SRI VENKATESWARA INTERNSHIP PROGRAM FOR RESEARCH IN ACADEMICS (SRI-VIPRA)

Project Report of 2022: SVP-2210

"Impact of Microplastics on Soil Structure"

IQAC
Sri Venkateswara College
University of Delhi
Dhaula Kuan
New Delhi -110021

SRIVIPRA PROJECT 2022

Title: Impact of microplastics on soil structure

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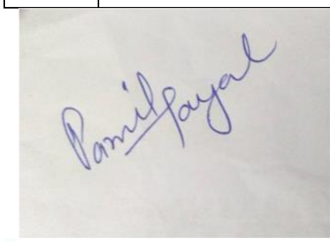
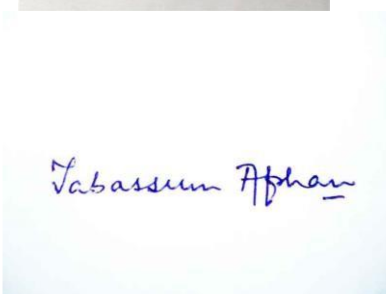
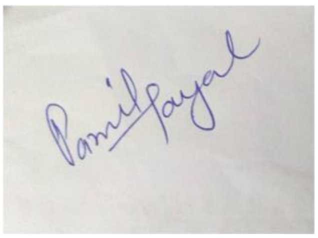




Signature of Mentor(s)

Certificate

This is to certify that the aforementioned students from Sri Venkateswara College have participated in the summer project SVP-2210 titled "Impact of Microplastics on soil structure ". The participants have carried out the research project work under my guidance and supervision from 21st June 2022 to 25th September 2022. The work carried is original and carried out in an online and offline mode.



Signature of Mentor(s)

Sri Venkateswara College

University of Delhi SRIVIPRA-2022

(Sri Venkateswara College Internship Program in Research and Academics)

This is to certify that this project on" **Impact of Microplastics on Soil Structure**" was registered under SRI-VIPRA and completed under the mentorship of Prof./Dr./ Mr./Ms. **Dr. Pamil Tayal and Dr. Tabassum Afshan**----- during the period from 21st June to 7th October 2022.

Sharda Pasricha and S. Krishna kumar

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Prof. C Sheela Reddy

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CONTENTS

MICROPLASTICS IN THE ENVIRONMENT

INTRODUCTION:

Plastics are composed of long-chain organic synthetic or semi-synthetic polymers (https://www.thoughtco.com/plastic-chemical-composition-608930). PET, PP, PE, and PS are the most common polymers used in plastics. Plastics are easy to manufacture, durable, available in all shapes and sizes, non-reactive, lightweight and insulators. These properties of plastics lead to their exponentially increasing demand worldwide. However, the biggest concern regarding plastics is their non-biodegradable nature. Almost all plastics manufactured to date persist in the environment. Plastic entities having a size smaller than 5mm are called microplastics. Based on origin, microplastics are classified as primary or secondary microplastics. Plastics having a size <5mm at the instant of their entry into the environment are termed primary microplastics. Secondary microplastics are formed from the fragmentation of larger plastic items. Photodegradation via UV light is the primary agent participating in the generation of secondary microplastics in association with chemical (oxidative) and physical degradation. Tyre abrasions and plastic fibres (from fabrics and fishing nets) form the biggest source of microplastics in the environment. Improper plastic waste management is the ultimate cause of the release of microplastics into nature. Once released into the environment, it becomes almost impossible to collect them back and efficiently reuse/ recycle them on a large scale. Hence microplastics are smaller plastic fragments, they inherit/retain most of the chemical and physical properties of plastics. Microplastics are chemically inert, but they provide surfaces for a variety of matter to the binding. This may include pesticides, metals, hydrocarbons, PBTs and POPs. These are often by nature bioaccumulants, toxins or carcinogenic. Microorganisms over time form biospheres on the microplastic surface. These may contain many pathogenic microbes. Exposure to microplastics is therefore directly proportional to increased exposure to these harmful entities adhered to microplastics.

Microplastics are an invisible threat that will escalate exponentially if current trends in plastic waste management and climate change continue. Potential impacts on human health are a concerning consequence of these microplastics invisibly present all around us. It becomes therefore necessary to analyse the consequences that these microplastics have on our bodies and ecosystem. This text summarizes the level of microplastics presents around us in the environment.

MPs in Air

Microplastics mark their presence in the air around us. Microplastics less than 5 um in size can settle deep inside the lungs. Larger microplastics present in the air might be too big to be inhaled but they can be ingested. Microplastics are also reported to be present in both indoor and outdoor dust. Suspended MPs can directly enter our bodies simply by inhalation and can persist in our lungs resulting in increased risks of respiratory irritation, interstitial lung disease, tumours and inflammation (Gasperi et al., 2018; Borm et al., 2000; Warheit et al., 2001; Greim et al., 2001). (Vianello, A., et. al., 2019) used FPA-μFTIR-Imaging analysis (Focal Plane Array-Fourier Transform-Infrared-micro-spectroscopy) to estimate the level of microplastics in indoor air in Denmark apartments. Similar to microplastics in water, airborne MPs are also capable to adsorb harmful substances (polycyclic aromatic hydrocarbons, metals, dyes, unreacted monomers, additives and pigments) onto their surface. The study found the levels of microplastics in indoor air can be as high as 16.2 p/m-3 which corresponds to an inhalation rate of 11.3 MP per hour. Indoor air was estimated to contain on Average 9.3 MPs/m-3. Synthetic MPs present in indoor air are primarily constituted by polyester (59–92%) followed by polyethene (5–28%), nylon (0–13%), and polypropylene (0.4–10%) and other polymers. https://www.nature.com/articles/s41598-019-45054-w

(Catarino, A.I., et. al., 2018) based on experiments in the UK, estimated that a mealtime inadvertent human consumption of airborne fibres can result in an exposure of between 13,731 and 68,415 particles/y/person. According to Dris et al. (2017), urban dust fallout can include 33 per cent microplastics, making it a potential source of MPs for human exposure, including through ingestion (Dehghani et al., 2017; Dris et al., 2017). With estimated rates of indoor dust intake ranging between 2.2 mg/d for teens to 41 mg/d for toddlers, younger children are particularly in danger of eating microplastics via dust and airborne fibres (Wilson et al., 2013). When compared to significantly greater amounts of exposure through ingestion of home dust, the risks to human health from MP consumption through shellfish are negligible. https://scihub.st/10.1016/j.envpol.2018.02.069

Pauly et al. (1998) showed that 87% of the studied lungs (n = 114) contained fibres. The length of the fibres was mainly around 50 um but could reach a length longer than 250 um. Textile fibres constituted the major microplastic in an indoor environment. (Dris, R., et. al., 2016) used Fourier Transform Infrared (FT-IR) microspectroscopy for the chemical characterisation of the fires. Indoor concentrations range between 0.4 and 59.4 fibres/m3 with a median value of 5.4 fibres/m3. With a median value of 0.9 fibres/m3, outdoor concentrations vary from 0.3 to 1.5 fibres/m3. One study in the winter that was done following a rainfall resulted in 5 times more fibres being caught on the filter, proving that rain causes the fibres to be washed down. Concentrations of fibres in the dust collected in the apartments in Paris from vacuum cleaner bags vary between 190.0 and 670.0 fibres/mg. https://sci-hub.st/10.1016/j.envpol.2016.12.013

(Brahney, J., et. al., 2020) analysed the deposition of atmospheric microplastics in protected areas in the US under wet and dry conditions. Fibres originating from textiles form the major constituent of outdoor atmospheric microplastics. Additionally, during the drying process for laundry, fibres are directly released into the atmosphere at rates that are several times higher than those that are released into wastewater during the washing process (Pirc, U., et. al., 2016; Duis, K. et. al., 2016). These fibres are then carried to protected areas during favourable wind speeds and trajectories. The mean plastic deposition rate in the western protected areas of the US was found to be 132 plastics/m2/day. Approximately >1000 tons of plastic from the atmosphere are delivered to western protected areas in the United States, including national parks and wilderness areas, each year. This is equivalent to ~120 to 300 million plastic water bottles. The author suggests that although urban centres may be the initial source, plastics accumulate in the atmosphere over long periods, are transported long distances, and are deposited during favourable conditions, such as slower air-mass velocities or intersections with mountain ranges. https://sci-hub.st/10.1126/science.aaz5819

(Abbasi S., et. al., 2018) studied street dust and suspended dust collected from the city and county of Asaluyeh, Iran. Samples were characterized by various microscopic techniques (fluorescence, polarized light, SEM) to quantify and classify MPs and micro rubbers (MRS) in the urban and industrial environments that are potentially ingestible or inhalable by humans. average of 900 MPs and 250 MRS per 15 g of sample were found in 5-mm street dust collected from 15 locations, with MPs displaying a variety of colours and sizes (1000 mm). The majority of street dust samples were mostly spherical and film-like particles, while the majority of MRS contained fibrous particulates and black fragments of various sizes. Estimates of acute exposure by ingestion are between 5 and 15 MP d-1 and between 2 and 7 MR d-1 for construction, respectively, based on the median concentrations in street dust. https://scihub.st/10.1016/j.envpol.2018.10.039

(Klein, M., Fischer, E. K., 2019) based on experiments in the outdoor air concluded microplastics are vastly present in the atmospheric deposition of the Hamburg metropolitan area. A total number of 2625 microplastic particles were found in the sampling area, resulting in a median abundance of 275 microplastics/m2 /day. The dominant shape of microplastics was fragmented, making up 95% of the total particle amount. The samples from the six different sampling sites varied in their microplastic contamination, with median concentration spans ranging from 136.5 to 512.0 microplastics/m2 /day. All six sites under investigation have different population densities and levels of forestation and infrastructure, suggesting an influence of dust emissions and the comb-out effect of e.g., forest canopy on microplastic contamination. https://scihub.st/10.1016/j.scitotenv.2019.05.405

(Allen, S., et.al., 2019) recorded MP deposition at a field site in a remote, pristine mountain catchment (French Pyrenees) equates to an average daily MP deposition of 365m–2d–1 (±69, particles ≥5μm). Relative daily counts of 249 fragments, 73 films and 44 fibres per square metre deposited on the catchment were recorded by the researchers. This deposition was compared to previous atmospheric fallout monitoring undertaken in high-density urban areas and identified a daily fallout of 110±96 and 53±38 particles m–2d–1 (Paris) and 228±43 particles m–2d–1 (36 MP particles m–2d–1 confirmed) (Dongguan). Despite its distant and mountainous location, which is a significant distance from urban city growth or infrastructure, the Pyrenees field site MP deposition is equivalent to the reported megacity atmospheric MP deposition. Microplastics are transported through the atmosphere for a distance of up to 95 kilometres, according to the research on air mass trajectories. The authors suggest that microplastics can reach and affect remote, sparsely inhabited areas through atmospheric transport. https://scihub.st/10.1038/s41561-019-0335-5

Found that the annual site deposition flux of atmospheric microplastics attained a maximum of 1.46×105 n/(m2 a), that of the fibres up to 1.38×105 n/(m2 a), and those of the fragments, films and foams up to 6.29×103, 7.65×102 and 2.45×102 n/(m2 a), respectively. Deposition fluxes of different shape types ranged from 0.0 to 6.02×102 n/(m2 d), and the fibres were also the commonest of the four shape types. The seasonal variation in the microplastic deposition flow was larger in the spring, summer, and winter and lower in the fall. The distance between the observation site and the coast (1.6 km), the length of the urban coastline in Yantai (100 km), and the annual deposition flux used in this study were used to estimate the total amount of microplastics deposited in the urban area, which was estimated to be 2.331013 particles or 0.9 to 1.4 tonnes. The authors suggest that atmospheric microplastics, through precipitation to land and sea, be a key source of microplastics in the coastal and oceanic environments. https://www.sciengine.com/CSB/doi/10.1360/N972017-00956;JSESSIONID=59a870c5-635e4a36-a0f8-aa174a7a25bc

<u>MPs in Water</u>

Microplastics are found in seawater and drinking water. The MP concentration was found to be 140 ± 19 p/L in single-use plastic-bottled water and 52 ± 4 p/L in glass-bottled water. Plastic bottles had a significantly higher MP quantity than the latter. Both 6.5–20 μm and 20–50 μm MPs showed significant dominance over the ≥50 μm fraction. Fibres accounted for 62.8% of the total particle content, followed by fragments. Under optical microscopy, ≥50 μm particles were 10 ± 1 p/L (on average), which did not differ largely from that of fluorescent-tagged particles in the same size range (12 ± 1 p/L), implying the suitability of both techniques to sort ≥50 μm MPs. https://sci-hub.st/10.1016/j.scitotenv.2020.137232

Research shows the microplastic concentration in the water bodies associated with developing countries is more than in other regions of the globe. This is explained by the mismanagement of plastic waste. The type of polymer varied among water bodies of developed and developing countries. The order of freshwater pollution in six continents was as follows: Asia> Europe> North America > South America > Oceania. China is the most polluted country in the world having the highest concentration of microplastics. Coastal tourist destinations act as hotspots of microplastic pollution. In India, Mumbai’s Juhu beach with the largest recreational activities was found to have the highest quantity of microplastic pollution (Jayasiri et. al., 2013). The average microplastic abundance is recorded to be highest in Maharashtra (46-343 items/m2) followed by

Karnataka (21-155 items/m2) and Goa (17-96 items/m2) (Maharana et. al., 2020). Polyethene dumping by people and pilgrims outperformed other kinds and the highest quantity of 389 pieces of polyethene/kg beach sediment was found in samples of the Mariana beach, Chennai (Tiwari et.al., 2019). Microplastics act as carriers for water-borne pathogens and also many opportunistic pathogens. Microplastics may also carry exotic species of microbes, this disturbs the natural food web of that ecosystem and may lead to the extinction of some species.
https://www.ijesonline.co.in/wp-content/uploads/2022/07/Tayal-et-al.-65-76.pdf

Tap waters in many parts of the world have MPs (IUCN, 2021). 82% of taps in New Delhi (India) supply water contaminated with MP fibres (Kosuth Mary, et. al., 2018). Plastic containers used for storing food and beverages also degrade (in negligible amounts) to release MPs. Analysis of bottled water across the world shows PP, the material used to make bottle caps happens to be the major MP constituent and PET was also found to be present significantly in bottled water (Tyree and Morrison, 2018).

MPs in Soil

The average abundance of microplastics in vegetable farmland in a suburb of Wuhan ranges from 320 to 12,560 items/kg (Chen et al., 2020). Microplastic pollution also occurs in the agricultural land of Nanjing and Wuxi. In Hangzhou Bay, microplastic concentration in the mulching cropped soils is much higher than that of non-mulching crops. On a worldwide scale, microplastics have been found in soil across Asia, Europe, North America, Africa, and Oceania. Microplastic abundance varies from almost none to tens of thousands per kilogram across different samples. Soil is potentially a sink of microplastics from various sources, but the types and amounts found in it can reflect local uses and artificial activity nearby or atmospheric deposition. The Kenilworth Park and Aquatic Gardens in Washington, USA, had a tidal freshwater wetland with a similar quantity of microplastics (1, 270 150 items/kg) (Helcoski et al., 2020). The Lahn River floodplain in Germany (1.88 1.49-8.59 items/kg), Franconia roads (0.34 0.36 items/kg), Mayan home gardens in Southeast Mexico (0.87 1.9 items/g), catchments and the textures of the floodplain soils in Switzerland (55.5 mg/kg), and the Lahn River floodplain in Germany all have low concentrations of microplastics (Huerta Lwanga et al., 2017a; Piehl et al., 2018; Scheurer and Bigalke, 2018; Weber and Opp, 2020). A high microplastic concentration of between 8.7 × 10^3 items/kg and 1.4 × 10^4 items/ kg is observed in biosolid samples collected from Ontario, Canada. the majority of the present microplastics are fragmented among others, which accounts for 86% of microplastic particles in agricultural soils of Spanish (van den Berg et al., 2020). Fragments are also found numerically dominant in mulching farmlands in Shihezi City (80.6%), cultivated soil of the whole Yunnan Province (80.6%), Hangzhou Bay plain (52.3%), and Wuhan City (51.3%) (B. Huang et al., 2020; Y. Huang et al., 2020; B. Zhou et al., 2020; Zhou et al., 2019). Microplastic fragments are easily associated with plastic packaging and plastic waste. That is, large plastic debris can be broken and decomposed into microplastic fragments with the force of mechanical abrasion, ultraviolet radiation, and biodegradation. According to a laboratory weathering experiment, PP pellets may yield about 6084 particles after two months of mechanical abrasion and a year of UV exposure (B. Zhou et al., 2020). Moreover, plastic bags and bottles used for pesticides and fertilizers are found to be common around farmland, which probably contributes significantly to the sources of fragmented microplastics in the soil. Fibre is the predominant form in both soil and sludge samples from Chile, indicating that sewage sludge discharge has resulted in the buildup of microplastics in agricultural soils (Corradini et al., 2019). Fibres are also the dominant shape found in the soil of Washington, DC (77–94%), Dian Lake (92%), and Nanjing and Wuxi (42–87%), which are likely closely connected to the increasing production of synthetic fibre (clothing, upholstery, or carpet). Fibrous and fragmented microplastics occupy a similar proportion in soil collected from Tianjin, China (Han et al., 2019). However, in Franconia, southeast Germany, floodplain areas of the Lahn River, and the northeast part of the Tibetan Plateau, the film occupies a considerable proportion of all microplastics (Feng et al., 2020; Piehl et al., 2018; Weber and Opp, 2020). These films are possibly linked to plastic mulching and plastic packaging. Plastic mulching has become a global agricultural practice. It has been used in some areas for more than 30 years, which can potentially be a major source of microplastics in cultivated land (Y. Huang et al., 2020). For other shapes, in an abandoned salt field in Shandong Province, China, microplastic pellets (76.3%) are far more abundant than other forms (Zhou et al., 2016). These pellet particles are related to personal care products including cosmetics and cleaning products, and they are also the masterbatch of products including industrial pellets (Xu et al., 2020). Moreover, a new class is built for “fibre balls” as fibres are often entangled into a ball. Such a type of fibre ball consists of fibres of several colours and usually appears in bundles (Weber and Opp, 2020).

https://www.sciencedirect.com/science/article/pii/S0048969721016144#s0055

Microplastics enter farms through sewage sludge that has been processed and utilised as mulch, fertiliser, or even purposefully applied as slow-release fertilisers and seed coatings. There have been worrisome potential effects of this pollution on many facets of agricultural systems, from soil quality to human health, in only the last few years, thanks to an increase in studies.
https://www.ehn.org/plastic-in-farm-soil-and-food-2647384684/sewage-sludge-mulch-andslow-release-fertilizers

The use of agricultural fertilisers and fish meals may have caused the concentration of microplastics in paddy soils to dramatically rise from the non-rice period (12.1 items kg-1) to the rice-planting season (27.6 items kg-1) (Lv et al., 2019). Recently, it was shown that microplastics may reach the terrestrial ecosystem through organic fertilisers. For instance, the compost used mostly in conventional farming and gardening included 14-895 microplastic particles kg-1 (about 50%) dry weight (Weithmann et al., 2018). Microplastics' source is directly tied to their form and makeup. In soils modified with sludge, wastewater, and agricultural fertilisers, for instance, fibres are regularly monitored (Corradini et al., 2019; Lv et al., 2019; Zhang & Liu, 2018); other pieces, flakes, or films are mostly produced by the fragmentation or breakdown of plastic wastes (Piehl et al., 2018; Zhou et al., 2018). Because PE and PP are the most popular plastics in the world, PE and PP are the predominant kinds of microplastics present in soil (Andrady & Neal, 2009).
https://www.tandfonline.com/doi/full/10.1080/10643389.2019.1694822

TECHNIQUES FOR IDENTIFICATION AND ANALYSIS OF MICROPLASTICS

In many cases, before separation of microplastics there is a need for purification of the sample. This is a vital step when the microplastic is covered by biogenic organic matter which does not allow visual identification.The methods proposed in this report include freshwater rinsing, ultrasonic cleaning and the treatment with various chemicals. Although if you are using chemicals to separate microplastics from biological material, extra caution should be exercised. The chemicals could alter the characteristics of the microplastic leading to misidentification or could even dissolve the sample required especially in the case of fibres. For example, treatment with hydrogen peroxide (30%) is effective in removing biogenic organic matter from microplastics. This is especially important for fibers, which can undergo large changes due to their large surface area. In many cases when performing surface-based identification techniques, simply scraping the plastic surface with a scalpel is sufficient. However, this is probably not practical for small items.

When identifying microplastics a few things should be kept in mind. The diameter of the fibre should be uniform and no bends should be observed as bends might indicate biological origin. No organic structures should be observed. But sometimes the absence of organic structures and bends leads us to mistake antennae of organisms and plant fibres as microplastics. However, we cannot exclude all such ambiguous samples as it will lead to biased results. Thus, a highmagnification microscopic examination, scanning electron microscope (SEM), fluorescence microscopy and staining techniques should be used to determine that the items are microplastics.

Visual identification is a very important technique. It follows the guidelines of a system known as standardised size and colour sorting (SCS) system. and the selection of an appropriate identification method is determined by the number of samples and the size of the desired microplastics affects the selection an appropriate identification method. After correct identification we can use the SCS system to sort, segragate and categorize the microplastic.

The SCS system has a total of 5 steps:

STEP1: <u>CATEGORY</u>

Plastics according to the measurement along their longest dimension are sorted into the following categories.

Macroplastic (MAP) ≥25mm

Mesoplastic MEP <25mm–5mm

Plasticle PLT <5mm

Microplastic MP <5mm–1mm

Minimicroplastic MMP <1mm–1μm

Nanoplastic NP <1μm

STEP2: <u>TYPE</u>

Sorting on the basis of appearance for plastics smaller than 5mm is still required.

PT Pellet <5 mm–1 mm

MBD Microbead <1 mm–1 μm

FR Fragment <5 mm–1 mm

MFR Microfragment <1 mm–1 μm

FB Fibre <5 mm–1 mm

MFB Microfibre <1 mm–1 μm

FI Film <5 mm–1 mm

MFI Microfilm <1 mm–1 μm

FM Foam <5 mm–1 mm A

MFM Microfoam <1 mm–1 μm

STEP3: <u>COLOUR</u>

Microplastics are segregated on the basis on their colour and given abbreviations like; Any colour - ALL, All opaque - AO, All transparent - AT, Amber - AM, Blue - BL etc.

STEP4: <u>POLYMER</u>

After segregation by color, the plastics are analysed by appropriate methods and techniques to determine the type of polymer. After determination, each plastic is given a polymer abbreviation. For example: Acrylonitrile-butadiene-styrene is ABS, Acrylate-styrene-acrylonitrile is ASA, High-density polyethylene HDPE, Poly(p-phenylene ether) is PPE, Poly(p-phenylene oxide) is PPO and Cellulose acetate is CA.

STEP5: <u>QUANTITY</u>

Finally we note down the quantity of each categorised microplastic.

Each piece of plastic should now have an SCS code which identifies the category, exact size (optional), type, colour, type of polymer and the quantity of plastic pieces.

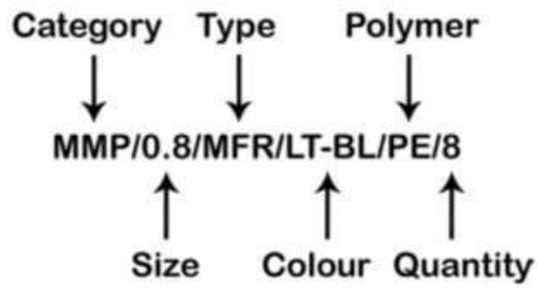


Figure 10.2 The standardised size and colour sorting (SCS) system coding method.

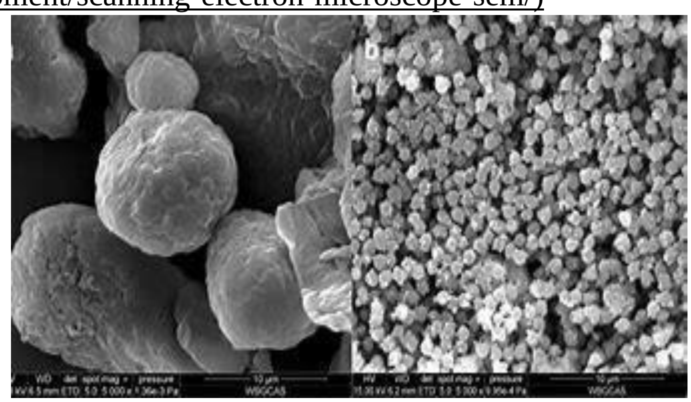
DOI:10.1016/B978-0-12-809406-8.00010-4

Microplastic identification techniques (researchgate.net)

SCANNING ELECTRON MICROSCOPE

The scanning electron microscope (SEM) uses a focused beam of high-energy electrons to generate a variety of signals at the surface of solid specimens. The signals that derive from electron-sample interactions reveal information about the sample including external morphology (texture), chemical composition, and crystalline structure and orientation of materials making up the sample.

(https://microimaging.utdallas.edu/equipment/scanning-electron-microscope-sem/)



PE (image on left) and PVC (image on right) https://www.researchgate.net/figure/SEM-images-of-polyethylene-PE-a-and-polyvinylchloride-PVC-particles-b_fig1_342342275

FUNDAMENTAL PRINCIPALS OF SEM

Accelerated electrons in an SEM carry significant amounts of kinetic energy, and this energy is dissipated as a variety of signals produced by electron-sample interactions when the incident electrons are decelerated in the solid sample. These signals include secondary electrons (that produce SEM images), backscattered electrons (BSE), diffracted backscattered electrons (EBSD that are used to determine crystal structures and orientations of minerals), photons (characteristic X-rays that are used for elemental analysis and continuum X-rays), visible light (cathodoluminescence--CL), and heat. Secondary electrons and backscattered electrons are commonly used for imaging sample.

Scanning electron microscopy can be used to analyse the physical characteristics of microplastics recovered from environmental samples, as well as to determine their physical size and the specific dimensions of any surface features. Thus, based upon the surface morphology, a scanning electron microscope (SEM) can help distinguish a plastic item from a non-plastic item.

STRENGTHS

Easy to operate and minimal sample prep. Data acquisition is very fast.

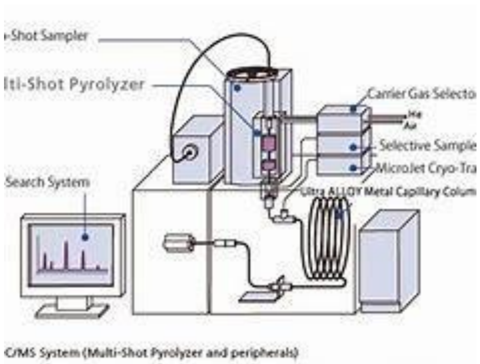
LIMITATIONS

Sample must be solid and should be able to fit into the microscope.

Scanning Electron Microscopy (SEM) (carleton.edu)

Pyrolysis–gas chromatography–mass spectrometry (Pyr-GC–MS)

Pyrolysis–gas chromatography–mass spectrometry (Pyr-GC–MS) is a technique which thermally decomposes the large high-molecular weight molecules of a sample into smaller low molecular weighted molecules. The technique needs as inert atmosphere to function. The molecular composition is determined by mass spectrometry (MS). T his helps us identify the sample as we get an insight into the structure and make of the large high-molecular weight molecules.



As such, the technique can be utilised for the identification of microplastics in environmental samples, as well as simultaneously identifying any plastic additives present. However, since samples must be manually placed in the instrument and analysed individually, the analysis of large quantities of microplastics is limited, as well as the range of sizes of items which can be effectively handled. https://scientificservices.eu/item/analytical-pyrolysis-py-gcgcms/1538

STRENGTHS

Minimal prep of sample and direct analysis is possible. No organic solution is required as in the case of traditional GC-MS.

LIMITATIONS

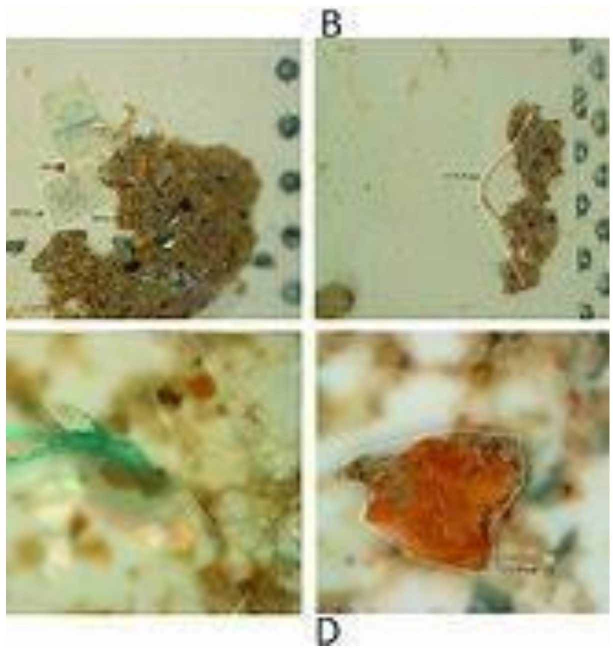
Since this technique involves the thermal breakdown of the sample it could be problematic in cases where further analysis of the sample is required.

Only small quantities of sample can be analysed.

Fourier-transform infrared (FTIR) spectroscopy

Fourier transform infrared (FTIR) spectroscopy is the most popular and widely used technique for reliably identifying the plastic types that make up microplastics in environmental samples. It is straightforward, reliable and highly accurate when in comes to identification of plastics. It differentiates between plastic and natural materials by an infrared spectra which has distinct band patterns. The technique's main principal is that most molecules absorb light in the infrared region of the electromagnetic spectrum.

Infrared spectroscopy involves illuminating a sample with infrared light of specific wavelengths and examining the transmitted light to derive the amount of energy absorbed by molecules at each wavelength, thereby providing information about the molecules present in the sample. By measuring the absorption of infrared radiation at various frequencies, an absorption spectrum can be generated that can provide information about the molecular structure of the sample. The infrared spectrum contains a series of absorption peaks corresponding to different vibrational frequencies between atomic bonds within the molecules of the sample. No two plastic materials produce the same IR spectrum because different types of plastics have unique combinations of atoms. Therefore, the FTIR spectrum is unique for each plastic type and can be used to uniquely identify the plastic types that make up the microplastics. However, infrared spectroscopy can present challenges in terms of sample preparation. For example, to use transmission techniques, the sample must be sufficiently transparent to allow infrared wavelengths to pass through the sample. This is not achievable with most polymers.



https://www.researchgate.net/figure/FTIR-spectroscopy-spectra-of-the-microplastics-1-mm-5mm-collected-in-the-small-islands_fig6_331061303

AN ALTERNATIVE FOR FTIR: **Attenuated Total Reflectance (ATR)**

As a technique for analyzing only the surface of plastic samples, ATR only requires that the sample be in close enough proximity to a small crystal made up of germanium (Ge), diamond, or zinc selenide (ZnSe). Upon contact with the crystal, an evanescent wave propagates through the crystal surface into the surface of the sample. Therefore, the main requirement for ATR is that the sample is in sufficient contact with this crystal so that infrared radiation can penetrate the sample. This can be achieved by using clamps to press the sample against the crystal. However, ATR is not a completely perfect technique and has some problems. For example, the material to be analyzed should have a refractive index lower than that of the crystal. Otherwise infrared light will be lost in the sample. Moreover, the degree of contact between the sample and the crystal directly affects the intensity of the observed bands. This is because shorter wavelengths cannot penetrate deeper into the sample. Importantly, signals from CdH, OdH and NdH oscillations are represented in this region and as a result can go unnoticed when insufficient pressure is applied. Additionally, it is important to apply enough pressure so that air is not trapped between the sample and the crystal. This forces the evanescent wave to pass through the sample rather than the trapped air. For this reason, instrument software typically displays a manometer in the user interface that provides feedback on the amount of clamp pressure being applied. The clamps can then be adjusted until the displayed pressure is within the recommended range to generate a suitable spectrum. However, handling and clamping of microplastics smaller than 500 µm can be difficult, and as a result, spectra for microplastics of this size are not always reliable.

Near-infrared (NIR) and short-wavelength infrared (SWIR) spectroscopy

Plastics can also be distinguished by irradiation with light in the near-infrared (NIR) and shortwave infrared (SWIR) (750-3000 nm) regions of the electromagnetic spectrum. When exposed to NIR light, the individual molecules of the plastic material absorb this electromagnetic radiation, producing molecular overtones and bond vibrations. As a result, plastic materials can be identified based on the differences in the characteristic CdH, NdH and CdO bands normally observed in these types of materials. This technique has the advantage that NIR spectroscopy can penetrate deeper into plastic materials than his FTIR spectroscopy, but the technique is not particularly sensitive. However, it is useful for examining bulk samples of plastics without the need to perform sample preparation to quickly identify the types of plastics present.

NIR Spectrometer https://sites.wustl.edu/planetaryspectroscopy/facilities/nir-mir-spectroscopy-laboratory/

Impact of microplastics on - Biodiversity

Physical and chemical anthropogenic influences on the Earth System has achieved a level comparable to that of natural geophysical processes. Consequently, human activities are among the most significant drivers of ecosystem functions and biodiversity threats. Microplastic pollution is perhaps one of the most widespread and long-lasting anthropogenic changes to the surface of our planet. In fact, microplastic pollution was identified to be among the most relevant topics for biodiversity conservation at global scale (Machado et al., 2017).

Microplastics are bioavailable to organisms, being detected in diverse organisms ranging from bottom preys to top predators and critically endangered species, including Asian clams, numerous fish species in the Amazonian stream, gentoo penguins from the Antarctic region and seabirds, Mediterranean small-spotted catsharks in the southern region of the central Mediterranean Sea, and North-East Atlantic Porbeagle sharks. Hence, microplastic pollution will continue to pose progressively greater risks to biota and potentially biodiversity and ecosystem processes in the future, being a global change factor concerning ecotoxicology (Agathokleous et al.,2021).

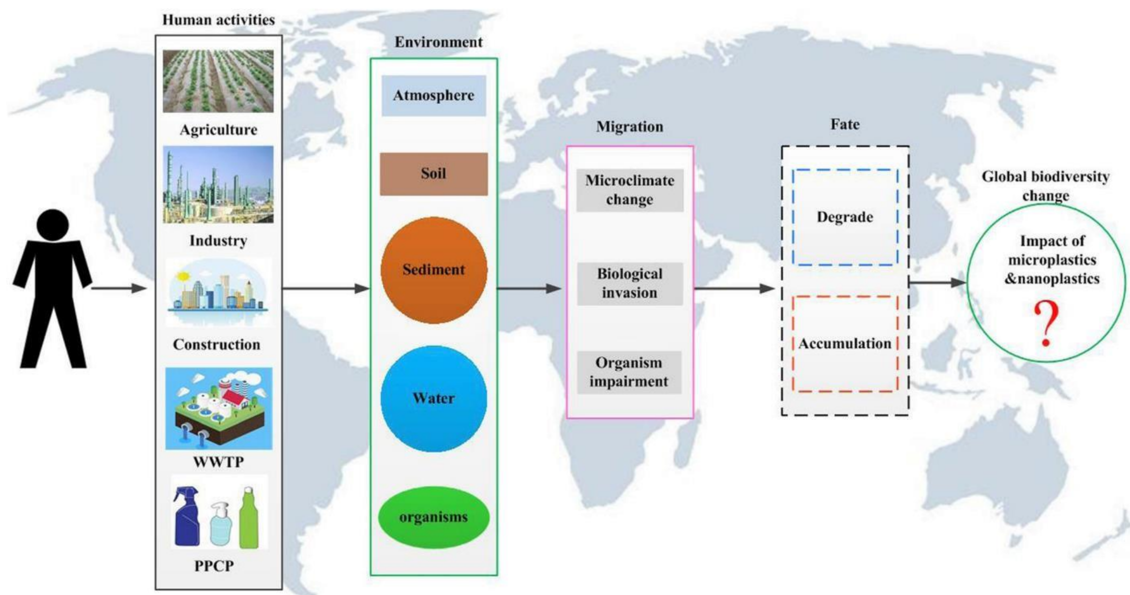


Fig. 2. Sources and occurrences of microplastics in the environment and their potential impacts on global biodiversity changes (Hu et al, 2019).

Soil

Microplastics enter soil via multiple sources, including landfills, soil amendments, land application of sewage sludge, wastewater-irrigation, compost and organic fertilizer, residues of agricultural mulching films, tire wear and tear, and atmospheric deposition etc. The presence of microplastics severely reduces soil quality, and the migration and trophic transfer of microplastics in heavily contaminated soils, particularly those in wastewater-irrigated and plastic-film covered areas, pose substantial risks to the ecosystem (Guo et al., 2019).

Effects of MPs on farmland ecosystems are different under different soil types and fertilization histories. Exposure to MPs could reduce the pH of acid soil but increase the pH of alkaline soil. Different fertilization histories could alter effects of MPs exposure on composition, structure, and function of soil microbial communities (Li et al.,2021).

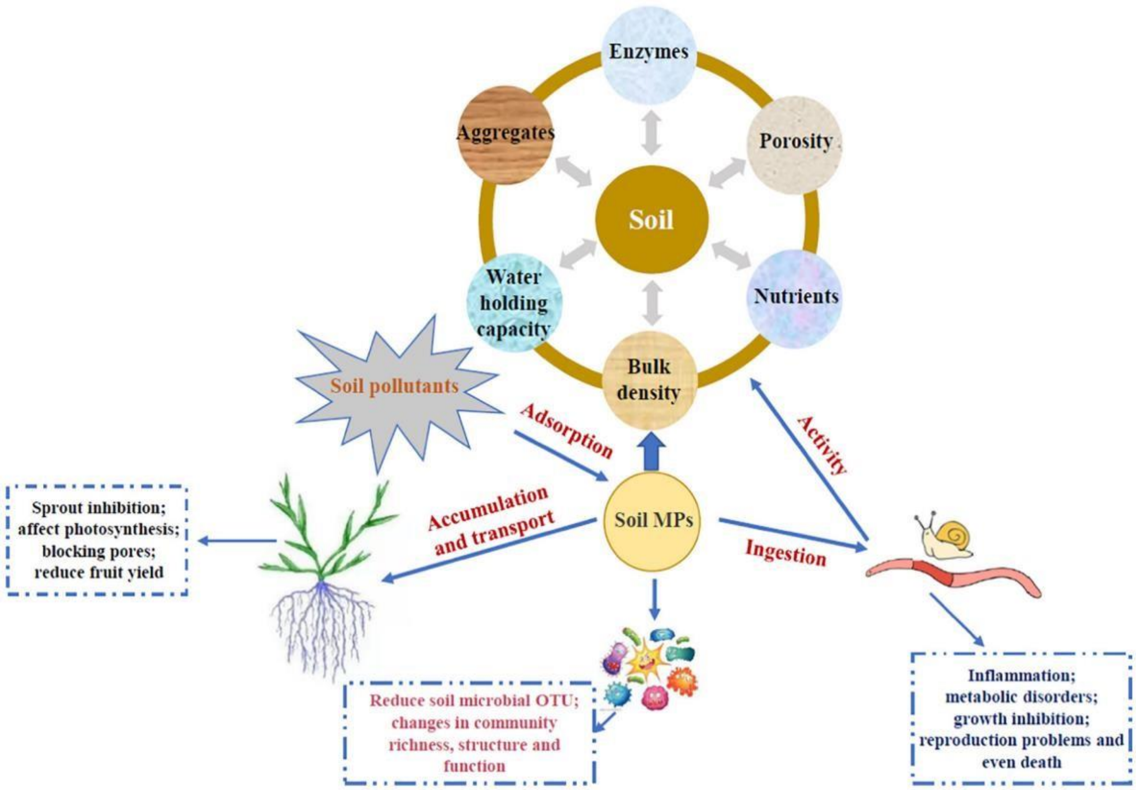


Fig. 3. The impact of microplastics on soil health and function (Ya et al, 2021).

Fish Population

Microplastics have been reported in all marine environments including the ocean surface, water column, deep sea and coastal sediments from the remote habitats in the Artic to the Antarctic Oceans (Bessa et al., 2018). In fish, MP have been found to cause physical and physiological defects, such as false food satiation, tissue damage and decreased swimming performance. However, despite the range of sub-lethal effects reported, the effects of MP on fish behaviour remain poorly understood. For example, while MPs have been reported to cause lethargic and erratic swimming behaviours in the European seabass, *Dicentrarchus labrax*, other studies found no significant effects on fish behaviour.

In fish, ingestion of non-nutritive elements, such as MP, and their subsequent accumulation in the digestive tract can lead to malnutrition and intestinal damages. Exposure to MP has also been reported to inhibit acetylcholinesterase (AChE) activity in fish. Such inhibition of AChE activity can adversely affect the nervous and neuromuscular function, resulting in a decrease in swimming activity (Jacob et al., 2019). In addition to their neurotoxicity, microplastics can increase cellular oxidative stress, by affecting antioxidant defense responses and consequently leading to lipid peroxidation (LPO) of cellular membrane (Barboza et al., 2019).

Microbiome

Microbes are comparatively abundant in the natural ecosystems, which may contain over hundreds of millions of bacterial organisms per unit volume. The abundance of microorganisms plays an important role in ecological systems, including substance metabolism, product formation, and trophic cycling. MPs could change the composition of microbial communities depending on the physical properties of the soil. For example, the phyla of Bacteroidetes, Proteobacteria, and Gemmatimonadetes were enriched in polyethylene-amended soil, which may contribute to the potential changes in soil DOM (Dissolved organic matter) content, bulk density, and soil moisture (Wang et al., 2021).

Microplastics provide a unique habitat for microorganisms, which promote adherence of microorganisms on their surface. However, microplastics might have a selective effect on microorganisms to promote growth of select bacteria. Microplastics can produce toxic substances, such as phthalates, during the degradation process, which have a toxic effect on microorganisms. Therefore, it is possible that only selected bacteria experience a growth advantage due to the presence of microplastics, and the remaining bacteria may be more negatively affected by microplastics (Li et al., 2020).

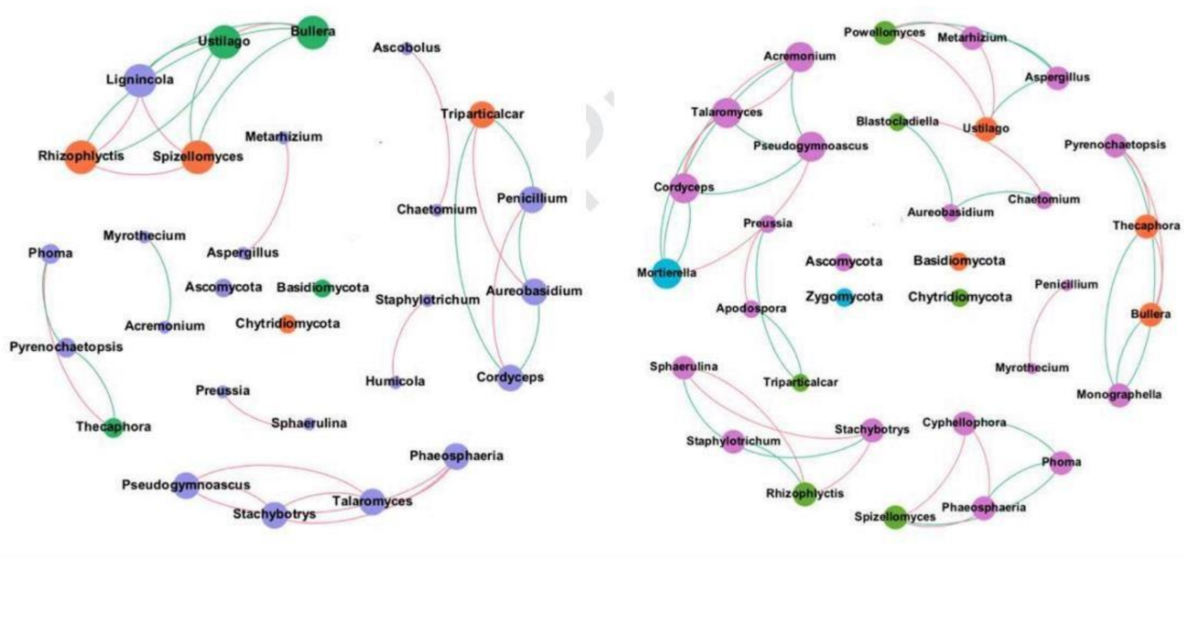


Fig. 4. Bacteria and fungi genera in soil with MPs (Ren et al., 2019).

Effects of microplastics on climate change

The term "microplastics" (MPs) refers to plastic particles with a diameter of less than 5 mm. These materials include primary MPs that are produced at the microscale (such as commercially available microbeads used in industrial cleaners and personal care products), as well as secondary MPs that start out as larger fragments or degrade into micro sizes. (20)

The probability that plastics will infiltrate the environment is increased by their massive manufacturing, broad use, and improper management. Plastics have accumulated in land, lakes, and oceans for many years because they are difficult to organically degrade. Over the past ten years, people's awareness of and concern about the emergency plastics catastrophe in the environment, particularly microplastics and nano plastics, has grown. The unavoidable contribution of plastics to global greenhouse gas emissions and climate change is emerging in this expanding issue. (10)

The widespread presence of plastics in the ocean can have a negative impact on carbon fixation. Marine plants and animals play a key role in the microbial carbon pump, which captures carbon from the atmosphere and transports it to the depths of the ocean to prevent it from re-entering the atmosphere Evidence suggests that plastic pollution reduces the ability of phytoplankton to fix carbon through photosynthesis (10)

Zooplankton transfer carbon to the deep sea and metabolic rates, reproductive success, and survival rates can all be affected by plastic pollution. Additionally, microplastics have the potential to disrupt the primary food web and marine food chain (11). Currently, climate change and eutrophication are significant environmental concerns. In eutrophic lakes, climate change increases the severity of microplastic pollution and sediment resuspension, but the presence of microplastics and resuspension events would also increase the severity of these two environmental effects (12).

In freshwater environments, two patterns of microplastic toxicity have been postulated. Firstly, because of their microscopic size and irregular structure, they directly harm freshwater ecosystems. Microplastic induce physical and histo-physiological harm to aquatic creatures can have a significant impact on population abundance changes, densities, and quantities. Secondly, they have a strong capacity to adsorb heavy metals and organic contaminants from the surrounding water environment, which can have detrimental consequences on freshwater ecosystems. Since the various toxicity patterns are linked to various harmful consequences and mechanisms, they must to be taken into account when evaluating environmental risks and human health. (20)

Microplastic pollution is a new stressor that puts more pressure on coral reef ecosystems, which are already under pressure from climate change. The combined effects of plastic pollution and global warming, on the other hand, are largely unknown. Corals' thermal tolerance can occasionally be harmed by microplastic. However, microplastic is a minor harm in comparison to heat stress. Treatment with microplastic particles have adverse effects on coral reefs as in the physiology, health, algal symbionts to lose photosynthetic efficiency, bleach, necrosis, and mortality. (13)

Microplastics largely could harm agroecosystems and other terrestrial ecosystems worldwide. Microplastics in soil and their negative effects on soil health and fertility have raised concerns in recent years. They are present in nearly all soil types, including agricultural, industrial, urban, and unused soils, but their abundance, type, shape, and size vary. Most of the time, they can alter the physical, chemical, and microbiological properties of soil. Changes in the availability of pollutants and soil fertility caused by microplastics may threaten crop productivity, safety, and plant performance. Particularly, they have an impact on the release of greenhouse gases from soil, which ultimately has uncertain effects on global climate change (14).

Microplastic contamination of the environment is now regarded as an emerging threat to ecosystem function and biodiversity. Although the effects of microplastics on soil ecosystems (such as those above and below ground) remain largely unknown. Varied biophysical response of the soil are observed to various kinds of microplastics such as biodegradable polylactic acid (PLA), conventional high-density polyethylene (HDPE), and microplastic clothing fibres. Adverse effects like reduced seed germination, stunted shoot height, lesser biomass, decreased pH of the soil, size distribution of water-stable soil aggregates changed, indicating potential changes in the stability of the soil (15).

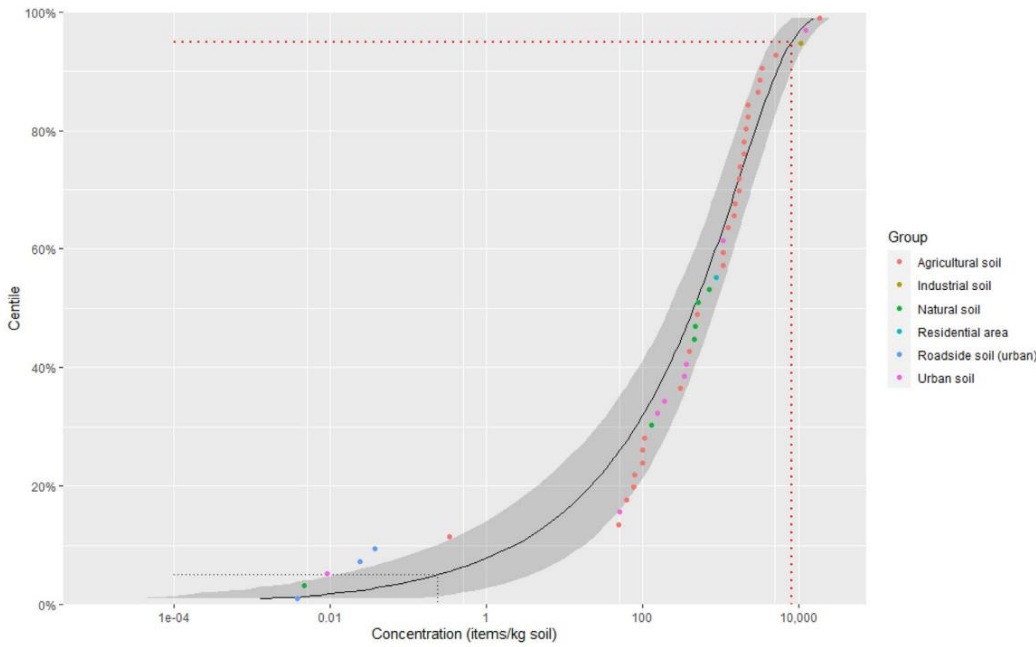


Fig. 2. Environmental exposure distribution of the concentration of microplastics (items/kg of soil) in different types of soil using data reported in the literature. The red dotted line represents the 95th centile of the distribution. The gray shaded area around the distribution is the 95% confidence interval of the distribution (Gamma distribution: scale = 5838.7601875; shape = 0.3074675). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

(16)

In order to address the potential ecological and human health risks posed by microplastics in soil, there are trophic transfer in food chains, migration of microplastics into the soil, soil ecotoxicity, adverse effects on the health and function of the soil, and adverse effects on soil organisms (plants and microbiota) (17).

In agricultural soil fields, the accumulation of microplastics can not only cover up the storage of soil organic carbon (SOC), but it can also affect how microbial decomposition produces carbon dioxide (CO2). However, little is known about how this new pollutant affects soil CO2 emissions and the SOC degradation-functional genes abundances related to starch (sga), hemicellulose (abfA, manB, and xylA), cellulose (cex), and lignin (lig and mnp) degradation. Low doses (0.01% and 0.1%) of virgin and aged Microplastics has negligible effects on SOC decomposition in comparison to soils without MPs; however, a high dose (1.0%) of microplastics significantly (p 0.05) accelerated the production of CO2 in soils by 15–17%, with a dose-dependent effect. Soil dissolved organic carbon and microbial biomass carbon were unaffected by microplastics' presence. At a concentration of 1.0 percent MP, a higher metabolic quotient indicated that the microbes remain under stress and require more substrates and energy for their metabolic processes, which may account for the increase in CO_2 emission caused by this dose of microplastics. (18)

Strategies for Mitigation of Plastic and Microplastic Pollution

Ten proposals are made for stakeholders to reduce plastic pollution, including (1) regulating production and consumption, (2) eco-design, (3) increasing demand for recycled plastics, (4) reducing the use of plastics, (5) using renewable energy for recycling, (6) extending producer responsibility over waste, (7) improving waste collection systems, (8) prioritising recycling, (9) using bio-based and biodegradable plastics, and (10) improving recyclability of e-waste. Such suggestions, arranged according to priority, are made to lessen the impact of (micro)plastic on the environment during manufacturing, consumption, and disposal are necessary to immediately implement.

Long-term measures include the following: a. Using renewable energy during waste collection and recycling to reduce the environmental impact of recycled plastics; b. Implementing LCA for each product and process to improve eco-design (including reuse, repair, and recyclability), taking into account expected end-of-life of products; c. Using bio-based plastics to reduce the environmental impact of fuel-based plastics; reducing production of harmfully biodegradable plastics. (19)

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