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Microplastic in Food, Food Residues and Composts: A Review

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ABSTRACT

Due to urbanization, population growth and modern lifestyle plastic was extensively used in the second half of the 20th century and became indispensable for humans of the 21st century. Plastic particles of less than 5 mm in diameter termed microplastic, due to indiscriminate use and mismanagement are found in all the environmental compartments (air, water, soil, food chain) and reach human food. Sewage sludge, plant composts, and food waste composts containing nutrient-rich soil amendments contain microplastic particles. The most common types of plastic polymers present in composts are polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS), polyester (PET), cellulose, polyurethane and nitrile fiber. When these organic composts are amended with the cultivated soil the plastic particles are accumulated in the plant roots and travel to shoot and crop yield i.e. fruits, vegetables, rice, etc. Microplastic particles enter human organisms mainly by ingestion (water, seafood, non-seafood, salt, honey, sugar, drinks, fruits and vegetables), inhalation (air), and dermal contact (personal care products, face washes, hand cleaners, toothpaste, and facemask). Accumulation of the microplastic particles in the human body causes several health problems such as hypertension, atherosclerosis, respiratory toxicity, cytotoxicity, immunotoxicity and reproductive toxicity. Accumulation of the organic compounds associated with plastic manufacturing (bisphenol A (BPA), bisphenone, nonylphenol, polyphenol, PFAS and phthalates) also has negative human health effects. Phthalates act as endocrine gland disrupters. Pathogenic, non-pathogenic and antibiotic-resistant bacteria form a biofilm on microplastic surfaces intake of such microplastic particles poses a serious challenge to Doctors. This work summarizes the concentration of microplastic in compost, food wastes, sewage, and the human food chain and their impact on plant growth and human health.

Introduction

Plastic after 1990 globally become an integral part of human everyday life (Kye et al., 2023) as it is used not only in packaging but also in construction, building material, electronics, electrical, agriculture, automotive sectors, furniture, sport, household appliances, health etc. The global report denotes that the global production of plastic bottles per minute is more than one million and only one-fourth are recycled or incinerated. It is calculated that by 2025 the annual production of plastic will be 600 million tonnes, and the global market which is 627 billion US dollars in 2023 will become 824 billion US dollars by 2030. The literature denotes that approximately half of the total plastic produced is disposed of in terrestrial and aquatic environments (Tursi et al., 2022).

Microplastic particles (< 5 mm diameter plastic) that can travel 6000km are present in every part of the planet. Microplastic is present in Antarctic sea ice, drinking water, surface water, sewage sludge, composts, soil, and guts of marine and river water animals even in the animals inhabiting the deepest ocean trenches, beaches of remote islands, food and beverages. As per (PEW Charitable Trusts, (2020) estimation in one square km of ocean about 46000 pieces of microplastic float and the total weight of microplastics in our ocean will be about 269000 tonnes. 24.4 trillion particles are present only in the upper region of the oceans worldwide.

Sewage sludge products of municipal wastewater, biologically treated organic waste, green waste, and food waste are globally applied to soils to increase soil fertility by enhancing soil carbon content and nutrients (Edo et al., 2022; Carabassa et al., 2020). Due to this practice globally, croplands are becoming reservoirs of microplastic. Researchers of Cardiff University have reported that in Europe alone 31000 to 42000 tonnes of microplastic (86 to 710 trillion microplastic particles) are added to croplands annually. A study done in the US has revealed that 300,000 microplastic particles are present per kg of grocery store food waste and 3.84 particles/g of food. Vithanage et al., (2021) during their research work on microplastic in compost of different countries found 10-2800 microplastic items/kg.

These particles are transferred to aquatic and terrestrial food chains via ingestion by aquatic organisms including fish, birds, bivalves, crustaceans and other invertebrates (Baldwin et al., 2020; Iannilli et al., 2020). Several researchers have found microplastic in different foods viz., fish and seafood, table salt, beer, honey, sugar, fruits/vegetables and water Studies have shown that in the USA an average person per year via food only consumes 50000 particles of microplastic and who also regularly drink plastic-based bottled water the number reaches to 90000.

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Studies by Doctors have reported an average of 20 microplastics per 10 grams of stool in several people. Researchers of Australia during their studies estimated that in Australia 0.1–5 g of microplastic is ingested by an average citizen per week.

This review article documents microplastic particles in food materials (fish and seafood, table salt, honey, sugar, fruits/vegetables etc.), composts, sewage sludge and food waste digests which will help in drafting policies for solid waste management.

2. **Classification of Plastic**

2.1 Based on their size

Plastic debris based on their size are divided into (i) Megaplastic (particle size >50cm), (ii) Macroplastic (particle size 5-50cm), (iii) Mesoplastic (size of particles ranged from 0.5-5 cm), (iv) Microplastic- (particles sizes < 0.5cm) and (v) Nanoplastic (size of particles 100 nm).

2.2 Based on their origin

Based on their origin in the natural environment microplastics are categorized into;

2.2.1 Primary Microplastics

Primary plastic means the plastic which is produced directly as microplastic. Those are used in the manufacturing of synthetic clothes (nylon), industrial manufacturing (plastic pellets), chemical formulations, sandblasting media etc. Microbeads (< 2mm) used in cosmetics and health care are also primary microplastics which are polyethene (PE), polypropylene (PP) and polystyrene (PS).

2.2.2 Secondary microplastic

Microplastic generated from macro- or mesoplastics (i.e. discarded tyres, clothing, disposables and electronic items) due to various environmental processes viz., biodegradation, photo-degradation, thermo-oxidative degradation, thermal degradation and hydrolysis is termed as Secondary microplastic. The wastewater of the washing machine also contains secondary microplastic.

3. Major sources of accumulation of microplastics in food, sewage sludge and compost are

The accumulation of microplastic in sewage, compost, food digests, and food materials is due to human activities.

The Major sources of microplastic are

3.1 Synthetic textiles

Synthetic fibre is the major source of microplastic. As per literature data 124-308 mg of microfiber/kg of washed fabric, equivalent to 640,000 to 1,500,000 microfibres/kg enters the environment

3.2. Vehicle tyres and road markings

It is estimated that 30-50% of total microplastic pollution is due to vehicle tyres and road markings. Studies have shown that approximately 6 million tonnes of tyre-wear particles enter the environment globally per year, out of which more than 20% is generated by European countries only (Bänsch-Baltruschat, et al., 2020).

3.3 Personal care products and cosmetics

Personal care products and cosmetics (incorporated in toothpaste, shower gels, shampoos, creams, eye shadows, deodorants, blush powders, make-up foundations and skin creams as exfoliators, emulsifiers, binding agents, opacifying agents, anti-static agents and film-forming agents) contain microbeads (Rahimi et al., 2022; Deng et al., 2022). The literature survey denotes that in more than 70% of Personal care products and cosmetics, the ingredient is one or more types of microbeads. Bashir et al. (2021) have reported that in South Asian cities more than 37 billion microbeads enter the environment /year via wastewater treatment plants. Polyethene is the main ingredient of microbeads.

3.4 Plastic pellets

Pellets the primary source of microplastic are the raw material of the plastic industry as it is used to make all plastic products. Pellets are composed of polyethene, polypropylene, polystyrene (non-expanded), PVC and acrylics or their mixture. These pollutants enter the environment due to poor handling and transportation practices and escape during industrial processes.

3.5 Sewage sludge, manure, food residue and composts are also the source of microplastic.

3.6 Municipal waste that contains plastic bags and bottles, fishing waste, farming film, and other large-sized plastic waste is the secondary source of microplastic.

3.7 City dust

City dust originates from urban areas, artificial turf, plastic running tracks in schools, rubber roads in cities, building paints, and industrial abrasives contribute 10-20% of the environmental microplastics.

3.8 Marine coatings

A major source of ocean and waterway contamination by microplastic is paint. Several researchers (Gondikas et al., 2023; Paruta et al., 2022) have reported that 7.4 Mt paint containing 63% microplastics is leaked per annum in the environment and 37% in oceans and waterways.

4. The most commonly used plastic polymers are

(i) Polyethene (PE) (HDPE & LDPE) (ii) Polypropylene (PP) (iii)Polyester (iv) Polystyrene (PS) (v) Polyetheneterephthalate (PET) (vi) Polyvinyl chloride (PVC) (vii) Polyvinyl acetate (viii) Polyurethane (PUR) (ix) Nylon (Polyamide) (PA) (x) Polyacrylonitrile (PAN) (xi) Polymethyl methacrylate (PMMA) (xii) Polyvinyl alcohol (PVA) (xiii) Poly Acrylonitrile-butadiene-styrene (PABS) (xiv) Styrene-butadiene rubber (SBR) (xv) Polylactic acid (PLA) (xvi) Melamine (xvii) Polybutylene succinate (PBS) (xviii) Polyhydroxyalkanoates (xix) Polyethyl Sulphones (PES) (xx) Alkyds (xxi) Polycarbonate (PC) and (xxii) cellulose nitrate and Cellulose acetate

5. Routes of Exposure to microplastic

The most commonly used synthetic plastics are polythene (low and high density), polystyrene, polyvinyl chloride, polypropylene, polyethene terephthalate

5.1. Sewage sludge

A large amount of microplastic particles are present in the wastewater. These particles originate from microbeads used in the plastic industry and in personal care products, fibres from clothes washing wastewater, tyres, and road wear particles from urban runoff. The majority of these particles end up in the sludge (Hassan et al., 2023). Studies have shown that sewage sludge contains 280-430 microplastic items per kg of sludge. Researchers have reported (Chand et al., 2022; Zhou et al., 2020) that fibres and fragments are the most common shapes found in sewage sludge. Globally in the last 30 years sewage sludge has been amended in agricultural soils as fertilizer to increase the fertility of soil as sewage sludge contains high amounts of organic matter and essential nutrients.

5.2 Compost

Compost an eco-friendly organic fertilizer (rich in organic matter and soil nutrients) produced from organic wastes and household biowaste has been used globally as a soil amendment since the early days of agricultural activities. Household bio-waste always contains a significant number of microplastic (MP) fragments mainly bags and foils, coffee and tea capsules (Steiner et al., 2023). The microplastics from organic compost which is used as an organic fertilizer globally are transported into the soil. The composts mainly contain (70-80%) PES, PP, and PE polymers (Gui et al., 2021)

5.3. Human Food: Includes plant food, aquatic food including seafood and other food

5.3.1. Plant food.

Microplastic particles have been reported in the food products obtained from plants. Research has shown that before transporting to aerial parts of plants including edible parts the microplastic particles are accumulated in roots (Garrido Gamarro & Costanzo, 2022; Li et al., 2021). Agricultural mulching, use of sewage sludge, green compost, atmospheric deposition, irrigation by sewage and production water, and landfill dumping are the major pathways of entering the microplastic particles in the soil (Jia et al., 2022; Choi et al., 2021). As the domestic dust also contains microplastic the plant food is also contaminated in the domestic environment.

5.3.2 Aquatic food

Most of the water Bodies Lake, rivers, seas, ponds, surface, and ground and sea water globally are contaminated with microplastic. In the freshwater environment, these particles enter from discharges from urban drainage systems, road runoff, wastewater treatment plant effluents, and landfill leachate and agricultural fields (Ritchie (2021). In the seawater, 70-80% (w/w) of microplastic is from land based sources transported via rivers and coastlines and 20-30% from marine activities i.e. fishing nets, ropes, lines, sea vessels and abandoned vessels. The aquatic animals which live in these water bodies accumulate the microplastic particles in their bodies and biomagnification in animals occurs. The microplastic particles in the aquatic medium clog the roots of plants and organs of animals causing toxicity in the aquatic ecosystem.

5.4 To Humans and other organisms

Contamination of human food by microplastic occurs through soil/water and atmosphere (Kirstein et al., 2021; Guo et al., 2020).

The exposure of microplastic to humans and other aquatic organisms occurs via:

(i) Ingestion: When uptake occurs via mouth i.e. gastrointestinal called ingestion. Common examples by which human uptake microplastic via ingestion are drinking water, beverages, beer, eating food, honey, salt, vegetables, fruits and seafood including fish.

(ii) Dermal: Dermal uptake means absorption occurs via the skin/gills. Microplastic enters the human body via the skin by using facial soaps and body scrubbers and during bathing and washing with contaminated water (Enyoh et al., 2020). Gills are the source of absorption and bioaccumulation of microplastic and/or nano plastic for fish and other aquatic animals.'

(iii) Inhalation: Humans and other organisms inhale the microplastic/ fibre particles present in the city dust, air and dust fumes at the workplace via respiration.

The concentration of the microplastic in food material, air, compost, and sewage sludge is given in Table 1.

6. Impact of microplastic on Plants

As the microplastic particles persist for a long period and can accumulate these particles negatively affect soil functioning (soil bulk density) and soil ecosystem biodiversity (enzyme activities and microbial biodiversity) resulting in negative effects on plant growth altering root growth and nutrient uptake and food production by altering root growth and nutrient uptake (Zhou et al., 2023). Cui et al. (2022); and Dong et al. (2021) have found that the presence of microplastic in soil causes deformation of cell walls, reduction of root and shoot length and leaves number and biomass in carrot, radish and cherry radish. In onion bulbs soil microplastic causes oxidative damage, genotoxicity and cytotoxicity (Gioregenti et al., 2020). Inhibition of root and plant growth, photosynthesis, stimulation of ROS, reduction of nutritional quality, oxidative stress, cell damage, and reduction in soluble protein and sugar content in lettuce leaves by microplastic particles were the findings of Gao et al. (2021); Lian et al. (2021). Microplastics in soil inhibit seed germination and seedling growth with damage to the seedling membrane in peas and lentils (Kim et al., 2022; De Silva et al., 2022), while in soybeans microplastic production also decreases plant growth and biomass production (Li et al., 2021). In strawberries, tomatoes, pumpkins and cucumbers the microplastic present in soil reduces the number of seeds germinated, root growth and root volume, surface area, leaf size, physiological and biochemical activities, chlorophyll content, photosynthesis, plant biomass and sugar metabolism (Sahasa et al., 2023; Shorobi et al., 2023; Pinto-Poblete et al., 2023)

7. Impact of microplastic on Aquatic animals:

The survey of the literature has indicated that bioaccumulation of the microplastic particles in aquatic organisms (fish, seafood etc) shows negative effects in 94.2% of fish, 90% of crustaceans and 93.5% of molluscs (Marino,2024). Microplastic in aquatic animals disrupts the digestive system, retards growth, damages reproductive organs, oxidative damage, DNA, intestine and tissue damage, behavioural, gut microbiota and reproductive changes (Mahamud et al. 2022; Yang et al. 2022). Altered gene expression, neurotoxicity, genotoxicity reduction in population and mortality has also been reported in fish and molluscs (Rendell-Bhatti et al. 2023; Sangkham et al. 2022).

8. Impact on Human

Microplastic particles cannot be easily biodegraded and persist in the environment for a longer period and due to their hydrophobic nature, large surface area, presence of hazardous chemicals (amended during their production) and sorption of Persistent organic pollutants and potentially toxic metals these particles pose a serious health problem to humans. These particles enter the human body through (i) breathing i.e. inhalation (via lung) of dust particles, (ii) by consuming food or drinking contaminated water i.e. ingestion (via the digestive system), humans consume these microplastic particles through consumption of seafood, non-seafood, and drinking water present in aquatic and terrestrial environments (Guo et al. 2020) (iii) dermal-via skin. During their studies, Kor et al. (2020) found that microplastic particles in the human body enter by (i) Endocytosis and (ii) persorption. As per data, it is found that the average global consumption of plastic by a human is 250g/year. The review of published research studies denotes that about 39,000-52,000 particles enter the human body per year via consuming food (seafood, non-seafood) and drinking beer, soft drinks and water (via ingestion) and 25000 particles per year via inhalation (Kye et al. 2023; Singh et al. 2020). Humans who drink only bottled water uptake 9000 particles additionally. That citizenry who drink energy drinks, wine, bottled tea and beer in large quantities uptake these particles additionally, as white wine from Italy contains 2563-5857 particles/L and beer from Germany contains 10-256 particles/L (Shruti et al., 2020). Health problems for humans are more caused by those aquatic animals whose whole bodies are consumed than the animals whose digestive system is separated and then consumed. The death rate of cells which came in contact with microplastic particles is three times faster than the cells which came in contact with other foreign bodies and the regeneration rate also decreases significantly. Microplastic damages cell membranes (Kim, et al. 2022). Cell apoptosis is induced very rapidly by very small size microplastic particles (Banerjee et al., 2022). Liang et al. (2021) reported that microplastic accumulation in the human body causes apoptosis, necrosis, and fibrosis and damage to the tissues.

Human health is adversely impacted by the shape, size, chemical structure and surface area of the microplastic particles. Microplastic particles of the size 150 um are absorbed by lymph nodes while particles of the size 110 um are passed in the portal vein and organs, microplastic particles of the size 100 um can pass through gastrointestinal epithelium, particles of the size 15-20 micron are transported to lymphatic and cardiovascular system (Yang et al., 2020), particles of the size 10 um can even cross the blood-brain barrier and can pass through the placenta. Microplastic particles of the size 100 um can pass through the gastrointestinal epithelium while particles of the size 10 um can cross the blood-brain barrier and can pass through the placenta. The inhaled microplastic particles cause irritation and inflammation in the respiratory tract resulting in coughing, wheezing and shortness of breath. These particles after entering lung tissues may cause cytotoxicity and genotoxicity effects on the pulmonary epithelium and macrophages (Sangkham et al., 2022). Rahman et al., 2021; Kannan and Vimalkumar, 2021 during their research studies found that textile industry workers are more prone to lung diseases, pneumoconiosis, asthma, and allergic alveolitis than non-workers. Inhaled microplastic particles may develop or worsen cardiovascular conditions, which include heart rhythm disorders, hypertension and atherosclerosis (Persinni et al., 2023; Zhao et al., 2021). Several researchers (Emenike et al., 2023; Goodman et al., 2022) have also reported that cardiovascular problems by microplastic accumulation in the human body are due to enhanced oxidative stress, inflammation, impaired endothelial function and irregular heart function. When human kidney and liver cells come in contact with microplastic particles causes structural abnormalities, decreases cell proliferation, and changes gene expression of enzymes (Goodman et al., 2022; Wu et al., 2022).

Microplastic particles when ingested cause inflammation of the digestive tract, constipation, irritable bowel, and blockage with the disrupted gut (Zhao et al., 2023; Deng et al., 2020). If humans remain exposed to microplastic for a long period causes immunodepression due to abnormal activation of immune cells (Prata et al., 2020), as these particles also generate more reactive oxygen species resulting in oxidative stress and damage to neuron cells. If the microplastic particles enter the circulatory system of a human it not only enhances the probability of cancer but also causes vascular inflammation, occlusions, blood cell cytotoxicity and retards functioning of organs (Campanale et al., 2020; Prata et al., 2020). Microplastic particle accumulation in the human body negatively impacts nutrient uptake, metabolic enzyme activity and energy consumption (Rahman et al., 2021). Several scientists (Sobhani et al., 2021: Chang et al., 2020) after their research studies have concluded that if microplastic particles are accumulated in gonads it significantly negatively impacts the reproductive capacity of humans. When microplastic particles come in dermal contact via personal care products, face washes, hand cleaners, toothpaste or facemasks clog/ disrupt the skin pores causing irritation, redness, itching and inflammation in the skin with some allergic reactions like anaphylaxis and hypersensitivity in cells (Wu et al., 2022; Kim et al., 2021; Campanale et al., 2020).

One of the major causes of infertility, cancer, and genetic mutation in humans is an accumulation of organic compounds bisphenol A (BPA),bisphenone, polylphenol, PFAS and phthalates that are used as additives in plastic production. These compounds particularly phthalates shorten the pregnancy time, and the birth of underweight babies, disrupts endocrine glands, which results in adverse hormonal balance, reproductive function, development and overall health (Surana et al., 2022). On the surface of microplastic pathogenic and non-pathogenic microorganisms' microbes' viz., *Pseudomonas aeruginosa*, *Legionella* spp., Vibrio spp., *Escherichia coli*, *Mycobacterium* spp. And *Naegleria fowleri* forms a biofilm, which in human may cause gastrointestinal, skin respiratory infections (Hu et al., 2021; Galafassi et al., 2021). On some microplastic particles, antibiotic-resistant bacteria biofilm is also reported which poses a serious challenge to Doctors (Wang et al., 2020). Hazardous pollutants such as PAH; PCB, DDT and potentially toxic metals that due to large surface area, are easily sorbed on microplastic particles are bioaccumulated within fatty tissues of humans posing a serious health problem (Zhang et al., 2020).

Conclusion

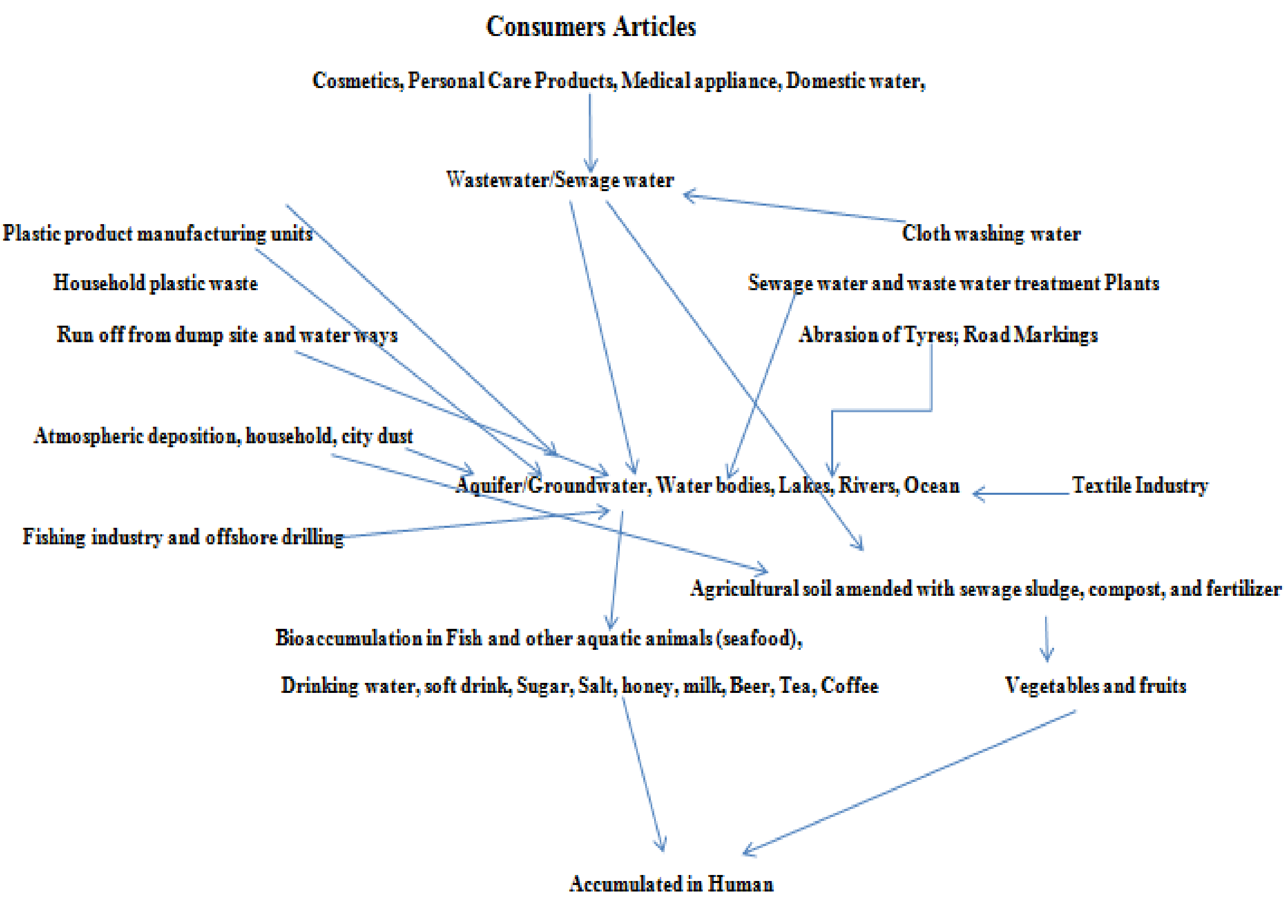
Due to the presence of microplastic in every compartment of the environment, the pollution by microplastic particles has become a focus of social and environmental concern. Due to high nutrient concentration and organic matter composts generated from plant waste, food waste and sewage sludge have been amended in agricultural soils to enhance soil productivity. Studies have shown that composts (generated from plant waste or food waste) and sewage sludge contain microplastic particles that accumulate in agricultural soils. These microplastic particles present in soil accumulate in the plant roots and regulate several physiological processes such as leaf and root ionome, redox homeostasis, hormonal regulation, photosynthesis, and energy dissipation of the plant resulting in the reduction of plant growth accumulation of these particles in the crop yield (fruit or vegetables) the concentration was higher in root vegetables such as carrots, radishes, turnips. The microplastic particles are also reported in common salt, honey, tea, milk and aquatic animals. These particles with other associated organic compounds enter the human body via the food chain. Human exposure to microplastic particles shows several negative effects such as digestive tract inflammation, constipation, blockage in the digestive system, oxidative stress, disordered immune system, abnormal hormonal activities, nervous system, endocrine gland disruption etc. So, it is the need of the hour for policymakers, and industries to take steps to minimize the use and exposure to plastic.

Table 1. Microplastics in food material, compost and sewage sludge

Source	Country	Quantity per kg or per individual	Composition	Reference
Commercial Salt	Sri Lanka	11-193	PVC, PE,PP, PET	Kapukotuwa et al., 2021
Rock salt		64		
Salt	African Countries	0.67-6.25	PP, PE, PEA.	Fadre et al., 2021
Salt	Bangladesh	2676	PET,PS,HPDE, Nylon	Parvin et al., 2022
Salt	Gujarat, India	230-575	PE,PVC,PS	Vidyasakar et al., 2021
Edible sea salt	India	1400-1900 particles /kg	PE, PP,PET, nylon, PS	Yarnal et al., 2021
Rock Salt		200-400 particles /kg	PE, PP,PET, nylon, PS	
Antarctica Snow	Ross Island Antarctica	29/ L	PET	Aves et al., 2022
Airborne	Jakarta, Indonesia	3-40 $n/m^2/d$	PE, PET, PS, PB	Purwiyanto et al., 2022
Airborne (indoor)	Wenzhou, China	1280-2140 n/m^3	PE, PS, PP, PA, PES	Liao et al., 2021
Airborne (outdoor)		166-235 n/m^3		
Airborne (Urban)		202-271 n/m^3		
Airborne (Rural)		89-158 n/m^3		
Street Dust	Xinjiang China	307-1526 particles	PE,PP, Flakes, Fibres	Li et al., 2022
Cold Tea	Mexico	8-16,/L	PA,PET, PEA, ABS	Shruti et al., 2020
Soft Drink		34-52/L		
Beer		0-28/L		
Milk	Mexico	5-9/L	PES, PSU	Kutralam-Muniasky et al., 2020
Apples	Italy	52600-307750		Oliveri Conti et al., 2020
Pears		98325-302250		
Broccoli		65025-201750		
Lettuce		26375-75425		
Carrots		72175-130500		
Sugar	Iran	57.6-226/kg	PE, PVC, HDPE	Makhdoumi et al., 2023
Salt		55.2-151.3/kg		
Vinegar	Iran	38-75 /L	PE, HDPE	Makhdoumi et al., 2021
Rice	Australia	52-283ug/g dw	PE,PET,PP	Dessi et al., 2021
Sheep Manure	Spain	0-5000items/Kg	PE	Beriot et al., 2021
Pig manure	China	902-1290 items/Kg	PE, PET, PP, Cellulose	Wu et al., 2021
Cow Manure		74-129 items/Kg		
Cattle Manure	USA	1460-1825 items/Kg	PP,PE,PET	Nadri Beni et al., 2023
Pig Manure	China	11175-20100items/kg	PE,PES, PP	Yang et al., 2021
Organic fraction municipal waste	Germany	39-102	PE,PVC, PS, PES, PET	Schwinghammer et al. 2021
Organic fraction municipal waste	Spain	10000-30000	PE,PVC, PS, PES, PP	Edo et al., 2022
Primary sludge	Sweden	4080/g	PE, PP, Fibres	Chand et al., 2021
Digested Sludge		214/g		
Primary sludge	Iran	206/g		Alavian Petroody et al., 2021
Aerobically digested sludge		238,g		
Secondary sludge	Thailand	104.3/L		Hongprasith et al., 2020
Anaerobically digested sludge	Spain	314/g		Edo et al., 2020
Activated sludge	Australia	7.91/L		Raju et al., 2020
Fresh Sludge	Morraco	40.5/g		El-Hayany et al., 2020
Digested Sludge	Iran	5.57-6.57/g		Naji et al., 2021
Activated Sludge	Spain	112/g		Bretas Alvim et al., 2020
Digested Sludge	Sweden	1413/g		Rasmussen et al., 2021
Sludge	Canada	541	PS, PE, PP, PUR, Polyester,	Crossman et al., 2020
Sewage sludge	Spain	5190	PE, PP,PS, Film, Fibre	van den Berg et al., 2020
Sludge	USA	37.6-545.9	PE,PP, PES, PS	Zhang et al., 2020
Anaerobic digested Sludge	China	4010	SBR, PVC, PUR, PE,PABS, PBMA	Xu et al., 2020b
Sewage sludge	Germany	97.66/g		Tagg et al., 2022
Activated Sludge	Australia	52.1/g		Ziajahormi et al., 2021
Bio solid	Spain	107.5/g		Schell et al., 2022
Anaerobically digested sludge	England	500-7657/g		Horton et al., 2021
Raw sludge	Finland	1560/L		Salmi et al., 2021

Source	Country	Quantity per kg or per individual	Composition	Reference
Anaerobically digested sludge	England	180.7/g		Harley-Nyang et al., 2022
Secondary digested sludge		286.5/g		
Raw Secondary Sludge	Thailand	8.12/g		Tadsuwan &Babel 2022
Raw Sludge	Mauritius	2.6-10.9/g		Ragoobur et al., 2021
Composts from green waste	Netherlands	1253	PE, PP	Van Scothorst et al., 2021
	Spain	2800	PE, PP, PS, PVC	
Organic Fertilizer	China	300-1000 items/Kg		Zhang et al., 2022
Organic Fertilizer (Commercial)	Bangladesh	433-3460 items/Kg	HPDE	Rana et al., 2023
Organic Fertilizer (Commercial)	China	6845-11256 items/Kg	PE,PP, PES	Xu et al., 2022
Composts of rural domestic Bio waste	China	2400	PP,PE,PES,PVPC, PS,PUR	Gui et al., 2021
Composts from Bio waste		70-146		
Composts from pig manure	China	43.8	PE, PS, PET	Yang et al., 2021
Composts from green waste	Lithuania	5733-6433	PP, PE, PAN, PES	Sholokhova et al., 2022
Composts from green waste	Germany	12-46	PP, PE, PAN,	Braun et al., 2021
Composts from household bio waste		32-48		
Composts from Bio waste	Netherland	82800	PLA	Huerta-Lwanga et al., 2021
Composts from food waste	Lithuania	3783-4066	PS, PE, PET, PP	Sholokhova et al., 2022
Compost from pulped food waste	Italy	1400	PP,PE,PS, Cellulose derivatives	Ruggero et al, 2021
Compost from grocery store	USA	300000	PES, PET, PE, PA, fibres	Golwala et al, 2021
Mackerel	North East Atlantic Ocean	1-3/Ind (GIT); 1-2 /Ind(Gills);0.04-0.14/gww (Muscle)	PE, PET	Barboza et al., 2020
Marine Fish		1.3 items/fish;54 items/kg of fish	PP, PET, fibres, Nylon	
River Fish	Minho, Galicia	6-7/Ind;0.003-0.01/g ww	PP,PE,PS, PA, PES	Guilhermino el et al., 2021
Red Algae	China	1-2.8/gww	PP, PA, PET	Li et al. 2020
Marine fish	Australia	1.58 item/fish	PE, PP, PS, Polyolefins, Synthetic rubber	Wotten et al., 2021
Marine fish	Fiji	0.86 items/fish		
Marine Fish	Adriatic sea	4.11items/fish; 0.011-0.52/g ww	PP, PET, PE Nylon	Mistri et al., 2022
Marine Fish	Egypt	28-7527/Ind	PP, PET, PVA, LDPE, Nylon	Shabaka et al., 2020
Pacific Oysters	USA	1.75/ind; 0.077/g	PS, PP, PE, Rayon, Polyacrylate	Martinelli, et al., 2020
Gastropods, bivalves and crabs	Hong Kong	0-9.68/g;0-18.4/ind	CP, PET, PA	Xu et al., 2020
Shrimp	Australia	0.5-1.05/ind; 18-45/g	PE, Rayon	Nan et al., 2020
Shrimp	Bangladesh	33–39/and; 3.40–3.87/g	PA, Rayon	Hossain et al., 2020
Prawn	Bangladesh	6-9items/Ind;1.55-4.84/g ww	PA, PP	
Bluecrab	USA	0.87/ind	Fibres, fragments	Waddell et al., 2020
Gibbula cineraria	Scotland	3-7/ind	PE, fibre	Jones et al., 2020
Chicken & Turkey	France	4-18.7/kg	PS, fibres	Kedzierski et al., 2020
Decapod	Ireland	1-3/ind.	PE, PA, PVC	Hara et al., 2020
Dried Marine Fish	Asia	550-580/kg	PE,PET,PS, PP,PVC	Piyawardhana et al., 2022
Canned Fish	Iran	50-220/kg	PE,PET,PS, PP,	Akhbarizadeh et al., 2020
River Fish	Bangladesh	1.85-3.5 items/fish	Fibber, film, foam	Khan & Setu, 2022
Marine fish	Southeastern Black sea	0.81-2.06 items/fish	PP, fibre	Aytan et al., 2022
Marine fish	Turkish Coast	1.1-1.9 items/fish	PP, fibre	Gundogdu et al., 2020
Marine fish	South Africa	3.72 items/fish	PET, PP, PE	Sparks & Immelman, 2020
Grey Mullet Fish	Giglio island Italy	1.0-2.0/ fish	PP, PE, PET,PA, PUR	Avio et al., 2020
Nile Tilapia	China	4-8items/fish	PP,PS, PVC	Zhang et al., 2020
Marine Fish	Kerala, India	0.10.5/Ind;0.0030.01/gww	PP,PE,PS	Daniel et al., 2021
Marine Fish	Persian Gulf	0.35-2.4/Ind; 0.11-0.62/g ww	PP,PE,PS	Ahmadi et al., 2022
Gadus morhua; Pollachius virens)	Ísafjörður, Iceland	0.23/fish	PE, PS, PET,PP	De Vries et al., 2020
Marine Fish	Malaysia sea	5-6.5 items/fish	PE, PET, fibres, Nylon	Foo et al., 2022

Source	Country	Quantity per kg or per individual	Composition	Reference
Scyliorhinus canicula.	Central Mediterranean Sea	0.7/fish	PE,PS,PET,PP	Mancia et al., 2020
Chanos chanos	Jakarta Bay	8.8-9.6/g	Fibers, film, granules	Priscilla and Patria, 2020
Fish	Mangrove wetland, China	0.6-8/fish	PE, PP, PET	Huang et al., 2020
Fish	USA	1-49/fish	PE, fibres	Hurt et al., 2020
Fish Gill		1-30/fish		
Fish Gut		0-28/fish		
Fish Gut & gill	Indonesia	2.22-2.33 /fish	Fibres , fragments	Fareza and Sembiring,2020
Fish Tissue		1.11-1.33 /fish		
Fish	Aquaculture site, China	2.1/fish	Cellulose, PP	Wu et al., 2020
Bivalves		1.5/ind		
Shrimps		0.9/ind		
Marine fish	South Caspian sea	1-5 items/Ind	PA	Zakeri et al., 2020
Golden anchovy	India	5-10 items/fish	PE,PP,PA.PES,PS	Gurjar et al., 2021
Shellfish	India	1000-1000particles/kg	PVC,PolyamidePolyacrylamide,polyacetylene	Saha et al., 2021
Finfish		300014000particles/kg		



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Declaration:

No original data have been used in this review all information is accessed from published work

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