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***Review Article*;**

Microplastic in the agro-ecosystem

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A B S T R A C T

The pollution of the Earth-system by microplastics (MPs) has attracted the scientific community's attention during the last decade due to the ability of MPs to alter the soil and agronomic lands properties and affect the soil flora and fauna, and thus via food chain may harm human health. The current review attempted to survey several previous studies to demonstrate the possible sources of MPs in soil characterised as primary and secondary sources depending on the way MPs are generated. Most of MPs released from these sources ended into the soil and can emigrate within soil profile, which negatively affects several physiochemical soil properties, soil biota, and plants that may alter biodiversity and agronomic land productivity. The bioremediation of MPs-polluted terrestrial environment using some microorganisms is an optimum economic and eco-friendly technology. This review is a first step to help researchers identify the main sources and effects of MPs pollution in Libyan farmlands to stand up on the current levels of these substances in soil and suggest future strategies to avoid possible harm impacts of MPs pollution over our country.

البلاستيك دقيق الحبيبات فى النظام البيئى الزراعى

سالم رحيمه سالم رحيمه

جذب تلوث النظام البيئي الأرضي بالبلاستيك دقيق الحبيبات (الميكروبلاستيك) اهتمام الوسط العلمي خلال العقد الماضي، والسبب يرجع إلى قدرة هذا البلاستيك على إحداث تأثيرات سلبيه مختلفة على بعض خصائص الأراضي، وخاصة الزراعية، ويؤثر على النباتات النامية فيها وعلى ما تحتويه من كائنات حية كالطحالب والفطريات والديدان والحشرات الأرضية، ويتراكم في أنسجتها و بذلك تصل تأثيراته السلبية للإنسان عبر السلسلة الغذائية، وتهدف هذه الورقه و ذلك من خلال دراسة بعض الأبحاث المسحية والمعملية في مجال تلوث البيئة الأرضية بالبلاستيك دقيق الحبيبات إلى تحديد مصادر تلوث التربة بذلك البلاستيك، والتي صُنفت على أنها مصادر أوليه وثانوية، تبعاً لطريقة تكون الحبيبات وطريقة وصولها للتربة، فقد أوضحت تلك الدراسات أن معظم الحبيبات البلاستيكية التي انبعثت من هذه المصادر تصل للتربة، ولها القدرة على التنقل فيها عمودياً وافقياً، وبذلك تؤثر سلباً على بعض خصائصها الفيزيوكيميائيه، وعلى بعض كائنات التربة الحية والنبات النامي فى التربة الملوثة بالبلاستيك دقيق الحبيبات، وهذا قد يؤثر سلباً على إنتاجية الترب الزراعية، والتنوع الحيوي في البيئة الأرضية. وتُعد المعالجة الحيوية للترب الملوثه بالبلاستيك دقيق الحبيبات تقنية واعدة، وذلك باستخدام بعض الأنواع من الأحياء الدقيقه، فقد أثبتت هذه الأنواع من الميكروبات قدرتها على تفكيك البلاستيك حيوياً بأقل كلفة اقتصادية، وأقل إضرار بيئية، وتعتبر هذه الدراسة خطوة أولى للتنبيه وجذب انتباه الباحثين في ليبيا لمزيد من العمل لتحديد وجود البلاستيك دقيق الحبيبات ومصادره وتركيزه بالترب الليبية لتلافى تفاقم هذه المشكلة في بلدنا مستقبلا.

1. INTRODUCTION

The demand and daily use of plastics increased dramatically during the last few decades, reaching 359 million tonnes in 2018 and will probably rise to 33 billion tonnes by 2050 (Chen *et al*., 2021). The increase in the use of plastic is related to its several unique properties, such as flexibility, extreme durability, buoyancy, corrosion resistance, light weight and cost-effective material (Xu *et al.,* 2020). Consequently, the disposed plastics into landfills recorded 60 % to 80% (215.4 – 287.2 million tons) of the manufactured amount of plastic in 2018, leading to an increase in the level of plastic pollution worldwide (Miloloža *et al.*, 2021). Plastics can be formed naturally, such as natural rubber, others are synthesised from several products of crude oil distillation such as polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), high-density polyethylene (HDPE), low-density polyethylene (LDPE), polyacrylonitrile (PAN), polyester (PES), polyamide (PA), polystyrene (PS), polyacrylic acid (PAA) and polyethylene terephthalate (PET) and others may be manufactured from some natural products such as polylactic acid (PLA) and Bio-starch plastic (sBio) (Zhang *et al.*, 2020; Du *et al.*, 2021; Irhema, 2021). One of the most hazardous plastics are microplastics (MPs) which are frequently defined as plastic pieces with size less than 5 mm (Cózar *et al.*, 2014), but some researchers advised modifying this definition by narrowing the size of MPs to range between 1-100 µm (Xu *et al*., 2020). MPs may enter the environment through two main sources, directly or indirectly. These small particles are utilised in the manufacture of several cosmetics and abrasives in detergents can inject into the ecosystem directly through the generated effluents of these industries, or it may be realised indirectly into the ecosystem due to the degradation of large plastic waste (e.g., domestic wastes including plastic bags, bottles and children's toys) by the effect of ultraviolet radiation, environmental conditions and/ or microbes. Some industries such as clothes factories, which can fragment MPs mechanically and discharge them into the ecosystem (Qi *et al.,* 2020; Yang *et al.,* 2021). Once MPs are presented in different environmental mediums (soil, water bodies and atmosphere), thus MPs may be distributed with different levels in the food chain accordingly, they can reach the human body causing severe health issues (De-la-Torre, 2020). Additionally, the pollution by plastic and particularly MPs is an important factor contributing to the decrease of global biodiversity and therefore affecting food security (Rillig, 2012). In the soil, the MPs pollution recently proposed by Rillig (2012), and according to Xu *et al*. (2020), since 2012 this issue has been attracted the consideration of the scientific community, thus the number of research on the pollution of soil by MPs have increased with time as they recognised that soil is an important sink of MPs due to receiving an amount of MPs by 4 - 23 times larger than water bodies and nearly 79% of plastic waste is ended into landfills. Qi *et al.* (2020) stated that, several studies reported high levels of PE, PP and lower concentrations of PVC and PET, and levels of other hazardous substances used as additives to improve plastic quality have been found in soils worldwide, even in agricultural soils that have never received any amount of fertiliser or used agriculture plastics. Most of the studies investigated the MPs pollution in soil were carried out in China (Wang *et al.,* 2020). Thus, the occurrence and impacts of MPs in soil ecosystem are not fully investigated yet globally, and still a gap of knowledge in the field of terrestrial environment and agronomic lands polluted with MPs (Qi *et al.*, 2020; Zhao *et al.,* 2022). Therefore, the current review attempts to address this issue by; (1) demonstrating the occurrence, major sources and migration of MPs in soils; (2) addressing the effects of MPs pollution on several soil properties; (3) illustrating the main ecological effects of MPs on soil fauna and flora, and (4) discussing briefly the most effective technique used to remediate MPs-polluted soils.

2. Sources and occurrence of MPs in soil

Wang *et al.* (2020) reported that human density and habits influence the source and presence of MPs in the terrestrial environment and agriculture soils; therefore, China is categorised as the main manufacturer and consumer of plastic worldwide leads to raising MPs pollution in this country. For instance, the levels of MPs recorded 1.3 – 14713 particles/kg in soil collected from the coastal of Bohai and Yellow seas in China (Zhang and Liu, 2018). Also, Liu *et al*. (2018) reported that the concentration of MPs in soils collected from co-cloture of fish-rice farm and vegetable fields just outside Shanghai contained 10.3± 2.2 and 78.8 ± 12.9 pieces of MPs/kg, respectively. Generally, the sources of MPs in the soil are classified into two categories depending on the way that MPs generated and entered the soil environment (Ding *et al.*, 2022; Kumar *et al.*, 2020; Xiang *et al.*, 2022), these sources are:

1- Primary sources include several items are using by humankind that contain MP particles in their matrices, e.g., cosmetics (masks and facial cleaners), shaving pastes, several drug carriers and toothpaste. MPs involved in the structure of these materials cannot be removed by sewage treatment processes and therefore may enter the soil environment directly. For example, Fu *et al.* (2020) stated that approximately 20.79 billion MP particles (306.8 tons MPs) were discharged through the sewage into the ecosystem due to the extensive use of facial masks in China, and other samples of facial masks collected from Chinese shops contained 5219 – 50391 MPs particles/kg. Conversely, Gatidou *et al.* (2019) found that nearly 3160 MPs pieces/ L in the input of sewage plant but in the output of same station the MPs level recorded 125 pieces/L and 17.09×10^4 particle/kg of amended wastewater and sludge, respectively.

2- Secondary sources which introduced the generated tiny plastics due to the degradation of large plastic waste such as plastic bottles, plastic food containers, plastic bags distributed in landfills, domestic waste treatment sites and several agricultural activities (Zhang *et al.,* 2020). The degradation of large plastics may happen as consequences of the effect of various environmental conditions (e.g., temperature, wind and UV radiation), soil biota and some oxidative routes (Irhema, 2021; Zhang *et al.,* 2021). In addition, the re-use of plastic items may be led to fragment them, hence, producing MPs. The use of animal compost and mulch films in farming sector can inject levels of MPs into the agriculture soils lead to increase the levels of MPs in soils (Xu *et al.,* 2020), for example as a result of mulching the MPs recorded levels of 0.34 ± 0.36 particles/kg of soil counting 206 MPs particles/hectare in agronomic lands located on the southeast of Germany (Piehl *et al.,* 2018). The mulch films are made from PVC and PE and used to increase crop yield, quality and minimise irrigation periods. The plastic mulch covered approximately 20 million hectares of agronomic lands globally, most of these lands in China (Yang *et al.,* 2021). The residues of mulch films cannot be easily removed from soil; therefore, these will accumulate over time and degrade, thus, producing more MPs in agriculture lands (Li *et al.,* 2020a). With growing the time of using mulch films, more levels of MPs are accumulated in farmland as mentioned by Li *et al.* (2020) that with increasing the mulching period from 5 to 30 years, the concentrations of MPs in soil significantly increased ranging from 10.10 to 61.05 mg/kg.

Additionally, Boots *et al.* (2019) and Zhu *et al.* (2019) concluded that soil is the main sink for MPs and acts as a potential source for MPs due to the diffusion of some MPs have been stored in the soil to surrounding ecosystems. The sources pointed out can introduce large quantities of MPs into the land ecosystem resulting to cause significant effects on soil biota, plants and biodiversity and may translocate to other environments and reach humane bodies, causing severe diseases (Wong *et al.,* 2020).

3. MPs distribution and migration in soil

The translocation of MPs throughout the soil medium is still not fully investigated, and the movement mechanisms are still unknown (Zhou *et al.,* 2020; Zhao *et al.,* 2022). Even though, the distribution of MPs in soils may be affected by several factors including soil aggregation, soil microorganisms, soil management processes, other various soil properties (e.g., soil macrospores and moisture) and weather conditions. MPs have found in deep soils due to the leaching of water vertically throughout the soil profile (Ya *et al.,* 2021). Rillig et al. (2021) stated that nearly 60% of PE MPs transferred from soil surface vertically down up to 10 cm. The levels of MPs in deep soil in China recorded 62.5 MPs particles /kg. But, in shallow soil measured 78.0 MPs particles /kg (Guo *et al.,* 2020). The changes in weather conditions (dry and wet periods) in 347 cities in China correlated positively with the diffusion of MPs through the soil profile as the migration rate of MPs ranged from 1.48 to 7.42 m, vertically (O'Connor *et al.,* 2019). In addition, plant development (e.g., root growth, movement and adsorption) and rhizosphere hyphen may work as a path for MPs translocation in soil. For instance, corn roots can play roles in MPs transportation up to deep 7-12 cm of soil (Li *et al.,* 2021). The soil composition and proprieties such as clay content, pH, soil organic matter, Fe_2O_3 and cation exchange capacity significantly impact the distribution and adsorption of PS MPs in soil (Lou *et al.,* 2020; Wu *et al.,* 2020). According to Zhou *et al.* (2020) and Ya *et al.* (2021) several studies have shown that the earthworms have the ability to distribute MPs within soil medium due to some activates of this animal such as ingestion, excretion and surface attachment. In addition to earthworms, other animals such as digging mammals, mites and collembola can carry and redistribute MPs within soil profile (Zhu *et al.,* 2018). Dris *et al.* (2016) and Gong and Xie (2020) stated that MPs and particularly microfibres that situated on the soil surface might translate to the air when the wind blows and remain in the atmosphere for a period and precipitate later on other lands or water bodies. Several human activities such as tilling and ridging may facilitate the distribution of MPs within soils. Also, the harvest of several crops such as potatoes and carrots can lead to vertically distributing of MPs in soil. The density, shape, and size of MPs play a vital role in their migration in soils. For example, MPs with spherical and granular shapes are migrated easily than others to deep soil (Li *et al.,* 2021). Conversely, MPs with low density cannot migrate vertically within soil profile (O'Connor *et al.,* 2019). Ultimately, this topic requires more research to explore the roles of MPs movement and distribution in the soil environment (Zhao *et al.,* 2022; Zhou *et al.,* 2020). Figure (1) shows the main routes may contribute to distribute and migrate MPs in soil medium within the ecosystem.

4. Effect of MPs on soil properties

The occurrence of MPs in the terrestrial ecosystem has a significant effect on several soil characteristics (Ding *et al.,* 2022). However, there is a limit of information about the effect of MPs on the soil characteristics (Xu *et al.,* 2020; Lozano *et al.,* 2021). Besides, Meixner *et al.* (2020) reported that most studies on the effect of MPs on soil properties are assumptions. Appling MPs to soils cannot be useful for soil health and fertility because the water-holding capacity, ion exchange capacity, mineral nutrient content of MPs are equal to zero, and their carbon skeleton cannot deliver beneficial carbon to the soil medium (Qi *et al.,* 2020). The MPs size, shape and type, are the main factors controlling the impacts of MPs on soil physicochemical properties (Mbachu *et al.,* 2021).

4.1 *Effect of MPs on soil bulk density*

There are not many studies that discovered the impacts of MPs on soil bulk density, even though as stated by several researchers that the presence of MPs in soil showed various effects on the bulk density of investigated soils.

For instance, applying 0.4% $^{w}/_{w}$ of PE fibres to two soil types led to a decrease in the bulk density of loamy sand soil, but no effect was observed on the bulk density of clay loam soil. The decline of soils bulk density is linked to the lower density of MPs than that of soil minerals

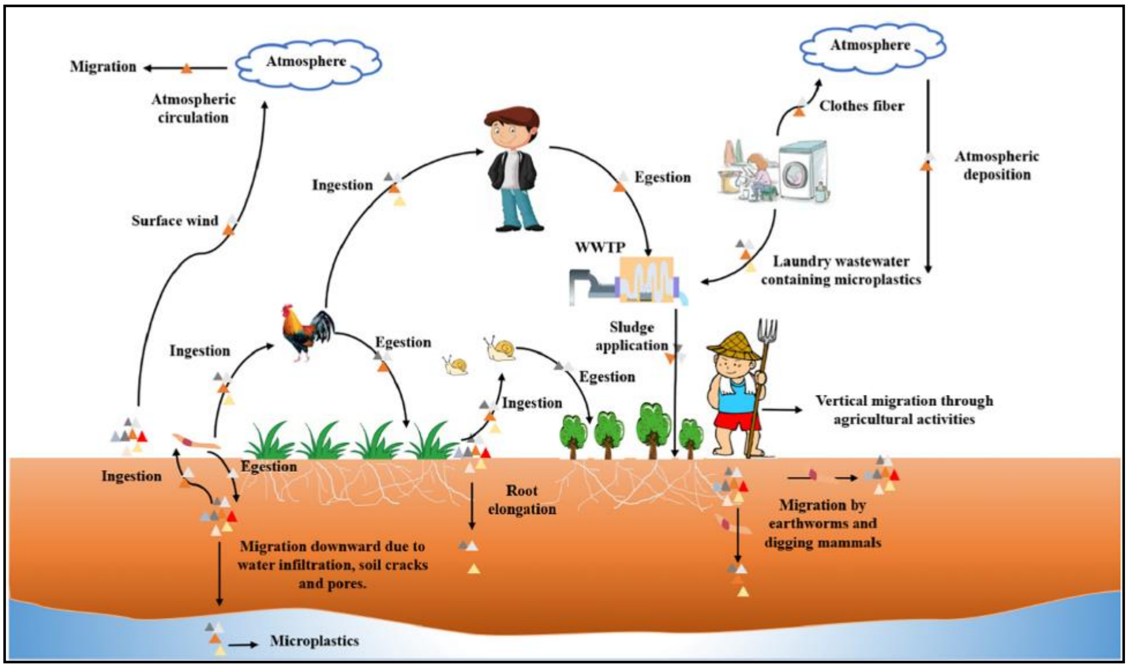

Figure 1. Distribution and migration of MPs in soil within the environment (adopted from Ya *et al.*, 2021)

density **(**Xu et al., 2020). Additionally, initial results implied that the application of microfibers might reduce soil bulk density (Wang *et al.*, 2020). Conversely, Zhang *et al.* (2020) concluded that the application of PS fibres did not change the bulk density of experimented soil.

4.2 *Effect of MPs on the soil structure*

The effects of MPs on soil structure are still not clearly investigated so far; therefore, more investigates are needed to study the behavior and interaction of MPs with soil to draw a beneficial knowledge that addressing the effect of MPs on the soil structure (Zhao *et al.*, 2022; Qi *et al.*, 2020).

4.3 *Effect of MPs on the water holding capacity (WHC) of soil*

The occurrence of MPs in the soil can alter the pore size distribution, affecting the WHC of MPs-polluted soil. Applying PE fibers to soil increased WHC significantly, but there is fluctuation in the impacts of PE and PAA particles on soil WHC (Mbachu *et al.*, 2021). Indeed, Zhang *et al.* (2019a) reported that the WHC of tested soil with PE MPs has declined. Mbachu *et al.* (2021) stated that several studies have mentioned that the effect of MPs on soil WHC is still not fully investigated and needs more studies to come up with an ultimate conclusion that may help understand the effect of MPs on soil WHC.

4.4 *Effect of MPs on some nutrients cycle*

The presence of MPs in soil may affect the dynamic of dissolved organic matter and alter the carbon cycle (Rillig *et al.*, 2021). The extensive use of plastic films in farming for a long-time can decrease the soil content of inorganic nitrogen (Xu *et al.*, 2020), and soil organic matter (Xu *et al.*, 2020).

Also, the residues of mulching diminished the levels of available phosphorus (P) and alkali-hydrolysable N by 60% and 55% relative to unpolluted soil. The addition of PE derived MPs to soil increased the activity of the urease enzyme cause changes in the nitrogen cycle (Xu *et al.*, 2020). Awet *et al.* (2018) found that PS and PE derived MPs can reduce the efficiency of N-acetyl-β-glucosaminidase and leucineaminopeptiddase lead to inhibit soil nitrogen cycle. Furthermore, the incorporation of PLA derived MPs into the soil for 12 days showed a significant decrease in the level of NH_4^+ and a major rise of NO_3^--N and NO_2^-—N levels in experimented soil. The incubation of 5% $^{w}/_{w}$ LDPE MPs with soil for 30 days led to influence the nitrification process linked to the rapid utilisation of NO_3^- by several microbes (Rong *et al.*, 2021). The application of 28% PP and 2% PLA MPs to soil showed an increase in the concentration of available P and no effect observed on the inorganic P level (Ren *et al.*, 2020). However, the effect of MPs on the soil P cycle still needs more investigations (He *et al.*, 2021). According to Ya *et al.* (2021) the presence of mulch film residues and other MPs negatively affects soil productivity, but these impacts still need more exploration under different ecological conditions.

Table 1. Summary of several studies conducted to evaluate the effect of MPs on some soil biota (Ya *et al.*, 2021 and Qin *et al.*, 2021).

Species	Type and dose of MPs	Period of trial / days	Toxic effects
Eisenia fetida	LDPE 10^3 mgkg^{-1}	28	Surface damage, triggered stress and inhabited neurotoxic reactions.
	PE 20%	14	Significant increase of the activity of peroxidase and catalase.
	PS 20%	14	Significant rise on the inhibition of superoxide dismantles.
	LDPE 1%, 2%	30	Decreased growth rate and increased the mortality rate.
Eisnia andrei	PE 10^3 mg kg^{-1}	21	Reduced the rates of growth, feeding and foraging.
Enchytraeus	PS fibers 0.02%, 1.5 %	28	Low effect on soil invertebrate.
Lumbricus terrestris	PS, PP, PET, LDPE particles 2.5%, 5%, 7% $^w/_w$	2	Ingestion and induced physical damage and no alteration in the avoidance behavior.
	PE 28%, 45%	60	Increased the mortality rate.
	PES MFs 1% $^w/_w$	35	No alteration in mortality and weight.
Caenorhabditis elegans	PS 100 mg kg $^{-1}$	10	Highly sensitive to large MPs.
Achatina fulica	PE 0.5 %, 11%	14	Reduced the gut of snails and damaging the digestive organs.
	PVC 10^3mg kg^{-1}	28	Increased the diversity of springtails gut, effect the growth rate and reproduction.
E. Crypticus	PA, PVC particles	21	Decreased the microbial diversity, but increased the antibiotic resistance genes in E. Crypticus.
Nematode community	LDPE particles 5, 10, 15 g/m^2	287	Reduced the abundance and altered community structure.
Metaphire guillelmi	HDPE, PP 0.25% $^w/_w$	28	No important changes in gut micro biota.

5. Effect of MPs on soil biota

The existence of MPs in soil may allow to several negative effects of MPs on soil biota to occur that are (1) damaging the external surface of fauna and obstructing the movement of the victim by holding on to the body's surface, (2) causing direct harm due to the ingesting of MPs by soil biota, and (3) the low degradable rate of MPs lead to accumulating them in different fauna tissues and then may translocate to the primary and other consumers causing high risk to them. Consequently, MPs in soil may impact the growth rate, fertility, lifetime, metabolism processes, digestive and neuronal systems, which lead to increase the mortality rate of soil animals (Ding *et al.,* 2022; Wang *et al.,* 2021). Noticeably, majority of studies used one species, and a small number of biota others briefly investigated the effect of MPs on the diversity, and structure of soil biota

(Barreto *et al.,* 2020; Wang *et al.,* 2021). Thus, there is a need for mor studies in this field to investigate the interaction between soil biota and MPs (Ding *et al.,* 2022; Zhang *et al.*, 2022). Table (1) summaries the results of several studies conducted with the aim to examine the effects of MPs on the health and development of some soil biota.

6. Effect of MPs on plant growth

Several studies indicated that MPs could inter plant roots and transfer to aboveground parts of the plant and accumulate in edible parts of crops leads to pollute food chain and reach the human body (Boots *et al.,* 2019). Ya *et al.,* (2021) stated that MPs reduced lettuce development due to diminishing photosynthesis processes and antioxidant defense. The application of 100 mg L^{-1} of MPs with size 100 nm to soil inhibited the growth rate of *Vicia fabaa* and the 100 nm MPs were more effective than 50 µm MPs in the genetic toxicity. The changing of several soil physicochemical characteristics due to soil pollution by MPs negatively impacts the growth processes, rhizosphere conditions and the delivery of nutrients to plant (Qi *et al.,* 2020). Further, several parameters may control the toxicity of MPs pollution on the plant that are: (1) MPs shape and type, (2) MPs structure content, and (3) MPs levels in polluted soil. For instance, the rate of 0.001% of PA fibers that have liner shape caused noticeable effects on the *Lolium perenne* development than a dose of 0.1% PLA and HDPE, and PA particles. The fibers reduced the seed germination by 7% compared to the control. Even though, several biodegradable plastic films are eco-friendly, but they contain quantities of chemical additives; these might have harmful effects on the soil-plant ecosystem. The negative effects of MPs pollution on plant growth may ascribe by diminishing the synthesis of chlorophyll-b, fluctuation of leaf nitrogen content and C-N ratio (Mbachu *et al.,* 2021). Moreover, MPs surface may adsorb several toxic materials or make bounds with organic hazard substances, heavy metals and other pollutants reducing the availability of these hazard materials to soil fauna and florae minimising the pollutant harm effects. But, the adsorbed contaminants may release later into the soil solution causing harm effects to plants and other soil ccontents (Guo *et al.,* 2020). Based on a review of Zhou *et al.* (2020), the uptake, translocation and accumulation of MPs within plant tissues and plant tolerance of MPs pollution needs more emphasis and continues efforts to examine the effect of different types of MPs (e.g., PE, PVC, PP) on various morphological and biological processes of different plant species under diverse environmental conditions in terrestrial ecosystems. That is in order to draw potential conclusions that may help realise the role of MPs pollution effects on the plant, and therefore may provide possible assistance to suggest suitable remediation technology to remove MPs and other plastics from the soil ecosystem. Some guidance has been provided in relation to possible routes that clarified the effects of MPs pollution on plant morphology, which may benefit future work on studying MPs-polluted soil remediation (Gou *et al.,* 2020; Ya *et al.*, 2021). Table (2) illustrates additional studies carried out by aim to investigate the effect of MPs on plant health and development processes.

7. Microplastic pollution treatment

Due to increasing the level of soil MPs pollution with time and unfeasibility to remove and/or physically clean up MPs from polluted environment due to its small size and invisibility, therefore this issue has attracted the attention of the scientific community, where some countries started with plastic pollution monitoring by discovering the sources of MPs pollution and suggesting the protocols with the aim to reduce the plastic emission sources and recommending the potential remediation technique (Irhema, 2021). Indeed, the promising suggested technology is using several microorganisms, which have shown high performances in the treatment of MPs-polluted soils (Zang *et al.,* 2021). This capable technique can be used widely as its cost-effective and eco-friendly method (Wang et al., 2022). The microorganisms can utilise the MPs carbon skeleton and convert it to energy and carbon dioxide (CO_2) (Irhema, 2021; Anjana *et al.*, 2020). According to Qin *et al.* (2021) few works have been done to study the biodegradation of MPs in soil. For example, Sullivan *et al.* (2019) found that burying PE bags and sheets of PV in soils under various environmental conditions for two years lead to increase soil moisture and elevate the pH of target soils which stimulated the PE biodegradation. Also, MPs fragmented with time from commercial plastic bags made from HDPE showed a loss of approximately 5% of initial weight after burring HDPE bags derived MPs in soil for 2 months. The loss of weight is ascribed to the production of hydrolytic enzymes by heterotrophic bacteria isolated from soil (Kumar *et al.,* 2017). Several literatures concluded that numbers of bacteria such as *Aspergillus niger*, *Pseudomonas aeruginosa*, *Bacillus subtilis*, *Staphylococcus aureus*, *Streptococcus pyogenes and Rhodococcus ruber* could generate exterior polymer sheets on the surface of MP particles to stimulate producing some enzymes that degrade MPs biologically by fragmenting the plastic particles to oligomers, then to dimmers and monomers and lastly mineralise them to CO_2, H_2O and CH_4 (Asiandu *et al.,* 2022; Auta *et al.,* 2017). The biodegradation of plastics and practically MPs by microbes in soils may follow several steps that are (Asiandu *et al.,* 2022; Ali *et al.,* 2021; Anjana *et al.,* 2020):

Table 2. The effects of several doses of MPs on the development of some plants during the laboratory trails (Modified from Mbachu *et al.,* 2021 and Ya *et al.,* 2021).

Added MPs $^{w}/_{w}$	Experiment conditions	Demonstrated Plant	Results
0.25, 0.5 and 1.0 mg L^{-1} of PE	-	Lettuce	Reduced plant growth, photosynthesis rate and Chlorophyll production.
2% PP, 2% PS, 2% PA 2% PET 0.2% PES 2% HDPE	Loamy sandy soil, irrigated daily to 60% WHC, for 3-5 months	*Allium fistulosum* (spring onions)	PA decreased the root-leaf biomass ratio, root average diameter, root tissue density and crop biomass. PA increased the total root area and leaf nitrogen content. PES decreased the root average diameter and leaf nitrogen content. PES increased the root biomass, root-leaf biomass ratio, total root area, root tissue density and crop biomass. PET decreased the root biomass and root average diameter. PET increased the root-leaf biomass ratio and total root area. HDPE decreased the root biomass and root average diameter. HDPE increased the root-leaf biomass ratio and total root area. PP decreased the root biomass and root average diameter. PP increased the root-leaf biomass ratio, root length and total root area. PS decreased the root average diameter, but increased the root biomass, root-leaf biomass ratio, total root area and root tissue density.
1% sBio 1% LDPE	Sandy soil, irrigated once a week for 4 months	*Triticum aestivum* (wheat)	LDPE decreased the total plant biomass, but increased the leaf area and root biomass. sBio decreased the plant height, shoot biomass, total plant biomass, leaf area, number of leaves and stem diameter.
0.001% PA Fibers 0.1% HDPE 0.1% PLA	Sandy clay loam soil, watered daily to 60% WHC, 21.1 C°, 30 days	*Lolium perenne* (perennial ryegrass)	PLA decreased the germination rate, shoot length and root biomass. PLA increased the Chlorophyll-a/b ratios. Fibres decreased the germination rate, but increased the Chlorophyll-a/b ratios. HDPE decreased the germination rate, but increased the root biomass and Chlorophyll-a/b ratios.

1- Formation of microbial biofilm

At first, the microbes situate on the surface of MPs and form biofilm covering the exterior side of MP particles named plastisphere. The formed film like mushroom layer can affect the MPs floating and hydrophobicity, and the coated layer on the surface of target MPs may be thick and with high performance to degrade plastics.

2- Biodetoriation procedure

After the biofilm is formed, the biodetoriation process of MPs is started by secreted a number of endoenzymes and exoenzymes by microbes that have a major role in the biodegradation procedure of plastic.

3- Bio-fragmentation process

As a result of biodetoriation, the fragmenting route of target MPs biologically leads to break down the polymer into smaller molecules that are in order oligomers, then dimmers, and finally, monomers. This is achieved by disturbing the carbon structure of MPs by depolymerisation procedure, which is highly stimulated

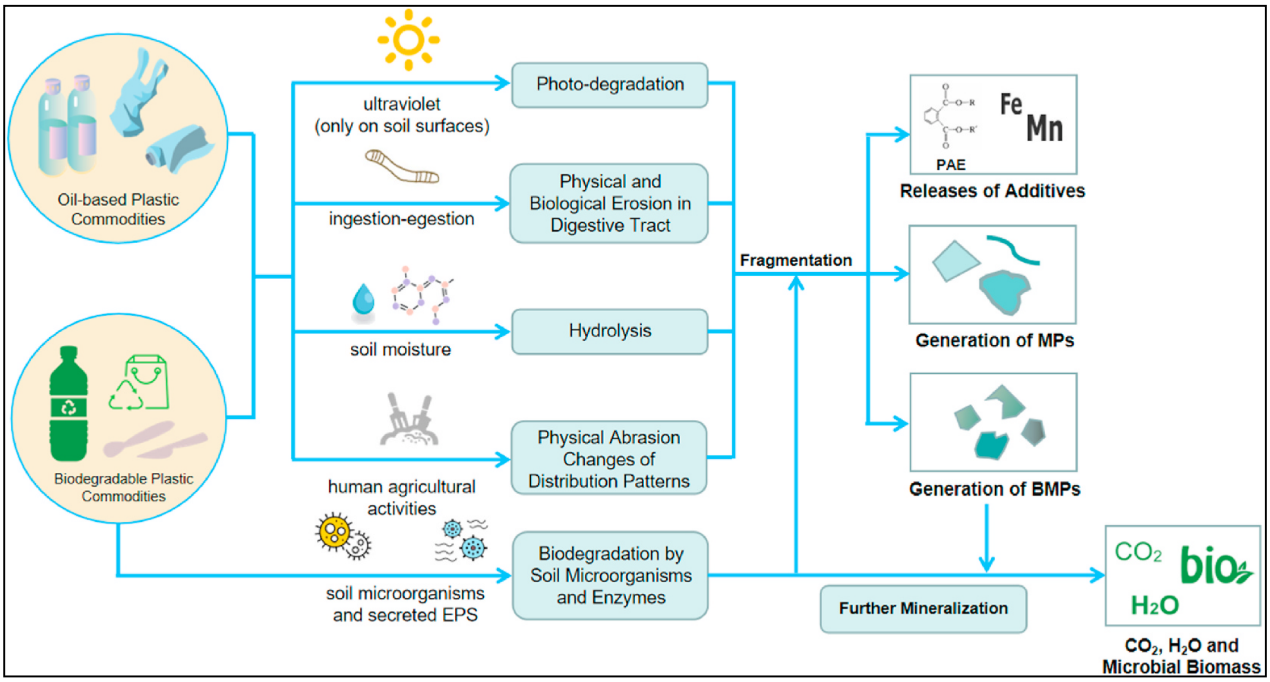

Figure 2. An overview about the potential methods involved in the degradation of plastic and particularly MPs (adopted from Qin *et al.*, 2021).

8. Conclusion

This review summarised the main sources of MPs in soils and agroecosystem, classified into two categories: primary and secondary sources. Due to continues the use of plastic mulching, sludge in farming and irrigation with treated wastewater, expanding the cosmetics industries and more utilising of manufactured plastics in the daily use of world citizens, the levels of MPs in the terrestrial environment are expected to rise. Consequently, MPs pollution may influence the production and quality of crop plants directly by altering soil characteristics and affecting soil biota, plant development and changing the soil conditions, and indirect impacts on human health through bioaccumulation of MPs in plant tissues. The most effective and promised technology that may help to decrease soil MPs pollution level is the biodegradation of MPs by several microorganisms as an environmentally friendly and cost-effective technique. The presence, distribution, impacts and pollution treatment of MPs in the terrestrial ecosystem should receive more emphasise to diminish the ecological, heath, and economic threats of MPs nationally and internationally.

by microbial enzymes, e.g., peroxidises, lactases, oxidases and amidases.

4- Mineralisation step

The last step in the biodegradation process of MPs degradation is mineralising the fragmented oligomers, dimmers and monomers to generate CO_2, CH_4 and H_2O. Figure (2) summarizes the main techniques involved in the degradation of plastic and particularly MPs.

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