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Microplastics Contamination in the Environment

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Abstract
The National Oceanic and Atmospheric Administration defines microplastics are the particles smaller than 5 mm. Plastic ingredients are present in different products of huge fractions even exceeds 90% in some cases. Microplastics are ingested through filter feeding and later egested in faecal pellets, typically within a matter of hours. Microplastics tends to accumulate on the external surface of dead zooplankton as it found to be trapped between the external appendages of live copepods. The uptake of microplastic particles by humans can occur through the consumption of terrestrial and aquatic food products, drinking water and inhalation. Organisms that are eaten whole present a greater risk of exposure compared with those having had the digestive tract removed. For example, the popular European seafood items, *Mytilusedulis*, contained on average 0.36 ± 0.07 MP particles g^{-1}, while *Crassostreagigas* contained 0.47 ± 0.16 g^{-1} (wet weight soft tissue) at the point of human consumption. Very fine particles crosses the cell membranes, the blood-brain barrier and the placenta, with documented effects including oxidative stress, cell damage, inflammation and impairment of energy allocation similar to that reported for marine organisms. The management of the microplastics is one of the tedious process as it was very tiny and cannot be detected easily. There are studies which helps in the Bio degradation of the microplastics. Some of the species of microorganisms involved in the degradation of polyethylene are *Staphylococcus sp.*, *Pseudomonas sp.*, and *Bacillus sp.*, isolated from soil from plastics contaminated sites in Mumbai. *Aspergillus niger*, *Pseudomonas aeruginosa*, *Bacillus subtilis*, *Staphylococcus aureus* and *Streptococcus pyogenes* have been isolated from soils degrade polyethylene terephthalate (PET) and polystyrene (PS).

Keywords: Microplastics, polystyrene, polyethylene terephthalate, Silician Sea salts, expanded polystyrene

Introduction
"Microplastics" are the plastic particles synthesized which are between the sizes few microns to5 millimetersin diameter. (Gregory and Andrady, 2003) [14]. The National Oceanic and Atmospheric Administration defines microplastics are the particles smaller than 5 mm. The plastics are differentiated mainly based on the size as small microplastics (0.33-1.00 mm), large microplastics (1.01-4.75 mm), mesoplastics (4.76-200 mm) and macroplastics (> 200 mm) (Erikson, 2014). The microplastics are further divided based on the voccurrence such as Fragments which are irregular shaped particles, crystals, fluff, powder, granules, shavings, flakes, films while the fibres are in the form of filaments, microfibres, strands and threads. The microbeads has the shape of grains, spherical microbeads and microspheres while the foams are further sub divided into Polystyrene, Expanded polystyrene. Pellets-Resin pellets, nurdles, pre-production pellets and nibs (Lusher *et al*., 2017) [20].

Chemical composition of microplastics
The chemical composition and structure of the microplastics is complex which helps in the understanding of the tranformation and bio degradation. It includes Expanded polystyrene (EPS), Low density polyethylene (LDPE), High density polyethylene (HDPE), Polypropylene (PP), Polyethylene terephthalate (PET), Polyamide – nylon (PA), Polystyrene (PS), Polymethyl methacrylate – acrylic (PMMA), Polyvinylchloride (PVC), Polycarbonate (PC), Polyurethane (PU), Alkyd, Polyester (PES) and Polytetrafluorethylene (PTFE).

Sources of microplastic pollution
The microplastics are sub divided mainly in to two types namely primary and secondary microplastics.

The primary microplastics which remain same from its production to bio transformation with the negligible changes. Secondary microplastics originate from the fragmentation of primary microplastics by mechanical action, microbial degradation, UV exposure while the synthetic fibers from the washing of clothes (Browne *et al.,* 2011). Secondary microplastics came from degradation and breakdown of larger plastic items of household origin (Free *et al.,* 2014) [13].

Fibers are dominant in household sewage effluent have at sewage disposal sites usually exhibit long residence times. The microplasticsused in various sectors are usually released in the water bodies and finally end up in to the marine systems. Some of the commonly found microplastics in the marine ecosystems includes polyethylene, polypropylene, and polystyrene particles mainly present in cleaning and cosmetic products discharged through household sewage enters in the aquatic system (Fendall and Sewell, 2009) [12]. Zbyszewski *et al.,*(2014) [37] reported that the industrial origin includes spillage of plastic resin powders or pellets used for airblasting and feed stocks used to manufacture plastic products. These secondary source microplastics are therefore also likely to have long residence times in freshwater systems (Zubris and Richards, 2005) [39] irrespective of natural water bodies, modified water bodies or artificial water bodies.

Primary microplastics of microbeadsare one of the raw material for commercial facial cleansers reported in North American Great Lakes (Eriksen *et al.,* 2013) [11]. Primary microplastics of industrial origins have been detected in rivers and lakes. The industrial production of microplastics releases plastic resin pellets were the second most dominant debris in rivers from the Los Angeles basin (Moore *et al.,* 2011). The plastic resin pellets are one of the dominant debris in Lake Huron (Zbyszewski and Corcoran 2011) [36]. The plastic raw materials were found in the Danube River, Lake Huron, and Lake Erie as they are released from plastic production sites (Lechner *et al.,* 2014) [19]. Secondary microplastics found to be in the Lakes of Hovsgol, Mongolia, and in Lake Garda, Italy. (Imhof *et al.,* 2013) [18].

Microplastics in cosmetics

Plastic ingredients are part of the formulation for a variety of Personal Care and Cosmetic Products such as toothpaste, shower gel, shampoo, creams, eye shadow, deodorant, blush powders, make-up foundation, skin creams, hairspray, nail polish, liquid makeup, eye colour, mascara, shaving cream, baby products, facial cleansers, bubble bath, lotions, hair colouring, nail polish, insect repellents and sunscreen. Plastic ingredients are present in different products of huge fractionseven exceeds 90% in some cases (Cosmetics Ingredient Review 2012).

Microplastics depending on the polymer type, composition, size, shape, the plastic ingredients have been included in formulations with a vast number of functions including viscosity regulators, emulsifiers, film formers, opacifying agents, liquid absorbents binders, bulking agents, for an 'optical blurring' effect (e.g. of wrinkles), glitters, skin conditioning, exfoliants, abrasives, oral care such as tooth polishing, gellants in denture adhesives, for controlled time release of various active ingredients, sorptive phase for delivery of fragrances, vitamins, oils, moisturizers, insect repellents, sun filters and a variety of other active ingredients, prolonging shelf life by trapping degradable active ingredients in the porous particle matrix.

Table 1: Composition of Microplastics in cosmetics

Product	Weight% microplastics	Size (mm) of particles	Plastic type
Face cleaning	1.62-3.04	0.1-0.2	PE
Hand cleaning	0.18-6.91	0.1-0.2	PE
Shaving foam	0.1-2	0.005- 0.015	PTFE
Tooth paste	0.1-0.4	0.04-0.8	PE
Face Scrub	0.4-10.5	0.04-0.8	PE
Tooth Paste	2 - 4	0.014-0.055	PES

***Source*:** Sundt (2014) [27]

Pigments in microplastics

The pigments in microplastics also occurs in the various organisms. The pigments are used in the colouring of the plastics which are synthetic in origin. The pigments are usually phthalocyanine dyes, hematite which are usually blue and red in colour. The particles being synthetic (Van Cauwenberghe and Janssen, 2014) [31]. The pigments being released enter in the water bodies and it pollutes the water resources.

Microplastic distribution in oceans

The microplastics from various sources make their way to oceans and based on their density the deposition and floating of the microplastics may vary. The polypropylene and polyethylene materials of densities 0.92 and 0.95 g/cu.cm floats in the seawater while the polystyrene materials with the density ranges from 1.01 – 1.09 g/cu.cm usually sink below the upper surface water. The polyamide and cellulose acetate materials with the density of 1.15 – 1.24 g/cu.cm sink in the ocean. The materials such as plastic films, polyester resin and soft drink bottles with the densities of 1.30, 1.35, 1.39 g/cu.m tends to sink to the bottom.

Auta *et al*., (2017) [2] reported that the microplastics occurrence in various oceans throughout the world includes North East Atlantic ocean (2.46 particles m^{-3}), Arctic polar waters (1.31 particles m^{-3}), Laurentian great lake (43,000 - 4,66,000 particles Km^{-2}), Jade bay, Southern North sea (1770 particles L^{-1})NW Atlantic (2500 particles Km^{-2}), Portugese coast (332-362 items m^{-2}), Mediterranean sea (0.10-0.9 MP g^{-1}), Yantze estuary and East sea china (144 particles m^{-3}), South East Brazil (12-1300 particles m^{-2}), Swedish Coast (2400–1,02,000 particles m^{-3}) and Chinese Bohai sea (63-201 items kg^{-1}).

Quantification of microplastics

Microplastics are visually identified before the polymer type identification was done. For larger particles (approximately >500 µm), FTIR can be carried out using an attenuated transverse reflection (ATR) unit as the particles need to be transferred on the crystal of the ATR unit manually (Doyle *et al.,*2011) [9]. Coupling of FTIR instruments to microscopes such as reflectance or transmission micro-FTIR allows the detection of smaller microplastics (Harrison *et al.,* 2012) [16]. Raman instruments can measure particle with sizes that are one to two orders of magnitude smaller, due to the smaller wavelengths that are applied for the excitation. Identification of the polymers by FTIR and Raman is susceptible to environmentally driven changes of the polymer surface or the additive application during polymer processing. Thus, microbial fouling, soiling, adsorption of humic acids, and colored plastics can interfere with the absorbance, reflection, or excitation of the polymer molecules and might lead to misidentification or totally prevent identification of the

particles (Rocha-Santos and Duarte (2015) [25], Harrison *et al.*,2017).

The application of pyrolysis-gas chromatography/mass spectrometry (Pyr-GC/MS) allows the simultaneous determination of the polymer type and polymer additives by combustion of the sample and the detection of the thermal degradation products of the polymers (Nuelle *et al.*, 2014, Trimpin (2009) [29]. The identification of thermal degradation products serves as amarker that is specific for each polymer. Pyr-GC/MS is a destructive method as the combustion takes place and the concentration of the microplastics are usually obtained as mass fraction or mass concentration of plastics. Thermal desorption GC/MS (TDS-GC/MS) in combination with thermogravimetric analysis (TGA) coupled with a solid-phase adsorber enables higher initial sample sizes compared to Pyr-GC/MS (Dumichen *et al.*, 2015) [10]

Microplastics in salts

The microplastics tends to occur in the sea salts. The microplastics from the various sources move to sewage and then it enters in to the lotic environments while it results in the pollution of the lotic systems. This inturn pave the way for the movement of microplastics to the oceans. Then from the oceans the low density microplastics such as poly ethylene and poly propylene floats in the upper surface of the oceans while the PET settle in the bottom leads to biofouling and eaten by the filter feeders. The microplastics floating in the oceans pave their way to salt pans and remains in the sea salt. The pacific sea salt shows maximum 806 particles/ kg followed by the himalayan rock salt with 367 particles/kg while the silician sea salt contains 220 particles/kg.

The celtic sea salt and atlantic sea salt has the microplastics of about 187 and 180 particles/kg respectively. On comparison with Baja sea salt and Mediterranean sea salt Baja sea salt possess high amount of microplastics of 173 particles/kg while Mediterranean sea salt has 133 particles/kg followed by Utah sea salt with the amount of 113 particles/kg. The North sea salt and Hawaii sea salt contains lower amount of microplastics with the value of 66.6 and 46.71 particles/kg. The WHO daily salt recommendation was about 5,000 mg/day. The daily uptake of the polluted salts leads to increased uptake and accumulation of the microplastics. (Yang *et al.*, 2015)

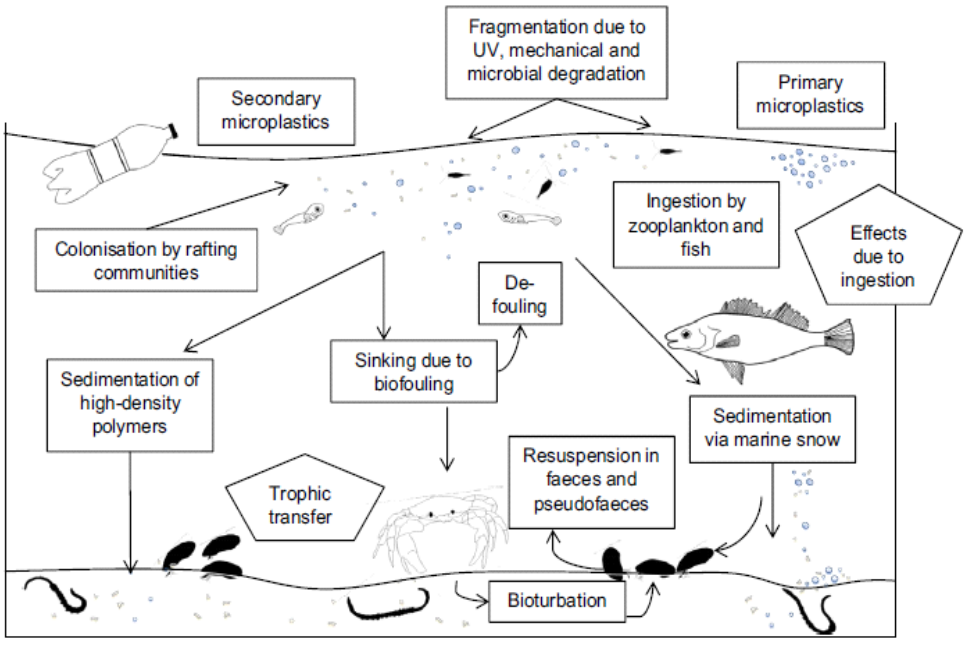
Microplastics in drinking water

There was a study all over the world on the microplastics and drinking water. The bottled water containing microplastics are as follows. The study finds that 93% of the bottled water found to have microplastics.

Table 2: Microplastics in water

S. No	Bottled water Brands	Amount of MP (Particles L^{-1})
1.	Aqua	4,713
2.	Aquafina	2-1,295
3.	Bisleri	0-5,230
4.	Dasani	2-335
5.	Epura	0-2,267
6.	Evian	0-256
7.	Gerolsteiner	9-5,160
8.	Minalba	0-863
9.	Nestle (Pure life)	6- 10,390
10.	San pellegrino	0-74
11.	Wahaha	1-731

The microplastics tend to occur in tapwater. The tapwater in Indonesia contains microplastics of 10.8 particles/L followed by United States of America (9.24 particles/L) while England, Cuba and Lebanon has thmicroplastics content o 7.73, 7.17 and 6.64 particles/L respectively. The Indian tapwater shows the range slightly lower than Lebanon with the average of 6.24 particles/L followed by Ecuador, Uganda and Slovakia of the values 4.2, 3.92, 3.83 particles/L respectively. The Switzerland, France and Ireland tapwaters found to be contaminated with the microplastics with the value of 2.74, 1.83 and1.82 particles/L respectively. From all the tapwater samples taken for analysis the tapwater from Germany was least contaminated with the microplastics of 0.91 particles/L.



(Wright *et al.*, 2013)

Fig 1: Interaction of microplastics in marine environment

Toxicity over different organisms

Trophic transfer

The investigation on the microplastics in zooplankton varies based on capacity for uptake varying between species, life-stage and microplastic size and it was present in northeast Atlantic ocean with the range of 1.4 – 30.6 µm diameter (Cole *et al.,* 2013). Microplastics are ingested through filter-feeding and later egested in faecal pellets, typically within a matter of hours. Microplastics tends to accumulate on the external surface of dead zooplankton as it found to be trapped between the external appendages of live copepods. The polystyrene beads of size 1.7 and 3.8 µm clustered within the alimentary canal and aggregated between the setae and joints of external appendages. The presence of 7.3 µm polystyrene beads reduces algal ingestion rate of the copepod *Centropagestypicus*. In aquatic organisms microplastics causes complications of endocrine-disruptors, carcinogenic or toxic, with repercussions for growth, sexual development, fecundity, morbidity and mortality.

Farrell and Nelson, (2013) studied the trophic transfer of microplastics from mussels to crabs as the Mussels (*Mytilusedulis*) were exposed to 0.5 mm fluorescent polystyrene microspheres fed to crabs (*Carcinusmaenas*). Tissue samples were then taken at intervals up to 21 days. The number of microspheres in the haemolymph of the crabs was highest at 24 h (15 033/ ml), and was almost gone after 21 days (267/ ml). The maximum amount of microspheres in the haemolymph was 0.04% of the amount to which the mussels were exposed. Microspheres were also found in the stomach, hepatopancreas, ovary and gills of the crabs in reducing numbers numbers during successive days. This study is the first to show 'natural' trophic transfer of microplastic, and its translocation to haemolymph and tissues of a crab. This has implications for the health of marine organisms, the wider food web and humans. Microspheres were found in tissue samples from the stomach.The microspheres were found in the highest concentrations in the 5 mm diametersamples of stomach at 1 h (1025 numbers), 2 h (883 numbers) and4 h (1007 numbers), but none at later time samples. Even after just 1 h, microspheres were present in the 5 mm diameter samples ofhepatopancreas (65 numbers), as well as ovary (68 numbers) and gills(75 numbers).

Table 3: Effect of microplastics on various organisms

Organism	Plastic type	Concentration	Mechanism of uptake/effect
Shore crab (*Carcinus*	PS	107 microspheres L^{-1}	Ventilation & ingestion (uptake and
maenas)		250 beads mg L^{-1}	retention through gills)
Bivalves (*Mytilusedulis*,	PE/PS microbeads		Ingestion/accumulation in soft tissues
Crassostreagigas/Macoma			
bathica, Mytilustrossulus			
Microalgae	PS		Ingestion/affected growth
Marine fish (*Pomatoschistus*	PE/PS beads	1.2×10^6 particles	Ingestion/pathological stress/inflammation
microps, *Artemianauplii*,		mg^{-1} and 12 mg L^{-1},	of liver/oxidative stress/lipid accumulation in liver
Daniorerio, *Oryzias*		0.5 mg - 2.5 particles	
latipes)		mg^{-1}	
		54 particles mg^{-1}	
Demersal (cod, dab,	PE		Ingestion
flounder/pelagic fish			
(herring & mackerel)		4000 mL^{-1}& 400 mg	
Zooplankton (*Centropages*	PS beads		Ingestion/decreased algal feeding/causes
typicus, *Daphnia magna*)			immobilization

***Source*:** (Auta *et al.*, 2017) [2]

Microplastics and human health

The uptake of microplastic particles by humans can occur through the consumption of terrestrial and aquatic food products, drinking water and inhalation (Vethaak and Leslie, 2016) [32]. Despite seafood being a recognised source of contaminants to the human diet, the occurrence of microplastics in seafood is neither quantified nor regulated (Ziccardi *et al.,* 2016) [38]. Seafood may be contaminated with microplastics through ingestion of natural prey, adherence to the organism's surface or during the processing and packaging phase (Cole *et al.,* 2011) [7]. Organisms that are eaten whole present a greater risk of exposure compared with those having had the digestive tract removed. For example, the popular European seafood items, *Mytilusedulis*, contained on average 0.36 ± 0.07 MP particles g^{-1}, while *Crassostreagigas* contained 0.47 ± 0.16 g^{-1} (w.w. soft tissue) at the point of human consumption (Van Cauwenberghe and Janssen, 2014) [31]. Similarly, bivalves from a fish market in China contained between 2.1 and 10.5 MP particles g^{-1} (Li *et al.,* 2015). Whole fish purchased from fish markets in Indonesia and the USA revealed that 28% and 25% of all individuals had plastics<4.5mm present in theirguts (Rochman *et al.,* 2015) [26], while commercially important species sourced from the Adriatic and Mediterranean Seas, English Channel and Portuguese coast demonstrated microplastic ingestion in the wild (Avio *et al.,* 2015b; Neves *et al.,* 2015; Bellas *et al.,* 2016; Tanaka and Takada, 2016) [3, 4]. Microplastics have also been reported in natural populations of the commercially important crustacean species, Crangoncrangon (Devriese *et al.,* 2015) [8] and Nephropsnorvegicus (Murray and Cowie, 2011) [23]. With plastics already present in a diversity of seafood items, there is strong support for the transfer of microplastic particles to humans. Medical studies on both rats and humans have demonstrated the translocation of PS and PVC particles<150 µm from the gut cavity to the lymph and circulatory system (Volkheimer, 1975; Hussain *et al.,* 2001) [33, 17].

Very fine particles crosses the cell membranes, the blood-brain barrier and the placenta, with documented effects including oxidative stress, cell damage, inflammation and impairment of energy allocation similar to that reported for marine organisms (Vethaak and Leslie, 2016) [32]. Exposure to hydrophobic contaminants can be a direct result of the ingestion of contaminated microplastic particles, while

secondary exposure can occur by ingesting fish, birds or other organisms that have accumulated contaminants within their tissue from previously egested microplastics (Ziccardi*et al.*, 2016) [38]. The human exposure to microplastics via seafood is plausible, however the contribution compared with other food and beverage products is unknown (Wright and Kelly, 2017) [34, 35]. Research into the factors influencing MP ingestion by marine organisms, bioaccumulation factors for popular seafood species and their trophic interactions are urgently needed to identify which species should be eaten in moderation or avoided compared with those that are considered safe to eat. The quantity of micro and nanoplastics in the environment is set to increase, and therefore this area of research requires urgent and thorough attention to discern the real impacts on human health.

Management

The management of the microplastics is one of the tedious process as it was very tiny and cannot be detected easily. There are studies which helps in the Bio degradation of the microplastics. Some of the species of microorganisms involved in the degradation of polyethylene are *Staphylococcus sp., Pseudomonas sp.,* and *Bacillus sp.,* isolated from soil from plastics contaminated sites in Mumbai (Singh *et al.,* 2016) *Aspergillus niger, Pseudomonas aeruginosa, Bacillus subtilis, Staphylococcus aureus* and *Streptococcus pyogenes* have been isolatedfrom soils degrade polyethylene terephthalate (PET) and polystyrene (PS) (Asmita *et al.,* 2015) [1]. The microorganisms produces enzymes for the breaking of the polymer chains which helps in the degradation of hemicroplastics. Some of the enzymes produced by microorganisms involved in the degradation of microplastics. Some of the microorganisms involved in the bio degradation mechanisms are *Rhodococcusruber* which degradation of polystyrene (Mor and Sivan, 2008) [22] while Polyvinyl chloride (PVC) degradation is assisted by *Pseudomonas putida* (Caruso, 2015) [6]. Some of the bacterial species helps in the polymer degradation are *Brevibacillusborstelensis, Streptomyces sp., Pseudomonasstutzeri,* and *Alcaligenesfaecalis.* The main mechaniam was the production of Extracellular polymer degrading enzymes in microbes degrade polymers (Trivedi *et al.,* 2016) [30].

Conclusion

The microplastics present in each and every part of our life is one of the major contaminant worldwide mainly found in oceans, cosmetics, tap water, sea salt, drinking water, mineral water, oyster fishes, crabs, beer, honey etc. The microplastics make their way to oceans and cause biofouling makes their way to food chain by which leads to trophic transfer of microplastics. The management practices includes policy formulation by the government, degradation mechanisms, monitoring of pollution, microplastics filter installation helps us to overcome microplastic pollution.

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