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Microplastic pollution: An emerging environmental issue

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Abstract
The presence of micro plastics in the environment is increasingly reported and has been recognized as a potential pollutant that may adversely affect aquatic environment and cause potential risk to the health of aquatic ecosystems. Micro plastics contain a mixture of chemicals added during manufacture, the so-called additives, and efficiently sorb (adsorb or absorb) persistent bio accumulative and toxic contaminants (PBTs) from the environment. Micro plastic contamination in aquatic environments will tend to increase in the future because at present there is a huge knowledge gap on the occurrence of micro plastic pollution in aquatic environments and their possible effects on the ecosystem. Currently there are no reliable methods available for the observation and quantification of micro or nano plastics in aquatic environments and organisms. Micro plastic contamination of aquatic environments will continue to increase in the foreseeable future and at present there are significant knowledge gaps on the occurrence in aquatic environments and organisms of the smaller sized micro plastics (less than 150 µm), and their possible effects on seafood safety.

Keywords: Pollution, micro plastic, environment, fisheries, aquaculture

1. Introduction

At present, the whole world is having several problems arising from different kinds of pollution among which plastic pollution is also a notable one. From the land around 8 million tons of plastic is being thrown to the ocean per year [1] of which 1% consists of the small plastic debris alone. The U.N. draft Resolution on Marine Litter and Micro plastic was being signed by nearly 200 countries in Nairobi in December 2017, who had recognized the importance of this problem. They acknowledged that if no action is being taken then the volume mentioned above will shoot up to double by 2030 and by 2050 it will become further double.

Plastic production has risen rapidly since the development of large-scale industrial manufacture started in early 1950. Almost all aspects of daily life involve plastics. The main application of plastic includes packaging, building and construction, automotive industry, electrical and electronic, agriculture and other applications including consumer and home appliances, furniture, sport, health and safety.

Micro plastics are small plastic particles, commonly defined as being 5 mm or less in their longest dimension, have been found in different environmental matrices (atmosphere, soils, freshwater and marine). Micro plastics are found in beaches, shelf, and deep water sediments and in surface and sub-surface waters in fresh and marine waters. Additionally, common phenomenon of micro plastic ingestion has been observed in many aquatic species, including important fish and invertebrates (GESAMP, 2016).

Plastic materials are known to be a major component of inland pollution and degradation of plastic products has been noted as a major issue for soil environments [2]. Though till now plastic pollution has gaining emphasis as marine pollution, but now attention has been deviated to terrestrial [3] and freshwater environments [3, 4, 5]. Monitoring observation has quantified microscopic plastics debris, so-called micro plastics (MPs), in freshwater systems, including riverine beaches, surface waters and sediments of rivers, lake, and reservoirs [6]. Different toxicological studies have reported micro plastic (MP) ingestion by various species and their effects on life history parameters [7]. Majority of the studies used primary microspheres of polyethylene (PE) and polystyrene (PS) at high concentrations [8] over short-term exposures. According to the report [9] MPs may pose a risk to freshwater ecosystems. [10] Reported that long term exposure may lead to bioaccumulation of submicron with the wider application of environmental health.

2. Plastic and its different effect on organisms

[2] Described macro plastics as >5 mm, mesoplastics as ≤ 5 to >1 mm, micro plastics as ≤1 mm to >0.1 µm, and nanoplastics as ≤ 0.1 µm. However, [11] report accepted the upper limit of 5 mm because this size is able to include a range of small particles that can be readily ingested by organisms.

Table 1: Medical literature on impact of Micro plastics and nanoplastics originating from inhalation and surgical materials at various levels of biological organization [12]

Level of biological organization	Particle type and size	Effect	Reference
Macromolecules	PE 100 nm–30 µm PS 50 nm –4.7 µm PMMA 1 µm–2 µm PC 1 µm–55 µm	DNA damage, changes in gene and protein expression	[13, 14]
Organelles	PMMA 10 µm	More micronuclei	[15]
Cells	PS 20 nm–4.7 µm PE 300 nm–10 µm PMMA 2 µm–35 µm PS 20 nm–200 nm PS 60 nm–200 nm	Cell clotting, necrosis, apoptosis, proliferation and loss of cell viability Oxidative stress Increased Ca ions	[16, 17]
Tissues	PE 600 nm–21 µ, PMMA 1 µm–35 µm	Inflammation and bone osteolysis	[18] [14]
Organs	PMMA 1 µm–10 µm	Lesions	[16, 14]

Courtesy: FAO, 2017

Generally, MPs can be divided as primary or secondary MPs. Primary MPs are manufactured as such and are used either as resin pellets to produce larger items or directly in cosmetic products such as facial scrubs and toothpastes or in abrasive blasting (e.g. to remove lacquers). Compared to this deliberate use, secondary MPs are formed from the disintegration of larger plastic debris.

Table 2: A selective list of additive compounds used to make plastics fit for purpose

Additive compounds	Function
Plasticisers	Renders the material pliable
Flame retardants	Reduces flammability
Cross-linking additives	Links together polymer chains
Antioxidants and other stabilisers	Increases the durability of plastics by slowing down the rate at which oxygen, heat, and light degrade the material
Sensitisers (e.g. pro-oxidant transition metal complexes)	Used to give accelerated degradation properties
Surfactants	Used to modify surface properties to allow emulsion of normally incompatible substances
Inorganic fillers	Used to reinforce the material to improve impact resistance
Pigments	For colour

Courtesy: The Handbook of Environmental Chemistry 58, Springer

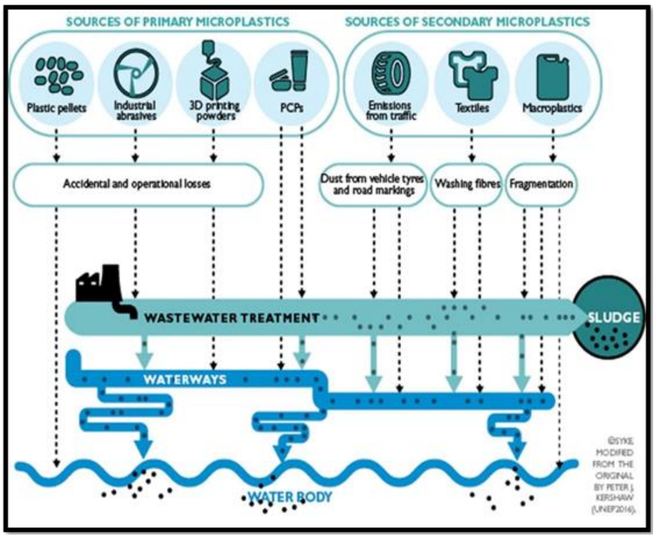
In the ecosystem itself, the local fauna may get heavily affected by the harmful effects of Micro plastics. Fish is the taxon which has been affected the most, among more than 600 taxa in the aquatic environment wherein consumption of Micro plastics has been reported [Secretariat of the Convention on Biological Diversity (2012) Marine biodiversity - One ocean, many worlds of life. Montreal, Canada.]. It has been observed that the ingestion in case of fish may occur purposefully where fishes mistake the Micro plastics for small food particles suspended in the column, or unintentionally when they ingest it along with food. Sometimes it may occur even preferentially which has happened in case of the larva of *Perca fluviatilis* [19]. Therefore it can be said that fish has been mostly getting contaminated with microplastic by ingesting it, whether it is intentional or unintentional.

As fish is the most affected one, several studies are already doneon the negative impacts of microplastic on fishes and it has been found that Micro plastics have both physical and physiological effects on fish fauna [19]. The physical effects of ingesting microplastic are as follows- clogging of the alimentary appendages and of the digestive system, inflammation and laceration of the gastrointestinal tissues which will prevent the accurate absorption of nutrients [20]. There are also some physiological effects which can be noticed in case of fishes. There will be stimulation of degranulation [21] change in the behaviour, even the ability of a predator to perceive will also be reduced [19].

The ability of the animal to feed get also disturbed by microplastic and eventually it will create difficulty in their capacity to grow, reproduce and function normally. Many laboratory experiments have been done on different aquatic organisms about the negative impacts of microplastic on their health conditions. Polystyrene, a very common microparticle caused energy uptake and energy allocation reduction and also subdued the reproduction and offspring performance in case of oysters. Survival as well as the egg hatching process was at stake in case of copepods due to diminished algal feeding which is also because of the ingestion of polystyrene microparticles [22]. The sediment-dwelling worms were also affected by Micro plastics viz. polyvinylchloride in micro form which diminished the energy reserves and functionality [23]. As we can see that Micro plastics can create great havoc among the aquatic organisms through which it may eventually imbalance the entire ecosystem. As for example, the vital component for life i.e. carbon is transferred to the deeper ocean depths and also the sediment gets aerated mainly by the marine organisms. Therefore, these organisms are very much essential for maintaining the nutrient cycle, which may be influenced by high levels of microplastic pollution as they can reduce the ability these organisms to carry out those functions.

3. Fisheries and aquaculture

In case of fisheries and aquaculture sectors, the main source of plastic waste are basically the Abandoned, lost or otherwise discarded fishing gears (ALDFG). However their relative contribution to the waste is not clearly not known at regional and global levels. During the manufacture of microplastic, certain chemicals are mixed such as the additives and efficiently sorb (adsorb or absorb) persistent bioaccumulatives and toxic contaminants (PBTs) from the environment itself. As the gastrointestinal tract is the only organ (FAO, 2017) where Micro plastics has been found in case of wild aquatic organisms, so in most of the seafood species by removing it, the danger of microplastic consumption can be lowered. But there are also some cases of microplastic exposure as in case of many bivalve species and some species of small fishes are being consumed as a whole without removing the gut content. Although at present there is a significant knowledge gap about the presence of smaller sized microparticles (less than 150µm) in the aquatic environment as well as its impact on the organisms; the contamination will continue to increase in the near future as a result of which the safety of the seafoods will definitely be hampered. But at the current time, for the observation and qualification of micro plastic in the aquatic ecosystem and its living resources; no proper routines or methods have been yet accomplished (FAO, 2017).



Sources: Peter J. Kershaw (UNEP, 2016)

Fig 1: Microplastic pollution

4. Sources of plastics and micro plastics into the aquatic environment

Plastic will enter freshwater environment through various sources and various routes. According to the report of [24] and [25] on land littering is an important environmental and public issue. This is a matter of increasing concern in protected areas and there is a need of mitigation of environmental damages. Micro plastic can enter the environment through different route and may vary from one geographical region to another. For example, primary MPs used in consumer cosmetics are probably more important in affluent regions [3]. Micro plastic has several potential environmental release pathways (1) passage through waste water treatment plan (WWTPs), either from MP use in personal care products or release of fibres from textiles during the washing of clothes, to surface waters, (2) application of biosolids from WWTPs to agricultural lands (3) storm water overflow events, (4) incidental release (e.g. during tyre wear), (5) release from industrial products or processes, and (6) atmospheric deposition of fibres. Plastic films used in agriculture is considered as one of the most important sources of plastic contamination of agricultural soils [26]. Manufacturing and construction sites also contribute to the microplastic pollution. The sources and emission routes of nanoplastics are also discussed in [9].

5. Occurrence in the freshwater environment

Sophisticated equipment's are requested for detection and analytical confirmation of micro plastics (e.g. micro-FTIR and micro-Raman). Recent findings have reported that similar to marine environments micro plastics are ubiquitously found in a variety of freshwater matrices. High surface water concentrations are reported at the Three Gorges Dam, China (192–13,617 particles km^{-2}), which are attributed to a lack of wastewater treatment facilities in smaller towns, as well as infrastructure issues when dealing with recycling and waste disposal [27].

6. Environmental transportation of Micro plastics

Plastic material entering the environment will not remain stationary. They will be transported between the environmental compartments with varying degree of residence time in each. For example, the movement from land to river systems will depend upon prevailing weather conditions, distance to a specific river site, and land cover type. [3] Mentioned that the collection of plastic litter at roadside habitats is easily observed, and the regular grass cutting practices of road verges in some countries means that littered items are quickly disintegrated by mowing equipment. River hydrology governs the movement of bulk plastics and MPs within the riverine system (e.g. flow conditions, daily discharge) and the morphology (e.g. vegetation pattern) at a specific river site that will have a large effect upon the propagation of litter because of stranding and other watercourse obstructions such as groins and barrages. Micro plastics may be subjected to different rate of degradation as they will be transported and distributed at quicker rates than micro plastic.

7. Distribution of micro plastics in freshwater and estuarine environment

There are a few reports mentioning the occurrence of micro plastics in a freshwater environment including lakes, rivers and estuaries as compared to marine environments. Recently several publications have reviewed current information on occurrence of micro plastics in freshwater environments [28, 29]; [4, 5] mentioned the interaction micro and nan plastics in freshwater systems [30]. In general, sediments show higher concentrations than water samples, and results are comparable to those obtained in coastal marine habitats. [31] reported that micro plastics tend to show higher abundance close to urban and industrial centers in lacustrine environments but this relation does not hold in some riverine systems due result of river flow dynamics and flooding. Improper waste disposal and windblown micro plastics could contribute to pollution of relatively isolated freshwater environments [32].

8. Identification of micro plastics by their chemical composition

Many sophisticated methods are used for identification of Micro plastics and polymer. In the following we will give a short overview of methods applied for polymer identification with a focus on the nowadays frequently used FTIR and Raman analyses of Micro plastics.

8.1 Density Separation with Subsequent C: H: N Analysis [33]

The specific densities of particles to identify the polymer origin of visually sorted Micro plastics. Sample was placed in distilled water and, depending on the density of the sample, either ethanol or concentrated solutions of calcium or strontium chloride were added until the sample was neutrally buoyant. The density of the particle was indirectly assessed by weighing a certain volume of the solution. This facilitated the determination of the density with high precision. Different groups of polymers possess a characteristic elemental composition, which was used to identify the plastic origin of a particle by a subsequent C: H: N analysis. By comparison with the densities and C: H: N ratios of virgin-polymer samples the particle could be assessed as either plastic or not and assigned to a group of potential polymers. This approach represents an approximation to the identification of microplastic particles by narrowing the search for the potential polymer type but not a rigorous chemical analysis. Further drawbacks are the relatively high time effort, which hampers a high sample throughput and that this technique is not applicable to smaller particles.

8.2 Pyrolysis-GC/MS [33]

Assessment of the chemical composition of potential microplastic particles by analyzing their thermal degradation products can be done by Pyrolysis-gas chromatography (GC) in combination with mass spectrometry (MS). The pyrolysis of plastic polymers results in characteristic pyrograms, which facilitate an identification of the polymer type. This analytical approach is already used after extraction and visual sorting of Micro plastics from sediments. The polymer origin of particles is then identified by comparing their characteristic combustion products with reference pyrograms of known virgin-polymer samples. Since only particles of a certain minimum size can be manipulated manually this results in a lower size limitation of particles that can be analyzed. Currently promising pyrolysis-GC/MS approaches for the qualitative/quantitative analysis of Micro plastics on whole environmental sample filters are being developed.

8.3 Raman Spectroscopy [33]

Raman spectroscopy is one of the important techniques used to identify microplastic particles in different environmental samples with high reliability [23]. During the analysis with Raman spectroscopy the sample is irradiated with a monochromatic laser source. The laser depends on the system used: available laser wavelengths usually range between 500 and 800 nm. The interaction of the laser light with the molecules and atoms of the sample (vibrational, rotational, and other low frequency interactions) results in differences in the frequency of the backscattered light when compared to the irradiating laser frequency. This so-called Raman shift can be detected and leads to substance-specific Raman spectra. Since plastic polymers possess characteristic Raman spectra the technique can be applied to identify plastic polymers within minutes by comparison with reference spectra.

8.4 IR Spectroscopy [33]

Similar to Raman spectroscopy, infrared (IR) or Fourier-transform infrared (FTIR) spectroscopy offers the possibility of accurate identification of plastic polymer particles according to their characteristic IR spectra. FTIR and Raman spectroscopy are complementary techniques. Molecular vibrations, which are Raman inactive are IR active and vice versa and can thus provide complementary information on microplastic samples. IR spectroscopy takes advantage of the fact that infrared radiation excites molecular vibrations when interacting with a sample. The excitable vibrations depend on the composition and molecular structure of a substance and are wave-length specific. The energy of the IR radiation that excites a specific vibration will depend on the wave length be absorbed to a certain amount, which enables the measurement of characteristic IR spectra. Plastic polymers possess highly specific IR spectra with distinct band patterns making IR spectroscopy an optimal technique for the identification of Micro plastics. FTIR spectroscopy can provide further information on physico-chemical weathering of sampled plastic particles by detecting the intensity of oxidation.

9. Conclusion

Micro plastics are currently a ubiquitous contaminant in aquatic environments and currently have been detected in beach sediments, sub-littoral and deep sea sediments, water surface and water column. Plastic contamination of aquatic environments has been increased since industries of high volume polymer production commenced in the 1950s. Thus, very little information exists on the relative contribution of different types of plastic and associated chemicals. Since which varies with time for the contribution of these factor, that limits the degree to which projections can be made on future trends of the potential effects of Micro plastics on fisheries and aquaculture. Very little information exists on the distribution of Micro plastics in the aquatic ecosystem. The Fisheries and aquaculture sector contribute to microplastic contamination but its overall quantitative contribution is as yet poorly understood. Abandoned, lost or otherwise discarded fishing gears (ALDFG) are thought to be the main contributor of this sector to the generation of Micro plastics in aquatic environments. Whereas the overall human health risks posed by Micro plastics in seafood at present appear to be low, it is important to consider the unavoidable increase of micro and nanoplastics in the future as a result of degradation of plastics already released in the environment as well as future inputs. The contamination of Micro plastics in the aquatic environment will degrade the habitat and life of the natural resources and thus stringent measures needs to be taken for conserving our aquatic resources for our future generations.

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