



## IMPACT OF MICROPLASTIC ON AQUATIC ANIMALS: SPECIAL EMPHASIS ON FISHES

**CHARADIYA JAYDIPSINH<sup>1</sup>, CHAUHAN HITESH<sup>1</sup>,  
LINZ-BUOY GEORGE<sup>1\*</sup>**

**DEPARTMENT OF ZOOLOGY, BIOMEDICAL  
TECHNOLOGY, HUMAN GENETICS & WILDLIFE  
BIOLOGY & CONSERVATION, SCHOOL OF  
SCIENCES, GUJARAT UNIVERSITY, AHMEDABAD-  
380009, INDIA.**

Corresponding Author's Email: [chauhanhitesh14198@gmail.com](mailto:chauhanhitesh14198@gmail.com)

ORCID ID: 0009-0000-8964-9882

(RECEIVED ON: 5<sup>th</sup> SEPTEMBER 2025; REVISED ON: 28<sup>th</sup> SEPTEMBER 2025;  
Accepted on: 29<sup>th</sup> SEPTEMBER 2025; Published on: 1<sup>st</sup> OCTOBER 2025)

### **ABSTRACT:**

Concerns about the ecological effects of microplastics plastic particles smaller than five millimetres have grown as a common source of contamination in aquatic environments. The particular impacts of microplastics on fish are the subject of this abstract, which discusses ingestion, bioaccumulation, physiological reactions, and possible ramifications for fish populations and ecosystems. Microplastics find their way into aquatic habitats from a variety of sources, including the decomposition of bigger plastic objects, synthetic fabrics, and goods derived from plastic. Due to their tiny size and persistent nature, these anthropogenic particles are widely dispersed, exposing aquatic organisms especially fish to them. Fish come into contact with microplastics both directly and indirectly when they eat contaminated prey. Ingestion of microplastics may have a variety of negative effects, from actual digestive system damage to the possible buildup of harmful compounds in fish tissues. Concerns about the possibility for biomagnification at higher trophic levels and the long-term

repercussions on personal health are raised by fish's absorption of microplastics. Microplastics may have detrimental physiological consequences on fish, including inflammation, tissue damage, and changes in metabolic systems. These physiological effects are made worse by microplastics' ability to absorb and concentrate toxins from the surrounding water, which adds to the total stress that fish populations are under. The ecological ramifications affect whole aquatic ecosystems in addition to individual fish. Microplastics have the potential to upset food chains, change predator-prey relationships, and have an impact on aquatic ecosystem health and biodiversity in general. It is crucial to comprehend these intricate relationships in order to develop management and conservation plans that work. Research in the fields of ecotoxicology, fisheries science, and environmental chemistry must be multidisciplinary in order to address the effects of microplastics on fish. Reducing plastic inputs, creating sustainable substitutes, and implementing strong waste management procedures should be the top priorities of mitigation initiatives. In the end, preserving fish populations' health is essential to keeping aquatic ecosystems resilient and in balance in the face of increasing microplastic contamination.

**KEY WORDS:** *Microplastics, Oceans, Fishes, Environment, Health.*

## **INTRODUCTION:**

The problem of plastic pollution is one that scientists and environmentalists are quite worried about. The ageing and micron-sized fragmentation of plastic caused by physical and natural elements like the sun, wind, and rain, as well as human-caused variables like commercial use and exploitation, pose a greater danger to human safety. These so-called "microplastics" are often defined as solid polymer particles with a size of less than 5 mm (Koelmans et al., 2019). Rain often sweeps these broken-down plastic particles into rivers, lakes, and sewers, where they ultimately end up in the seas. Microplastics have a variety of physiochemical characteristics, are insoluble in water, and do not decompose. These characteristics make them potentially dangerous to the environment (Zhang et al., 2018). Due to the widespread usage of plastics, their waste products have been building up in metropolitan areas and often wind up in water bodies (Pazos et al., 2017). Because of their unique physical and chemical

characteristics, namely their low density and durability, plastics are utilised extensively over the globe (Andrady et al., 2011; Andrady & Neal, 2009). Plastics have been produced in large quantities annually since the 1950s, when industrial manufacturing began. China accounted for 30% of the 3.6 billion tonnes of plastic items produced worldwide in 2018 (Plastics Europe, 2019). The health of the ocean and freshwater systems has been adversely affected by the buildup of plastic waste. The current estimate for the amount of plastic in the seas is 250,000 tonnes on average. The buildup of plastic debris and pollution in aquatic ecosystems have a significant impact on marine life (Wang et al., 2020). Plastic Europe (2022) stated that 390.7 million metric tonnes of plastic were produced globally in 2021 (Plastic Europe, 2022). Plastic garbage has entered the maritime ecosystem via a variety of channels as a result of improper management, including fishing, wastewater discharge, atmospheric transport, and tourism (Rabari et al., 2023). The primary factor contributing to the pervasive issue of microplastics in the biosphere is plastic's high antidegradation properties and inexpensive cost of manufacture. In addition, microplastics are strong, lightweight, easy to transport, and have a rapid rate of dispersal and fixation throughout the global biosphere. While some of the microplastics on the land stay fixed in the soil, others stay in the shallow soil layer and are carried into the water body by runoff (Melanie Bergmann et al., 2019). MPs may exist in several areas of the aquatic environment because to their varied morphological traits. Because of biological rains or the usage of minerals, some of these structures—like polyester and nylon fibers—are denser than water and sink, while others are less dense than water and float (Baldwin et al., 2016; Rhodes et al., 2018). Microplastics (MP) are suspended in groundwater and eventually find their way into air and water currents that travel farther into the ocean because they are more minuscule and mobile than other materials (Barnes et al., 2009). Fish are often contaminated with MPs (Bessa et al., 2018), especially those inhabiting coastal environments (Ferreira et al., 2018). Fish are crucial to the marine food chain because they move and distribute certain MPs (Boerger et al., 2010), MPs then go from zooplankton to more advanced trophic levels. More significantly, being a mainstay of seafood, fish are intimately related to human health. The possible health effects of MPs and similar chemicals on a variety of foods make their contamination very concerning (Santillo et al., 2017). The mass production and dumping of plastic into the marine environment exacerbates an already dirty media landscape (Thushari & Senevirathna, 2020). Moreover, MPs have the ability to build up in marine species, where they may have a variety of negative consequences. These include oxidative damage, inflammation, liver stress, intestine obstruction and internal abrasion, and growth reduction (Von Moons et al., 2012; Rochman et al., 2013). MPs come in a variety of morphologies, including films, fibres, foams, pieces, and granules (Villagran et

al., 2020).

In addition, microplastics have the ability to adsorb persistent pollutants (POPs) including polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs) because of their huge surface area to volume ratio and non-aqueous water content. They have (Jinfeng et al., 2019). Synthetic polymers that create microplastic pollution include polyethylene (PE), polypropylene (PP), polystyrene (PS), and polyethylene terephthalate (PET) (Hidalgo-Ruz et al., 2012, 2013). Moreover, fish traps release polyamide (PA) residues into the environment (Duis & Coors, 2016). The most prevalent kind, PE, has both mono- and di-unsaturated hydrocarbons (Serrano et al., 2005). PP, which is made up of alkanes, alkenes, and alkadienes, is the second most utilised polymer (Sojak et al., 2007). Regretfully, recycling (29.7%) and energy recovery (39.5%) procedures only recover 69.2% of plastic (Plastic Europe., 2015). Microplastics have the ability to quickly accumulate and release dangerous organic pollutants into water, such as DDT, polybrominated diphenyl ethers, and other additives used during manufacturing. This increases the concentration of these pollutants (Gonte & Balasubramanian, 2012; Gore et al., 2017, 2018a,b, 2019; Rajhans et al., 2019; Campanale et al., 2020). Over 700 marine species have been reported to have consumed microplastics, and other studies have found plastic in sea turtles, seabirds, and other iconic megafauna, such whales and dolphins (Besseling et al., 2015; Gall & Thompson, 2015; Germanov et al., 2018; Worm et al., 2017). It has been determined that MP contamination poses a serious ecotoxicological risk to marine life. MP particles may be divided into two classes: main MPs and secondary MPs, depending on their origins (Yuan et al., 2023; Lippiatt et al., 2015). Primary MPs are purposefully created as microbeads for use in industrial abrasives, medicine transporters, and cosmetics (Wu et al., 2023; Andrady et al., 2011). While large-sized plastics deteriorate and break under a variety of environmental physical and chemical conditions, such as UV radiation, photodegradation, and oxidation, secondary MPs are formed as a result (Rabari et al., 2022; Wu et al., 2023). Pellets, granules, spherical beads, filaments, films, pieces, and foams are among the many forms of MPs (Cole et al., 2011). There is evidence of microplastics in the digestive tracts of fish that are taken in the wild (Foekema et al., 2013) and aquatic invertebrates (Cole et al., 2011); even in clams and mussels that were prepared for sale as food for humans (Van Cauwenberghe & Janssen, 2014; Davidson & Dudas, 2016). Microplastics are a common marine contaminant in aquatic environments because of their buoyant and persistent nature, which also serves as a vehicle for the spread of other contaminants (Rodrigues et al., 2019) to the creatures found in water. Because microplastics are so minute, a variety of aquatic animals absorb them and their

physiological processes are disrupted. This disruption spreads down the food chain and affects human health (Figure I). Since many marine animals quickly absorb them and expel them, definitive evidence of biomagnification cannot be acquired (Cozar et al., 2014). The first route by which microplastics enter a fish's body is by feeding, yet this route has seldom been explored in prior research (Ory et al., 2018). Keep in mind that microplastics' bioavailability differs greatly from that of conventional soluble contaminants. The two primary methods by which soluble contaminants are absorbed are passive diffusion and cell membrane transit (Schwarzenbach et al., 2006; Chen et al., 2010; Xiong et al., 2019). Furthermore, a broad range of creatures, including fish, benthic fauna, and birds, have been shown to contain microplastics, which not only limit their development but also pose a risk to human health via the food chain (Wu et al., 2023).

A variety of fish species from freshwater, marine, and estuarine aquatic systems—from shallow to deep waters—have been discovered to contain microplastics (Kasamesiri & Thaimuangphol, 2020; Talley et al., 2020; Valente et al., 2019; Yuan et al., 2019). Furthermore, it has been shown that the intestines and tissues of fish raised for aquaculture, wild fish, and fish gathered from markets all have varied concentrations of microplastic (Rochman et al., 2015; Wootton et al., 2021b). Microplastics are readily consumed by fish because of their microscopic size (Karami et al., 2017; Roch & Brinker, 2017), shellfish (Browne et al., 2008; Li et al., 2016; Zhao et al., 2018), marine organisms (Murray & Cowie, 2011), causing the oesophagus to become blocked or die. Numerous studies have been conducted on fish behaviour in reaction to changes in the environment, particularly the presence of microplastics (Allgeier et al., 2020; Collard et al., 2019; Savoca et al., 2021). Fish that consume microplastic may do so by primary ingestion, which is when they directly swallow the plastic; often, this happens when they mistake it for food or inadvertently swallow it (Worm et al., 2017) or by subsequent digestion after ingesting prey that has previously been exposed to plastic (Watts et al., 2014). Because microplastics are accumulating in the environment, it is advised to regularly check them (Grbic et al., 2019). In most cases, microplastics are difficult to find by unassisted observation. In experimental settings, a variety of forms, dimensions, and characteristics, such as transparency and translucency, make identification difficult (Asamoah et al., 2019). At the moment, the main issue is to restrictions in microplastics detection methods. There's already evidence of a higher concentration of microplastics (MPs) in basins with a predominance of urbanisation compared to basins with forested surroundings, as a result of the expansion of urban centres and agricultural activities surrounding river basins (McNeish et al., 2018; Luo et al., 2019).

The quantity and makeup of microplastic particles in freshwater ecosystems, as well as their consequences on the freshwater biota, are currently poorly understood (Triebkorn et al., 2019). Commercial fish species are vulnerable to several human challenges, such as habitat loss, overfishing, pollution, and climate change (Baechler et al., 2020). Fisheries and aquaculture contribute significantly to the world's food supply and are crucial for supplying dietary protein in terms of global food security (Be'ne' et al., 2015), 10% of people have access to essential social resources and income (Be'ne' et al., 2006; FAO et al., 2020). One of the explanations might be the significance of fluorescent tagging of particles and commercially marked polystyrene or polyethylene spheres. To allow for the study of plastics and polymers, a fluorescent labelling technique for any kind of plastic is required (Karakolis et al., 2019).

It is difficult to create a standardized approach for microplastic-related data categorization and comparison because of the wide variety of sizes of microplastics. The difficulty of detecting microplastics increases with their size. Accurately recognizing or categorizing microplastics is made more difficult by the ambiguous properties of both plastics and non-plastics (Song et al., 2015). These limitations in detecting microplastics are a significant drawback affecting containment and microplastic pollution prevention.

### **Sample preparation**

We looked at the existence of microplastic in fish by doing a thorough literature search. We adhered to PRISMA as it is preferred and well-accepted in the scientific community (Preferred Reporting Items for Systematic Reviews & MetaAnalyses) guidelines (Moher et al., 2010). Collecting fish samples is the initial step. In coastal regions of states, the most common human activities include fishing, industry, urbanization, and tourism (Trivedi et al., 2015). Fish had had the stomach and intestine removed from them. To determine the wet weights of contents, the wet mass of the digestive system was measured both with and without contents (Hyslop et al., 1980; Hadwen et al., 2007). A gridded Petri dish was used to estimate the food proportionately for each fish. The diet components (i.e., silt, algae, molluscs, crustaceans, worms, fish, insects, and unknown) were volumetrically analyzed to coarse taxonomic resolution. Metal forceps were used under a dissecting microscope to remove any potential material.

### **Extraction methodology**

(1<sup>st</sup> protocol), It was essential to ascertain if the filter or the polymer particles were

susceptible to deterioration as a consequence of the dissolving process before moving further with the chemical dissolution of fish stomachs. Therefore, before conducting additional experiments, polycarbonate filters and five microplastics (PE, PVC, PET, PP, and PS) were soaked in 10% KOH solution for 4 hours and then in 10% HCl for an overnight period in Petri dishes in order to ascertain the filter and particles' resistance to the dissolution process. Each polycarbonate filter sample and the microplastic particles were inspected using a stereo-zoom microscope after being soaked for the whole night (Figure II). Every dissolving test was carried out between 22 and 23 degrees Celsius, or lab room temperature (Wang et al., 2020).

(2<sup>nd</sup> protocol), Every fish's GT was put in a beaker with 10% potassium hydroxide added to it to break out organic matter (Daniel et al., 2020). After that, it was heated to 60 °C in a hot air oven until all of the organic tissue had been completely digested (Karami et al., 2017). The MPs were lowered in accordance with the density gradient by adding a supersaturated NaCl aqueous solution (1.2 g/mL) (Rabari et al., 2022; Robin et al., 2020). It was followed by the solution being continuously stirred with a glass rod and let to stand at room temperature for a 24 h (Gurjar et al., 2021). The supernatant containing floated MPs was filtered through ash-less Whatman filter paper (Grade No. 41, pore size: 20 µm) (Figure III).

### **Identification of microplastics**

The identification of microplastics is usually done by visual observation, including macroscopic, microscopic observation, Fourier transform infrared spectroscopy (FTIR), and Raman spectroscopy.

#### **Visual identification**

Visual detection of microplastics involves both microscopic and direct visual inspection. Larger particle plastics are immediately visible to the unaided eye. For instance, Morét-Ferguson et al. said that during the investigation of the western North Atlantic, every plastic particle (0.41–420 mm) was visually recognized (Moret-Ferguson et al., 2010). In cases when plastic particles are tiny in size, microscopes are required. categorized microplastics with an anatomical microscope at a 6x magnification (Doyle et al., 2011).

#### **Microscopy**

The most widely utilized method for any kind of detection is microscopy. Sensible methods for detecting microplastics may be obtained by using structural information from enlarged,

detailed photographs of surfaces (Hidalgo-Ruz et al., 2013). In order to identify microplastics, light microscopy and stereomicroscopy are often used microscopy methods (Song et al., 2015), fluorescent microscopy (Cauwenberghe et al., 2015) and scanning electron microscopy (SEM) (Wang et al., 2017). Using scanning electron microscopy (SEM), the plastic particles and the filtered polycarbonate subsamples of the fish gut were examined. The results showed high-resolution pictures of the surface structure of the particles and elemental composition signatures, which aid in the separation of microplastic from non-plastic material. For each of the different polymers, distinct peaks were seen. The collected optical images showed signs of deterioration and discoloration. Nonetheless, this investigation is limited to morphological structure and surface studies since FTIR and Raman spectroscopy were required for a cross-analysis of the data (Wagner et al., 2017). Despite the constraints of quantitative analysis by microscopy, such as the difficulty in characterising particles with certain shapes and lack of colour (Song et al., 2015)

### **Fourier transform infrared spectroscopy (FTIR)**

Plastic polymer analysis may benefit from both qualitative and quantitative examination using Fourier transform infrared spectroscopy (FTIR) (Cincinelli et al., 2017; Besseling et al., 2015). For many years, the introduction of microplastics has been an issue. Apart from offering precise details on chemical components and polymer structure, Fourier Transform Infrared (FTIR) offers distinct spectra that may differentiate plastics from other organic and inorganic materials and pinpoint the source or sources (Turner & Holmes, 2011). Attenuated total reflection (ATR) Fourier transform infrared spectroscopy's primary drawback is its high expense. nonetheless, may aid in identifying microplastics with asymmetrical forms (Harrison et al., 2012). This technique can identify polymers as thin as 20  $\mu\text{m}$  and covers a large filter surface area (diameter > 10 mm). When the sample's complete pore surface is inspected with a high degree of spatial precision, this takes time. Because of this, FTIR spectroscopy method has to be further refined in order to identify microscopic microplastics in complicated environmental samples (Lv et al., 2021).

### **Raman spectroscopy**

Raman spectroscopy can detect polymers as tiny as 1  $\mu\text{m}$  and reacts favourably to nonpolar plastic functional groups (Lenz et al., 2015). Weakly scattered photons are employed in Raman spectroscopy, which may be used to detect sub-micron size and identify microplastics (Zada et al., 2018; Collard et al., 2015; Imhof et al., 2016). It creates a certain spectrum depending on the sample composition by using laser light focused on the sample. Because

this technique makes use of a laser beam with a shorter wavelength, it can also detect microplastics. This non-destructive method works similarly to FTIR when paired with microscopy. In an overview of the quick identification of microplastics using Raman scattering microscopy (Zada et al., 2018).

## **CONCLUSION:**

Microplastics are tiny plastic bits under 5mm wide causing serious environmental damage. They're found often in waters, such as lakes, rivers, and oceans, which worries experts about potential harm to sea creatures and even human health. This summary touches on key findings and impacts linked to the presence of microplastics in fish, referenced from related scientific works. The phenomenon of fish contaminated by Microplastics has been documented worldwide. Multiple studies found these microplastics in fish's digestive tracts. This happens because fish ingest these particles while feeding normally. The prevalence of microplastics in fish serves as a reminder of how bad plastic pollution is in aquatic habitats (Rochmen et al., 2018). Plastic bits, tiny as they are, get stuck in fish bodies over time. It's like slowly filling a cup; worryingly it might make the fish sick. As if that's not enough, these little plastics stick around, slowly adding up, much like a penny jar fills up with time (Nel et al., 2018). Microplastics can hurt a fish's body parts. Studies reveal that these tiny particles can lead to swelling, tweak how a fish functions, and generally harm its health. Top it off, microplastics often carry dangerous stuff like heavy metals and hard-to-remove organic pollutants (POPs). This makes life for fish even harder (Wright & Kely, 2017). Eating fish that contain tiny bits of plastic could have some health risks. This is because humans are usually the final consumers in the sea food chain. Harmful particles from water bodies might seep into fish through these small plastic bits. They then act like carriers. So, if people eat this fish, they might ingest harmful substances connected to these small bits of plastic (Wright & Kely, 2017). Addressing microplastic pollution requires a multi-pronged approach. This includes lessening plastic production and usage, implementing effective rubbish handling methods, and developing earth-friendly alternative materials. Crucially, educating the masses through campaigns is required. This can foster a collective responsibility to cut down on plastic use and promote correct trash management (Rochmen et al., 2018). Tiny plastic particles in fish can impact more than just individual species. When fish eat these particles, it can disturb the equilibrium of ocean habitats, altering the makeup of marine communities and possibly shifting hunter-prey relationships. Scientists are now studying what these ecological shifts could mean in the long run (Wright & Kely, 2017). Microplastics enter the food chain of the sea through a process called trophic transfer. Tiny

marine beings swallow these miniature plastic pieces. When bigger sea animals eat the smaller ones, these plastics build up and move up the chain. Humans often consume fish, which might make microplastics move from smaller creatures to us, potentially causing problems (Rochmen et al., 2018). Investigating microplastics in fish presents some challenges. We need sophisticated tools to pinpoint and measure these tiny pieces of plastic in biological tissues. Equalizing our methods of study is key for reliable comparisons. Our knowledge of where microplastics are and how often they occur in fish can be improved with the refinement of our analytical methods (Ziajahromi et al., 2017). The body of research showing fish to contain microplastics is increasing, necessitating legislative and policy measures. Governments and international organisations must think about putting policies into place to lessen the production of plastic, improve the infrastructure for managing garbage, and establish guidelines for the use of microplastics in consumer goods (Rochmen et al., 2018).

## REFERENCES:

- Allgeier, J. E., Cline, T. J., Walsworth, T. E., Wathen, G., Layman, C. A., & Schindler, D. E. 2020 Individual behavior drives ecosystem function and the impacts of harvest. *Science Advances*, 6(9), eaax8329.
- Andrady, A. L. 2011 Microplastics in the marine environment. *Marine pollution bulletin*, 62(8), 1596-1605.
- Andrady, A. L. 2011 Microplastics in the marine environment. *Marine pollution bulletin*, 62(8), 1596-1605.
- Andrady, A. L., & Neal, M. A. 2009 Applications and societal benefits of plastics. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364(1526), 1977-1984.
- Asamoah, B. O., Kanyathare, B., Roussey, M., & Peiponen, K. E. 2019 A prototype of a portable optical sensor for the detection of transparent and translucent microplastics in freshwater. *Chemosphere*, 231, 161-167.
- Baechler, B. R., Stienbarger, C. D., Horn, D. A., Joseph, J., Taylor, A. R., Granek, E. F., & Brander, S. M. 2020 Microplastic occurrence and effects in commercially harvested North American finfish and shellfish: current knowledge and future directions. *Limnology and Oceanography Letters*, 5(1), 113-136.
- Baldwin, A. K., Corsi, S. R., & Mason, S. A. 2016 Plastic debris in 29 Great Lakes tributaries: relations to watershed attributes and hydrology. *Environmental science & technology*, 50(19), 10377-10385.
- Barnes, D. K., Galgani, F., Thompson, R. C., & Barlaz, M. 2009 Accumulation and fragmentation of plastic debris in global environments. *Philosophical transactions of the royal society B: biological sciences*, 364(1526), 1985-1998.
- Béné, C. 2006 *Small-scale fisheries: assessing their contribution to rural livelihoods in*

*developing countries* (Vol. 1008, pp. 1-57). Rome, Italy: Food and Agriculture Organization of the United Nations.

- Béné, C., Barange, M., Subasinghe, R., Pinstup-Andersen, P., Merino, G., Hemre, G. I., & Williams, M. 2015 Feeding 9 billion by 2050—Putting fish back on the menu. *Food Security*, 7, 261-274.
- Bergmann, M., Gutow, L., & Klages, M. 2015 *Marine anthropogenic litter* (p. 447). Springer Nature.
- Bergmann, M., Mützel, S., Primpke, S., Tekman, M. B., Trachsel, J., & Gerdts, G. 2019 White and wonderful? Microplastics prevail in snow from the Alps to the Arctic. *Science advances*, 5(8), eaax1157.
- Bergmann, M., Mützel, S., Primpke, S., Tekman, M. B., Trachsel, J., & Gerdts, G. 2019 White and wonderful? Microplastics prevail in snow from the Alps to the Arctic. *Science advances*, 5(8), eaax1157.
- Bessa, F., Barría, P., Neto, J. M., Frias, J. P., Otero, V., Sobral, P., & Marques, J. C. 2018 Occurrence of microplastics in commercial fish from a natural estuarine environment. *Marine pollution bulletin*, 128, 575-584.
- Besseling E, Foekema EM, Van Franeker JA et al 2015 Microplastic in a macro filter feeder: humpback whale Megaptera novaeangliae. *Mar Pollut* 95:248–252
- Besseling, E., Foekema, E. M., Van Franeker, J. A., Leopold, M. F., Kühn, S., Rebolledo, E. B., ... & Koelmans, A. A. 2015 Microplastic in a macro filter feeder: humpback whale Megaptera novaeangliae. *Marine pollution bulletin*, 95(1), 248-252.
- Boerger, C. M., Lattin, G. L., Moore, S. L., & Moore, C. J. 2010 Plastic ingestion by planktivorous fishes in the North Pacific Central Gyre. *Marine pollution bulletin*, 60(12), 2275-2278.
- Browne, M. A., Dissanayake, A., Galloway, T. S., Lowe, D. M., & Thompson, R. C. 2008 Ingested microscopic plastic translocates to the circulatory system of the mussel, *Mytilus edulis* (L.). *Environmental science & technology*, 42(13), 5026-5031.
- Campanale, C., Massarelli, C., Savino, I., Locaputo, V., & Uricchio, V. F. 2020 A detailed review study on potential effects of microplastics and additives of concern on human health. *International journal of environmental research and public health*, 17(4), 1212.
- Chen, X., & Schluesener, H. J. 2010 Multi-walled carbon nanotubes affect drug transport across cell membrane in rat astrocytes. *Nanotechnology*, 21(10), 105104.
- Cincinelli, A., Scopetani, C., Chelazzi, D., Lombardini, E., Martellini, T., Katsoyiannis, A., ... & Corsolini, S. 2017 Microplastic in the surface waters of the Ross Sea (Antarctica): occurrence, distribution and characterization by FTIR. *Chemosphere*, 175, 391-400.
- Cole, M., Lindeque, P., Halsband, C., & Galloway, T. S. 2011 Microplastics as

- contaminants in the marine environment: a review. *Marine pollution bulletin*, 62(12), 2588-2597.
- Collard, F., Gilbert, B., Eppe, G., Parmentier, E., & Das, K. 2015 Detection of anthropogenic particles in fish stomachs: an isolation method adapted to identification by Raman spectroscopy. *Archives of environmental contamination and toxicology*, 69, 331-339.
- Collard, F.; Gasperi, J.; Gabrielsen, G. W.; Tassin, B. 2019 Plastic particle ingestion by wild freshwater fish: a critical review. *Environ. Sci. Technol.* 53, 12974–12988.
- Cózar, A., Echevarría, F., González-Gordillo, J. I., Irigoien, X., Úbeda, B., Hernández-León, S., ... & Duarte, C. M. 2014 Plastic debris in the open ocean. *Proceedings of the National Academy of Sciences*, 111(28), 10239-10244.
- Daniel, D. B., Ashraf, P. M., & Thomas, S. N. 2020 Microplastics in the edible and inedible tissues of pelagic fishes sold for human consumption in Kerala, India. *Environmental Pollution*, 266, 115365.
- Davidson, K., & Dudas, S. E. 2016 Microplastic ingestion by wild and cultured Manila clams (*Venerupis philippinarum*) from Baynes Sound, British Columbia. *Archives of environmental contamination and toxicology*, 71, 147-156.
- Doyle, M. J., Watson, W., Bowlin, N. M., & Sheavly, S. B. 2011 Plastic particles in coastal pelagic ecosystems of the Northeast Pacific ocean. *Marine Environment Research*, 71(1), 41–52.
- Duis, K., & Coors, A. 2016 Microplastics in the aquatic and terrestrial environment: sources (with a specific focus on personal care products), fate and effects. *Environmental Sciences Europe*, 28(1), 1-25.
- Europe, 2015 P. L. A. S. T. I. C. Plastics—The Facts
- Europe, 2022 P. L. A. S. T. I. C. Plastics—The Facts
- Facts, P. E. P. T. 2019 An analysis of European plastics production, demand and waste data. *Plastics Europe*.
- FAO 2020 The State of World Fisheries and Aquaculture 2020. Sustainability in action. Rome, Italy.
- Farrell, P., & Nelson, K. 2013 Trophic level transfer of microplastic: *Mytilus edulis* (L.) to *Carcinus maenas* (L.). *Environmental pollution*, 177, 1-3.
- Ferreira, G. V., Barletta, M., Lima, A. R., Morley, S. A., Justino, A. K., & Costa, M. F. 2018 High intake rates of microplastics in a Western Atlantic predatory fish, and insights of a direct fishery effect. *Environmental Pollution*, 236, 706-717.
- Gall, S. C., & Thompson, R. C. 2015 The impact of debris on marine life. *Marine pollution bulletin*, 92(1-2), 170-179.

- Germanov, E. S., Marshall, A. D., Bejder, L., Fossi, M. C., & Loneragan, N. R. 2018 Microplastics: no small problem for filter-feeding megafauna. *Trends in ecology & evolution*, 33(4), 227-232.
- Gonte RR, Shelar G, Balasubramanian K 2014 Polymer–agro-waste composites for removal of Congo red dye from wastewater: adsorption isotherms and kinetics. *Desalin Water Treat* 52:7797–7811
- Gore PM, Kandasubramanian B 2018 Heterogeneous wettable cotton based superhydrophobic Janus biofabric engineered with PLA/ functionalized-organoclay microfibers for efficient oil–water separation. *J Mater Chem A* 6:7457–747.
- Gore, P. M., & Kandasubramanian, B. 2018 Functionalized aramid fibers and composites for protective applications: a review. *Industrial & Engineering Chemistry Research*, 57(49), 16537-16563.
- Grbic, J., Nguyen, B., Guo, E., You, J. B., Sinton, D., & Rochman, C. M. 2019 Magnetic extraction of microplastics from environmental samples. *Environmental Science & Technology Letters*, 6(2), 68-72.
- Gurjar, U. R., Xavier, K. M., Shukla, S. P., Deshmukhe, G., Jaiswar, A. K., & Nayak, B. B. 2021 Incidence of microplastics in gastrointestinal tract of golden anchovy (*Coilia dussumieri*) from north east coast of Arabian Sea: The ecological perspective. *Marine Pollution Bulletin*, 169, 112518.
- Hadwen, W. L., Russell, G. L., & Arthington, A. H. 2007 Gut content-and stable isotope-derived diets of four commercially and recreationally important fish species in two intermittently open estuaries. *Marine and Freshwater Research*, 58(4), 363-375.
- Harrison, J. P., Ojeda, J. J., & Romero-González, M. E. 2012 The applicability of reflectance micro-Fourier-transform infrared spectroscopy for the detection of synthetic microplastics in marine sediments. *Science of the Total Environment*, 416, 455-463.
- Hidalgo-Ruz, V., & Thiel, M. 2013 Distribution and abundance of small plastic debris on beaches in the SE Pacific (Chile): a study supported by a citizen science project. *Marine environmental research*, 87, 12-18.
- Hidalgo-Ruz, V., Gutow, L., Thompson, R. C., & Thiel, M. 2012 Microplastics in the marine environment: a review of the methods used for identification and quantification. *Environmental science & technology*, 46(6), 3060-3075.
- Hidalgo-Ruz, V., Gutow, L., Thompson, R. C., & Thiel, M. 2012 Microplastics in the marine environment: a review of the methods used for identification and quantification. *Environmental science & technology*, 46(6), 3060-3075.
- Hurt, R., O'Reilly, C. M., & Perry, W. L. 2020 Microplastic prevalence in two fish species in two US reservoirs. *Limnology and oceanography letters*, 5(1), 147-153.
- Hyslop, E. J. 1980 Stomach contents analysis—a review of methods and their application. *Journal of fish biology*, 17(4), 411-429.

- Imhof HK, Laforse C, Weisheu AC et al 2016 Pigments and plastic in limnetic ecosystems: a qualitative and quantitative study on microparticles of different size classes. *Wat Res* 98:64–74.
- Jang, Y. C., Lee, J., Hong, S., Lee, J. S., Shim, W. J., & Song, Y. K. 2014 Sources of plastic marine debris on beaches of Korea: more from the ocean than the land. *Ocean Science Journal*, 49, 151-162.
- Karakolis, E. G., Nguyen, B., You, J. B., Rochman, C. M., & Sinton, D. 2019 Fluorescent dyes for visualizing microplastic particles and fibers in laboratory-based studies. *Environmental Science & Technology Letters*, 6(6), 334-340.
- Karami, A., Golieskardi, A., Choo, C. K., Romano, N., Ho, Y. B., & Salamatnia, B. 2017 A high-performance protocol for extraction of microplastics in fish. *Science of the total environment*, 578, 485-494.
- Karami, A., Golieskardi, A., Choo, C. K., Romano, N., Ho, Y. B., & Salamatnia, B. 2017 A high-performance protocol for extraction of microplastics in fish. *Science of the total environment*, 578, 485-494.
- Kasamesiri, P., & Thaimuangphol, W. 2020 Microplastics ingestion by freshwater fish in the Chi River, Thailand. *Geomate Journal*, 18(67), 114-119.
- Koelmans, A. A., Nor, N. H. M., Hermesen, E., Kooi, M., Mintenig, S. M., & De France, J. 2019 Microplastics in freshwaters and drinking water: Critical review and assessment of data quality. *Water research*, 155, 410-422.
- Lenz, R., Enders, K., Stedmon, C. A., Mackenzie, D. M., & Nielsen, T. G. 2015 A critical assessment of visual identification of marine microplastic using Raman spectroscopy for analysis improvement. *Marine pollution bulletin*, 100(1), 82-91.
- Li, J., Qu, X., Su, L., Zhang, W., Yang, D., Kolandhasamy, P., ... & Shi, H. 2016 Microplastics in mussels along the coastal waters of China. *Environmental pollution*, 214, 177-184.
- Lippiatt, S., Opfer, S., & Arthur, C. 2013 Marine debris monitoring and assessment: recommendations for monitoring debris trends in the marine environment.
- Luo, W., Su, L., Craig, N. J., Du, F., Wu, C., & Shi, H. 2019 Comparison of microplastic pollution in different water bodies from urban creeks to coastal waters. *Environmental pollution*, 246, 174-182.
- Ly, L., Yan, X., Feng, L., Jiang, S., Lu, Z., Xie, H., ... & Li, C. 2021 Challenge for the detection of microplastics in the environment. *Water Environment Research*, 93(1), 5-15.
- McNeish, R. E., Kim, L. H., Barrett, H. A., Mason, S. A., Kelly, J. J., & Hoellein, T. J. 2018 Microplastic in riverine fish is connected to species traits. *Scientific reports*, 8(1), 11639.
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & PRISMA Group\*. 2009 Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Annals of internal medicine*, 151(4), 264-269.

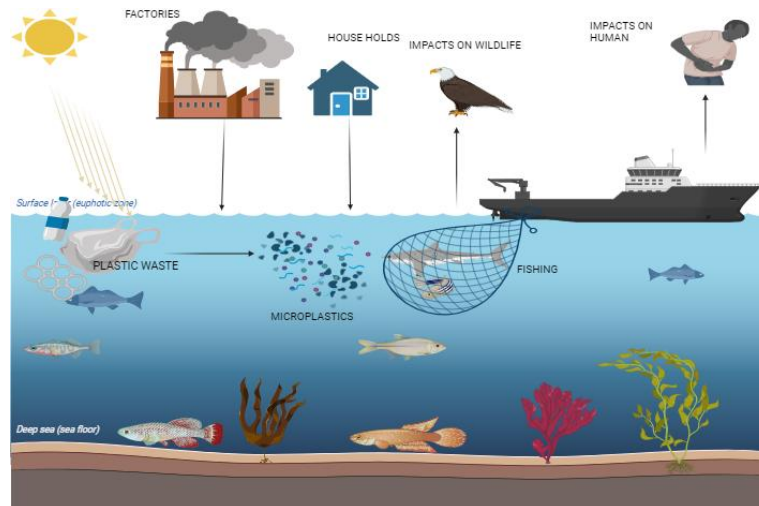
- Moret-Ferguson, S., Law, K. L., Proskurowski, G., Murphy, E. K., Peacock, E. E., & Reddy, C. M. 2010 The size, mass, and composition of plastic debris in the western North Atlantic Ocean. *Marine Pollution Bulletin*, 60(10), 1873–1878. <https://doi.org/10.1016/j.marpolbul.2010.07.020>
- Murray, F., & Cowie, P. R. 2011 Plastic contamination in the decapod crustacean *Nephrops norvegicus* (Linnaeus, 1758). *Marine pollution bulletin*, 62(6), 1207–1217.
- Nel, H. A., Dalu, T., & Wasserman, R. J. 2018 Sinks and sources: Assessing microplastic abundance in river sediment and deposit feeders in an Austral temperate urban river system. *Science of the Total Environment*, 612, 950–956.
- Ory, N. C.; Gallardo, C.; Lenz, M.; Thiel, M. 2018 Capture, swallowing, and egestion of microplastics by a planktivorous juvenile fish. *Environ. Pollut.*, 240, 566–573.
- Pazos, R. S., Maiztegui, T., Colautti, D. C., Paracampo, A. H., & Gómez, N. 2017 Microplastics in gut contents of coastal freshwater fish from Río de la Plata estuary. *Marine pollution bulletin*, 122(1-2), 85–90.
- Rabari, V., Patel, H., Patel, K., Patel, A., Bagtharia, S., & Trivedi, J. 2023 Quantitative assessment of microplastic contamination in muddy shores of Gulf of Khambhat, India. *Marine Pollution Bulletin*, 192, 115131.
- Rabari, V., Patel, K., Patel, H., & Trivedi, J. 2022 Quantitative assessment of microplastic in sandy beaches of Gujarat state, India. *Marine Pollution Bulletin*, 181, 113925.
- Rajhans, A., Gore, P. M., Siddique, S. K., & Kandasubramanian, B. 2019 Ion-imprinted nanofibers of PVDF/1-butyl-3-methylimidazolium tetrafluoroborate for dynamic recovery of europium (III) ions from mimicked effluent. *Journal of Environmental Chemical Engineering*, 7(3), 103068.
- Rhodes, C. J. 2018 Plastic pollution and potential solutions. *Science progress*, 101(3), 207–260.
- Robin, R. S., Karthik, R., Purvaja, R., Ganguly, D., Anandavelu, I., Mugilarasan, M., & Ramesh, R. 2020 Holistic assessment of microplastics in various coastal environmental matrices, southwest coast of India. *Science of the Total Environment*, 703, 134947.
- Roch, S., & Brinker, A. 2017 Rapid and efficient method for the detection of microplastic in the gastrointestinal tract of fishes. *Environmental Science & Technology*, 51(8), 4522–4530.
- Rochman CM, Tahir A, Williams SL, Baxa DV, Lam R, Miller JT, Teh FC, Werorilangi S, Teh SJ 2015 Anthropogenic debris in seafood: plastic debris and fibers from textiles in fish and bivalves sold for human consumption. *Sci Rep* 5:14340.
- Rochman, C. M. 2018 Microplastics research—from sink to source. *Science*, 360(6384), 28–29.
- Rochman, C. M., Hoh, E., Kurobe, T., & Teh, S. J. 2013 Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress. *Scientific reports*, 3(1),

- Rodrigues JP, Duarte AC, Santos-Echeandía J, Rocha-Santos T 2019 Significance of interactions between microplastics and POPs in the marine environment: a critical overview. *TrAC Trends Anal Chem* 111:252–260.
- Santillo, D., Miller, K., & Johnston, P. 2017 Microplastics as contaminants in commercially important seafood species. *Integrated environmental assessment and management*, 13(3), 516-521.
- Savoca, M. S.; McInturf, A. G.; Hazen, E. L. 2021 Plastic ingestion by marine fish is widespread and increasing. *Glob. Chang. Biol.* 27, 2188.
- Schwarzenbach, R. P.; Escher, B. I.; Fenner, K.; Hofstetter, T. B.; Johnson, C. A.; Gunten, U. v.; Wehrli, B. 2006 The challenge of micropollutants in aquatic systems. *Science* 313, 1072–1077.
- Serrano, D. P., Aguado, J., Escola, J. M., Rodríguez, J. M., & San Miguel, G. 2005 An investigation into the catalytic cracking of LDPE using Py–GC/MS. *Journal of analytical and applied pyrolysis*, 74(1-2), 370-378.
- Soják, L., Kubinec, R., Jurdáková, H., Hájeková, E., & Bajus, M. 2007 High resolution gas chromatographic–mass spectrometric analysis of polyethylene and polypropylene thermal cracking products. *Journal of Analytical and Applied Pyrolysis*, 78(2), 387-399.
- Song, Y. K., Hong, S. H., Jang, M., Han, G. M., & Shim, W. J. 2015 Occurrence and distribution of microplastics in the sea surface microlayer in Jinhae Bay, South Korea. *Archives of environmental contamination and toxicology*, 69, 279-287.
- Song, Y. K., Hong, S. H., Jang, M., Han, G. M., & Shim, W. J. 2015 Occurrence and distribution of microplastics in the sea surface microlayer in Jinhae Bay, South Korea. *Archives of environmental contamination and toxicology*, 69, 279-287.
- Talley, T. S., Venuti, N., & Whelan, R. 2020 Natural history matters: Plastics in estuarine fish and sediments at the mouth of an urban watershed. *Plos one*, 15(3), e0229777.
- Thushari, G. G. N., & Senevirathna, J. D. M. 2020 Plastic pollution in the marine environment. *Heliyon*, 6(8).
- Triebksorn, R., Braunbeck, T., Grummt, T., Hanslik, L., Huppertsberg, S., Jekel, M., ... & Köhler, H. R. 2019 Relevance of nano-and microplastics for freshwater ecosystems: a critical review. *TrAC Trends in Analytical Chemistry*, 110, 375-392.
- Trivedi, D. J., Trivedi, J. N., Soni, G. M., Purohit, B. D., & Vachhrajani, K. D. 2015 Crustacean fauna of Gujarat state of India: A review. *Electronic Journal of Environmental Sciences*, 8, 23-31.
- Turner, A., & Holmes, L. 2011 Occurrence, distribution and characteristics of beached plastic production pellets on the island of Malta (central Mediterranean). *Marine Pollution Bulletin*, 62(2), 377-381.

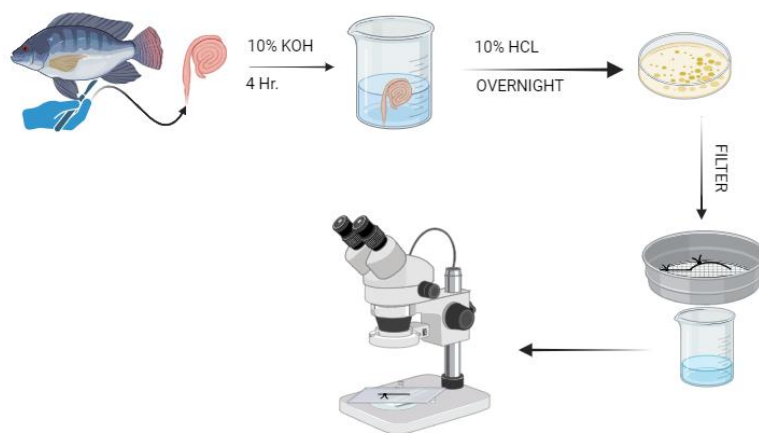
- Valente, T., Sbrana, A., Scacco, U., Jacomini, C., Bianchi, J., Palazzo, L., ... & Matiddi, M. 2019 Exploring microplastic ingestion by three deep-water elasmobranch species: A case study from the Tyrrhenian Sea. *Environmental Pollution*, 253, 342-350.
- Van Cauwenberghe, L., & Janssen, C. R. 2014 Microplastics in bivalves cultured for human consumption. *Environmental pollution*, 193, 65-70.
- Van Cauwenberghe, L., Claessens, M., Vandegehuchte, M. B., & Janssen, C. R. 2015 Microplastics are taken up by mussels (*Mytilus edulis*) and lugworms (*Arenicola marina*) living in natural habitats. *Environmental pollution*, 199, 10-17.
- Villagran, D. M., Truchet, D. M., Buzzi, N. S., Lopez, A. D. F., & Severini, M. D. F. 2020 A baseline study of microplastics in the burrowing crab (*Neohelice granulata*) from a temperate southwestern Atlantic estuary. *Marine Pollution Bulletin*, 150, 110686.
- Von Moos, N., Burkhardt-Holm, P., & Köhler, A. 2012 Uptake and effects of microplastics on cells and tissue of the blue mussel *Mytilus edulis* L. after an experimental exposure. *Environmental science & technology*, 46(20), 11327-11335.
- Wagner J, Wang Z-M, Ghosal S et al 2017 Novel method for the extraction and identification of microplastics in ocean trawl and fish gut. *Anal Method* 9:1479–1490.
- Wang, W., Ge, J., & Yu, X. 2020 Bioavailability and toxicity of microplastics to fish species: a review. *Ecotoxicology and environmental safety*, 189, 109913.
- Wang, Z. M., Parashar, M., Ghosal, S., & Wagner, J. 2020 A new method for microplastic extraction from fish guts assisted by chemical dissolution. *Analytical Methods*, 12(45), 5450-5457.
- Wang, Z. M., Wagner, J., Ghosal, S., Bedi, G., & Wall, S. 2017 SEM/EDS and optical microscopy analyses of microplastics in ocean trawl and fish guts. *Science of the Total Environment*, 603, 616-626.
- Watts, A. J., Lewis, C., Goodhead, R. M., Beckett, S. J., Moger, J., Tyler, C. R., & Galloway, T. S. 2014 Uptake and retention of microplastics by the shore crab *Carcinus maenas*. *Environmental science & technology*, 48(15), 8823-8830.
- Wootton, N., Ferreira, M., Reis-Santos, P., & Gillanders, B. M. 2021 A comparison of microplastic in fish from Australia and Fiji. *Frontiers in Marine Science*, 8, 690991.
- Worm, B., Lotze, H. K., Jubinville, I., Wilcox, C., & Jambeck, J. 2017 Plastic as a persistent marine pollutant. *Annual Review of Environment and Resources*, 42, 1-26.
- Wright, S. L., & Kelly, F. J. 2017 Plastic and human health: a micro issue?. *Environmental science & technology*, 51(12), 6634-6647.
- Wu, B., Quan, Q., Yang, S., & Dong, Y. 2023 A social-ecological coupling model for

- evaluating the human-water relationship in basins within the Budyko framework. *Journal of Hydrology*, 619, 129361.
- Wu, F., Wang, T., Li, X., Zhao, R., & He, F. 2023 Microplastic contamination in the dominant crabs at the intertidal zone of Chongming Island, Yangtze Estuary. *Science of The Total Environment*, 896, 165258.
- Xiong, X., Tu, Y., Chen, X., Jiang, X., Shi, H., Wu, C., & Elser, J. J. 2019 Ingestion and egestion of polyethylene microplastics by goldfish (*Carassius auratus*): influence of color and morphological features. *Heliyon*, 5(12).
- Yuan, L., Wu, X., He, W., Degefu, D. M., Kong, Y., Yang, Y., ... & Ramsey, T. S. 2023 Utilizing the strategic concession behavior in a bargaining game for optimal allocation of water in a transboundary river basin during water bankruptcy. *Environmental Impact Assessment Review*, 102, 107162.
- Yuan, W., Liu, X., Wang, W., Di, M., & Wang, J. 2019 Microplastic abundance, distribution and composition in water, sediments, and wild fish from Poyang Lake, China. *Ecotoxicology and environmental safety*, 170, 180-187.
- Zada L., Leslie HA, Vethaak AD et al 2018 Fast microplastics identification with stimulated Raman scattering microscopy. *J Raman Spectrosc* 1–9.
- Zhang, Q., Xu, E. G., Li, J., Chen, Q., Ma, L., Zeng, E. Y., & Shi, H. 2020 A review of microplastics in table salt, drinking water, and air: direct human exposure. *Environmental Science & Technology*, 54(7), 3740-3751.
- Zhao, S., Ward, J. E., Danley, M., & Mincer, T. J. 2018 Field-based evidence for microplastic in marine aggregates and mussels: implications for trophic transfer. *Environmental science & technology*, 52(19), 11038-11048.
- Ziajahromi, S., Neale, P. A., Rintoul, L., & Leusch, F. D. 2017 Wastewater treatment plants as a pathway for microplastics: development of a new approach to sample wastewater-based microplastics. *Water research*, 112, 93-99.

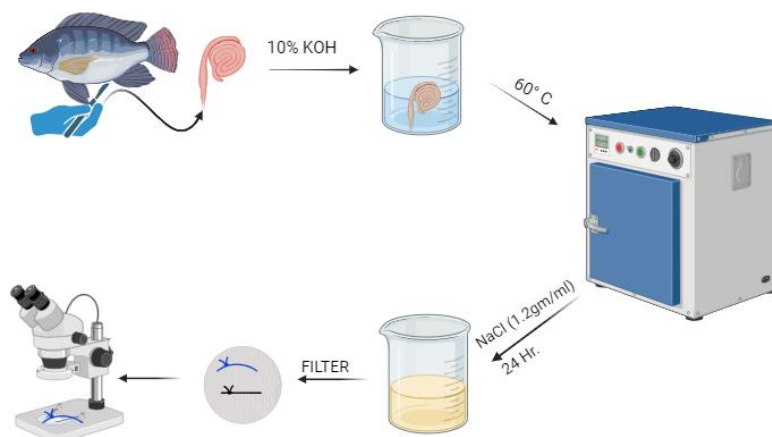
## Annexure 1: Figures



**Figure I: Effect of Microplastics**



**Figure II: Protocol 1**



**Figure III: Protocol 2**