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Microplastics in the food chain

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ABSTRACT

The world surrounding us is more over covered with plastics and we are in a "plastic era". The bigger plastic materials, as the time moves, disintegrate into micro or nano particles may be as a result of radiations or weathering. These are termed as microplastics and nanoplastics. Technically these microparticles do not create a direct impact, instead they make their way to the food chain or rather a complex food chain. These can be through various steps ranging from filter feeding to adherence. They will start to accumulate, as the trophic level increases their accumulations also get increased. These trophic transfer is mainly through ingestion of smaller to higher organisms. Thus they create various damages and diseases to organisms in successive trophic levels. That can be ranging from respiratory disorders to endocrine or oncogenic issues. Not only in the marine world, the terrestrial world is also prone to these microplastics, either by airborne or through sewage water plants. Moreover in a developing or developed country, exposure to these tiny things is much more. The impacts are showing now and will entangle in the near future, unless this is not dealt as a serious issue to be considered. This article focuses on the classification, sources, exposure to food chain or food web, trophic concentrations, health issues, and remedies of microplastics.

Keywords: Microplastics, Food chain, Aquatic ecosystem, Phytoplanktons, Health issues, Remedial measures.

INTRODUCTION

Nowadays plastics have gained their importance in our day to day life, even starting from the hook of our buttons to materials of big aircraft. Since we know plastic products are useful in many terms, that these are more convenient and cheaper. Moreover we are leading to a plastic era, in which along with the usefulness we need to face many negative effects also [Díaz-Torres ER et al., 2017; Ryan PG et al., 2014; Ryan PG, 2014; Eriksen M et al., 2013; Derraik JG, 2002].The formation of Microplastics or Nano plastics are quite tedious.

They are formed by the fragmentation or UV irradiation of bigger plastics [Yousif E et al., 2013; Gewert B et al., 2015; Song YK et al., 2013]. The negative impacts of these micro villains are screened recently, and tests reveal that these are more vulnerable for aquatic fishes and sea birds [Derraik JG, 2002]. The sizes of microplastics are less than 5 mm, thus they cause many negative impacts to mussels including in their circulatory system [Browne MA et al., 2008]. While we consider the size ranges of the microplastics, filter feeders and benthic organisms in the basal marine part are more affected. This needs to be validated further [Thompson RC et al., 2004]. Recent studies suggest that, due to fishes feeding on fishes contaminated with plastics the microplastics are transferred across different trophic levels of the food chain [Eriksson C et al., 2003]. It will be necessary to elucidate how microplastics deplete the food chain and indirectly affect human beings [Barnes DK et al., 2009]. Filter feeding of either plastic contaminated fishes or plastics which are mistaken to be as prey, are the direct or indirect exposure of microplastics to trophic level organisms in the food chain [Bos RP, 2019]. Zooplanktons are more exposed towards indirect ingestion of microplastics [Botterell ZL et al., 2019] and that consumption of zooplankton, such as pelagic shellfish larvae (by larviphagy) is a common pathway in marine food webs. Because of characteristics of microplastics regarding size and shape, they can put a hand over prey-predator interactions. These properties may alter the prey swimming efficiency and benthic filter feeders can easily ingest them much more effectively [Van Colen C et al., 2020]. Prochlorococcus is one of the main aquatic oxygen producers, which may produce 20% of it. But accumulation of microplastics will alter the oxygen synthesis of Prochlorococcus and several other microalgaes [Tetu SG et al., 2019; Liu G et al., 2019]. The impacts of microplastics in terrestrial ecosystems remain unexplored much despite various reported effects on aquatic organisms [de Souza Machado AA et al., 2019]. The growth of Earthworms also gets altered due to accumulation of microplastics [Boots B et al., 2019] and that may affect the soil food chain or detritus food chain. There is a presence of microplastics in the faecal matter of humans [Schwabl P et al., 2019] and studies say that humans usually consume microplastics through the channel of sea foods [Korez S et al., 2019; Cho Y et al., 2019; Li J et al., 2019; Li J et al., 2020; Miller E et al., 2019] and through contaminated water [Cox KD et al., 2019; Kniggendorf AK et al., 2019, Panno SV et al., 2019; Welle F et al., 2018; Mason SA et al., 2018; Besseling E et al., 2013; Huang Q et al., 2020], etc. This writing mainly focuses on the impacts of microplastics within the phenomenon, food chain interactions, health issues caused by them and solutions to reduce microplastics and nanoplastics.

MICROPLASTICS: CLASSIFICATION AND SOURCES

Microplastics are fragments of plastics that may pollute the environment [Frias J et al., 2018]. According to the U.S. National Oceanic and Atmospheric Administration (NOAA), microplastics may have a size range around 5 mm. Through the worlds of cosmetics, medicines, automobiles etc, microplastics may enter the ecosystems [Arthur C et al., 2008; Collignon A et al., 2014].

They are generally classified into Primary and Secondary microplastics respectively (Table 1). Apart from these two, nanoplastics and microplastics produced by dust emission during industrial wear and tear were also reported.

Table 1. Classification of microplastics as primary and secondary microplastics with references.

Primary microplastics	**Secondary microplastics**
Microplastics, those may be produced as deliberately [Steinfeld B et al., 2015]. These are used in air blasting techniques and mechanisms [Cole M et al., 2011].	These are synthesised as a result offragmentation of bigger plastics [Masura J et al., 2015].
They can be used as vectors in medicinal fields [Patel MM et al., 2009]. Many MNC tried to reduce microbead production.	This fragmentation can be due to exposure to sunlight, photodegradation, chemo degradation, etc.
Microbeads have a very long biodegradation period as normal plastics.	Microplastics may get further degraded to form very small debris of 1.6 micrometers size [Conkle JL et al., 2018].

Regarding the sources of microplastics, they can be derived from the cloth industry, cosmetics, medicinal fields, automobile industry, production of single-use items, etc (Figure 1).

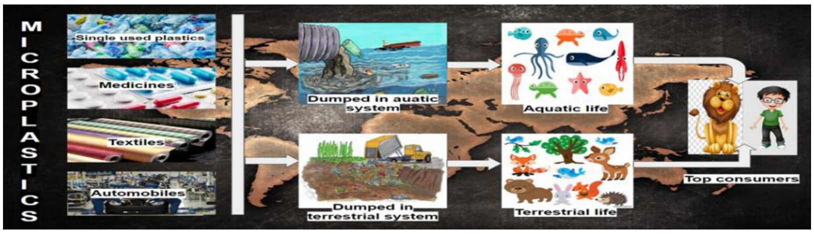

Figure 1. Sources and entry of microplastics to aquatic and terrestrial systems.

Various researchers have postulated many definitions for the term "microplastics" [Gregory MR et al., 2003]. Recent studies using neuston nets with a practical lower limit of 333 micrometers, microplastics are with size of 500 micrometers and are generally traced from aquatic habitats than terrestrial [Fendall LS et al., 2009; Yonkos LT et al., 2014; Ng KL et al., 2006]. For more specificity, this particular range of size alone is observed as 'microplastics' here and the larger particles like 'virgin resin pellets' are observed as 'mesoplastics' after [Collignon A et al., 2004].

Commonly plastics are of many types including Poly Ethylene (PE), Polyester (PES), Poly Ethylene Terephthalate (PET), Poly Etherimide (PEI) (Ultem), Polystyrene (PS), Poly Propylene (PP), Low-Density Poly Ethylene (LDPE) High-Density Poly Ethylene (HDPE), vinyl resin (PVC), poly Vinylidene Chloride (PVDC) (Saran), Poly Carbonate (PC), polycarbonate/acrylonitrile butadiene styrene (PC/ABS), High-Impact Poly Styrene (HIPS), poly Amides (PA) (nylon), Acrylonitrile Butadiene Styrene (ABS), Poly Urethanes (PU), Urea–Formaldehyde (UF), Melamine Formaldehyde (MF), Poly Tetra Fluoro Ethylene (PTFE), and Poly Lactic Acid (PLA), etc. [Ghosh SK et al., 2013] (Figure 2).

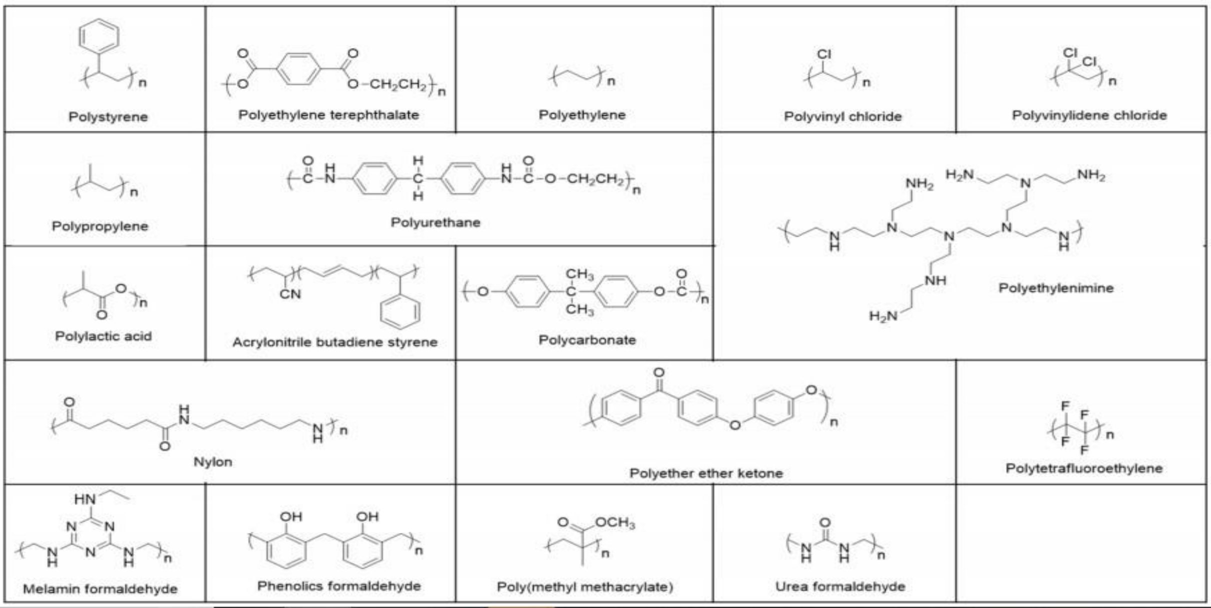

Figure 2. Numerous polymers of plastics types and their chemical structures (pc: Yung-Li Wang et al).

MICROPLASTICS: JOURNEY THROUGH FOOD CHAIN OR FOOD WEB

A food chain is an organic phenomenon that connects the organisms in a vertical or horizontal manner based on their feeding habits. This is organized based on different trophic levels. These trophic levels range from lower to higher. Unlike them, the food web is the interconnections between organisms but not in a linear fashion. On the food web, one trophic level organism can be connected to more than one organism in another trophic level. Though, food chains can be of aquatic or terrestrial and gracing or detritus. Recent studies suggest that in a food chain, 10% energy will transfer from lower to higher trophic level [Briand F et al., 1987; Lafferty KD et al., 2006].

MICROPLASTICS: EXPOSURE TO FOOD CHAIN OR FOOD WEB

Microplastics are more exposed to the marine ecosystem and that through bioaccumulation mainly. It is the chemical and physical characters of microplastics that disrupt marine creatures [Borgå K et al., 2004; Rochman CM, 2013]. One of the major things about microplastics is that they can be porous and can absorb pesticides, chemical fertilizers, polychlorinated biphenyls, etc. [Mato Y et al., 2001]. This in turn may cause devastating effects to marine organisms and their food chain.

Recent studies indicate that microplastics can be transferred through specific trophic levels in a food chain and they can be entered to the marine world through various mechanisms like ingestion, microbial assemblage, bioaccumulation, biomagnification, etc. Along with these, adherence, entanglement, etc. also pave a way for exposure of microplastics to the food chain (Figure 3).

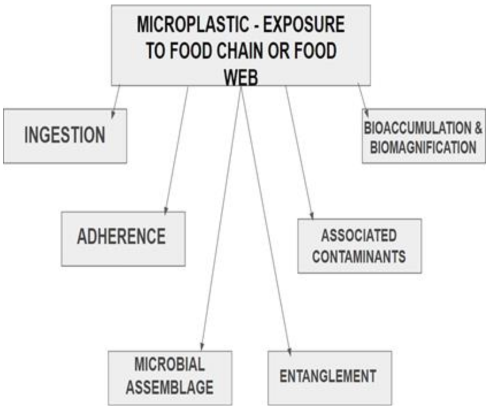

Figure 3. Microplastic exposure to food chain and food web, through ingestion, adherence, microbial assemblage, entanglement, associated contaminants, bioaccumulation, biomagnification, etc.

MICROPLASTICS: CONCENTRATION AT DIFFERENT TROPHIC LEVELS

As microplastics accumulate on shorelines 56, coastal biotas are exposed to them. As in a food chain the initial trophic level will be producers (algal species or phytoplanktons). Trophic transfer is the major mechanism by which a plastic contaminated fish is being preyed by another [Tosetto L et al., 2017; Borgå K et al., 2004; Setälä O et al., 2016] Predator fish [Sundbæk KB et al., 2018]. Algal species are also prone to microplastics and they can be in the form of poly acrylic fibres or microbeads. Microbeads usually have a size range of 10-20 micrometers and poly acrylic fibres in 80-2300 micrometers [Walkinshaw C et al., 2020] Algal species can aid in transferring microplastic contents through the food chain, eg: *Fucus vesiculosus* absorbs polystyrene microparticles which have a size range of 20-30 micrometers. This particular algae is getting ingested by *Littorina littoria* which is commonly called as common periwinkle and forming a trophic transfer across a food chain [Gutow L et al., 2016].

In terms of zooplanktons, they are also prone to microplastics since they live in the bottom line of the oceanic world, eg: Chaetognaths [Von Moos N et al., 2012]. Zooplanktons are the second trophic level organisms and primary consumers.

Fishes are also studied for the ingestion of microplastics. They form the next trophic level of organisms. They are of pelagic and fishes in reefs especially, which are used as edible sea foods for humans. Microplastics are entangled in fishes mainly because they are feeding the other plastic contaminated other small fishes and zooplanktons. Most studies in fishes are conducted in the fishes like Silver carp, Nile tilapia, Crucian carp, and Common carp. By studying all these average of microplastic content per organism in them are 3.5-3.8 (microplastic) MP/individual for Silver carp, 2.2-2.5 MP/individual for Common carp, 1.0-1.9 MP/individual for crucian carp, etc. Unlike the data about Nile tilapia are vaguer and researchers came to a conclusion that they may possess about 16% of microplastic/individual [Karbalaei S et al., 2019; Grbić J et al., 2020]. Recent studies indicate that it is the morphological feature of microplastics that influences their vulnerability towards marine fishes. Specifically, it is the fiber structures of them which are more prone than the globular structure of microplastics. They are more entangled with the gastrointestinal tracts of these fishes. Their percentages ranges from 23-24% for Yellow tuna, 2.6-2.9% to Atlantic cod, 76.4-76.6% for Japanese anchovy, 23.1-23.4% for Pecific chub mackerel, 8.1-8.8% for Atlantic herring, 24.2-24.6% for Jack and Horse mackerel, 9.1-10.0% for Skipjack tuna, 0.1-1.0% for Peruvian anchovy, etc.

Rather in the case of shellfishes, a microplastic amount is detected as microplastics per gram of wet tissue. They form the next trophic level of organisms. Large numbers of studies were conducted in the family *Mytilidae* where the publications revealed that the aquatic as well as marine mussels generally contain about 0.1-5.63 microplastics/gram w.w. But in Cupped oysters the range lies between 0.18-3.85 MP/gram w.w and 0.9-2.6 MP/gram w.w for Japanese carpal shells [Li J et al., 2019]. While we compare oysters and mussels, studies suggest that in terms of microplastics >100 micrometers oysters (32%) greater than mussels (11%). In terms of 20-50 micrometers of size range, mussel (37%) is greater than oysters (15%). But investigations show that both of them ingest microplastics in the range of 50-100 micrometers.

The crustaceans are a more diversified group of marine organisms. They have a range of organisms including crabs, lobsters, shrimps, octopus, etc. Though the study on infestation of microplastics in them is studied less compared to others. In which the most studied form is *Crangon crangon,* called commonly as Brown shrimp. In this, 62%-64% of shrimps out of 165 shrimps were tested positive for containing microplastics which is about 0.55-0.64 MP/gram w.w. [Jang M et al., 2020; Amin RM et al., 2020].

Thus from these organisms, microplastics are infested to higher trophic levels of organisms including big fishes and terrestrial predators because these higher trophic level organisms consume upon the lower ones. More than that, humans are exposed to microplastics not only through consumption of plastic contaminated sea foods ranging from algae to fishes, but also through various day to day plastic materials. These may range from plastic bottles, plastic bags, medicines, plastic spoons, hardware cases, many instrumental covers and many more [Wang YL et al., 2020]. Not only through water and terrain, humans are occupied with microplastics which are also sourced from air [Wang YL et al., 2020]. Along with these data which are published, microplastics are getting entered to each and every trophic level in a food chain. Yung-Li et al presented that the amount of microplastics will increase in terms of gram/w.w to all trophic levels in a food chain. The increase in the amount of microplastics in each trophic level organism is roughly given in Figure 4.

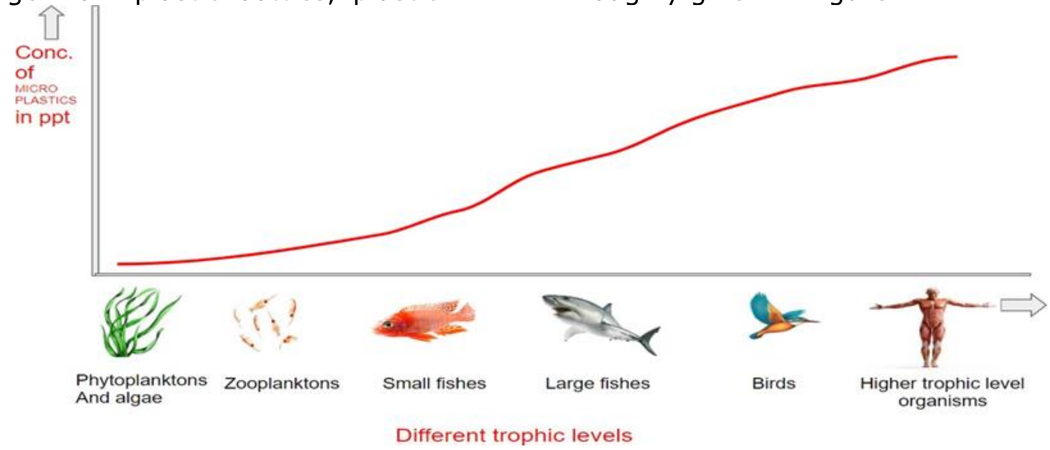

Figure 4. Rough graph showing the inclining concentration of microplastics in ppt along with the increase in trophic levels of a particular food chain. As we could see the concentration of microplastics is increasing in each trophic level indicating bioaccumulation in microplastics.

MICROPLASTICS: HEALTH PROBLEMS TO ORGANISMS

The recent studies on microplastics suggest that the organisms may get several health issues by ingesting them though the direct proofs or ambient evidence focusing this are very few. There are no direct results suggesting that the microplastic transverse through tissues of organisms especially marine varieties. But the human health issues due to microplastics are arising because of the plastic contaminated sea fishes, anchovies, algal species, oysters, etc. So there is a greater risk in human health also by consuming the plastic contaminated marine organisms. Microplastics may accumulate and cause blockage in the gut or several species of organisms. This may induce gradual inflammations to organs [Berry KL et al., Wang YL et al., 2020]. Accumulation of microplastics also causes disruptions and decline to the production of oxygen from algae and microalgae [Ward JE et al., 2019; Liu G et al., 2019] and have a disrupted effect in the consumption of zooplanktons [Liu LY et al., 2020]. In crabs, they will accumulate and cause malformations and disrupted effects in gills, pancreas, stomach, etc. [Wang YL et al., 2020]. They have a negative influence on fish tissue histological features also [Yong CQ et al., 2020]. There are positive proofs indicating the lesser sperm velocity and egg production numbers in oysters due to microplastic accumulation [Sussarellu R et al., 2016; Wang F et al., 2020]. These studies reveal that the accumulation of microplastics causes negative implications in gastrointestinal tract and intestinal walls of humans [Meng Y et al., 2020; Korez S et al., 2019]. Studies conducted in mice indicate that the negative impacts of microplastics may cause disruption in synthesis of amino acids, bile acids, liver lipids, etc. along with decline in mucus secretion and malfunctioning of microbiota in gut regions as well [Jin Y et al., 2019; Zhang R et al., 2019]. It was Brown et al who demonstrated that the accidental ingestion of microplastics may carry pollutants, chemicals, and additives through their journey to tissues and causes many negative impacts [Nam PN et al., 2019; Wang YL et al., 2020; Gallagher LG et al., 2015; Kern DG et al., 1998; Turcotte SE et al., 2013; Huang NC et al., 2011; Vianna NJ et al., 1981; Elliott P et al., 1997; Rochman CM et al., 2014; Barboza LG et al., 2018; Gardon T et al., 2018; Tallec K et al., 2018; Pitt JA et al., 2018; Martins A et al., 2018; Liu Z et al., 2019; Mato Y et al., 2001; Rochman CM et al., 2013; Andrady AL, 2011].

In humans, it is through the trophic transfer of microplastics it induces cytotoxicity by blocking efflux pumps in cells in the intestine and also enters to the gut and circulatory system. This induced cytotoxicity inturn activates oxidative stress *via* free radical generation initiated from Reactive Oxygen Species (ROS) [Andrady AL, 2011; Qu M et al., 2018; Tang J et al., 2018]. This ROS in turn influences the antioxidants and causes negative impacts for DNA, carbohydrates, proteins and lipids. This may cause disruptions in the structure of genes, alteration in them, instability in them and finally leading to carcinogenesis [Birben E et al., 2012; Nita M et al., 2016].

Microplastics can cause negative effects in the synthesis and metabolism of amino acids. This is made possible by the increase in production of arginine and tyrosine. This may negatively alter the metabolism of bile acids *via* controlling the levels and production of Cholesterol 7a-hydroxylase, taurocholic acid, ATP-binding cassette, beta-muricholic acid, Abcb11 (member 11), and subfamily B [Jin Y et al., 2019]. By controlling the levels of Pyruvic acid, Cholesterol and triglyceride they affect the lipid metabolism of the liver [Lu L et al., 2018]. In addition, the accumulation of microplastics induces toxicity in genes 104, alter gene expression 100, elicit immunological responses [Brandts I et al., 2018; Revel M et al., 2018], etc. This also causes the stimulation of proteins related to fibrosis, such as CTGF, PAI-1, and Collagen-1, and proteins related to autophagy, such as Beclin-1 and LC3-11 in kidney cells [Hsu YH et al., 2019].

MICROPLASTICS: THROUGH AIR

These microplastics pave a way to enter into the atmosphere and even develop into a potential airborne contaminant [Xanthos D et al., 2017]. It is the workers in the synthetic textile industry, cosmetics industry and flock industry, who are more prone towards these air microplastic pollutants [Tshikotshi V, 2010]. They along with those who are breathing the air along with microplastics are exposed towards lung cancer [Wang YL et al., 2020; Barboza LG et al., 2019; Margolin V, 1998; Ghosh SK et al., 2013], stomach cancer, oesophagus cancer, intestinal cancer and many more lung diseases mainly. Microplastics Induce many negative variations for the endocrine system in various manner, initiate toxicity to neurons and induce reproductive abnormalities with many other after effects [Papadopoulou A et al., 2019]. In addition, microplastics absorb persistent organic pollutants (POPs) and many oceanic pesticides [Browne MA et al., 2013], because these materials or compounds are of high nature of affinity towards plastics or microplastics rather than normal water.

MICROPLASTICS: IN WASTEWATER TREATMENT

Waste treatment plants are one of the places where microplastic accumulations culminate [Dris R et al., 2015]. As we all know, wastewater treatment is done through three main steps. Out of which Primary treatment clears major amounts of microplastics, it is about 78%-98% [Dris R et al., 2015]. That is followed by secondary treatment, where 7%-20% is removed [118]. Tertiary treatment has null functions in removing microplastics [Murphy F et al., 2016]. So, day by day a huge volume of the effluent carrying microplastics are removed to the marine ecosystem and they make a way for the entry of microplastics to the food chain [Talvitie J et al., 2017; Magnusson K et al., 2014]. Moreover we could say that the country with more wastewater treatment plants is one of the major sources for the expulsion of microplastics to the ecosystems [Prata JC, 2018].

In wastewater treatment plants, after most of the amount of microplastics released downstream to the marine or aquatic world some solid fractions may also entangle at last. These ambient solid fractions may pollute the terrestrial ecosystem as well. There are many potential strategic measures implemented by the government to reduce microplastic amounts. Out of which the most acclaimed and applauded one is the Source reduction method. Along with this many other methods were also postulated so as to reduce the amount of microplastics and their negative effects in the food chain [Prata JC, 2018].

MICROPLASTICS: REDUCTIONS AND SOLUTIONS

1. The world has postulated many strategic measures like the above given Source reduction method to reduce microplastic production and reuse them in an effective way as soon as possible. In turn by reducing plastics the release of microplastics will also get reduced.
2. Out of which India also contributed some including the reduction and abandoning of fishing nets which were replaced by surfboards [Xanthos D et al., 2017] and banning of single use plastics were also amended from 2 october, 2019 [Wang YL et al., 2020].
3. Netherlands made the microplastics to be reused as a constituent in construction of roads [Cordell D et al., 2014].
4. The European Union also implemented many methods and strategies to reduce the use of single use plastics and eliminate them by 2021.
5. Africa introduced Plastic reduction policy to prevent and reduce the increased use of microplastics.
6. In the research held in the UK, some students made a remedy to reduce plastics and developed the use of red

algal matter and skin of marine fishes to substitute plastics.

7. Recently many researches were held to develop and culture many strains of fungi and many strains of microorganisms that can degrade plastics like Polyvinyl chloride (PVC), PHB, etc. along with the production of several enzymes that can degrade PET.
8. In Mexico, researchers developed edible plastics from the normal fruits of cactus, which in turn cause many health benefits.

CONCLUSION

The times are changing. We are now in the "Plastic era", where the whole world is somewhat dependent on plastics. But overuse of them is causing not only plastic pollution but the production of new members like microplastics, nanoplastics, etc. These more fragmented and less biodegradable little things also cause abnormalities in our food chain, in that marine grazing food chain is more affected than others. The cosmetics world, medicinal industry, automobile parts, textile industry, wastewater treatment plants, etc. paved a way for the entry of micro plastics to air, water or terrain. They may bioaccumulate there and by various ways they enter the food chain. Thus they travel through different trophic levels of organisms through Trophic transfer and cause many devastating health issues to the successive animals. These are causing many carcinogenic and several other harmful effects in organisms ingested, mainly they will get accumulated in top predators as the recent studies reveal. Different countries in the world have formulated various methods to overcome these issues and we all are looking forward to this. So that the negative effects of microplastics could be eliminated and abandon them for restabilising the ecosystem balance.

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