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Microplastic Interference in the Food Chain and Its Adverse Effects on Human Health: A Review

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Abstract: Nowadays, microplastics are a major environmental concern as it is entering the food chain through the ecosystem. In this review we have focuses on the current understanding of microplastics in food and their potential health risks to humans. Such tiny plastic particles are found in various food items like beverages, salt, milk, packaged drinking water, packaged and processed food items, seafood etc. The prevalent presence of microplastics results from the breakdown of larger plastic waste and from direct release of microplastics during food production, processing, supply and serving. The intake of microplastics can lead to several health problems including oxidative stress, excretory problems, immune system related issues and potential carcinogenic impact. Numerous studies show that microplastics contain harmful chemicals and pathogens, which increase health risks. The toxic effects of microplastics depend on their size, shape and chemical composition. As smaller particles can pass through the body's protective barriers, causing damage to organs. This review provides insights into research work and highlights the urgent need for further research on the effects of microplastics on human health and also calls for action to reduce plastic pollution in our food.

Keywords: Microplastics, plastic waste, microplastic toxicity, plastic pollution, human health.

I. Introduction

Microplastics are non-degradable, tiny plastic pieces or particles with size ranging from one micrometre to less than five millimetres and most of them are microscopic[1] in nature. Microplastics are found in a lot of everyday items like food items, clothing, household products, bottles, lids, beverages, cigarette butts, bags, cutlery and cleaning supplies etc. They may also present in various commercial and industrial products[2]. As the time progresses, microplastics break apart into smaller and smaller pieces and eventually become tiny fragments that degrade slowly, whether in nature or in our homes. Microplastics are often found in cosmetics, beauty and personal care products to improve colour, texture or other qualities. Even premium quality beauty products, toothpastes and shower gels etc. contain these tiny plastic particles but they are not shown on the labels[2]. The widespread production and use of plastics has led to the emission of microplastics, which has become a global problem.

The microplastic particles are found everywhere, right from oceans to freshwater and soils[1,3]. The gradual increment of microbeads and microplastics has created chaotic situation in the air we breathe, the water we drink and the food we eat. Even though microplastics are tiny, but they have a huge impact on our environment. They are responsible to harm the species at every level of the food chain. Their impacts on marine life are so alarming that experts warn us as there could be more plastics than fish in the oceans by 2050[1,2]. As such particles are very dangerous for humans and animals and even for plant kingdom including aquatic species. The widespread presence of microplastics in our food chain makes them a major factor in contaminating the food we consume. Single-use plastic items, which we usually use unknowingly, may contain harmful chemicals and can be one of the major sources of the problem.

As a result, the effects of microplastics on both human and animal health are becoming a growing concern. Generally, excessive dependence on plastic in almost all sectors, poor waste management and various accidents often result as plastic waste in the air, soil and water. Plastic waste commonly contains non-biodegradable polymers such as polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), polyvinyl chloride (PVC) and polystyrene (PS). Out of these PE, PP and PET are widely recycled[1,2,4]. Once plastic in the atmosphere, it breaks down slowly due to exposure to sunlight, physical forces or interactions with living organisms[1]. This breakdown process causes plastics to break down into smaller pieces, named microplastics (MPs) and nano-plastics (NPs). The scientific community has not yet agreed on a precise definition of microplastics (MP) and nano-plastics (NP). The scientific community hasn't yet agreed on the exact definitions of microplastics (MPs) and nano-plastics (NPs). Some researchers classify MPs as particles ranging from 1 µm to 5 mm and NPs from 1 nm to 1 µm[5,6], while others define NPs as particles smaller than 100 nm, in line with the European Commission's definition of nanomaterials (1–100 nm) [7]. For instance, Schwaferts et al. (2019) categorized MPs as 1 µm to 5 mm, submicron plastics as 100 nm to 1 µm and NPs as 1 nm to 100 nm[7,8]. Based on standard size prefixes, plastics are usually grouped into categories like mega, macro, meso, micro and nano. Plastics are also classified into microplastics (MP) and nano-plastics (NP) depending on their origin. Primary MPs are tiny in sizes and are used in manufacturing processes, industrial cleaners and personal care products such as toothpaste, facial scrubs etc. Whereas on the other hand, secondary MPs are produced in the environment due to breakdown and fragmentation of larger plastics. Clothing consists synthetic fibres is also considered a source of secondary MPs[2,3]. Recently, there has been growing interest among scientists and the public regarding the environmental impacts and potential threats of MP and NP, as evidenced by an approximately 800% increase in research on the topic over the past five years[9].

II. Sampling Methods and Separating Techniques of Microplastics:

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There are three main methods for collecting microplastics from the surroundings i.e. selective, bulk and volume-reduced sampling methods. Selective sampling involves picking out plastic particles that are visible on the surface of sediments. While this method works for larger plastics that are easy to see, it might miss smaller or hidden particles. Bulk sampling, on the other hand, involves collecting all of the sediment, including the microplastics buried inside, giving a more comprehensive sample[10]. Volume-reduced sampling takes a bulk sample and reduces it through sieving and filtering to isolate the specific portion needed for analysis[10]. Researchers frequently use trawl nets to collect water samples, while Grab samplers are used to collect sediment. After the collection, microplastic is separated from the sample through various methods such as density separation, which depends on how the material floats or sinks, chemical digestion to remove organic matter, sieving or filtration to separate the microplastic particles. To identify microplastics, visual sorting is often used which is based on their size, shape and colour, but this method can be inaccurate as some plastics may be unnoticed or misidentified[1]. Density separation is more effective sampling technique when it mixes with Nile red solution in which sample mix with density solution to separate microplastic then mix with dyes or stained solution. This solution then analysed fluorescent microscope[11]. For atmospheric microplastics, the use of special pumps or portable samples, usually at a specific flow rate in a prescribed period, is done to collect airborne particles on the fibre filter[11,12]. While collecting sediment samples from the sea, the first large particles are sieved with a 5 mm mesh to separate, then the microplastic between 2 mm to 5 mm has to be dry in an oven before sieve again to separate. Oxidative analysis method also suitable method for soil, biological samples and even for the food samples. In this method hydrogen peroxide is used to oxidised the organic matter in the sample and then sample is heated at 60°-80°C and then microplastics is obtained on filtration. Oxidative method enhanced the visibility and identification under microscopic or other analytical techniques[11]. Another method for sample preparation is enzymatic digestion method, this use applies enzymes like proteinase, lipase or cellulase in order to digest protein and fat in the sample. This method is suitable for biological samples like body tissues, meat and fish guts etc.[66, 67.] But this method is slow and more costly than other chemical digestion method. By using an optical stereo microscope, larger particles can be counted and further using ATR-FTIR spectroscopy technique for precise identification[11-14]. Although these methods have some limitations. Selective sampling may not capture all types of microplastics from the environment, small particles may slip through trawl nets and visual identification is also likely to be inaccurate. These challenges highlight the need for better, more standardized methods for sampling and separating microplastics, so that accurate and reliable samples can be obtained from different potential sources.

Characterization Methods of microplastics:

As we know, microplastics are made from different types of molecules and polymers. Polypropylene (PP), low-density polyethylene (LDPE), high-density polyethylene (HDPE), polyethylene terephthalate (PET), polyvinyl chloride (PVC), polyurethane and polystyrene (PS) are among the most common polymers. As these polymers vary in shape, size, colour and material and dissipate in the environment as microplastics through various sources[1,2] their analysis in a standardized way is very Such difficulties arises because of complex changes they undergo, contamination and differences in their shape, size and chemical composition[13]. To identify and isolate microplastics in tissues, the tissues are first needed to digest. For this purpose, Nitric acid is often used, but it can degrade certain polymers like polyamide[13]. Studies have been tested for six different methods to digest tissue, including potassium hydroxide, sodium hydroxide, peroxydisulfate in sodium hydroxide, hydrochloric acid, pepsin in hydrochloric acid, nitric acid and nitric acid in perchloric acid. But, most of these methods either degraded the plastics or didn't break down the tissues efficiently. One of the best methods in which the tissues are well digested without significantly damaging most of the plastics by using potassium hydroxide at 60 ° C for 24 hours, except for cellulose acetate[12]. Another recent method utilises sodium hydroxide for the digestion of tissue and sodium iodide for separation. The process finishes in about an hour and recovery of the microplastics is over 95%. However, this method can still change the shape, size and even colour of the recovered microplastics[12]. A newly developed method, thermal extraction/desorption-gas chromatography-mass spectrometry (TED-GC-MS)[11], these methods detect effect of temperature on the chemical and physical properties of the material. TED-GC-Ms working involves heating solid water samples at high temperatures under atmospheric nitrogen. This process generates decomposed gases, which are analyzed using gas chromatography–mass spectrometry (GC-MS)[11] to produce chromatograms with mass spectra. These chromatograms are extremely helpful to identify common microplastics like polyethylene terephthalate (PET), polyethylene (PE), polypropylene (PP), polystyrene (PS), polyamide (PA), styrene-butadiene rubber (SBR) and polymethylmethacrylate (PMMA) from tire components[15]. Some other methods such as proton nuclear magnetic resonance (1H-NMR) which identify the material on the basis of their proton spin in magnetic field and attenuated total reflectance Fourier transform infrared spectroscopy (ATR-FTIR) uses the infrared radiation to creating the spectra of subjected material also used by researchers to identify the plastic fragments and polymer extracts[11-14]. Molecular spectroscopic techniques are also among the common methods used to identify and characterize microplastics. The Micro-FTIR can analyse microplastics as small as 5–10 µm [11,16], while micro-Raman uses laser light scattering to create a fingerprint of sample and can analyse even smaller particles up to 0.2–0.5 µm[3,13,11,16,17]. In fact, analysing the microplastics is time-consuming and making it difficult to monitor large quantities. A semi-automated Raman micro-spectroscopy method, as an alternative method, combined with static image analysis has been used and validated. The morphological parameters and characterization of the microparticles have also been completed in less than three hours and hence speeds up and simplifies the process[15-17]. With the use of a liquid nitrogen-cooled mercury cadmium telluride (MCT) detector, the speed, accuracy, resolution and analytical performance of micro-FTIR can be boosted and further enable it to detect microplastics as small as 10 microns[11]. But FTIR spectrometer is limited only hydrate sample and this technique fails to test liquid samples. Still FTIR and Raman spectroscopy is most favourable technique to identify microplastics in food products Focal plane array (FPA) based reflectance micro-FTIR imaging, recognised as a novel technique, removes any biases that might come from visually inspection of samples before analysis.

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This method can effectively identify various types of microplastics like polyethylene, polypropylene, nylon-6, polyvinyl chloride and polystyrene[18].

Sources of microplastics in food chain:

The sources of MPs are numerous; the binding agent, which is the basis of most MPs of organic origin, is the reason why most of them are classified based on the specific material they are made from. However, analysts believe that almost every consumer product produced recently contains MPs, unexposed. The most common ones are textiles, which release fibers when they are washed (a T-shirt releases up to 1,900 fibers per washing cycle)[1,2], packaging (including food packaging) and personal care products (toothpastes, shampoos, shower gels, body lotions and creams etc.)[1]. Fibers are released into the environment through effluent and wastewater and have been found to gather up on beaches, muddy riverbanks and even in the ocean [2,3]. These fibres have been present in the environment for over two hundred years. Studies show that their microplastics composition and carbon dating go back to around 1704, suggesting that microplastics existed even before plastic products were widely produced and used.

Researchers in the year 2006, reported 2.3 million microplastics in sediment and seawater samples from the Seine River, which serve nearly 8.2 million people. It has been observed that the microplastics are spread by wind, rains, sewage and stormwater discharges significantly and can contribute to their presence in water bodies over time[2]. Apart from that, several disposable items like tea and coffee cups, containers, water bottles, beverage containers and many others items frequently contain plastics and break down into microplastic particles over time[3,4]. Unknowingly, these microscopic particles often enter in our body through food and drinks, especially from the items packaged, cooked or stored in plastics. Plastic items like soft drink, water and juice bottles, milk containers and grocery bags etc. are likely to release microplastic, especially when they used repeatedly or exposed to sunlight[17,19]. Similarly, as sources of microplastics, frozen food packaging, tetra pack milk cartons and yogurt containers slowly break down and get mixed into food[11]. A huge list of household products like detergent and shampoo bottles, plastic kitchen items such as freezer bags, lunch boxes and storage containers also prone to release microplastics when exposed to heat or used in the microwave or placed in direct sunlight[2]. Products like potato chip bags, plastic cutlery, cling wraps and snack wrappers release microplastics directly into food through direct contact, while kitchen staples such as rice, flour, sugar etc. when stored in plastic bags are also prone to get contaminated. The personal care products like toothpaste, hair oils and other cosmetics often containing plastic microbeads and capable to contaminate the wastewater systems, which ultimately can impact the aquatic food sources[2]. Plastic in agricultural practices is often used in many ways such as irrigation pipes, packaging of fertilizers, moisture protection film, polyhouses, storage and transportation of food products. These plastic items have a high risk of becoming a source of microplastics and may eventually enter in to the food chain directly or indirectly[1,3].

Above studies confirms that microplastic particles are everywhere and they can exist in the air, soil, drinking water, food and in water bodies. The wastewater treatment and filtration plants can't filter these tiny particles, so they remain in the environment. Researchers are continuously in quest to find out whether the contamination happens before or after the food is packaged or prepared and also applies to water. There are major concerns about microplastics that exists in plastic bottles[20,21].

Some of the common food products that have been found and reported to contain microplastics are as follows:

Packaged drinking water: Numerous studies have shown that microplastics are present in packaged drinking water which is commonly stored in plastic bottles and such bottles are made of polyethylene terephthalate (PET)[20,21]. In one of the investigations, a sample size of 30 bottles have been picked and selected 3 bottles from each of 10 different brands. To ensure the accuracy in the results, included three procedural blanks in the testing process. Surprisingly, microplastics were detected in every sample that was analyzed. The concentration of microplastics ranged from 3.16 ± 0.7 particles per litre to 1.1 ± 0.8 particles per litre. The type and quality of the plastic material used in the bottles, appeared as microplastics. Soft and easily squeezable bottles made of thin and easily deformable plastics released more microplastic particles, but these particles were smaller in size. In contrast, harder and less flexible plastic bottles released larger fragments of microplastics[20], but in smaller quantities. It means that the quality of the bottle plays an important role in the microplastic contamination levels[20]. The microplastics can also interact with microalgae which are found in the water. When the smaller microplastic particles of different densities come into the contact of microalgae, they may stick to the surfaces of microalgae and disrupt their normal functions by blocking the pores on it. When their pores are covered, it limits the transfer of energy, oxygen, carbon dioxide and nutrients. That can negatively affect the health and function of microalgae, which are an important part of aquatic ecosystems[22,23].

Table Salt: Recent research has found that the most table salt brands in Africa are contaminated with microplastics[24]. A study in South Korea, tested 39 brands of salt and found microplastics in 36 of them. This study laid a foundation as it is the first to connect microplastic contamination to table salt of the regions with high levels of plastic pollution[1,14]. The findings highlighted the widespread presence of microplastics in Table salt, which is an essential food ingredient used worldwide daily, In another study in China, analysed 16 brands of table salt and found varying levels of microplastic particles depending on the source of the salt. Sea salt had the highest levels, with 550–681 microplastic particles per kilogram. Lake salt contained 43–364 particles per kilogram, while rock salt had about 204 particles per kilogram[14]. The types of microplastics identified in these studies are polyethylene and polypropylene. These two types of plastics are commonly used in packaging or emerged in the source through contamination. Significantly, the contamination of table salt is not limited to aquatic sources but the manufacturing process itself poses a momentous risk of introducing microplastics into the final product[14]. This suggests that both environmental pollution and industrial practices may contribute to the problem.

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Honey: It is also a commonly used household product and get contaminated through various sources. A detailed study of 19 honey samples collected from France, Italy, Germany, Spain and Mexico revealed that all the honey samples contained non-pollen particles. These included both coloured and transparent fibres and particles. To identify whether the fibers were natural, such as cellulose or chitin or synthetic, researchers used fuchsine and rose bengal stains. The fibres and fragments that did not absorb these stains were confirmed to be synthetic polymers. On average, the honey samples contained 166 ± 147 fibers per kilogram and 9 ± 9 other fragments per kilogram[25]. Similarly, in another study researchers analysed 47 honey samples collected from supermarkets and beekeepers. It found 10 to 336 fibres per kilogram and 2 to 82 other fragments per kilogram of honey. Interestingly, fibres were also found at the plant level, with an average presence of 77.9%. This suggests that these particles first contaminate flower nectar then get transferred to beehives and eventually end up into honey consumed by humans[25,26]. The synthetic fibres identified in the honey included materials commonly used in industries like polyester, polyethylene, polypropylene, polyamide and polytetrafluoroethylene[26]. These fibres also originate from various other sources such as sewage, the abrasion of clothing and the fragmentation of larger plastic items under environmental conditions like sunlight, oxygen, temperature and humidity. These evidences highlight the growing issue of microplastic contamination in the environment, which is now making its way into human food chain through products like honey.

Sea food: The consumption of seafood is one of the ways humans are exposed to microplastics. As of 2015, seafood accounted for 6.7% of all protein consumed worldwide and 17% of animal protein intake[27,28]. The global seafood trade in 2016 was valued at $132.6 billion.

Over 90% of seafood consumed in the world was imported from the regions where the levels of plastic pollution in the oceans is high[13,14,29]. The seafood production can be divided into two main types i.e. farmed and wild-caught. The farmed seafood or aquaculture involves raising fish and shellfish in controlled environments such as ponds, tanks or selected water bodies. These controlled conditions may reduce the risk of microplastic exposure. Generally, farmed seafood has shorter lifespans as compared to wild-caught seafood, giving less time for microplastics to accumulate in their bodies. However, there is limited research on the differences in microplastic levels between farmed and wild-caught seafood. Either directly or indirectly, through the food chain number of marine organisms can ingest microplastics. For example, small organisms like plankton and larvae which are at the bottom of the food chain, can ingest microplastics.[28,30,31] Larger animals such as fish and invertebrates may consume these smaller organisms, resulting in microplastics accumulating in their bodies. Studies have shown that microplastics can also move through the food web, as seen in predatory fish like Crucian carps[27]. Many other marine species that humans commonly consumed, including invertebrates, crustaceans and various fish have been found to contain microplastics[13,14]. The microplastic particles are often concentrated in their digestive tracts. Bivalves like mussels and clams, as well as small fish that are eaten whole, pose a higher risk for humans to be exposed to microplastics because when consumed, the entire organism, including their digestive track, is ingested. As seafood to be a major source of protein worldwide, it is important to recognize and address their issues of contamination[13,27].

Other foods: Microplastic contamination has also been found in various other types of food, including dietary staples like rice[12]. Rice is a globally consumed food and a primary source of nutrition for millions of people. Several studies in Australia have detected microplastics in both uncooked and instant rice. The predominant types of microplastics found in these samples include polyethylene (PE), polypropylene (PP) and polyethylene terephthalate (PET)[3,4]. In addition to rice, vinegar which is a common ingredient in food preparation, especially in Chinese cuisine has also been found to contain microplastic fragments. A study conducted in Iran identified fragments of polyethylene (PE) and high-density polyethylene (HDPE) in vinegar[32]. Microplastic contamination is not confined to solid foods but is also present in beverages like milk[26]. A study detects the polypropylene microplastics in 16 samples of skimmed milk powder of 8 different European countries and reported that in the majority of microplastics particles in milk are PE, PS, PET[68]. Another study found microplastics of different fragments in milk packets[69]. Studies have observed microplastics in a variety of drinks, including energy drinks, soft drinks and even wine[11]. These findings highlight the pervasive nature of microplastic pollution in the human food chain and raise concerns about its potential impact on health.

Toxic effect of microplastic on human health:

According to current studies on microplastic particles present in human body, it has confirmed that such particles ingested in human body through different routes and damage the body organs[69]. Researchers investigated that the microplastics can permeate biological barriers, including the blood-brain barrier and can create neurological imbalance, cardiac, respiratory and dermatological disorders as well[64]. Numerous in vitro and in vivo studies have demonstrated that micro and nano-plastics can significantly impact the human body, leading to physical stress, tissue damage, apoptosis, necrosis, inflammation, oxidative stress, immune system responses etc. The following impacts have been investigated by researchers:

Inflammation: An in vitro study investigated the effects of polystyrene particles of varying sizes on human A549 lung cells and found that larger particles, measuring 202 nm and 535 nm, induced significant inflammatory responses. According to study the larger particles with a size of 64 nm, triggered higher levels of IL-8 expression as compared to smaller particles[33]. This study also suggests that the size of the particles is one of the important factors in causing inflammation. Likewise, research on unaltered or carboxylated polystyrene nanoparticles revealed substantial upregulation of IL-6 and IL-8 gene expression in human gastric adenocarcinoma, leukaemia and histiocytic lymphoma cells. Such results suggest that the inflammation may be causes due to the particles' composition or just their presence, rather than their surface charge[33,34]. Another study observed that how two types of polystyrene particles carboxylated and amino-modified, each 120 nm in size, affected human macrophages. It has been reported that even though no changes were found in the expression of M1 markers, such as CD86, NOS2, TNFα, and IL-1β, the presence of these particles decreased the expression of the scavenger receptors CD163 and CD200R in M2 macrophages, as well as IL-10 release. Amino-modified particles further impaired E. coli phagocytosis in both M1 and M2 macrophages, whereas carboxylated particles selectively affected only M1 phagocytosis. It has mentioned that the carboxylated particles increased protein mass in both types of macrophages, promoted the release of TGFβ1 in M1 macrophages and increased ATP levels in M2 macrophages[33]. The unmodified polyethylene particles, ranging from 0.3 µm to 10 µm in size, have been shown to cause murine macrophages to produce higher levels of pro-inflammatory cytokines, like IL-6, IL-1β and TNFα[34]. The studies on long-term use of polyethylene prostheses have revealed that wear particles, typically between 0.2 µm and 10 µm[35-38], build up in the tissue around the prostheses and trigger the release of inflammatory substances like TNFα, IL-1 and RANKL. These factors not only promote bone resorption but also increase the risk of prosthesis failure[33]. In the cases of ultrahigh molecular weight polyethylene implants, high concentrations of polyethylene particles have detected in the tissues surrounding the implant, along with a significant presence of macrophages which indicates an active inflammatory response[33,63,67]. In the cases, where titanium alloy hip replacements failed, polyethylene particles of averaging 530 nm in size, have identified as the main type of wear debris in the interfacial membranes[39]. Such findings highlight the harmful impact of polyethylene wear particles on the stability of the joint and the health of surrounding tissues. To overcome these challenges, metal-on-metal joints replacement have been a growing preference among specialists, with the aim of minimizing the negative impacts associated with polyethylene debris.

Oxidative Stress and Apoptosis: Many in vitro studies have established that the polystyrene nanoparticles have harmful effects on cells, including causing oxidative stress, apoptosis (programmed cell death) and autophagic cell death, depending on the type of cell involved[63,64,66]. For example, amine-modified polystyrene nanoparticles were found to strongly interact with mucin, a protective protein in the intestinal lining and this interaction led to cell death in both mucin-secreting and non-mucin-secreting intestinal epithelial cells[33]. Likewise, cationic polystyrene nanoparticles trigger the production of reactive oxygen species (ROS) and induce stress in the endoplasmic reticulum (ER), a cell structure responsible for protein folding, in mouse macrophages and lung epithelial cells. Due to this method, the buildup of misfolded proteins, ultimately led to autophagic cell death in RAW 264.7 macrophages and BEAS-2B lung epithelial cells[40,41]. Studies also reported that, both unmodified and modified polystyrene nanoparticles have been found to induce cell death i.e. apoptosis in various human cell types, including those from the lungs, leukaemia cells and cancer cells from the colon[63] and lungs[42-45]. These nanoparticles were also shown to influence the ROS levels by regulating long non-coding RNAs (lincRNAs) like linc-61, linc-50, linc-9 and linc-2 in the model organism Caenorhabditis elegans[46]. Even though these studies demonstrated significant toxic effects in controlled laboratory settings, similar outcomes were not always observed in animal models. For example, when mice exposed to a mixture of microplastics via oral intake, there is no severe toxicity observed in major organs like liver, lungs, heart, spleen, kidneys or testes[47,70]. However, some studies did report harmful effects, such as liver inflammation, neurological problems[48], reduced body and liver weight and decreased mucin production in the colon[49,63]. While, other studies found disruptions in metabolism, including amino acid and bile acid metabolism[50,51] and changes in the gut microbiota composition[52,53,67], which plays a main role in digestion and overall health. Interestingly, long-term effects such as changes in lipid metabolism were also seen in the offspring of mice exposed to microplastics[54,66].

Metabolic Homeostasis: Recent studies have highlighted that inflammation and apoptosis are not only caused through microplastics and nano-plastics but are also responsible to disrupt cellular metabolism in both laboratory and animal models. For example, polystyrene nanoparticles have been shown to interact with cell membranes and interfere with signalling systems in airway epithelial cells. Similarly, negatively charged carboxylated polystyrene nanoparticles (20 nm) activated basolateral K^+ ion channels in human lung cells, leading to a sustained increase in short-circuit currents[55]. This effect was due to the activation of ion channels and the stimulation of chloride (Cl^-) and bicarbonate (HCO_3^-) ion release[55]. One of the studies suggested that the polystyrene nanoparticles, measuring 30 nm, formed large vesicle-like structures in the endocytic pathways of macrophages and cancer cells such as A549, HepG-2 and HCT116. This interrupted vesicle transport and blocked the distribution of proteins involved in cell division, resulting in the formation of abnormal binucleated cells[56]. Furthermore, positively charged polystyrene nanoparticles disrupted iron transport in the intestines and affected the ability of cells to take nutrients after short-term oral exposure [57]. In another studies, mice that were fed polystyrene microparticles (5 µm and 20 µm) for 28 days and it has been observed that these particles accumulated in the liver, kidneys and gut. It was interesting to observed that larger particles were spread across all tissues, while smaller particles were more concentrated in the gut[58]. Further, tissue analysis revealed the signs of inflammation, presence of fat droplets and major disruptions in energy and lipid metabolism. Including lower levels of ATP, the mice also showed signs of oxidative stress and neurotoxic effects, cholesterol and triglycerides in the liver, along with reduced catalase enzyme activity. It has been also reported that, there was an increase in biomarkers like LDH, SOD, GSH-Px and AchE [58,59,60]. When pregnant mice exposed to microplastics, it has showed imbalances in their gut microbiota, weakened intestinal barriers and metabolic disorders. These effects were not only limited to the mothers but also caused long-term metabolic changes in their offspring, affecting both the F1 and F2 generations[61,62]. The changes in gut microbiota composition, reduced mucus production in the intestines, lower expression of ion transporter genes and disrupted lipid metabolism are among the key findings. These metabolic changes are evident in changes in triglyceride and cholesterol levels in the blood and liver tissues of exposed animals[60,62,66,67].

Strategies to mitigate microplastics:

Microplastics pollution is a serious concern for human civilization as well as the environment and it is omnipresent throughout the ecosystem, particularly in air, water and foods. Therefore, there is an urgent need to adopt a comprehensive approach to address microplastics pollution. The United Nations also laid down suggestive measures in terms of UN Sustainable Goals to maintain the

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sustainability of our planet. Now, it is joint responsibility of governments, policy makers and implementing agencies to ensure the safe production, disposal and monitoring of plastics. So that, at every possible stage, the contamination of microplastics can be minimized. Researchers have suggested various techniques for the removal of microplastics from environment. In order to remove polypropylene and other polymer particles from water bodies like river, ponds and lakes, the natural light and ZnO nanoparticles as a photo catalyst have been used[65]. ZnO nanoparticles makes the microplastics more hydrophilic or can easily remove by filter after partial degradation. In place of plastic based disposable items, alternative disposable articles made with natural ingredients should be promoted. Such ecofriendly initiatives can help us to avoid the direct chances of microplastics contamination in food. In air, the major sources of microplastics are textile industries and transport. The textile industries must use specific filters to prevent microplastics dispersion in the environment. To get clean air prominently, we have to promote plantation which can provide further natural filters to us.

III. Conclusion

The review studies revealed that the microplastics are highly resistant to degradation and remain in the environment for a long time. Microplastics are found in all ecosystems, including the air, soil and water. Now, they are also universally present in human food chain like in sea foods, drinking products and dietary foods etc. There is an urgent need to take global action to reduce the usage of plastic. As the studies suggested that, there is no effective way to remove microplastics from the food chain and entire ecosystem. The overuse of plastic worldwide worsens their buildup in natural ecosystems. Harmful chemicals and pollutants that stick to microplastics can harm humans in the many ways like inflammation, oxidative stress, disfunctions of organs and metabolic homeostasis. However, there is a huge gape to fully understand the toxicity of microplastics in humans and still there is no safety limits have been set for the presence of microplastics in the human body. At the same time, extracting and analysing microplastics is a complicated, challenging and time-consuming task. The methods used so far to digest and extract microplastics from tissues or from other samples are not yet standardized, which can lead to inaccurate results due to chemical changes and degradation during the processing of samples. Even after microplastics are isolated from tissues, cosmetics, water, sediment or food items, confirming their presence requires expensive equipment and specialized skills. Hence, there is a need to develop simpler, viable, economical and user-friendly methods that do not require advanced expertise. Presently developed methods like FTIR, Raman etc. should ideally quantify microplastics in food for quality control and safety, as well as in the environment, within a shorter time frame. These analytical techniques can be making more advance and accurate by combining with artificial intelligence and nano technology. As the interaction between humans and microplastics increases day by day, advances in measurement techniques will become crucial in the future. To better understand the threats posed by microplastics to human health and the environment, we need improved, standardised and advanced methods to assess exposure, risk and impacts[70]. Finally, as said “Prevention is better than cure”, it is significant to focus on reducing the amount of microplastics in the environment. As a part of the United Nations Sustainable Development Goals, additional efforts and approaches are needed worldwide to reduce plastic use.

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