, and of various colours [40].

In 2019, it was observed that marine plastic litter posed a significant risk to the fin whale in the Mediterranean, with the highest risk of plastic ingestion in the Central Ligurian Sea, and all three sources of plastic litter contributing to impacting cetaceans in the Pelagos Sanctuary [41]. Also, 9 out of 11 marine fish species found in Seri Kembangan, Malaysia, contained plastic debris in their viscera and gills. Up to 76.8% of isolated particles were plastic polymers, with sizes ranging from 200 to 34,900 μm [42]. Moreover, it was seen that different fish species from Haizhou Bay, China, had microplastics in their tissues, where the microplastics were mostly fibres, black or grey, and made of cellophane. It was also observed that the skin and gills had more microplastics than the gut, and scaleless fish had higher microplastic abundances in their skin [43].

In 2020, it was observed that sea anemones, abundant along the Amazon coast, ingest meso- and microplastics, with 75.6% of the examined individuals containing plastic particles, primarily fibres (84%), followed by fragments and films, with a mean of 1.6 items per individual, and a weak positive correlation between anemone weight and plastic particles [44]. Also, microplastics were found in 12 fish species from the Beibu Gulf, with 0.027–1 item per individual, mostly transparent fibres, polyester, and nylon, with demersal fish having a higher microplastic abundance [45]. Additionally, microplastic contamination was found in the seawater and fish from Tuticorin, the southeastern coast of India, with epipelagic fish having higher levels; most microplastics were small blue fibres, with polyethylene being the most common type [46]. Moreover, microplastics were found in 49% of 150 fish from the Northeast Atlantic Ocean, and the estimated human intake through fish consumption ranged from 518 to 3078 microplastic items per year per capita [47]. Also, microplastic pollution was found in the Han River and its tributaries, with varying concentrations and types. Polyethylene, silicone, and polystyrene were most common in the river, while polytetrafluoroethylene, polyethylene, and polyester dominated in the tributaries. Microplastics were found in fish intestines and gills, but not flesh, with fragments being the most common form [48]. In addition, microplastics were found in brown shrimp and tiger shrimp from the Northern Bay of Bengal, Bangladesh. A total of 33 and 39 microplastic items were found, respectively, with an average of 3.40 and 3.87 items per gram of gastrointestinal tract. Filament and fibre shapes were most common, with black being the dominant colour [49]. Also, microplastics were present in the guts of rabbitfish (*Siganus fuscescens*) in coastal Philippines, with semi-synthetic microfibers (rayon) being dominant in sediment samples from Silliman Beach but absent in the fish guts [50].

In 2021, it was observed that Longnose stingrays in the Western Atlantic Ocean had ingested microplastics, with almost a third of the examined specimens containing microplastics in their stomach contents, primarily fibres (82%), blue in colour (47%), and made of polyethylene terephthalate (PET) (35%) [51]. Also, microplastics were found in the water, sediment, and marine organisms (shellfish and finfish) in the Sal Estuary, Goa, India, with high concentrations in finfish, as well as small-sized microplastics dominant in biota [52]. Moreover, 85.4% of commercial fish from the Bohai Sea had ingested microplastics, with an average of 2.14 items per individual, mostly fibrous and PET [53].

In 2022, it was observed that microplastic contamination was widespread in dolphinfish from the Eastern Pacific Ocean, averaging 9.3 pieces per individual, with the majority being polyester (46.8%) and polyethylene terephthalate (38.1%) [54]. Also, microplastics were found in 14 marine dried fish products from seven Asian countries, mostly fibres, with polyethylene, polyethylene terephthalate, and polystyrene being the main polymers, and the highest count was in *Etrumeus micropus* from Japan [55]. Moreover, microplastics were found in dried Bombay duck and ribbon fish from the Bay of Bengal, with higher levels in samples from Kuakata; fibres were the most common type, followed by fragments and other types, with polyethylene, polystyrene, and polyamide polymers identified [56]. Furthermore, microplastics were found in the water, sediment, and fish samples from Mumbai's coastal waters, where fibres were the most common shape, and eleven types of plastic polymers were identified [57]. In addition, microplastics were found in 47.8% of 180 fish specimens from the Northern Adriatic Sea, with a total of 233 fragments identified. The mean concentration ranged from 1.75 to 4.11 items/individual across six species, and polyethylene and polypropylene microplastics were found, ranging in size from 0.054 to 0.765 mm [58]. Also, microplastics were found in the gills and guts of 26 fish species in Haizhou Bay and the adjacent waters, with blue fibre being the most common form [59].

In 2023, it was found that 30% of fish from 24 beaches in the Machado River, Western Brazilian Amazon, had microplastics in their digestive tracts, with 617 microplastics found; contamination was higher in fish from beaches closer to urban settlements, particularly carnivorous fish [60]. Also, microplastics were found in three fish species from the Bay of Bengal, with dried fish having significantly higher amounts than fresh fish; fibres were the most common type found, followed by fragments and other types, with most being small and red, and low-density polyethylene was the most common polymer [61]. Moreover, 35 freshwater fish species in India were analysed, and the highest abundance of microplastic contamination was found in *Channa punctatus*. Fiber-type microplastics were the most dominant, while polyethylene-type polymer microplastics were found mainly in edible tissue [62]. In addition, microplastics were found in fish species from the Pasig and Marikina Rivers in the Philippines, and polypropylene and polyethylene fragments were the most common microplastics identified [63]. Also, a separate research study observed that the Sundarbans mangrove forests in Bangladesh were highly contaminated with microplastics. It was noted that nine fish species had microplastics in their gastrointestinal tract and muscles, where most particles were smaller than 1 mm and black in colour, with polyamide being the most abundant polymer type [64].

### *1.3. Microplastics Detected in Different Regions and Different Fish Species*

The infiltration of microplastics into marine habitats is a pervasive issue affecting a multitude of species. Research has identified their presence in the digestive systems of numerous marine organisms, spanning from the majestic whales to the humble yellow crabs and green turtles [35,41]. Among the affected species, the Longnose stingray, Cangicum anemone, shrimp, mussels, dolphin, various molluscs, and even Japanese anchovies have been found to ingest these harmful particles [30–32,36,44,51,52,54,65]. Notably, microplastics have also been detected in fish populations from diverse regions, such as the Beibu Gulf in the South China Sea, the Machado River in the Western Brazilian Amazon, and the Bohai Sea in China [45,53,60]. Furthermore, the global scope of this issue is evident in the presence of microplastics in dried marine fish sourced from different countries [55,56]. Table 1 provides a comprehensive overview of the fish species affected by microplastic contamination, emphasising the widespread nature of this environmental concern. These findings collectively highlight microplastic pollution's global distribution and their impact on marine ecosystems.

**Table 1.** List of regions and fish specifies where microplastics are detected.

| Ref. | Region | Fish Species |
|---|---|---|
| [52] | Goa, India | Gray mullet, Catfish, Whipfin silver-biddy, Pearlspot |
| [37] | Persian Gulf | Mackerel, Longfin lizardfish, Barramundi, Tongue sole |
| [66] | Tyrrhenian Sea, Italy | Gray mullet, Annular seabream, Red mullet |
| [67] | Western Pacific Ocean | Highfin seabream, Flying gurnard |
| [61] | Bay of Bengal | Bombay duck, Ribbon fish, Hairfin anchovy |
| [46] | Tuticorin, India | Bombay duck, Goldspot herring, White sardine, Indian mackerel, Skipjack tuna, Sailfish |
| [47] | Northeast Atlantic Ocean | European seabass, Atlantic horse mackerel, Atlantic chub mackerel |
| [48] | Han River, South Korea | Carp, Crucian carp, Bluegill, Bass, Catfish, Snakehead |
| [57] | Mumbai coast, India | White sardine, Shrimp, Belanger croaker, Bombay duck, Malabar sole fish |
| [49] | Northern Bay of Bengal, Bangladesh | Brown shrimp, Tiger shrimp |
| [68] | South America | Brown hoplo |
| [62] | India | Spotted snakehead, Rohu, Bata labeo, Spotted mahseer, Amphibious barb |
| [63] | Pasig and Marikina Rivers, Philippines | Nile tilapia, Manila Sea catfish, Armored catfish |
| [58] | Adriatic Sea, Italy | European pilchard or sardine, European anchovy, European hake, Spotted flounder, Striped red mullet, Rock goby |
| [33] | North Sea, Netherlands | Atlantic herring, Sprat, Common dab, Whiting |
| [38] | Persian Gulf | Shrimp scad, Orange-spotted Grouper, Pickhandle barracuda, Bartail flathead |
| [64] | Mongla port, Bangladesh | Ilish, Bhetki, Poa, Tengra, Payra, Loitta, Chemo, Bele |
| [43,59] | Haizhou Bay, China | Kamala River sprat, Red-finned mudskipper, Half-smooth tongue sole, Blackbarred sandperch, Chinese silver pomfret |
| [50] | Central Philippines | Rabbitfish |

### *1.4. Microplastics Detected in Different Body Parts of Fishes*

Table 2 illustrates the various research endeavours focusing on marine fish species, detailing the anatomical regions examined for microplastic presence, the geographical origins of the specimens, and the data analysis methodologies employed. The investigations predominantly prioritise the gastrointestinal tracts and gills of fish, with statistical analysis emerging as most commonly utilised approach by researchers.

**Table 2.** List of observed parts of fish, region of collection of fish, data analysis techniques, and name of the software used.

| Ref. | Observed Parts | Region of Collection | Microscope | Data Analysis Approach and Software |
|---|---|---|---|---|
| [36] | Mussel tissues | United Kingdom | Olympus SZX10 (Tokyo, Japan) | Statistical |
| [54] | Gills, stomachs, intestinal tracts, and muscles | Eastern Pacific Ocean | Leica M205A, OPUS 7.8 (Wetzlar, Germany) | Statistical |
| [52] | Gastrointestinal tracts | Goa, west coast of India | AIM-3800, Olympus SX10 | Statistical, PAST |
| [45] | Gastrointestinal tracts, and gills | Beibu Gulf, South China Sea | Olympus SZX10, Nicolet iN 10 | Experimental |
| [53] | Gastrointestinal tracts | Bohai Sea, China | Olympus, SZX10, Nicolet™ iN10 | Statistical, SPSS v. 20 |
| [55] | Gastrointestinal tracts, muscles and gills | Taiwan, Thailand, Japan, China, South Korea, Vietnam, Sri Lanka | Olympus SZX16, JobinYvon LabRAM HR800 | Statistical |
| [56] | - | Cox's Bazar and Kuakata, Bay of Bengal, Bangladesh | Daffodil MCX100 (Gurgaon, India), Nicolet iS5 FT-IR (Green Bay, WI, USA) | Statistical, SPSS v. 22 |
| [66] | Muscles and gills | Tyrrhenian sea, Italy | Nicolet™ iN10, Omnic™ Picta™ | Statistical |
| [61] | Muscles and gills | Chattogram and Kuakata, Bay of Bengal, Bangladesh | Daffodil MCX100, Nicolet iS5 FT-IR | Statistical |
| [46] | Gastrointestinal tracts | Tuticorin, Southeast coast of India | Thermo Nicolet model iS5 (Waltham, MA, USA) | Statistical |
| [47] | Gastrointestinal tracts, muscles and gills | Northeast Atlantic Ocean | LEICA S9i | Statistical, SPSS v. 24 |
| [48] | Gastrointestinal tract, gills, and fillets | Han River, South Korea | FTIR Microscope, NicoletTM iN10TM MX | Experimental |
| [57] | Gastrointestinal tracts | Mumbai coast, India | SZX16 Model | Statistical, SPSS v. 20 |
| [49] | Gastrointestinal tracts | Northern Bay of Bengal, Bangladesh | XSZ-107BN, IR Affinity-1, Model-8900 | Statistical, R software |
| [68] | Gastrointestinal tracts, and Stomachs | Pajeú river, Northeast of Brazil | dissecting microscope (45×) | Statistical, R v. 3.2.1 |
| [62] | Gastrointestinal tracts, muscles and gills | Lucknow, Uttar Pradesh, India | Leica, EZ4, Witec Alpha 300RA | Statistical, GraphPad PRISM v. 8.4.0 |
| [63] | - | Pasig River, Marikina River, Philippines | Olympus Microscope BX41, Origin-Prov2021 | Experimental |
| [58] | - | Adriatic Sea | Nikon SMZ745T, LabSpec 6 (Tokyo, Japan ) | Experimental |
| [42] | Viscera and gills | Malaysia | Motic SMZ-140 (Hong Kong), Horiba LabRam HR (Tokyo, Japan) | Statistical, SPSS v. 24 |
| [33] | Digestive tract | Coasts of the Netherlands, Belgium, France and Great Britain | Scimitar 1000 FT-IR | Experimental |
| [38] | Muscles | Northeast of Persian Gulf, Iran | Inductively coupled plasma mass spectrometry | Statistical |

**Table 2.** *Cont.*

| Ref. | Observed Parts | Region of Collection | Microscope | Data Analysis Approach and Software |
|---|---|---|---|---|
| [34] | Livers | Mediterranean Sea, Europe | Olympus Provis AX-70, LabRam 300 | Experimental |
| [64] | Gastrointestinal tracts, and muscles | Pasur river, Mongla, Bangladesh | Motic B410E, Stemi 508 | Statistical |
| [43] | Gut, skin and gills | Haizhou Bay, China | Nikon SMZ 1500N, Thermo Nicolet iN10 MX | Statistical, SPSS v. 23 |
| [59] | Gills and guts | Haizhou Bay, China | Olympus SZX2-FOF | Statistical, SPSS v. 25 |
| [39] | - | Saudi Arabian coast of the Red Sea | Stemi 2000 Zeiss (Oberkochen, Germany) | Statistical, RStudio v. 1.1.419 |
| [40] | Digestive tract | Coasts of Panama, Colombia, Ecuador, Peru, and Chile | Agilent Handheld 4300 FTIR (Santa Clara, CA, USA) | Experimental |
| [69] | - | West coast of India | Olympus DSX 110, LUMOS II | Statistical, SPSS v. 22 |

Different types of plastic polymers have been found in different fish species, and their percentage presence in fish species is shown in Table 3. PE, PET, PS, PP, and PES are observed to be the most detected polymers in fish species. Additionally, CP is not a plastic polymer but a natural polymer, which is also highly found in fish species.

**Table 3.** Percentage of different types of polymers found in fish species.

| | References | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Types of Polymers (Microplastics) | [54] | [45] | [53] | [55] | [61] | [46] | [63] | [43] | [39] | [69] |
| PE | 0.7 | 6 | 0.5 | 36 | 38 | 54 | 30.95 | 13 | 42 | 33 |
| PET | 38.1 | 0 | 16.9 | 26 | 0 | 0 | 2.38 | 4.5 | 0 | 4 |
| PS | 5 | 0 | 0.4 | 18 | 22 | 7 | 2.38 | 0 | 4 | 14.5 |
| PVC | 0 | 0 | 0 | 12 | 16 | 0 | 0 | 0 | 8 | 11.5 |
| PP | 7.9 | 6 | 2.5 | 8 | 0 | 7 | 57.14 | 15 | 42 | 21.5 |
| PES | 46.8 | 44 | 0 | 0 | 0 | 14 | 0 | 0 | 0 | 0 |
| PMMA | 0 | 6 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 |
| PA | 0 | 38 | 0.4 | 0 | 13 | 15 | 0 | 8 | 0 | 0 |
| EVA | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 0 |
| Polyethylene-polypropylene copolymer | 1.4 | 0 | 0 | 0 | 0 | 0 | 7.14 | 0 | 0 | 0 |
| PAN | 0 | 0 | 0.9 | 0 | 0 | 0 | 0 | 0 | 4 | 0 |
| PVAc | 0 | 0 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PB | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PC | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 6.5 |
| PMMA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| PVA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| Unidentified | 0.1 | 0 | 0 | 0 | 2 | 0 | 0.01 | 19.5 | 0 | 0 |
| Non-plastic particles | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6.5 | 0 | 0 |
| CP | 0 | 0 | 77.5 | 0 | 0 | 0 | 0 | 33.5 | 0 | 0 |

### *1.5. Microplastics in Human Body*

Humans are exposed to microplastics through various sources, including air, water, food, and soil. In particular, fish is a significant component of the human diet, and the presence of microplastics in fish means that humans are indirectly exposed to microplastic pollution. In 2024, researchers have discovered that these microplastics are potentially associated with cardiovascular diseases [70] and have identified microplastics in different types of human arteries [71]. Researchers have also uncovered tiny plastic particles, including microplastics, within bodily fluids [72]. Laser direct infrared spectroscopy has enabled scientists to detect and measure microplastics in tissues like the endometrium [73], gallstones [74], placenta [75], and even in the amniotic fluid of preterm births [76]. Furthermore, microplastics have been found in human urine and kidney tissue [77,78], lower limb joints [79], vitreous humor [80], and lung tissue [81]. Advanced detection methods have revealed microplastics in the testes and semen [82,83], and even blood [84] itself. Even samples of human stool [85], and from patients undergoing heart surgery [86], have shown traces of microplastics. Details are presented in Table 4.

**Table 4.** Presence of microplastics in human organs, fluids, and waste products.

| Ref. | Sample Type | Detection Method | Type of Microplastics | Average Concentrations |
|---|---|---|---|---|
| [71] | Arteries | Pyrolysis–Gas Chromatography–Mass Spectrometry | PET (73.70%), PA-66 (15.54%), PVC (9.69%), PE (1.07%) | 118.66 ± 53.87 µg/g tissue |
| [72] | Bodily fluids | Raman Microspectroscopy | PP (13.04%), PS (43.48%), PTFE(4.35%), PVB (8.70%), PA-6 (8.70%), LDPE (8.70%), PEAA (4.35%), PSAN (4.35%), PVA (4.35%) | - |
| [73] | Endometrium | Laser Direct Infrared Spectroscopy | EAA (34.58%), FR (14.87%), CPE (11.47%), PE (9.95%), ACR (7.76%), PET (6.63%), PP (6.68%), PS (0.85%), PVC (0.98%), EVA (0.41%), PU (2.09%), BR (2.61%) | 0 to 117 particles/100 mg |
| [74] | Gallstones | Pyrolysis–Gas Chromatography–Mass Spectrometry and Laser Direct Infrared Spectroscopy | PS, PE, PP, PET, EVA | - |
| [75] | Placenta | Laser Direct Infrared Spectroscopy | PVC (43.27%), PP (14.55%), PBS (10.90%), PET (7.27%), PC (6.91%), PS (5.82%), PA (5.45%), polyester fibre (2.91%), PE (1.45%), PAM (0.73%), PSF (0.73%) | 2.70 ± 2.65 particles/g |
| [78] | Urine | Micro-Fourier Transform Infrared Spectroscopy | Healthy donors: PE (27%), PS (16%), PP (12%), Endometriosis participants: PTFE (59%), PE (16%) | - |
| [79] | Lower limb joints | Micro-Fourier Transform Infrared Spectroscopy | PET (27.1%), PE (21.9%), RA (12.0%), PES (11.1%), PP (9.3%), PA (8.5%), PVC (4.7%), PS (4.4%), PC (2.0%) | 5.24 ± 2.07 particles/g |
| [80] | Vitreous humor | Pyrolysis–Gas Chromatography–Mass Spectrometry and Laser Direct Infrared Spectroscopy | PA (74.8%), PVC (7.3%) | - |
| [81] | Lung tissue | Micro-Fourier Transform Infrared Spectroscopy | PP (23%), PET (18%), RA (15%), PE (10%), PTFE (10%), PS (8%), PAN (2%), PES (2%), PMMA (3%), PUR (3%) | 1.42 ± 1.50 MP/g of tissue |
| [82] | Testes and semen | Pyrolysis–gas Chromatography–Mass Spectrometry | Semen: PVC (25%), PE (25%), PA (17%), PS (13%), PP (13%), PET (7%) Testis: PS (67.7%), PVC (12.9%), PE (12.9%), PP (6.5%) | Semen: 0.23 ± 0.45 particles/mL, Testis: 11.60 ± 15.52 particles/g |
| [84] | Blood | Pyrolysis–gas Chromatography–Mass Spectrometry | PE, PS, PET, PMMA | 1.6 µg/mL |
| [85] | Stool | Fourier-Transform Infrared Microspectroscopy | PP (62.8%), PET (17.0%), PS (11.2%), PE (4.8%), PVC (0.54%), PU (0.40%), PA (0.54%), PC (0.67%) | - |

## 2. Conclusions and Future Outlook

Microplastic pollution in marine environments represents a significant and growing environmental challenge with extensive implications for marine biodiversity, ecosystem functionality, and human health. This review has underscored the ubiquity of microplastics in marine ecosystems, tracing their origins to various sources such as synthetic textiles, packaging, and personal care products. Once introduced into the environment, these microplastics infiltrate marine food webs, impacting a wide array of marine organisms, particularly fish.

The ingestion of microplastics by fish has been well documented, with particles being found in their gastrointestinal tracts, gills, and other tissues. These ingested microplastics can cause physical harm, such as blockages and injuries, as well as physiological stress, including reduced feeding, impaired growth, and reproductive issues. Furthermore, microplastics can act as vectors for harmful chemicals and pathogens, exacerbating their detrimental effects on marine life. Human exposure to microplastics primarily occurs through the consumption of seafood. The detection of microplastics in human tissues and their potential link to health issues such as inflammation, cellular damage, and endocrine disruption raises significant concerns. Despite the advancements in detection techniques and growing evidence of the adverse effects, the complete extent of microplastic pollution's impact on human health remains underexplored. Comprehensive and long-term studies are essential to mitigate microplastic pollution's impacts. Future research should focus on the chronic effects of microplastic exposure on marine organisms and the subsequent implications for human health. Such studies should consider various species, developmental stages, and environmental conditions to provide a holistic understanding.

Furthermore, identifying and quantifying the primary sources and pathways through which microplastics enter marine environments is crucial for developing targeted mitigation strategies. Enhanced detection methods and data collection and analysis standardisation are necessary to accurately assess microplastic concentrations across different matrices and studies. Innovation in material science to develop biodegradable alternatives to conventional plastics can offer a sustainable solution to reducing plastic pollution. However, understanding these alternatives' degradation process and environmental impact is vital for ensuring their effectiveness. The development of effective policies and regulations is critical to addressing the issue of microplastic pollution. Interdisciplinary research that integrates environmental science, public health, and policy studies can inform the creation of regulations to reduce plastic production and improve waste management practices. Evaluating the effectiveness of existing policies will also be beneficial in shaping future interventions.

Public awareness and education play a pivotal role in combating microplastic pollution. Educating communities about the sources, impacts, and mitigation strategies can foster behavioural changes that reduce plastic waste. Innovative and effective educational campaigns can engage the public in environmental stewardship. Therefore, addressing the complex issue of microplastic pollution requires a multifaceted approach involving comprehensive research, innovative solutions, effective policies, and public engagement. By advancing our understanding and implementing targeted actions, we can protect marine ecosystems and safeguard human health from the pervasive threat of microplastics.

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## References


1. Saha, S.C.; Saha, G. Effect of microplastics deposition on human lung airways: A review with computational benefits and challenges. *Heliyon* **2024**, *10*, e24355. [CrossRef]
2. Huang, X.; Saha, S.C.; Saha, G.; Francis, I.; Luo, Z. Transport and deposition of microplastics and nanoplastics in the human respiratory tract. *Environ. Adv.* **2024**, *16*, 100525. [CrossRef]
3. Miller, M.E.; Hamann, M.; Kroon, F.J. Bioaccumulation and biomagnification of microplastics in marine organisms: A review and meta-analysis of current data. *PLoS ONE* **2020**, *15*, e0240792. [CrossRef] [PubMed]
4. Guo, X.; Wang, J. The chemical behaviors of microplastics in marine environment: A review. *Mar. Pollut. Bull.* **2019**, *142*, 1–14. [CrossRef] [PubMed]
5. De Falco, F.; Di Pace, E.; Cocca, M.; Avella, M. The contribution of washing processes of synthetic clothes to microplastic pollution. *Sci. Rep.* **2019**, *9*, 6633. [CrossRef] [PubMed]
6. Weis, J.S. Most Microplastics Come from Clothes. *Bioscience* **2021**, *71*, 321. [CrossRef]
7. Sobhani, Z.; Lei, Y.; Tang, Y.; Wu, L.; Zhang, X.; Naidu, R.; Megharaj, M.; Fang, C. Microplastics generated when opening plastic packaging. *Sci. Rep.* **2020**, *10*, 4841. [CrossRef]
8. Bashir, S.M.; Kimiko, S.; Mak, C.W.; Fang, J.K.H.; Gonçalves, D. Personal Care and Cosmetic Products as a Potential Source of Environmental Contamination by Microplastics in a Densely Populated Asian City. *Front. Mar. Sci.* **2021**, *8*, 683482. [CrossRef]
9. Dąbrowska, A.; Mielańczuk, M.; Syczewski, M. The Raman spectroscopy and SEM/EDS investigation of the primary sources of microplastics from cosmetics available in Poland. *Chemosphere* **2022**, *308*, 136407. [CrossRef]
10. Jan Kole, P.; Löhr, A.J.; Van Belleghem, F.G.A.J.; Ragas, A.M.J. Wear and tear of tyres: A stealthy source of microplastics in the environment. *Int. J. Environ. Res. Public Health* **2017**, *14*, 1265. [CrossRef]
11. Wright, L.S.; Napper, I.E.; Thompson, R.C. Potential microplastic release from beached fishing gear in Great Britain's region of highest fishing litter density. *Mar. Pollut. Bull.* **2021**, *173 Pt B*, 113115. [CrossRef]
12. Syversen, T.; Lilleng, G. *Microplastics Derived from Commercial Fishing Activities*; IntechOpen: London, UK, 2023. [CrossRef]
13. Luo, Y.; Naidu, R.; Fang, C. Toy building bricks as a potential source of microplastics and nanoplastics. *J. Hazard. Mater.* **2024**, *471*, 134424. [CrossRef] [PubMed]
14. Yuk, H.; Jo, H.H.; Nam, J.; Kim, Y.U.; Kim, S. Microplastic: A particulate matter (PM) generated by deterioration of building materials. *J. Hazard. Mater.* **2022**, *437*, 129290. [CrossRef]
15. Luo, Y.; Naidu, R.; Fang, C. Accelerated transformation of plastic furniture into microplastics and nanoplastics by fire. *Environ. Pollut.* **2023**, *317*, 120737. [CrossRef] [PubMed]
16. Luo, Y.; Awoyemi, O.S.; Naidu, R.; Fang, C. Detection of microplastics and nanoplastics released from a kitchen blender using Raman imaging. *J. Hazard. Mater.* **2023**, *453*, 131403. [CrossRef] [PubMed]
17. Luo, Y.; Naidu, R.; Fang, C. Raman imaging to capture microplastics and nanoplastics carried by smartphones. *Sci. Total Environ.* **2023**, *864*, 160959. [CrossRef] [PubMed]
18. Luo, Y.; Zhang, Z.; Naidu, R.; Zhang, X.; Fang, C. Raman imaging of microplastics and nanoplastics released from the printed toner powders burned by a mimicked bushfire. *Sci. Total Environ.* **2022**, *849*, 157686. [CrossRef] [PubMed]
19. Luo, Y.; Chuah, C.; Amin Md, A.; Khoshyan, A.; Gibson, C.T.; Tang, Y.; Naidu, R.; Fang, C. Assessment of microplastics and nanoplastics released from a chopping board using Raman imaging in combination with three algorithms. *J. Hazard. Mater.* **2022**, *431*, 128636. [CrossRef] [PubMed]
20. Luo, Y.; Al Amin, M.; Gibson, C.T.; Chuah, C.; Tang, Y.; Naidu, R.; Fang, C. Raman imaging of microplastics and nanoplastics generated by cutting PVC pipe. *Environ. Pollut.* **2022**, *298*, 118857. [CrossRef]
21. Luo, Y.; Gibson, C.T.; Chuah, C.; Tang, Y.; Naidu, R.; Fang, C. Raman imaging for the identification of Teflon microplastics and nanoplastics released from non-stick cookware. *Sci. Total Environ.* **2022**, *851*, 158293. [CrossRef]
22. Luo, Y.; Qi, F.; Gibson, C.T.; Lei, Y.; Fang, C. Investigating kitchen sponge-derived microplastics and nanoplastics with Raman imaging and multivariate analysis. *Sci. Total Environ.* **2022**, *824*, 153963. [CrossRef] [PubMed]
23. Luo, Y.; Gibson, C.T.; Chuah, C.; Tang, Y.; Ruan, Y.; Naidu, R.; Fang, C. Fire releases micro- and nanoplastics: Raman imaging on burned disposable gloves. *Environ. Pollut.* **2022**, *312*, 120073. [CrossRef] [PubMed]
24. Luo, Y.; Naidu, R.; Zhang, X.; Fang, C. Microplastics and nanoplastics released from a PPE mask under a simulated bushfire condition. *J. Hazard. Mater.* **2022**, *439*, 129621. [CrossRef] [PubMed]
25. Fang, C.; Awoyemi, O.S.; Luo, Y.; Naidu, R. Investigating Microplastics and Nanoplastics Released from a Rubber Band Used for Orthodontic Treatment with Improved Raman Imaging Algorithms. *Environ. Health* **2023**, *1*, 63–71. [CrossRef]
26. Passos, R.S.; Davenport, A.; Busquets, R.; Selden, C.; Silva, L.B.; Baptista, J.S.; Barceló, D.; Campos, L.C. Microplastics and nanoplastics in haemodialysis waters: Emerging threats to be in our radar. *Environ. Toxicol. Pharmacol.* **2023**, *102*, 104253. [CrossRef] [PubMed]
27. Hossain, M.B.; Yu, J.; Banik, P.; Noman, M.A.; Nur, A.A.U.; Haque, M.R.; Rahman, M.M.; Albeshr, M.F.; Arai, T. First evidence of microplastics and their characterization in bottled drinking water from a developing country. *Front. Environ. Sci.* **2023**, *11*, 1232931. [CrossRef]

28. Chen, Y.; Xu, H.; Luo, Y.; Ding, Y.; Huang, J.; Wu, H.; Han, J.; Du, L.; Kang, A.; Jia, M.; et al. Plastic bottles for chilled carbonated beverages as a source of microplastics and nanoplastics. *Water Res.* **2023**, *242*, 120243. [CrossRef] [PubMed]
29. Cole, M.; Gomiero, A.; Jaén-Gil, A.; Haave, M.; Lusher, A. Microplastic and PTFE contamination of food from cookware. *Sci. Total Environ.* **2024**, *929*, 172577. [CrossRef]
30. Li, J.; Qu, X.; Su, L.; Zhang, W.; Yang, D.; Kolandhasamy, P.; Li, D.; Shi, H. Microplastics in mussels along the coastal waters of China. *Environ. Pollut. (1987)* **2016**, *214*, 177–184. [CrossRef]
31. Tanaka, K.; Takada, H. Microplastic fragments and microbeads in digestive tracts of planktivorous fish from urban coastal waters. *Sci. Rep.* **2016**, *6*, 34351. [CrossRef]
32. Gray, A.D.; Weinstein, J.E. Size- and shape-dependent effects of microplastic particles on adult daggerblade grass shrimp (*Palaemonetes pugio*): Uptake and retention of microplastics in grass shrimp. *Environ. Toxicol. Chem.* **2017**, *36*, 3074–3080. [CrossRef] [PubMed]
33. Hermsen, E.; Pompe, R.; Besseling, E.; Koelmans, A.A. Detection of low numbers of microplastics in North Sea fish using strict quality assurance criteria. *Mar. Pollut. Bull.* **2017**, *122*, 253–258. [CrossRef] [PubMed]
34. Collard, F.; Gilbert, B.; Compère, P.; Eppe, G.; Das, K.; Jauniaux, T.; Parmentier, E. Microplastics in livers of European anchovies (*Engraulis encrasicolus*, L.). *Environ. Pollut.* **2017**, *229*, 1000–1005. [CrossRef] [PubMed]
35. Andrades, R.; Santos, R.G.; Joyeux, J.C.; Chelazzi, D.; Cincinelli, A.; Giarrizzo, T. Marine debris in Trindade Island, a remote island of the South Atlantic. *Mar. Pollut. Bull.* **2018**, *137*, 180–184. [CrossRef] [PubMed]
36. Li, J.; Green, C.; Reynolds, A.; Shi, H.; Rotchell, J.M. Microplastics in mussels sampled from coastal waters and supermarkets in the United Kingdom. *Environ. Pollut.* **2018**, *241*, 35–44. [CrossRef] [PubMed]
37. Abbasi, S.; Soltani, N.; Keshavarzi, B.; Moore, F.; Turner, A.; Hassanaghaei, M. Microplastics in different tissues of fish and prawn from the Musa Estuary, Persian Gulf. *Chemosphere* **2018**, *205*, 80–87. [CrossRef] [PubMed]
38. Akhbarizadeh, R.; Moore, F.; Keshavarzi, B. Investigating a probable relationship between microplastics and potentially toxic elements in fish muscles from northeast of Persian Gulf. *Environ. Pollut.* **2018**, *232*, 154–163. [CrossRef] [PubMed]
39. Baalkhuyur, F.M.; Bin Dohaish, E.-J.A.; Elhalwagy, M.E.A.; Alikunhi, N.M.; AlSuwailem, A.M.; Røstad, A.; Coker, D.J.; Berumen, M.L.; Duarte, C.M. Microplastic in the gastrointestinal tract of fishes along the Saudi Arabian Red Sea coast. *Mar. Pollut. Bull.* **2018**, *131 Pt A*, 407–415. [CrossRef]
40. Ory, N.; Chagnon, C.; Felix, F.; Fernández, C.; Ferreira, J.L.; Gallardo, C.; Ordóñez, O.G.; Henostroza, A.; Laaz, E.; Mizraji, R.; et al. Low prevalence of microplastic contamination in planktivorous fish species from the southeast Pacific Ocean. *Mar. Pollut. Bull.* **2018**, *127*, 211–216. [CrossRef]
41. Guerrini, F.; Mari, L.; Casagrandi, R. Modeling plastics exposure for the marine biota: Risk maps for fin whales in the Pelagos Sanctuary (North-Western Mediterranean). *Front. Mar. Sci.* **2019**, *6*, 1–10. [CrossRef]
42. Karbalaei, S.; Golieskardi, A.; Hamzah, H.B.; Abdulwahid, S.; Hanachi, P.; Walker, T.R.; Karami, A. Abundance and characteristics of microplastics in commercial marine fish from Malaysia. *Mar. Pollut. Bull.* **2019**, *148*, 5–15. [CrossRef] [PubMed]
43. Feng, Z.; Zhang, T.; Li, Y.; He, X.; Wang, R.; Xu, J.; Gao, G. The accumulation of microplastics in fish from an important fish farm and mariculture area, Haizhou Bay, China. *Sci. Total Environ.* **2019**, *696*, 133948. [CrossRef] [PubMed]
44. Morais, L.M.S.; Sarti, F.; Chelazzi, D.; Cincinelli, A.; Giarrizzo, T.; Martinelli Filho, J.E. The sea anemone *Bunodosoma cangicum* as a potential biomonitor for microplastics contamination on the Brazilian Amazon coast. *Environ. Pollut.* **2020**, *265*, 114817. [CrossRef] [PubMed]
45. Koongolla, J.B.; Lin, L.; Pan, Y.-F.; Yang, C.-P.; Sun, D.-R.; Liu, S.; Xu, X.-R.; Maharana, D.; Huang, J.-S.; Heng-Xiang Li, H.-X. Occurrence of microplastics in gastrointestinal tracts and gills of fish from Beibu Gulf, South China Sea. *Environ. Pollut. (1987)* **2020**, *258*, 113734. [CrossRef] [PubMed]
46. Sathish, M.N.; Jeyasanta, I.; Patterson, J. Occurrence of microplastics in epipelagic and mesopelagic fishes from Tuticorin, Southeast coast of India. *Sci. Total Environ.* **2020**, *720*, 137614. [CrossRef] [PubMed]
47. Barboza, L.G.A.; Lopes, C.; Oliveira, P.; Bessa, F.; Otero, V.; Henriques, B.; Raimundo, J.; Caetano, M.; Vale, C.; Guilhermino, L. Microplastics in wild fish from North East Atlantic Ocean and its potential for causing neurotoxic effects, lipid oxidative damage, and human health risks associated with ingestion exposure. *Sci. Total Environ.* **2020**, *717*, 134625. [CrossRef] [PubMed]
48. Park, T.-J.; Lee, S.-H.; Lee, M.-S.; Lee, J.-K.; Lee, S.-H.; Zoh, K.-D. Occurrence of microplastics in the Han River and riverine fish in South Korea. *Sci. Total Environ.* **2020**, *708*, 134535. [CrossRef] [PubMed]
49. Hossain, M.S.; Rahman, M.S.; Uddin, M.N.; Sharifuzzaman, S.M.; Chowdhury, S.R.; Sarker, S.; Chowdhury, M.S.N. Microplastic contamination in Penaeid shrimp from the Northern Bay of Bengal. *Chemosphere* **2020**, *238*, 124688. [CrossRef]
50. Bucol, L.A.; Romano, E.F.; Cabcaban, S.M.; Siplon, L.M.D.; Madrid, G.C.; Bucol, A.A.; Polidoro, B. Microplastics in marine sediments and rabbitfish (*Siganus fuscescens*) from selected coastal areas of Negros Oriental, Philippines. *Mar. Pollut. Bull.* **2020**, *150*, 110685. [CrossRef]
51. Pegado, T.; Brabo, L.; Schmid, K.; Sarti, F.; Gava, T.T.; Nunes, J.; Chelazzi, D.; Cincinelli, A.; Giarrizzo, T. Ingestion of microplastics by *Hypanus guttatus* stingrays in the Western Atlantic Ocean (Brazilian Amazon Coast). *Mar. Pollut. Bull.* **2021**, *162*, 111799. [CrossRef]
52. Saha, M.; Naik, A.; Desai, A.; Nanajkar, M.; Rathore, C.; Kumar, M.; Gupta, P. Microplastics in seafood as an emerging threat to marine environment: A case study in Goa, west coast of India. *Chemosphere* **2021**, *270*, 129359. [CrossRef] [PubMed]

53. Wang, Q.; Zhu, X.; Hou, C.; Wu, Y.; Teng, J.; Zhang, C.; Tan, H.; Shan, E.; Zhang, W.; Zhao, J. Microplastic uptake in commercial fishes from the Bohai Sea, China. *Chemosphere* **2021**, *263*, 127962. [CrossRef] [PubMed]
54. Li, W.; Pan, Z.; Xu, J.; Liu, Q.; Zou, Q.; Lin, H.; Wu, L.; Huang, H. Microplastics in a pelagic dolphinfish (*Coryphaena hippurus*) from the Eastern Pacific Ocean and the implications for fish health. *Sci. Total Environ.* **2022**, *809*, 151126. [CrossRef] [PubMed]
55. Piyawardhana, N.; Weerathunga, V.; Chen, H.-S.; Guo, L.; Huang, P.-J.; Ranatunga, R.R.M.K.P.; Hung, C.-C. Occurrence of microplastics in commercial marine dried fish in Asian countries. *J. Hazard. Mater.* **2022**, *423 Pt B*, 127093. [CrossRef]
56. Hasan, J.; Islam, S.M.M.; Alam, M.S.; Johnson, D.; Belton, B.; Hossain, M.A.R.; Shahjahan, M. Presence of microplastics in two common dried marine fish species from Bangladesh. *Mar. Pollut. Bull.* **2022**, *176*, 113430. [CrossRef] [PubMed]
57. Gurjar, U.R.; Xavier, K.A.M.; Shukla, S.P.; Jaiswar, A.K.; Deshmukhe, G.; Nayak, B.B. Microplastic pollution in coastal ecosystem off Mumbai coast, India. *Chemosphere* **2022**, *288 Pt 1*, 132484. [CrossRef]
58. Mistri, M.; Sfriso, A.A.; Casoni, E.; Nicoli, M.; Vaccaro, C.; Munari, C. Microplastic accumulation in commercial fish from the Adriatic Sea. *Mar. Pollut. Bull.* **2022**, *174*, 113279. [CrossRef] [PubMed]
59. Gao, S.; Li, Z.; Wang, N.; Lu, Y.; Zhang, S. Microplastics in different tissues of caught fish in the artificial reef area and adjacent waters of Haizhou Bay. *Mar. Pollut. Bull.* **2022**, *174*, 113112. [CrossRef] [PubMed]
60. da Costa, I.D.; Costa, L.L.; da Silva Oliveira, A.; de Carvalho, C.E.V.; Zalmon, I.R. Microplastics in fishes in amazon riverine beaches: Influence of feeding mode and distance to urban settlements. *Sci. Total Environ.* **2023**, *863*, 160934. [CrossRef]
61. Hasan, J.; Dristy, E.Y.; Mondal, P.; Hoque, M.S.; Sumon, K.A.; Hossain, M.A.R.; Shahjahan, M. Dried fish more prone to microplastics contamination over fresh fish—Higher potential of trophic transfer to human body. *Ecotoxicol. Environ. Saf.* **2023**, *250*, 114510. [CrossRef]
62. Pandey, N.; Verma, R.; Patnaik, S.; Anbumani, S. Abundance, characteristics, and risk assessment of microplastics in indigenous freshwater fishes of India. *Environ. Res.* **2023**, *218*, 115011. [CrossRef] [PubMed]
63. Espiritu, E.Q.; Rodolfo, R.S.; Evangelista, S.M.J.; Feliciano, J.J.G.; Sumaway, A.M.N.; Pauco, J.L.R.; Alvarez, K.V.N.; Enriquez, E.P. Microplastics contamination in the fishes of selected sites in Pasig River and Marikina River in the Philippines. *Mar. Pollut. Bull.* **2023**, *187*, 114573. [CrossRef] [PubMed]
64. Nawar, N.; Rahman, M.M.; Chowdhury, F.N.; Marzia, S.; Ali, M.M.; Akbor, M.A.; Siddique, M.A.B.; Khatun, M.A.; Shahjalal, M.; Huque, R.; et al. Characterization of microplastic pollution in the Pasur river of the Sundarbans ecosystem (Bangladesh) with emphasis on water, sediments, and fish. *Sci. Total Environ.* **2023**, *868*, 161704. [CrossRef] [PubMed]
65. Li, J.; Yang, D.; Li, L.; Jabeen, K.; Shi, H. Microplastics in commercial bivalves from China. *Environ. Pollut. (1987)* **2015**, *207*, 190–195. [CrossRef] [PubMed]
66. Squillante, J.; Scivicco, M.; Ariano, A.; Nolasco, A.; Esposito, F.; Cacciola, N.A.; Severino, L.; Cirillo, T. Occurrence of phthalate esters and preliminary data on microplastics in fish from the Tyrrhenian sea (Italy) and impact on human health. *Environ. Pollut. (1987)* **2023**, *316 Pt 1*, 120664. [CrossRef] [PubMed]
67. FishBase. Psenopsis Anomala Summary Page. 2019. Available online: https://www.fishbase.se/summary/497 (accessed on 1 April 2024).
68. Silva-Cavalcanti, J.S.; Silva, J.D.B.; de França, E.J.; de Araújo, M.C.B.; Gusmão, F. Microplastics ingestion by a common tropical freshwater fishing resource. *Environ. Pollut. (1987)* **2017**, *221*, 218–226. [CrossRef] [PubMed]
69. Rukmangada, R.; Naidu, B.C.; Nayak, B.B.; Balange, A.; Chouksey, M.K.; Xavier, K.A.M. Microplastic contamination in salted and sun dried fish and implications for food security—A study on the effect of location, style and constituents of dried fish on microplastics load. *Mar. Pollut. Bull.* **2023**, *191*, 114909. [CrossRef] [PubMed]
70. Afzal, Z.; Basit, A.; Habib, U.; Aman, M.; Azim, M.; Cao, H. Emerging risks of Microplastics and Nanoplastics (MNPs): Is a silent threat for cardiovascular disease? *Int. J. Cardiol. Cardiovasc. Risk Prev.* **2024**, *21*, 200280. [CrossRef]
71. Liu, S.; Wang, C.; Yang, Y.; Du, Z.; Li, L.; Zhang, M.; Ni, S.; Yue, Z.; Yang, K.; Wang, Y.; et al. Microplastics in three types of human arteries detected by pyrolysis-gas chromatography/mass spectrometry (Py-GC/MS). *J. Hazard. Mater.* **2024**, *469*, 133855. [CrossRef]
72. Guan, Q.; Jiang, J.; Huang, Y.; Wang, Q.; Liu, Z.; Ma, X.; Yang, X.; Li, Y.; Wang, S.; Cui, W.; et al. The landscape of micron-scale particles including microplastics in human enclosed body fluids. *J. Hazard. Mater.* **2023**, *442*, 130138. [CrossRef]
73. Sun, J.; Sui, M.; Wang, T.; Teng, X.; Sun, J.; Chen, M. Detection and quantification of various microplastics in human endometrium based on laser direct infrared spectroscopy. *Sci. Total Environ.* **2024**, *906*, 167760. [CrossRef] [PubMed]
74. Zhang, D.; Wu, C.; Liu, Y.; Li, W.; Li, S.; Peng, L.; Kang, L.; Ullah, S.; Gong, Z.; Li, Z.; et al. Microplastics are detected in human gallstones and have the ability to form large cholesterol-microplastic heteroaggregates. *J. Hazard. Mater.* **2024**, *467*, 133631. [CrossRef] [PubMed]
75. Zhu, L.; Zhu, J.; Zuo, R.; Xu, Q.; Qian, Y.; Lihui, A.N. Identification of microplastics in human placenta using laser direct infrared spectroscopy. *Sci. Total Environ.* **2023**, *856*, 159060. [CrossRef] [PubMed]
76. Halfar, J.; Čabanová, K.; Vávra, K.; Delongová, P.; Motyka, O.; Špaček, R.; Kukutschová, J.; Šimetka, O.; Heviánková, S. Microplastics and additives in patients with preterm birth: The first evidence of their presence in both human amniotic fluid and placenta. *Chemosphere* **2023**, *343*, 140301. [CrossRef] [PubMed]
77. Massardo, S.; Verzola, D.; Alberti, S.; Caboni, C.; Santostefano, M.; Eugenio Verrina, E.; Angeletti, A.; Lugani, F.; Ghiggeri, G.M.; Bruschi, M.; et al. MicroRaman spectroscopy detects the presence of microplastics in human urine and kidney tissue. *Environ. Int.* **2024**, *184*, 108444. [CrossRef] [PubMed]

78. Rotchell, J.M.; Austin, C.; Chapman, E.; Atherall, C.A.; Liddle, C.R.; Dunstan, T.S.; Ben Blackburn, B.; Mead, A.; Filart, K.; Beeby, E.; et al. Microplastics in human urine: Characterisation using μFTIR and sampling challenges using healthy donors and endometriosis participants. *Ecotoxicol. Environ. Saf.* **2024**, *274*, 116208. [CrossRef] [PubMed]
79. Li, Z.; Zheng, Y.; Maimaiti, Z.; Fu, J.; Yang, F.; Li, Z.-Y.; Shi, Y.; Hao, L.-B.; Chen, J.-Y.; Xu, C. Identification and analysis of microplastics in human lower limb joints. *J. Hazard. Mater.* **2024**, *461*, 132640. [CrossRef] [PubMed]
80. Zhong, Y.; Yang, Y.; Zhang, L.; Ma, D.; Wen, K.; Cai, J.; Cai, Z.; Wang, C.; Chai, X.; Zhong, J.; et al. Revealing new insights: Two-center evidence of microplastics in human vitreous humor and their implications for ocular health. *Sci. Total Environ.* **2024**, *921*, 171109. [CrossRef] [PubMed]
81. Jenner, L.C.; Rotchell, J.M.; Bennett, R.T.; Cowen, M.; Tentzeris, V.; Sadofsky, L.R. Detection of microplastics in human lung tissue using μFTIR spectroscopy. *Sci. Total Environ.* **2022**, *831*, 154907. [CrossRef]
82. Zhao, Q.; Zhu, L.; Weng, J.; Jin, Z.; Cao, Y.; Jiang, H.; Zhang, Z. Detection and characterization of microplastics in the human testis and semen. *Sci. Total Environ.* **2023**, *877*, 162713. [CrossRef]
83. Montano, L.; Giorgini, E.; Notarstefano, V.; Notari, T.; Ricciardi, M.; Piscopo, M.; Motta, O. Raman Microspectroscopy evidence of microplastics in human semen. *Sci. Total Environ.* **2023**, *901*, 165922. [CrossRef] [PubMed]
84. Leslie, H.A.; van Velzen, M.J.M.; Brandsma, S.H.; Vethaak, A.D.; Garcia-Vallejo, J.J.; Lamoree, M.H. Discovery and quantification of plastic particle pollution in human blood. *Environ. Int.* **2022**, *163*, 107199. [CrossRef] [PubMed]
85. Schwabl, P.; Koppel, S.; Konigshofer, P.; Bucsics, T.; Trauner, M.; Reiberger, T.; Liebmann, B. Detection of various microplastics in human stool: A prospective case series. *Ann. Intern. Med.* **2019**, *171*, 453–457. [CrossRef] [PubMed]
86. Yang, Y.; Xie, E.; Du, Z.; Peng, Z.; Han, Z.; Li, L.; Zhao, R.; Qin, Y.; Xue, M.; Li, F.; et al. Detection of Various Microplastics in Patients Undergoing Cardiac Surgery. *Environ. Sci. Technol.* **2023**, *57*, 10911. [CrossRef] [PubMed]


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