Chapter 1
Environmental Micropollutants and Their Impact on Human Health with Special Focus on Agriculture

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Abstract Micropollutants (MPs) are key contaminants present in the soil, water, and environment. They vary based on natural properties and classified as organic (polychlorinated biphenyls, polyaromatic hydrocarbons, organochlorine pesticides, DDT, hormones, EDC, pesticides) to inorganic (heavy metals). They enter the soil-water-environment system through variable sources that include irrigation water to agricultural system, disposal of expired pharmaceuticals, bio-solids or animal excreta, sewerage wastewater, fertilizer application, industrialization, etc. They further enter into the food system via a number of entry points such as groundwater, agricultural soil, irrigated water, etc. and become part of the food chain. Micropollutants largely impact the human health by triggering thyroid disorders, neurodevelopmental dysfunctions in children, endocrine-associated malignancies, and metabolic and bone abnormalities. Soil acts as an ultimate host for all such pollutants where soil microbes degrade them biologically, addition of chemical inputs can accelerate degradation, while use of physical approaches in remediating MPs is costly. These MPs damage soil quality and soil microbial diversity, alter various soil biogeochemical processes, and induce genetic changes in the microbial ecology. Persistence of the MPs makes them more vulnerable for human health as they enter the food chain. Phytoremediation is considered a proven technology to remediate MPs in soil and multiple types of hyperaccumulator plants are used in remediation. Developing nations do not yet have access to discharge limitations for new MPs into the environment. This requires attention so that limitations may be set based on scientific evidence.

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1.1 Introduction

Micropollutants (MPs) are inorganic and organic substances that can adversely impact the environment at very minute concentrations, in the range of micro-, nano-, and pico-grams (μg/L (10^{-6} g/L); ng/L (10^{-9} g/L); pg/L (10^{-12} g/L)) (Chapman 1996). Micropollutants are ubiquitous and are often used to improve human life as they are involved in daily life in the form of pharmaceutical and hygiene kits, pesticides, plastics, endocrine-disrupting chemicals, etc. The general tendency toward urbanization is the increasing number of untreated and treated wastewater, and MPs stay in water. The extensiveness of MPs in aquatic systems is a major worry worldwide. These MPs need disposal with minimum deterioration to the environment and a new generation of MPs, usually called emerging MPs. Wastewater is the standard source of these compounds, and this has generated difficulties among researchers and decision-makers dispensing with water use for household and production of food. These comprise of (a) need to change thought of wastewater disposal, (b) when water tables are intentionally recharged in order to rise volume of water sources, (c) in soil-aquifer treatment systems, (d) reuse of water for consumption and the reuse of wastewater for irrigation, and (e) where water levels are recharged indirectly through this activity. Earlier advances in mass selective detection and chromatographic separation techniques have approved the occurrence of organic micropollutants (OMPs) in environmental matrices (surface water, water table, soil, deposits, biota, and air-born particles), which enable a variety of concentrations to be recognized for some of these contaminants (Hao et al. 2007). Micropollutants are largely categorized into two types based on the nature of MP:

1. Heavy metals (specific density > 4.5 kg/L), for example, cadmium (Cd), lead (Pb), and copper (Cu), or "metal traces," such as iron (Fe) and manganese (Mn), and metalloids like arsenic (As) and vanadium (V). Heavy metals in various soil organic amendments such as compost and vermicompost bound onto organic matter and in convertible or adsorbed form. İn addition, typical chemical forms are, in general, split between soluble and insoluble species in relation to the condition of the metal in the starting materials and nature and chemistry of composting process (Zucconi 1987).
2. Organic MPs (DDT, PCB, PAH, Hormones and EDC, PPCPs, and pesticides) are comprised of a broad spectrum of compounds belonging to different chemical classes and used for many applications. Persistent organic pollutants (POPs) are poisonous, consistent with nondegradability and strong hydrophobicity, can compile in flora and fauna, and have the potential to wide-range move across atmosphere (Cindoruk et al. 2020; Olatunji 2019). The presence and toxicologic impact on environmental and human health of organic MPs have been broadly examined in different environmental spheres (air, soil, and aquatic environment) and food chains (Babut et al. 2019; Montuori et al. 2016; Poté et al. 2008). Three main types of POPs are commonly stated in the environment for many years. They are especially anthropogenically derived compounds involving polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons (PAHs), and organochlorines

pesticides (OCPs). Furthermore, according to the Stockholm Convention 2004 regulations, conservation of the environment and human health from POPs' risk is a high preference. For instance, through a variety of food matrices' (e.g., vegetables, eggs, fish, meat, oils, and milk) usage, these contaminants were stated to induce health impacts such as neurotoxicity, endocrine disruption, cancer, reproductive disorders, leukemia, asthma, and health risks to fetal development (Fernandes et al. 2019; Kim et al. 2017). The POPs are very determined in soil and can affect crop quality and yield. Therefore, many studies stated the organic MP degradation mechanism pathways (such as photocatalytic degradation) and the remediation effectiveness of multielement contaminated soil to minimize exposure, guarantee food safety, and protect human health (Weber et al. 2019; Ye et al. 2020).

1.2 Sources of Micropollutants

In natural and urbanized environments, water resources can be contaminated by organic MPs through an extensive range of pathways, involving agricultural irrigation using wastewater (Calderón-Preciado et al. 2011); inappropriate disposal of expired pharmaceuticals (Tong et al. 2011); use of biosolids or animal excreta to modify agricultural soils (Clarke and Smith 2011); exfiltration of wastewater in sewerage systems (Wolf et al. 2012); and in some cases Arial deposition (Loos et al. 2007); in this perspective, it has been stated that wastewater is the major pathway of organic MPs to enter into the environment (Kümmerer 2008) (Fig.1.1).

The rapid intensification of soil contaminants caused real concern for people living around. Micropollutants attained more consideration in the last couple of decades. They get released from multiple sources such as antibiotics, anti-inflammatories, disinfectants, heavy metals, rare earth elements, iodized contrast media, spillage, leaching from dumps or landfills, endocrinedisrupting chemicals (EDCs), personal care products, pharmaceuticals mainly through domestic sewerage systems, etc. (Hai et al. 2018; Verlicchi et al. 2010). They further enter into the system through urban groundwater.

The dyeing industry is a major water-consuming and dye-utilizing economic sector (Spagni et al. 2012). It is evaluated that more than 50 billion tons of dyes are utilized annually in the process of dyeing, of which ~20% is released directly into aqueous effluent during the coloration process (Yurtsever et al. 2015) (Fig. 1.2).

Landfills are considered a major source of emerging contaminants (ECs). The leachate from the landfills carries organic MPs of anthropogenic origin (Table 1.1). The leachate may carry filtrate comprised of pharmaceutical, cleaning products, disinfectants, flavorings, etc. These ECs are persistent and have been found to withstand the natural attenuation process. Samples from differently aged landfills have highly resistive ECs. Exhaust from vehicles pollutes soil with heavy metals. A sharp rise in heavy metals concentration has been observed in soils of areas adjoining the heavy traffic. The upper layers of soil profile are polluted with high concentrations

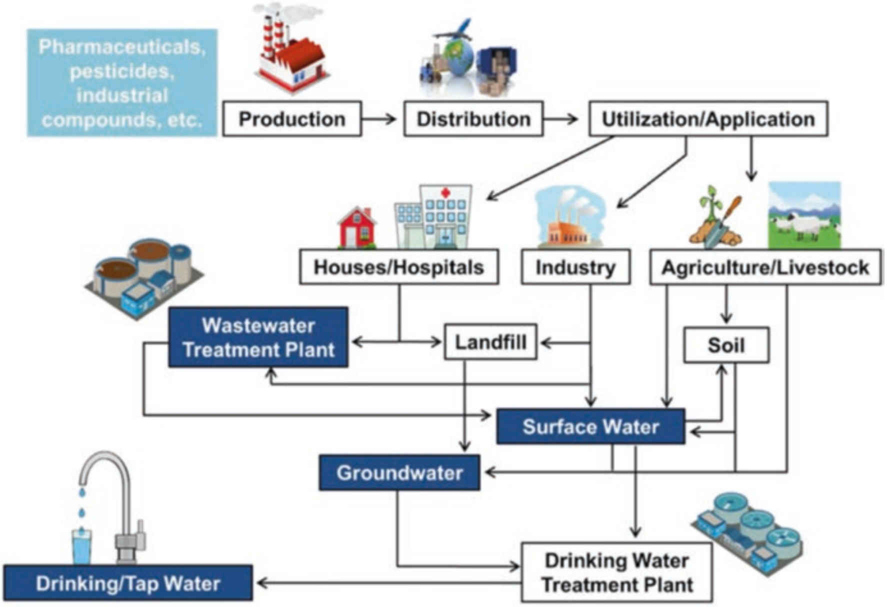

Fig. 1.1 Representative sources and routes of MPs in the environment. (Adapted from Barbosa et al. 2016)

of heavy metals intake mostly by aerogenic sources (Yudina 2017). Studies revealed that soil resists contamination of groundwater resources from contamination of As and Pb. Analysis of soils affected by the Chernobyl atomic reactor accident showed that Cs-137 could only penetrate for a few centimeters after 8 years. This shows that soil also protects the groundwater out of air too. The application of biosolids has been associated with the accumulation of MPs in soil. Application of biosolids from wastewater raised MP levels by 10 times in soil (Andrade et al. 2010). In water-scarce regions, wastewater is used for irrigation of agricultural fields. In developed countries, wastewater is treated and applied to the soil. However, studies revealed that even after treatment, recycled water carries many organic MPs. The level of these compounds gradually increased in the soil posing threat to environmental sustainability (Kinney et al. 2006).

1.3 Sources of MPs in Wastewater

The municipal wastewater comprises of numerous MPs due to anthropogenic activities. These MPs get added to municipal water through domestic and pharmaceutical wastes. The origin of every MP can be traced from sources associated with human activities directly or indirectly. The corrosion of metal surfaces leads to the addition of heavy metals into wastewater. Similarly, use of plastic retardants, etc. also adds

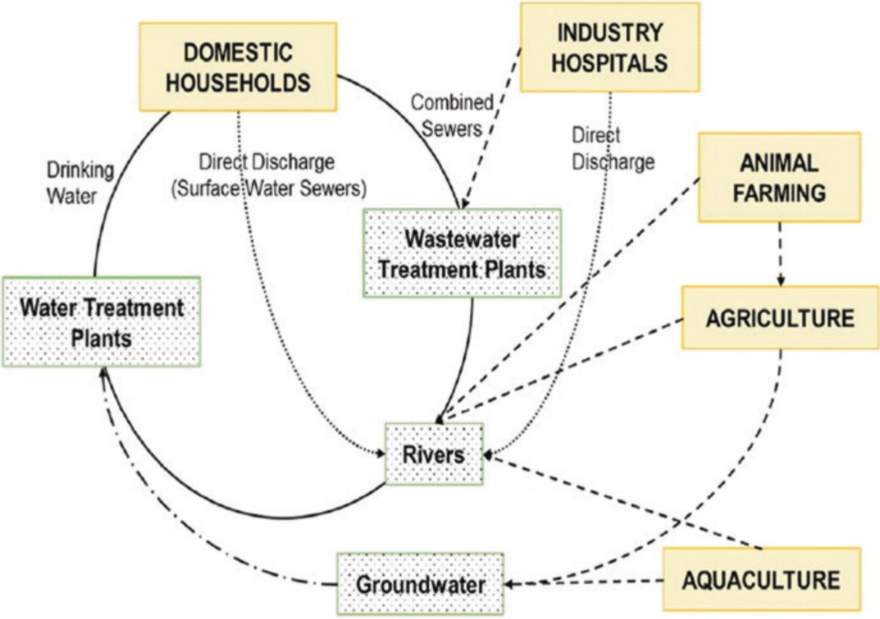

Fig. 1.2 Sources and pathways of MP (PPCPs) in the urban water cycle. (Adapted from Kim and Zoh 2016)

Table 1.1 Anthropogenic sources of inorganic MPs

	Cr	Hg	Sn	Fe	Cu	Mn	Zn	Ni	Cd	Pb
Paperboard, pulp, peppermills, board mills, paperboard, building paper, mills	×	×			×		×	×		×
Petrochemicals, organic chemicals	×	×	×	×			×		×	×
Inorganic chemicals, chlorine, alkalis	×	×	×	×			×		×	×
Fertilizers	×	×		×	×	×	×	×	×	×
Refineries of petroleum	×			×	×		×	×	×	×
Steel work foundries	×	×	×	×	×		×	×	×	×
Nonferrous metal work foundries	×	×			×		×		×	×
Plating and finishing of aircraft and motor vehicles	×	×			×			×	×	
Cement, flat glass, asbestos products	×									
Textile mill products	×									
Leather finishing and tanning	×									
Power plant of steam generation	×						×			

MPs to water. The urine and feces mostly contain MPs from pharmaceuticals, illicit drugs, and hormones. Artificial sweeteners are another important source of pollution in wastewater that enters through excretory products (Table 1.2). Some MPs are released into the wastewater directly. Surfactants, corrosion retardants, and personal care products are part of the MPs that are added directly into the municipal water.

Table 1.2 Origin of MPs, their class, and mode of entry into the environment

Organic micropollutants (OMPs)	Class	Mode of entry
Endocrine disruptive chemicals, personal care products, pharmaceuticals,	Veterinary drugs, cardiovascular drugs (-blockers), blood lipid regulators, psychiatric drugs, analgesics, and antibiotics	Farmland waste, accidental spills, hospital disposal, and discharge
Detergents, surfactants, and per-fluorinated compounds.	Insect repellents, fragrances, steroids, hormones antiseptics, UV filters, synthetic musks, per-fluorooctane sulfonate, Per-fluorooctanoic acid	Soil and groundwater, industrial waste, laundries, households, dispersants, dilutants, and pesticides
Agriculture Flame retardants	Herbicides, pesticides Organophosphorus compounds, organohalogen compounds	Household and agriculture waste, industries, baby products, electronics, furniture, etc.
Additives	Industrial, gasoline	Municipal waste, disposed engine oil
By-products of swimming pool disinfectants	Haloacetic acids, trihalomethanes	Chlorinated human material such as saliva, urine, skin, and hair

Besides these, synthetic chelating products and various industrial products are added into the water directly. The runoff water is contaminated by diffusion of plastic additives, flame retardants, and water-repellant compounds. The corrosion of metal surfaces also leads to the addition of heavy metals into the wastewater. The biocides and pesticides applied in the fields are leached into the runoff water during rain. Aside from this, rainfall is tainted by heavy metals and other persistent organic contaminants. In European countries, wastewater treatment plants (WWTPs) are installed to treat sewage waste of urban areas. Monitoring of the released water from WWTPs showed that it contains MPs. The treatment of water does not eliminate the MPs completely and is a threat to the environment if remains unnoticed for a longer period (Heeb et al. 2012).

1.4 Impacts of MPs

The influence of persistent organic pollutants (POPs) on human health may be highlighted in terms of exposure and the impacts of endocrine disruptors. Exposure to endocrine disruptor chemicals (EDCs) is now recognized to have a larger role in the causation of many more endocrine illnesses and disorders than previously assumed. Female reproductive dysfunction, impacts on male reproductive health, adrenal diseases, and the development of immune system difficulties are examples. Thyroid-related disorders, neurodevelopmental dysfunctions in children, endocrine-associated malignancies, and metabolic and bone abnormalities are further examples (Grob et al. 2015; Hughes et al. 1994; Humans 2010).

Soil is the ultimate host for all chemicals released as a result of anthropogenic activities. However, soil is enabled with a peculiar ability to maintain its natural composition and resist potential changes. In this regard, soil microorganisms have a pivotal role. They help to decompose contaminants and convert them into mobile and available forms for plants. The impact of microorganisms on soil and the environment can be ascertained through the relation of these compounds with soil and water microorganisms. As soil and water depend upon microorganisms for degradation of xenobiotics and ultimate restoration in the natural state, their study is very important. In this regard, soil microbial ecology helps to define the impacts of MPs on the environment and their possible degradation mechanism. The emerging MPs are a potential threat to the biogeochemical cycle, element cycles as well as energy flow of an ecosystem. Microorganisms, specially bacteria, have a variety of mechanisms to interact with xenobiotics. However, there are some species of bacteria that can be used for bioremediation of contaminated soils.

Microorganisms play similar roles in nutrient cycles in groundwater, and they help to attenuate a variety of chemical processes in subsurface ecosystems, such as MPs' breakdown and immobilization, redox cycling, and nutrient transport (Griebler and Lueders 2009). Several novel phylogenetic lineages have been discovered in groundwater environments, indicating that groundwater has a bacterial community capable of degrading xenobiotics and other MPs.

1.5 Xenobiotic Micropollutants

Xenobiotic: Both words are used interchangeably to refer to a man-made substance that is not recognized by the enzyme systems of living organisms and is frequently released into the environment at amounts that produce negative consequences. In recent years, a large number of xenobiotic chemicals have been released into the environment as a result of various industrial and/or agricultural activities. Pesticides, fuels, solvents, alkanes, polycyclic aromatic hydrocarbons (PAHs), nitrogen, and phosphorus compounds are examples of typical organic xenobiotics, whereas hazardous heavy metals are the most common inorganic MPs. Xenobiotic chemicals are substances that are present in living organisms or the environment but are not generated by the organism. Most bacterial strains in soil cope with xenobiotics through breakdown. Pesticide and pharmaceutical degradation characteristics are found in microbes on plasmids and transposons. Horizontal gene transfer (HGT) – also known as lateral gene transfer – or xenobiotic catabolic mobile genetic elements like plasmids allow them to acquire genetic information from comparable or phylogenetically distinct populations in the community. It is commonly assumed that MP-degrading enzymes are developed from isozymes in reaction to industrial production and xenobiotic environmental discharge. Individual cells that are most adapted to resisting or degrading the xenobiotic are selected, and their populations grow in number in comparison to the rest of the microbial community. When a xenobiotic, or organic substance in general, enters the soil, it might be exposed to two fundamental processes (Cheng 1990):

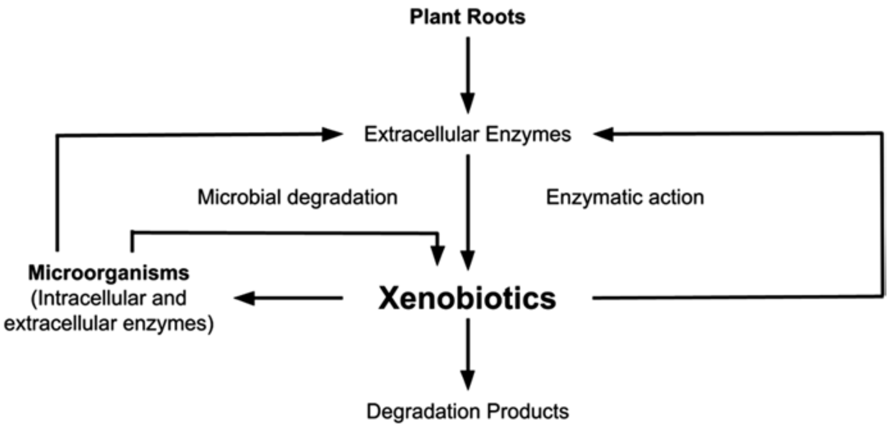

Fig. 1.3 Mutual interactions of xenobiotics with soil microorganisms and enzymes. (Adapted from Gianfreda and Rao 2008)

1. Transfer procedures that move a material without changing its structure. They include adsorption, crop retention, dissolved or sorbed runoff movements, diffusion and vapor-phase diffusion, and sorption and desorption on soil colloid surfaces. Among these processes, the interactions at interfaces between organic and inorganic soil colloids and xenobiotics through sorption/desorption mechanisms are the most important. Adsorption processes allow an organic molecule to be weakly or firmly linked with inorganic and organic colloids. Pure and polluted clays, humic compounds, and humic–clay associations are the abiotic soil components involved in the interaction with xenobiotics. Several of the processes just outlined will be heavily influenced by the existing interactions. They may impact xenobiotic mobility, availability for plant or microbial absorption, transformation by abiotic or biotic agents, and effect on soil activities.
2. Organic chemical degradation processes that change the chemical structure of the organic substances. They happen as a result of chemical, biological, and photochemical changes. Microorganisms, plants, and their enzymatic proteins, whether intracellular or extracellular, are the biotic components engaged in the biological breakdown of xenobiotics and, in general, in their interactions with them (Fig. 1.3).

1.6 Impact of Pharmaceutical MPs on Soil

The impact of pharmaceutical residues on soil flora and fauna is negatively related. It is reported that phenol has negative impact on soil microorganisms. It denatures the proteins formed by the bacteria (Zavarzin and Kolotilova 2001). Application of animal manures produces bacteria in soil that generate antibiotics resistant to these medicines. Later, these resistant genes get transferred to other bacterial strains found in plants and become a potential threat to humans that consume such plants. Genetic changes in bacteria appear on exposure to antibiotics. A study showed that antibiotic tetracycline impacts bacteria at pH 6–7 more actively as compared to pH 8. In soil, tetracycline deteriorates more as it forms complexes with metals and becomes more reactive towards bacteria. The biogeochemical cycles of many elements get disturbed by the action of pharmaceutical contamination of soil. Use of antibiotics for humans, poultry, animals and contamination of soil disturb the natural cycles of sulfate reduction, methanogenesis, and nitrogen (Ding and He 2010). Antibiotics such as glimepiride, glibenclamide, gliclazide, and metformin have been studied for their fate in soil. Drugs with high concentration of polar organic compounds had better sorption capacity. Hence, they were difficult to be biotransformed. They remain in the soil for a longer period and are potential threat to environmental safety. Studies have shown that due to better mobility, metformin is readily decomposed in the soiland has reduced half life. A comparison of sulfonylurea herbicides and their derivative pharmaceutical drugs showed that herbicides have less sorption ability and easier to degrade compared to sulfonylurea drugs (Mrozik and Stefańska 2014). Penicillin is a widely used antibiotic and its effect on cultured microorganisms has been studied. It has adverse impact on bacterial cell wall synthesis. Tetracycline and streptomycin also have an adverse impact on bacteria. They disturb the ribosomal protein synthesis of bacteria (Zavarzin and Kolotilova 2001) (Table 1.3).

1.7 Impact of MP Pesticides on Soil and Soil Organisms

Unjustified use of pesticides on crops and consequent deposition in soil poses threat to soil fertility. These contaminants can adsorb onto soil particles and contaminate soil for a longer period by deposition at the surface. In addition, crop pesticides can also influence soil microbes and disturb their physiological and metabolic processes. In this way, indiscriminate use of these chemicals degrades soil and disturbs the natural biogeochemical and elemental cycle in the environment (Savonen 1997).

1.7.1 Herbicides

- Triclopyr is a common herbicide used in landscape plants. It inhibits bacteria that helps in the transformation of ammonia into nitrate (Pell et al. 1998)
- Glycine/Glyphosate is the world's most frequently used herbicide (Dill et al. 2010). It functions by binding to enzymes and inhibits from the synthesis of aromatic compounds that are essential for bacteria and fungi. It is polar and has high sorption affinity in soil that makes it immobile. However, it is not persistent and can be transformed to aminomethylphosporic acid. Glyphosate adversely

Table 1.3 Micropollutants' application and their peculiar characteristics

Micropollutants	Applications	Characteristics
Carbamazepine	Anticonvulsant	Potential ecotoxicity, water-persistent in environment, degradation in sewage treatment plant, low removal efficiency on wastewater treatment plants (WWTPs).
N,N-Diethyl-m toluamide (DEET)	Insect repellent	Persistent in environment, little data about detection in aquatic environment, toxic for freshwater invertebrates, birds, and fish
2-Methylthio-benzothiazole (MTBT)	Stabilizers or fungicide in production of rubber	Sources include industrial plants, tire debris
Triphenyl phosphate (TPP)	Hydraulic fluid and flame retardant	Possibly neurotoxic, bioaccumulation, toxic effect to aquatic organisms
Tris(2-chlorethyl) phosphate (TCEP)	Plasticizers and flame retardants	Classified in the European Union as potential human carcinogen, nonbiodegradable, hazardous, toxic to aquatic organisms
Tris-(chlorpropyl)-phosphate (TCPP)	Flame retardants	Bioaccumulation potential, hazardous, readily biodegradable
Fluoranthene	Pyrene and fluoranthene like other PAHs form during combustion	Among the PAHs, persistent organic MPs, slow environmental degradation, bioaccumulation potential, toxicity, priority substances
Lidocaine	Local anesthetic, antiarrhythmic drug	Low potential for bioaccumulation
Caffeine	Psychomotor stimulant	High solubility in water, high stability under varied environmental conditions
Tonalide, Fixolide, (AHTN)	Polycyclic musk, chemosensitizers	Bioaccumulation potential
Galaxolide 50, Abbalide (HHCB)	Polycyclic musk, chemosensitizers	Bioaccumulation potential
Triclosan	Antibacterial and antifungal agent	Bioaccumulation, aquatic toxicity
Pyrene	Found in many combustion products	Among the PAHs, persistent organic MPs, toxicity, bioaccumulation

affects microbial population of soil. However, most microorganisms can tolerate its impacts using many functions such as rapid detoxification.

- Chloroacetamide includes metolachlor and acetochlor, which have different methods of detection (Table 1.4). They are commonly used herbicides that function in soil through inhibition of elongase enzyme. These enzymes play various important functions in bacteria and fungi (Rose et al. 2016)
- Sulfonylurea and Imidazolinone are used in cereal crops at relatively low concentrations. They act for inhibition of acetolactase synthase enzyme that is present in microorganisms. Application and deposition of this herbicide are expected to negatively impact microbes (Boldt and Jacobsen 1998).

- Triazines, phenylureas, and amides kill plant through disrupting photosystem ll. However, they are only expected to kill photosynthesizing microbes and have no such direct link with non-photosynthetic bacteria and fungi. Nevertheless, the mobile nature of these herbicides is a potential threat for off-site damage of other soil organisms.
- Phenoxycarboxylic acids are like the shape of auxins. They mimic the auxins and disrupt important roles played by them. One of the most significant roles of auxins is the facilitation of plant microbial association. So, the application of such herbicides can potentially affect association and disturb soil ecology.

Table 1.4 Group of chemical substances and analytical methods available

Group of substances	Analytical methods available		
Old organochlorines	GC-MS	LM-MS	GC-ECD
Chlordane	×		
PCBs	×		×
Metoxychlor	×	×	
HCHs	×		
Hexachlorobenzene	×		
Heptachlor	×		
Endrin	×		
Endosulphan	×	×	
Dieldrin	×		
DDTs	×		
New pesticides			
Alachlor	×	×	
Trifluralin	×	×	
Simazine	×	×	
Isoproturon		×	
Diuron		×	
Dicofol	×	×	
Chlorpyrifos	×	×	
Atrazine	×	×	
Chlofenvinphos	×	×	
PAHs			
Priority set and/or individual PAHS	×	×	
Old organochlorines			
BRFs, PBDEs, HBCD, TBBP-A	×	×	
Pentachlorobenzene	×		
hexachlorobutadiene	×		
Endocrine disruptors			
NP/NPEOs and related substances		×	
Dibutyl and diethylhexyl phthalate	×		
Octylphenol		×	
PFOS		×	

- Dinitroanilines such as trifluralin and pendimethalin halt cell mitosis through prevention of tubulin elongation. They hinder plant growth. However, not only eukaryotes but prokaryotes also divide using tubulin proteins (Löwe and Amos 1998). Microbes depending on tubulin cannot divide after interaction with Dinitroanilines.

1.8 Interaction of MPs and Sustainable Agriculture

Worldwide MPs are of great concern and they are present in various forms such as heavy metals, gases, volatile organic compounds, loud sounds, over-dumped places, excessive use of chemical fertilizers, pesticides, automobiles, and many others forms.

These MPs are involved in acute environmental changes. Changes caused by environmental MPs involve a variety of factors, such as: land degradation, water scarcity, damage to plants, food famine, biodiversity, climatic changes, etc. Agriculture is playing a noteworthy role from many decades in the economy and survival of humans. It is considered the backbone for many countries. Agriculture is a source of livelihood, revenue, economic development, foreign exchange, food supply, fodder for animals, raw materials, etc. Micropollutants are emerging contaminants that contain anthropogenic as well as natural substances. These MPs are leaving their impact on the environment as well as on agriculture. Continuous emissions of gases such as chlorofluorocarbon, carbon dioxide, lead, carbon monoxide, etc. causes the continuous rise in climatic changes. Emissions of gases are depleting the ozone layer and increase the temperature of the atmosphere. Excessive rise in temperature damages growth and yield of crops. It is damaging the soil, specially the areas with low annual rainfall. Excessive rise of temperature is another reason for drought conditions. It affects soil conditions, causing land degradation, erosion, etc.

Emission of sulphur and nitrogenous gases is the reason for acid rain, which affects soil and damages crops. Industries such as pharmaceuticals, pesticides manufacturers, etc. are emitting gases on combustion and dump their waste in water. The MPs are the reason for water scarcity for useful purposes. It is impossible to use the contaminated water for production of crops because it affects the yield of crops. This contaminated water also affects the soil nutrients' availability and microbial activities. Excessive concentration of nitrate that results because of nitrogen and oxygen is the reason of eutrophication. Its damages aquatic life and contaminates water. Excessive nitrate concentration makes the water unavailable for agricultural and household purposes.

MPs are an important issue to solve worldwide. It is affecting the land and atmosphere leaving its impact on agriculture. It is affecting our efforts of sustainable agriculture. These MPs are the reason for food scarcity in many areas, leading future generations to hunger, poverty, poor health, and economic losses. These problems can be solved by minimizing the use of sprays, organic fertilizers, pesticides, etc.; there is a need for awareness to avoid this problem.

1.9 Interaction of MPs and Microbial Activities in Soil

Microorganisms account for <0.5% of soil mass. These organisms are a major footprint for most soil properties and processes. About 60–80% of soil process and metabolism activities occur due to microflora. Microbial activities play a noteworthy part in the transformation of MPs. Microorganisms have the ability to control MPs and release useful chemical compounds. Microorganisms play a key role in the cycling of nutrients and their formation. Microbial activities are involved in a variety of processes, such as: nitrification, nitrogen fixation, carbon mineralization, nutrient availability, etc. Microorganisms commonly present in soil are bacteria, fungi, actinomycetes, protozoa, algae, etc. These organisms in soil help to control quality, depth, moisture, structure, and properties of soil. Most of the external factors, such as climate, topography, pollution, bedrock, etc., affect microbial activities. The interaction among multiple factors is responsible for variation in microbial activities and soil. Microorganisms decompose MPs present in soil and transform it to nutrients or organic compounds.

Pollutants are emerging contaminants involved in environmental changes. These MPs are leaving their impact on the microbial activities. Micropollutants allow the conversion of a large amount of nitrogen through the process of denitrification, ammonification, etc. Conversion of nitrogen will lead to the emission of sulfur dioxide and sulfur compounds that will result in acid rain. Acid rain reduces nutrient availability and soil processes. It results in soil erosion and ecological imbalance. It affects the microbial activities because of erosion and changes in soil process. Acidification impacts soil fertility and causes death of microorganisms responsible for the microbial activities in soil. Increase of salinity in soil is linked with the MPs present in soil. Deposition of nitrate and phosphorus because of irrigation and agricultural process results in increased salt concentration in soil. Rise in salt concentration affects microorganisms' growth and their activities which will result in growth of crops and reduce groundwater quality. Soil MPs result in water pollution. When chemicals such as heavy metals leach down the groundwater, it affects microbial growth and their activities. For proper functioning of microorganisms, it is important to provide favorable conditions. For proper microbial activities, it is important to reduce MPs' concentration from the soil.

1.10 Interaction of MPs and Human Health

Micropollutants are emerging contaminants that contain anthropogenic as well as natural substances. These MPs are leaving their impact on the environment as well as on human health. Humans always interact with environment on daily basis. This interaction between humans and the environment results in pollution, global warming, deforestation, etc. These problems have a major impact on the human health.

Pollutants present in the atmosphere are causing human health problems such as:

- Increase the chance of respiratory diseases.
- Risk of developing asthma problems.
- Increase the respiratory inflammation.
- Reduce lungs' functioning.
- Damage reproductive system and endocrine system.
- Commonly show wheezing and coughing.
- Increase risk of heart failure.
- Increase the risk of developing cancer.

Pollutants present in water are causing human health problems such as:

- Cancer development
- Hormone's disruption
- Rashes
- Hepatitis
- Damage reproductive system
- Damage immune system
- Damage respiratory system
- Cause heart problems
- Cause kidney failure
- Cause typhoid
- Cause polio and cholera

Pollutants present in soil are causing human health problems such as:

- Headache, vomiting
- Breakdown of central nervous system
- Cough, pain in chest
- High chances of developing of cancer
- Irritation of skin and eyes
- Damage to kidney
- Damage liver
- Muscular blockage

These all problems are caused by MPs present in the environment. These all problems are reducing the lifespan of humans. It is important to resolve these problems to reduce the risk of human health.

1.11 Strategies for Management of MPs

Micropollutants are of great concern worldwide. Changes caused by environmental MPs involve variety of factors, such as: land degradation, water scarcity, damage to plants, food famine, biodiversity, climatic changes, etc. Micropollutants also cause a major impact on human health. Management practices are required to reduce the risk of MP. There are different practices that are performed to reduce the risk of micro-pollution such as forest buffer (trees, shrubs, grasses) should be planted across the streams and banks of rivers. It will help to reduce pollution in water. It will reduce the risk of temperature increase.

Hydrochars produced through hydrothermal carbonization (pistachio shells) are a sustainable and efficient replacement to activated carbons for the removal of MPs from wastewaters that are difficult to treat using traditional methods. For the investigation of caffeine/hydrochars aqueous systems, a combined experimental and molecular simulation method is used. This case study is used to fine-tune a generic framework for rationally customizing surface functional groups on hydrochars for the selective adsorption of MPs from wastewaters (Román et al. 2018).

1.11.1 Air Pollutants

Air pollutants' control strategies involve two categories:

- Control of emission
- Control of gaseous emission

There are many methods and instruments used to control the emission from air, such as:

- Cyclone collector
- Wet scrubber
- Settling chamber
- Filtration devices
- Electrostatic precipitation

1.11.2 Water Pollutants

Water pollution may be controlled using a variety of methods and equipment, including:

- Physical method
- Chemical method
- Biological method

Many methods and equipment are used to reduce water contamination through physical processes, such as:

- Infiltration
- Screening
- Sedimentation
- Flotation

Many methods and equipment are used to reduce water contamination through chemical processes, such as:

- Chemical precipitation
- Adsorption
- Disinfection reaction

1.11.3 Solid Pollutants

There are many methods and techniques to control solid MPs such as:

- Landfilling
- Incineration
- Composting

These all are modern and most used methods for the reduction of MPs. These problems can be solved by minimizing the use of sprays, organic fertilizers, pesticides, etc.; there is a need of awareness to avoid this problem.

1.12 Conclusion

Micropollutants are of great concern worldwide as they are sublethal to the environment and living organisms on the planet. A wide range of toxic effects of MPs affect the organisms at cellular level. Changes caused by MPs involve a variety of factors, such as land degradation, water scarcity, damage to plants, food security, biodiversity, etc. Micropollutants also cause a major impact on human health. It is important to reduce problem for the better survival of mankind. Reduction of pollution is beneficial in many ways such as prevention of MPs will minimize the greenhouse gas emissions. Traditional bioremediation approaches such as phytoremediation, biostimulation, and bioaugmentation might all play a significant role. It leads to sustainable environment for ages by remediating the agricultural soils and limiting the MPs. In some situations, a mix of biological and chemical treatments may be advantageous to achieve optimum remediation efficiency. It reduces the finical cost (waste management and cleanup cost) and environmental cost (health problems and environmental damage). Reduction of environmental MPs is important for future generations, for their health and better life. Developing nations do not yet have access to discharge limitations for new MPs into the environment. This requires attention so that limitations may be set based on scientific evidence. To estimate the related pathophysiological risk to humans and other creatures, it is critical to determine the toxic effects of MPs in organisms using specialized and suitable assays at each level of biological organization. A comprehensive and cost-effective method for detecting and analyzing MPs and their metabolites in environmental samples is desperately needed. As a result, there is a need for a revised risk assessment methodology that incorporates consolidated toxicity data generated from systematic research in determining acceptable limits to safeguard human and ecological health.

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