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MICROPLASTIC: ITS EFFECT ON HUMAN HEALTH

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Abstract– The non-biodegradable nature of plastic has made a serious problem in human life. Various sources of single used plastics in the form of packaging material, carry bags, plastic bottles, straws, cutlery, containers, etc. have been increasing the problems in normal life of the society. The smaller plastic fragments less than or equal to 5 mm in length are referred to as microplastics. Microplastics may enter into the food chain through a variety of ways. The sorbed toxic compounds and the chemical additives present in microplastics serve as a carrier for toxicity in the environment. Human health may suffer due to inhalation and ingestion of microplastics through different ways.

INTRODUCTION

Plastic is used for a wide variety of different purposes but it has become a serious problem for human health due to its non-biodegradable nature. The problem is further increasing through the use of single use plastics in the form of packaging material such as carry bags, food packaging, plastic bottles, straws, cutlery and containers (Singh and Mathur, 2019). As per estimation in 2017, it was reported that 348 million tones of plastic was produced globally, of which over 10 per cent was intended for single use and then disposed off as waste and only about 3 per cent was recycled (Verla *et al.*, 2019). These plastics which fragments into small pieces are termed as microplastics. Microplastic represents heterogenous mixture of smaller plastic fragments in the size range of 0.001 – 5 mm (Shim *et al.*, 2017). Microplastics can enter into the environment through a variety of sources *viz.* agricultural run-off, tyre and road wear particles, wear and tear of clothes, plastic packages, industrial effluents, microbeads, etc. The exact toxicity of microplastics to human is not yet resolved but they have been detected in human faeces (Schwabl *et al.*, 2019). Human health risks are mainly attributed to the chemical additives on plastics and sorbed toxic compounds present on microplastics (Kumar *et al.*, 2020).

The transmission of microplastics in the food chain may occur through various means (Fig. 1).

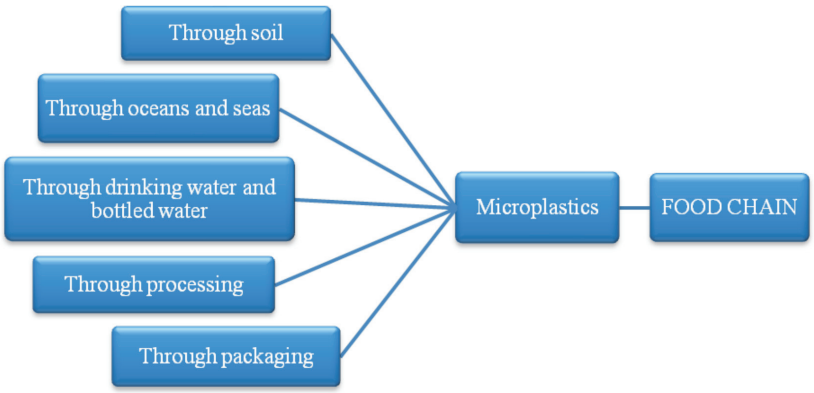


Fig. 1. Transmission of microplastics through different means in food chain

Health risks from microplastics

Due to the large surface area of microplastics (as high as 4.37 m^2/g) asreported by Teuten *et al.* (2007), the toxic chemicals such as heavy metals and organic pollutants get adsorbed on its surface and are carried into the environment.

The adsorption mechanism of toxic chemicals to plastics are diverse and complex and remain relatively unexplored by researchers.There are three probable mechanisms by which chemicals are adhered onto microplastic particles (Verla *et al.*, 2019) which includes-(i) adsorption onto microplastics as hydrophobic adsorbents, (ii) biofilm growth assisted and (iii) plastic additives and related chemicals contained with resins.

Hydrophobic adsorption of chemicals

Microplastics accumulate mostly in surface microlayer (SML) in seawater as they are less dense than water. Since, microplastics exhibit low polarity on their surface due to low electrostatic interactions and pH point of zero charge (pH_{pzc}) than most environmental pHs, they tend to be hydrophobic in nature which enables the adsorption of chemicals onto their surfaces from aquatic environment like sea water. Chemicals like persistent organic pollutants (POPs) including polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs) and pesticides such as DDT and DDE concentrate on the microplastic which forms a micelle shape-like structure.Microplastics exhibiting low polarity could also be a reason for aqueous metal ions adsorption on their surfaces. Aqueous metal ions are positively charged (M+) which bind to the negatively charged groups on the surface of the plastic by electrostatic attraction and neutralize their charge thus forming structures that are micelle shaped.

Although the binding form might differ with the types of plastic and metal ion (cationic or anionic), the mechanism of adsorption follows the same principle irrespective of the adsorption medium, *i.e.*, whether it is soil, sediment, water or air(Verla *et al.*, 2019). The accumulation of toxic chemicals or metals on microplastics takes longer time in the natural environment than in a controlled laboratory experiment because oxygen groups are generated when plastics continue to degrade thusincreasing the polarity and also the surface area is changed which increases the porosity and charge, making the plastic's surface more reactive.

Biofilm growth assisted

Biofilms are formed by microorganisms through a process called quorum sensing (QS) which is known to control gene expression in which microbial cells form matrix of extracellular polymeric substance (EPS) by adhering to each other on a living or non-living surfaces.EPS may act as a ligand and bind metals by chelation to control their mobility or distribution in the aqueous environment. Biofilms occur commonly on hard surfaces submerged in or exposed to an aqueous solution such as microplastics accumulating in surface microlayer (SML) of sea water.

Table 1. Common toxic chemical additives/metals to plastic

Toxic chemical additive	Products in which they can be found	Health impact
Bisphenol A(BPA)	Plastic tableware, water bottles, baby bottles, dental fillings and lenses for glasses. They are also used to make epoxy resins that are used as coatings in glass container's lids and in the linings of aluminium cans.	Breast cancer, prostate cancer, heart disease, obesity, diabetes, altered immune system and effects on reproduction.
Acrylonitrile	Drinking cups, acrylic carpet and other textiles, plastic furniture, 3-D printing, automotive parts and appliances.	Carcinogen
Phthalate	Plastic packaging film and sheets, inflatable toys, blood-storage containers, etc.	Growth of breast cancer cells increases and also interferes with reproductive hormones. They harm the reproductive and nervous systems, especially in children before and after birth.
Styrene	Polystyrene plastics and expanded polystyrene.	Carcinogen
Vinyl Chloride	Plastic furniture, carpet backing, packaging or wall covering.	Liver cancer

Plastic additives and chemicals in resins

Additives used in plastic production and related chemicals containing resins may be another probable mechanism. Most common chemical additives, *i.e.*,bisphenol A (BPA), styrene, acrylonitrile, polyvinyl chloride and phthalates are added to plastics to make it flexible as well as long lasting but they get transported with microplastics into the environment and potentially cause harm to wildlife and human (Table 1).

Uptake pathways of microplastics and its effect on human body

Humans are exposed to microplastics through inhalation and ingestion (Wright and Kelly, 2017).

Inhalation

(a) The Upper airway where the lining is thick, i.e., the central lung, reduces the chance of microplastic displacement by the lung lining fluid (surfactant and mucus). Here is likely for Particles greater than 10 μm are likely for mucociliary clearance and for particles less than 10 μm, uptake across the epithelium is possible.

(b) Microplastics may penetrate the thinner lung lining fluid and contact the epithelium, thus translocating through diffusion or active cellular uptake. Depending on individual differences in metabolism and susceptibility, the response to inhaled particles may be expressed as immediate bronchial reactions (asthma-like), diffuse interstitial fibrosis and granulomas with fiber inclusions (extrinsic allergic alveolitis, chronic pneumonia), inflammatory and fibrotic changes in the bronchial and peribronchial tissue (chronic bronchitis) and interalveolar septa lesions (pneumothorax). Microplastics in the form of fibres can be deposited in terminal bronchioles, alveolar ducts, and alveoli, resulting in chronic inflammation, granulomas or fibrosis.

Ingestion

(a) The major sites of uptake and translocation of particles in the gastrointestinal tract are the Peyer's patches of the ileum (third portion of the small intestine). These domed regions are characterized by an epithelial layer of M cells and enterocytes beneath which is the subepithelial dome, *i.e.,* a cavity containing lymphocytes and/or macrophages. The subepithelial dome of the Peyer's patches act as sinks that safely stores non-degradable particles. M cells play a key role in immune homeostasis by sampling and transporting particles (0.1 < 10 μm) from the intestinal lumen to the mucosal lymphoid tissues.

(b) A phenomenon known as persorption is another route of uptake in the gastrointestinal tract. Persorption is the phenomenon that describes the mechanical kneading of solid particles (up to 130 μm diameter) through gaps in the single-layer epithelium at the villus tips of the gastrointestinal tract and into the circulatory system. Dendritic cells bind to such particles and transport them to the underlying lymphatic vessels and veins. The resulting toxicity is through inflammation due to the persistent nature of microplastics, as well as their unique properties such as hydrophobicity and chemical composition. Undigested microplastics would be largely excreted through fecal matter, but smaller microplastics could potentially enter the circulation (Yong *et al.,* 2020). Extremely high concentration of microplastics (500-1,000 μg/ml) (Hwang *et al.,* 2020) or those carrying adsorbed toxicants would likely cause cell death through necrotic plasma membrane rupture or some form of programmed cell death resulting in acute impairment of viability and inflammation of the gut lining (Wright and Kelly, 2017). The smaller nanoplastics (degraded microplastics) could be taken up depending on the cell type through endocytosis.

Cellular mechanism of toxicity in mammalian cell

Extremely high concentration of microplastics/ nanoplastics (500-1,000 μg/ml) can cause cell death through rupture of necrotic plasma membrane or some form of programmed cell death (Hwang *et al.,* 2020). Depending on the cell type, the smaller nanoplastics (degraded microplastics) could be taken up through endocytosis. Endocytosis is a cellular process in which substances are brought into the cell by folding a portion of the membrane by itself, encircling extracellular fluid and various molecules or microorganisms.

Endocytosed nanoplastics can cause the following-

a) Firstly, if they are present at high concentrations they could potentially permeabilize the endosomal membranes. As a result, the nanoplastics which are released into the cytosol

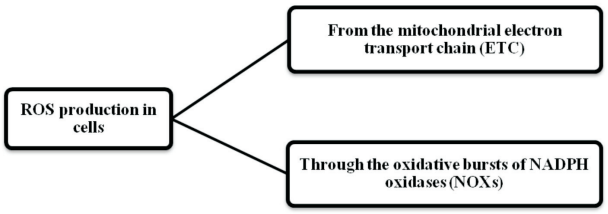
could potentially interact with important organelles such as the mitochondria or the nucleusand affect them, as well as interact with cellular processes such as mitotic spindle formation and chromosomal migration during cell division.

b) Secondly, microplastics or nanoplastics would likely to interfere with the trafficking of transport carriers in the cell along the exocytic pathway, and as a result would potentially inhibit the cell surface expression of important signaling receptors or membrane transporters.

c) Thirdly, nanoplastics perturb the endosomal membrane traffic on which many important cellular processes are dependent such as surface protein turnover and signaling attenuation, as well as retrograde signaling from endosomal compartments.

Nanoplastic's accumulation in late endosome or lysosomes would perturb the degradative functions of these organelles and may impair the critical cellular membrane turnover process of macroautophagy (Lim *et al.,* 2019) which would constitute a form of cellular stress. A generally associated phenomenon with cellular stress response is the production of ROS (reactive oxygen species).

Impairment of mitochondrial functionmay increase the reactive oxygen species (ROS) from the mitochondrial electron transport chain (ETC), while through the oxidative bursts of NADPH oxidases (NOXs) is normally a consequence of bacterial invasion, as NOXs are activated by bacterial products and cytokines. All cells are provided with an evolutionarily conserved innate immunity mechanism which typically functions against the invasion of pathogens or exposure to xenobiotics (Riera Romo *et al.,* 2016). Toll-like receptors (TLRs) which is a component of the innate immune system responds to a set of endogenous molecules known as alarmins, or damage-associated molecular patterns (DAMP) collectively (De Lorenzo *et al.,* 2018; Gong *et al.,* 2019), and the outcome is termed as sterile-inflammation, i.e., inflammatory responses without pathogenic infection (Shen *et al.,* 2013). Pro-inflammatory cytokines released from such localized inflammations would attract circulating immune cells, and this could deteriorate the local inflammation, and cause cell and tissue death.If the gut-vascular barrier is compromised, microplastics/ nanoplastics may gain access into the circulation or it may speculatively occur by transcytosis, a process by which various macromolecules are transported across the interior of a cell, thus reaching other organs.



CONCLUSION

Uptake of microplastics in human takes place through inhalation from the air or ingestion from various food sources. Microplastics are found in various food products *viz.* from seafood to processed foods and bottled water contaminated by different sources. Health risks of human are mainly attributed to the adsorbed toxic compounds or metals on the microplastics or the chemical additives used in the manufacturing of plastic products and leaching of such chemicals or retention of such contaminated particles inside the body may lead to detrimental health effects.

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