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MICROPLASTICS: POLLUTANT OF EMERGING CONCERN- WHAT DO WE KNOW SO FAR? - A REVIEW

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ABSTRACT

The increasing consumption of plastic material in our daily life is generating enormous amount of plastic waste which deteriorate the environment. Microplastics are defined as any piece of plastics in size range between 1 micron to 5 mm are a diverse contaminant group that is raising an alarming concern worldwide due to their abundance, minute size, diverse characteristic, trans-boundary migration and Eco-toxicological impacts. Microplastics research is in its infancy andits very challenging to assess the global abundance owing to their characteristic. Microplastics are present in various environmental matrices and they are found in body of wide range of aquatic and terrestrial biota. Due to their minuscule size, they act as vector for toxic chemicals and pathogens. Microplastics loaded with toxic chemicals enters the food web through trophic transfer at various level in aquatic ecosystem where they get consumed by organisms. Human are exposed to microplastics through contaminated food or water and through inhalation of atmospheric microplastics present in air. The eco-oxicological impact of microplastics present in guts of animals and human are being researched globally as they have potential to bio-accumulate, trans-locate and release toxic chemicals into the body. Microplastics though being a pollutant of emerging concern has garner significant attention in recent year. In this review paper an attempt has been made to discuss various types of microplastics, its sources and entry routes to the environment. We further discussed various mechanisms through which fragmentation and degradation of plastics occurring in environment. We also reviewed the sorptivebehaviour of microplastics to highlight microplastics interaction with toxic chemicals. Lastly we discussed the negative impact of microplastics on animal and human health.

KEY WORDS : Microplastics, Contaminants, Toxicity, Environment, Degradation, Bio-accumulation

INTRODUCTION

There is an alarming concern among environmental experts regarding a new source of pollution that is deteriorating our environment since last century and we were not aware of it (Jambeck *et al.,* 2015). Plastic made our life easier but it came with grave consequences, producing a new type of pollutant known as microplastics which is now a global crisis due to their global presence in different environmental matrices, habitats, and ecosystems and various life forms including humans (Machado *et al.,* 2018; Avivo *et al.,* 2017).

Plastic being a versatile material enables humans to use it in every aspect of life. This versatile nature comes from adaptive physio-chemical properties of plastics, which offer wide scope of ever-growing application. Discovery of vulcanization by Charles goodyear, in 1843, motivated innovators, which lead to series of research, culminated at discovery of bakelite (First fully synthetic plastic) by Leo hendrikbaekeland in 1909. The discovery of Bakelite started Plastic era where new synthetic polymers are being discovered and heavily used. Meanwhile in 1869, John Wesley Hyatt discovered first synthetic polymer called celluloid as substitute for natural ivory. The discovery of celluloid was revolutionary as Celluloid can easily be molded and crafted to any shape and size, and will save the natural world from cataclysmic force of human need (Meikle, 1995).

The adaptive physio-chemical properties of plastic which made plastic as such widely used material also pose a significant threat to environment. Eco toxicological effect of plastic waste on aquatic and human life is widely researched and documented (Anbumani and Kakkar, 2018; Barboza *et al.,* 2018; Karbalaei *et al.,* 2018; Prokiæ *et al*., 2019). Plastic production throughout the world has increased tremendously since inception of synthetic polymers. A report estimates that annual global plastic production increased from 1.5 million tons in 1950 to 359 million tons in 2018 (Plastic Europe, 2019).

The pervasive nature and ubiquitous presence of plastic in various environmental matrices have caused great concern worldwide recently. Although most plastic we use in our daily life is very observable, some might not be so observable, mainly microplastics (Eriksen *et al.,* 2014; Chae and An, 2018; Blettler and Wantzen, 2019).

The large plastic debris also known as macroplastics have been widely studied and documented in environmental habitats but smaller plastic debris also known as microplastics gained little attention in last century and only in last decade, investigations related to its presence in environmental matrices caught attention of researchers (Carpenter and Smith, 1972; Derraik, 2002; Barnes 2002; Gregory, 2009; Barnes *et al.,* 2009; Moore, 2008; Ryan *et al.,* 2009; Rands *et al.,* 2010; Sutherland *et al.,* 2010; Andrady, 2011).

Microplastics are synthetic and semi synthetic plastic polymer with micro being the pivotal defining term based on the size. The earliest literature that defined microplastics based on size was 'Lost at Sea: Where Is All the Plastic? The study denoted Microplastics as any plastic particle whose diameter is in size range of 20 micron (Thompson *et al.,* 2004). The first international workshop on microplastics held at National Oceanic and Atmospheric Administration (NOAA) proposed upper size limit of 5 mm for defining microplastics in order to shift our focus on possible environmental affect rather physical blockage of gastrointestinal tracts (Arthuret *al.,* 2009). UN Environment published a report in 2015 titled 'Plastic in cosmetics' defines any particle as microplastics when they are, 'solid phase materials, and particulates < 5mm, water insoluble, non-degradable and made of plastic' (UNEP, 2015).

The aforementioned definition is not globally accepted by research community due to lack of standard protocol and identification limitations of instruments. Hence, different size limits have been considered in various studies which make comparative studies challenging leading to unavailability of unanimous standards (GESAMP, 2015). The common consensus among scientific community is to define microplastics as 'any piece of plastic in size range between 1 micron to 5mm'.

Microplastics are now considered as 'diverse contaminant group' as they are a heterogeneous, complex group of different polymers, sizes, colors, shapes, and additives, which are ubiquitous in environment and their presence have been reported in all environmental matrices (marine water, fresh water, soil, atmospheric fall-outs, wastewater and municipal solid waste) around the globe (Murphy *et al.,* 2016; Horton *et al.,* 2017; Hanvey *et al.,* 2017; Enyoh *et al*., 2019; Frias and Nash, 2019; Rochman *et al.,* 2019).

Due to their diverse nature, they pose an ability to interact with toxic chemicals already present in the environment and get consumed by all type of life-forms including humans. Our understanding on eco-toxicological effect of microplastics on biotic and abiotic environment is very limited though it is well established that microplastics act as vector for toxic chemicals and pathogens and their transference exist at different trophic levels (Barboza *et al.,* 2018; Karbalaei *et al.,* 2018; Zhang *et al.,* 2020).

Sources and pathways of microplastics

Plastic enters in environment from various sources using different entry routes, most significantly terrestrial. The major sources and entry routes of microplastics are (i) intentionally made microplastics for personal care products and textile fibers from laundry enters wastewater treatment plants and ends up in surface water where effluent is released, (ii)bio-solids contaminated with microplastics originating from wastewater treatment plants are used for agricultural purpose (iii) industrial release of microplastics, (iv) accidental release of microplastics, (v) stormwater containing microplastics from land-based liters (microplastics from construction sites and road dust containing tire wear), (vi) atmospheric deposition, (vii) microplastics lost into marine environment during nautical activities, (ix) disintegration of plastic films used in agriculture activity (Magnusson *et al.,* 2016; Duis and Coors, 2016; Rochman, 2018; Liu *et al.,* 2019; Allen *et al.*, 2019; Huang *et al.,* 2020; Crossman *et al.,* 2020).

Microplastic particles in the environment will not remain stationery and their passage from one environmental matrix to other is inevitable, though a complex process depending upon several factors, mainly density, shape and size. Majority of microplastics are of terrestrial origin yet their highest abundance is reported in aquatic environment especially in marine ecosystem suggesting that oceans act as final sink for microplastics (Horton and Dixon, 2018; Bank and Hansson, 2019).

Types of microplastics

A microplastic pollutant that enters to environmental matrices comes from variety of sources. These sources provide us an opportunity to classify microplastics based on their origin i.e *primary microplastics* and *secondary microplastics*. Primary microplastics are those plastic particles which are intentionally made in size range of microplastics for specific application. Primary microplastics are used in household items, variety of personal care products such as facial cleansers, tooth pastes and scrubs, feedstock material for plastic processing industry etc. Secondary microplastics results from environmental degradation of largemacroplastics in the environment and accidental release of primary microplastics in the environment either during transportation activities or industrial spillage. Wearing of tyres and degradation of plastics used in agricultural activities also comes under umbrella of secondary microplastics (Fendall and Sewell, 2009; Cole *et al.,* 2011; Verschoor *et al.,* 2014; Hoffffman and Hittinger, 2017; Horton *et al.,* 2017; Belzagui *et al.,* 2019).

It is important to note that the process of degradation and fragmentation of plastic starts as soon as it enters into different environment. Furthermore, primary microplastics also undergo through these processes. The process of degradation and fragmentation of plastics is result of weathering actions. Large plastic particles when enters into the environment experiences wide variety of biotic and abiotic degradation and fragmentary processes resulting into reduction in size and altered chemical properties. Environmental degradation depends upon various factors and are not time bound. Some plastics are stronger and offer more resistance towards degradation. In such cases it might take thousands of years to degrade (Barnes *et al.,* 2009).

Degradation of macroplastics to microplastics

Physical degradation through mechanical forces and weathering phenomenon is the most significant plastic degradation process in aquatic environment. Major mechanical forces are compression, tension, flexure, abrasion, sheer, impact and torsion. When above forces act on a piece of plastic, large plastic breakdown into smaller plastic progressively, there by conversion of macroplastics tomicroplastics. Once the piece of plastic is in size range of microplastic, physical degradation doesn't stop thereby further reduction in size.

Thermal degradation of plastic reefers to breakdown of plastic due to change in temperature. Thermo-oxidative degradation requires sufficient amount of heat to initiate oxidative reaction in polymer chain. This oxidative reaction is self-propagating producing free radicals by breaking large polymer chains into small chains. These free radicals will react with atmospheric oxygen to form more reactive peroxide and hydroxyl radicals. These radicals will keep reacting with oxygen to form more radicals and in process facilitate breakdown of plastic. In Photooxidative degradation, the photons of ultraviolet lights produce free radicals through breakdown of large polymer chains and free radical polymer chain reaction occurs. In chemical degradation due to atmospheric oxidative action, oxygen, ozone and other gases present in environment propagate oxidation of some plastic particles. These gases alter the chemical bonds present in polymer chain, replacing elements thereby weakening the chain. Above process in conjunction with mechanical processes makes plastic particles more susceptible to degradation.

In biological degradation of plastic, organisms such as sulphur bacteria and acid releasing fungis attach themselves on surface of plastics (biofouling) and releases acids. Plastic susceptible to acids will be susceptible to damages due to acids. Few examples of such microorganisms and fungis are Ideonellasakaiensis, *Pseudomonas chlororaphis* and Rhizopus Delmar etc.

Microplastics as a vector for toxic chemicals

Degradation of plastic alters the chemical properties and morphology as well. Reduction in size means more specific surface area making plastic particles highly susceptible to oxidation and sorption of toxic chemicals. Plastic manufacturing processes use different chemicals called plasticizer to enhance physio-chemical properties of plastic. Most often they are used for coloring, fire retardant and enhance durability. Plastic releases these chemical additives in aquatic environment posing serious threat to water quality. Microplastics is aquatic environment have been found to be contaminated with persistent organic pollutant through sorption processes (Mato *et al.*, 2001; Rochman, 2015; Ziajahromi *et al.*, 2016; Koelmans *et al.*, 2016).

Microplastics are ubiquitous in aquatic environment and are capable of entering from one environmental matrix to other combined with fact that they can easily release toxic chemical pollutants in their adjacent environment is very serious concern. Microplastics are most often eaten by aquatic organisms and releases these chemicals after ingestion there by providing a new route for toxic chemical to enter into food web. Interaction of microplastics and toxic chemicals requires intensive investigations to asses the risks and exposure. Various studies have found microplastics contaminated with PCB, DDT, chloradane, PAH etc.. Few studies have investigated interaction of microplastics and heavy metals, and concluded that microplastics readily interact with heavy metals. Microplastics can also act as vector for water borne contaminants (Alimi *et al.*, 2018; Hartmann *et al.*, 2019; Hui *et al.*, 2020).

Impact of microplastics on animal health

Microplastics have been found in guts of aquatic animals such as fish and crab, planktonand even in terrestrial birds globally (Watts *et al.*, 2014; Setälä *et al.*, 2014; Zhao *et al.*, 2016). It is important to understand the biological effects of microplastics which has been studied extensively. The primary route through which microplastics ends up in guts of animals is through ingestion. Microplastics ingestion creates blockage in digestive tracts resulting in chocking and internal injuries such as damage of issues. Ingestion provides a route for toxic chemicals and additives sorbed on microplastics and act as vector which ends up interacting with tissues of these organisms. Ingestion of microplastics also creates starvation and various studies have inferred that microplastics ingestion changes he feeding pattern of animals where animals are drawn towards shinny microplastics. The ingested microplastics either leaves the body through defaecation or trans-located to other part of the body (Lusher *et al.*, 2017; Wang *et al.*, 2020).

In vitro studies conducted globally on wide range of aquatic and terrestrial biota shows that microplastics are not only being ingested by organisms butt they are also being transferred from lower trophic level to higher trophic level confirming microplastics presence in food web (Carbery *et al.*, 2018; Rezania *et al.*, 2018; Prinz and Korez, 2020).

Impact of microplastics on human health

Due to ubiquity of microplastics, human exposure of microplastics can happen either through ingestion of microplastics contaminated food or through inhalation of atmospheric microplastics present in air (Barboza *et al.*, 2018). Microplastics are present in human food web (fruits, fish, mussels, drinking water, honey, table salt etc.) making it easier to find their way into guts of humans (Pivokonsky *et al.*, 2019; Peixoto *et al.*, 2019; Diaz-Basantes *et al.*, 2020).

A recent study published by WHO on microplastics in drinking water suggested that there is a little evidence of harmful effect of microplastics on human life but detailed studies are required in order to asses the risk of exposure. Nonetheless microplastics have been found in stool samples and gastrointestinal tracts of humans concluding that humans ingest microplastics (Liebmann *et al.*, 2018). There is a lack of conclusive evidence of transference of chemical pollutant from microplastics to human tissues. However research on impact of microplastics on human health is under going and further studies will give us expert insight.

CONCLUSION

Microplastics, an emerging pollutant comes from variety of sources and they are globally abundant in various environmental matrices. Research community treats microplastics as diverse group of contaminants rather than single contaminant. Microplastics have potential to act as vector for toxic chemicals and pathogens. Owing to their ubiquity and abundance they are being consumed by animals and biota. The eco-toxicological and direct impact of microplastics interaction with organisms leaves negative impact which leads to starvation, choking and death. Their presence in marine food web is not only of priority concern from animal health perspective but they also presents a challenge for humans as well. The human exposure of microplastics due to ingestion and inhalation have been reported hence further research is needed to asses their toxicological impact on human health. Microplastics research is very challenging due to lack of standard operating protocols, unanimous definition and wide spectrum of microplasticcategory. This makes comparative studies very challenging coupled with expensive identification and characterization methods is holding back researchers to go in full depth.

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