PLASTIC POLLUTION IN SOIL

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KEY MESSAGES

- More than 80% of plastics found in marine environments has been produced, consumed and disposed of on land.
- Microplastic contamination on land is estimated to be between 4 to 32 times higher than in the oceans.
- In addition to inadequate end-of-life treatment of plastic waste, plastics reaches our soils through increasing use for agricultural purposes.
- Yearly inputs of microplastics in European and North American farmlands are estimated to be 63,000-430,000 and 44,000-300,000 tonnes respectively.
- A greater consideration of the issue of plastic pollution in soil and its implications is needed in policies and legislation.

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The issue

Since its rise in the 1950s, the plastics sector has increased significantly and today represents one of the largest and most economically important sectors to our society. The properties of this material, such as its durability, malleability, light weight and low costs, have contributed to the growth of the sector and its multiple applications. For instance, plastics are extensively used in packaging, car manufacturing, building and construction, and agriculture.

Despite the multiple benefits that the material offers, plastics are associated with high levels of waste and leakage to the environment. This is the result of single-use plastics applications, inadequate end-of-life treatment, low recyclability and reusability rates and high potential of disintegration into microplastics (Geyer et al., 2017).

Global plastic production has reached unprecedented levels, with 322 million tonnes of plastics produced globally in 2015 (Plastics Europe, 2016). In 2015, 6,300 million tonnes of plastic waste were generated, 9% of which was recycled, 12% incinerated and the remaining 79% sent to landfills or leaked to the environment.

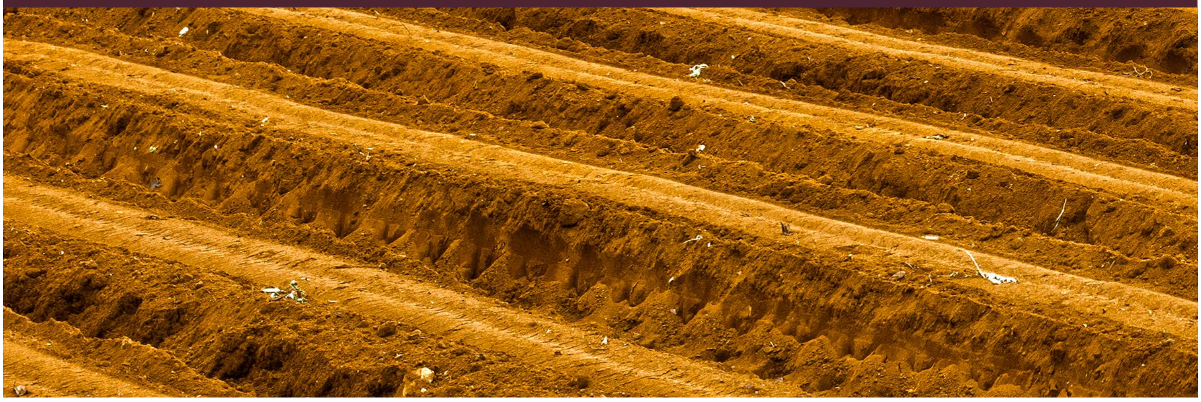
The accumulation of plastics in the environment is a global issue which will increase if current production, consumption and waste management practices remain unchanged. An estimated 12,000 million tonnes of plastics waste are expected to accumulate in landfills or in the environment by 2050 if action is not taken (Geyer et al., 2017).

Microplastics

Microplastics are small plastic particles, of less than 5 mm in size. Microplastics are found in both the terrestrial and aquatic environment and can be of two types – primary and secondary.

Primary microplastics are intentionally manufactured in small sizes (less than 5 mm). These generally leak to the environment through drainage systems and wastewater treatment streams. Examples include production pellets, microbeads used in cosmetics, household cleaners and other products.

Secondary microplastics are formed from the fragmentation of meso and macroplastic waste due to weathering degradation (GESAMP, 2016).



The presence of plastics in the environment, whether as macroplastic debris or as microplastics, has widely been recognised as a global issue. It represents one of the most challenging anthropogenic phenomenon that affects our planet and is among the major threats to biodiversity due to potential entanglement and ingestion.

While the issue of plastic and microplastic pollution in aquatic environments (marine and freshwater) has been gaining increasing attention, the problem of plastic contamination in the terrestrial environment has remained widely unexplored. Plastic and micro plastic pollution may be more dramatically seen in the oceans; however, more than 80% of the plastics found in marine environments has been produced, consumed and disposed of on land. Therefore, plastic pollution on land is a problem both of contamination and damage to terrestrial environments and of transfer to aquatic systems. High levels of microplastics contamination on land have been observed – an estimated 4 to 23 times larger than in the oceans (Machado et al., 2017, Horton et al., 2017).

Sources and pathways

As is the case for marine litter, plastics find their way to terrestrial environments through different sources and as a result of certain trends and practices. A distinction of sources and pathways can be made based on the type of plastic particles found in the environment – whether as intentionally manufactured microplastics leaking to the environment (primary microplastics), fragments of macroplastics already present in the environment, or plastics disintegrating into microplastics prior to reaching the environment (secondary microplastics).

While primary microplastics represent an important source of marine and freshwater litter, these have also been identified in terrestrial environments as a result of sewage sludge containing micro fibres and microplastics being applied to agricultural land (Horton et al., 2017).

Sewage sludge – A widespread practice which is an important source of primary microplastics contamination in soil is the application of sewage sludge from municipal wastewater treatment plants as a fertiliser for agricultural land. The practice is common in many developed regions, with Europe and North America processing approximately 50% of sewage sludge for agricultural use. It is estimated that annual additions of microplastics to agricultural land in Europe are between 125 and 850 tonnes of microplastics/million inhabitants. This translates into a yearly input of microplastics in European and North American farmlands of 63,000-430,000 and 44,000-300,000 tonnes respectively (Nizzetto et al., 2017).

Controlled-release fertilisers (CRF) – CRF is a fertilization technology which provides a system to reduce both the quantity of fertiliser needed per unit of area and manages the time of application. The N, P and K nutrient combinations are encapsulated within a nutrient pill, a coating made with a polymer. The coating allows the fertiliser to diffuse into the soil over a given time period. While the technology offers a number of benefits for agriculture, it also represents an important source of microplastics contamination. The nutrient pill does not degrade after the nutrients have been released (GESAMP, 2016).

Secondary microplastics are released during municipal solid waste collection, processing, transportation and landfilling. In addition, wind contributes to the dissemination of microplastics, either across land, or from land to water and vice versa. On land, secondary microplastic contamination is also linked to the use of agricultural plastics, such as polytunnels, silage bailing and plastic mulches. Additional plastic items used for agricultural purposes and which therefore represent potential sources of microplastic contamination in soil are containers, packaging and netting. Fragmentation on land is then enhanced through sunlight, which has a greater impact on these plastics than it does on those in the water (Horton et al., 2017).

Plastic mulching – Plastic mulching is the use of plastic films on crops acting as insulation to protect seedlings and shoots. This technique is widely used due to the economic benefits its application offers, including increased crop yields, better crop quality, prevention of soil erosion and reduced pest pressure. Nevertheless, while the plastic mulches create the ideal microclimatic conditions to increase productivity, they also have a number of limitations. Plastic mulches are generally made of polyethylene (PE) which does not degrade well in the soil and therefore is associated with discharges of plastic residues. The use of PE also adds to the problem of recovering and recycling used mulching films (Steinmetz et al., 2016). In some cases, plastic mulches are made with oxo-plastics. When used for this purpose, littering may increase as oxo-plastics are sold to farmers as products not to be collected after use. However, research shows that the biodegradability potential of oxo-plastics is limited, therefore the use of oxo-plastic mulches contributes to plastic pollution in soil (European Commission, 2018b).

According to the European Commission (SWD/2016/64 final), the EU the market for plastic mulch is estimated to be 100,000 tonnes per year. However only 32% of plastic is collected at the end of use, with the rest either landfilled, left in soils or burnt. In addition, 3000 tons/year of plastic mulch current on the EU market are biodegradable, of which only 2000 tons/year meet the highest degradability criteria. Only France and Italy have standards for biodegradability of plastics in soil, whilst Spain, the UK and Germany do not.

The use of plastic mulch is particularly common in China. A four-fold increase was reported between 1991 and 2011, from 319 to 1,245 million tonnes (Steinmetz et al., 2016).

China – From white revolution to white pollution

Plastic mulching is a common practice in China playing a key role for Chinese food security. Its use has significantly increased, from 0.032 million tonnes in 1991 to 1.5 million tonnes of plastic film covering 20 million hectares of arable land in 2016. An estimated 2 million tonnes of plastic films are expected to cover 22 million hectares of farmland in 2025. The use of plastic mulching films in China has contributed to improved dryland agricultural production and crop water use efficiency. However, its use has been found to contribute to reduced soil fertility and soil pollution from film residues. Pollution from plastic residues, known as white pollution, has increased significantly – between 60 and 300 kg/ha in some provinces. In addition to generating aesthetic pollution, plastic residues directly affect soil properties, retarding crop growth, affecting field operations, and potentially harming wildlife through ingestion.

While action is being undertaken from the Chinese Government to tackle white pollution, removing and recycling plastic residues is associated with high levels of water and energy consumption, making new plastic films a more affordable alternative (Liu et al., 2014) (Tiglu, 2017).

The introduction of biodegradable films for mulching as an alternative to PE films is recently being explored in China. Solutions of this kind have been developed by international and domestic companies. Despite their success for certain crops, the application of biofilms comes with drawbacks as their complete breakdown is not ensured in all types of soil. Partial breakdown of biofilms can lead plastic fragments to accumulate in the soil (Tiglu, 2017) (Sintim and Flury, 2017).

Almeria's plastic sea

The Spanish region of Almeria is often called "Mar del plastico" (Plastics Sea) due to the wide surface covered by plastic greenhouses. These currently cover 30,000 hectares of land – 2.7% of the province's land surface.

The EU represents Spain's main export partner of agricultural products (99.8%). 40% of all Spanish exports of vegetables are produced in the greenhouses in Almeria. In the last decades, Almeria has witnessed a complete transformation from what used to be one of the poorest, driest and least inhabited areas in Spain and the most arid region in Europe, to what is now known as "Europe's garden".

While such intensive agriculture has contributed to the growth of what used to be Spain's poorest province, the practice is associated with environmentally and socially damaging impacts. These include intense fresh water use and desertification, aquifer contamination, soil degradation, biodiversity loss as well as poor labour force conditions. In addition, the use of plastic greenhouses is an important source of plastic litter in soil. When the plastics covering the greenhouses is replaced, the used plastic covers are rarely recycled or incinerated and are often left on the land, leaving high temperatures to disintegrate plastic debris in the soil or strong winds to transfer residues into the sea. In some cases, plastic residues are illegally burnt, contributing to soil contamination (Gómez, 2008) (Balaguer Rosillo, 2014) (Husarova, 2016).

Plastic greenhouses – Among the plastics used for agricultural purposes, plastics covering greenhouses have been identified as a source of plastic litter on land. The application of plastic greenhouses is a particularly intense practice in the Spanish province of Almeria.

Plastics in compost – Organic fertilisers obtained from household and industry recycled bio-waste are increasingly being applied on agricultural land and considered as an environmentally sound practice with several beneficial effects on soil. Nevertheless, recent studies have shown that the use of bio-waste as a source of fertiliser represents a potential source of microplastics contamination in terrestrial environments. This is due to the fact most bio-waste from households and industry contains plastics (Weithmann et al., 2018). For instance, an investigation carried out by the Italian Composting Council showed that organic waste collected in Italy had an average contamination of 4.9%, with non-compostable plastics representing the principal material found (Novamont, 2018).

Procedures such as sieving and sifting can help reduce the amount of plastics in fertilisers. However, small plastic particles are more challenging and are rarely removed completely (Weithmann et al., 2018).

Challenges

Harmful substances and chemicals – Additive substances such as chemicals are commonly added to plastics and are therefore likely to be present in microplastics in the environment, representing a potential harm. Examples of these substances include polybrominated diphenyl ethers (PBDEs) and other brominated flame retardants as well as Bisphenol A (BPA). Several EU risk assessments for phthalates show that plastics accumulated in the natural environment are one of the main sources of phthalates releases to the environment (Lassen et al., 2015).

Biodegradability concerns – Plastics are widely used in agriculture and all present differences in their rate and level of degradability in the soil, depending on the main polymer component (Adhikari et al., 2016). What makes plastics a pervasive environmental pollutant is the fact that biodegradation may not be achieved under normal conditions in the natural environment (Horton et al., 2017). For instance, degradation of PE, which is a common polymer in agricultural plastics, is a very slow process under environmental conditions (Steinmetz et al., 2016). The International Organisation for Standardisation (ISO) technical committee on plastics (TC 61) is in the process of developing new standards for biodegradability and the composting of plastics under its current work programme on “plastics and the environment”[1].

Bioplastics

The term bioplastics refers to plastics which are bio-based, biodegradable or both (European Bioplastics, 2017).

Bio-based plastics are polymers derived from biomass resources such as starch or sugar. While bio-plastics can in certain cases be biodegradable and recyclable if the appropriate infrastructure is available, they do not always have these properties (GESAMP, 2016) (Surfrider Foundation et al., 2017).

Bioplastics are increasingly being used in common products which, even though do not come into direct contact with soil, might be mismanaged leading to littering. This is because often bioplastics present complex design, making collection and recycling processes more challenging (Surfrider Foundation et al., 2017). Moreover, bioplastics often create perverse incentives and can lead to increased littering as they are generally associated by consumers to items which can easily biodegrade (EPA Network, 2017, Surfrider Foundation et al., 2017).

Oxo-plastics

Oxo-plastics, or oxo-fragmenting plastics, are conventional plastics containing chemical additives aimed at accelerating their fragmentation under the action of UV light and/or heat, and oxygen. A faster fragmentation would then allow and accelerate biodegradation of the material.

Thanks to these properties, oxo-plastics are often presented as a potential solution to the plastic litter problem. However, concerns over the biodegradability rate of oxo-plastics under uncontrolled conditions in the natural environment question the efficacy of the material to provide a solution to the plastic litter issue. If biodegradation does not happen within a reasonable time-frame, oxo-plastics can be significant contributors to microplastic contamination in both soil and water in addition to potentially misleading consumers and leading to increased littering trends (European Commission, 2018b).

1 https://www.iso.org/committee/6578018/x/catalogue/p/0/u/1/w/0/d/0

Ingestion – Microplastics could enter the food chain and therefore potentially contaminate food for human consumption, inevitably leading to ingestion. The health impacts of microplastic particles ingestion are still widely unknown and research on the topic is increasing (Weithmann et al., 2018).

Policies and regulations to address the challenges

A range of measures are implemented throughout the plastics value chain which can either directly or indirectly reduce the leakage of plastics into soils and the wider environment.

Product design – Upstream measures affect the production of plastics, aiming at increasing its reusability and recyclability.

Extended Producer Responsibility (EPR) schemes and the modulation of fees based on criteria of reusability, durability and recyclability play an important role. The aim of EPR schemes is to create incentives for producers to improve the design of their products so that their environmental performance is optimised and their end-of-life management costs minimised. Examples include the French EPR scheme CITEO and the Italian CONAI (Zero Waste Europe, 2017, Watkins et al., 2017). In addition, several Member States have implemented EPR schemes for agricultural films (Belgium, Finland, France, Germany, Ireland, Italy, Sweden, Spain) (European Commission, 2014).

From January 2018, CONAI's new systems includes three different rates established for recyclable industrial packaging (179 EUR/tonne), recyclable domestic packaging (208 EUR/tonne) and unrecyclable packaging (228 EUR/tonne) (CONAI, 2017). The aim of modulating fees is to encourage producers to design easily recyclable packaging, and to support the market for secondary plastics.

Bans and phase-outs – Bans and phase-outs are widely applied to plastic products or even specific uses (e.g. cosmetics) due to the increasing concern over the health and environmental risks of certain plastics applications.

Ban on microbeads in cosmetics: Microbeads are small plastics particles often used in cosmetic products. The presence of such particles in the environment (both terrestrial and aquatic) has given rise to a number of national restrictions and bans. A ban on microbeads in cosmetic products has been adopted in several countries including the Netherlands, the US, Canada, Australia, and most recently in the UK. A similar ban is expected to become effective in 2018/2019 in Ireland, New Zealand and Italy (Beat the Microbead, 2018). A ban of this kind has the potential to reduce the presence of microplastics in sewage sludge which is then applied in agricultural land.

Bans on single-use and/or non-biodegradable plastic bags: Several regulations have been introduced to regulate the use and sale of plastic bags. For instance, a ban on single use plastic bag exists in several countries and municipalities: 132 cities in the US, the city of São Paulo in Brazil (2007), the city of Paris (2007), France (2017) and Australia (with the exception of New South Wales). France has introduced a ban on ultrathin (less than 50 microns) single-use plastic bags[2]. Italy has adopted a regulation on non-biodegradable plastic bags[3].

In addition to reducing litter, regulations of this kind can reduce the contamination of plastics in compost.

Restrictions on the use of oxo-plastics: Due to the concerns over the use of oxo-plastics, EU-wide measures to restrict the use of this material are being considered. Under the EU Strategy for Plastics, a process to restrict the use of oxo-plastics via REACH in the EU is ongoing (European Commission, 2018a). In addition, over 150 organizations worldwide, including NGOs, business, scientists, industry asso-

2 https://www.planete-energies.com/en/medias/close/france-s-single-use-plastic-bag-regulation
3 From 1st January 2018, plastic bags allowed for commercialisation (intended as free of charge or with a fee applied) are biodegradable, compostable or lightweight bags with a minimum of 40% renewable raw materials (percentage to be increased in following years). See: http://www.minambiente.it/comunicati/shopper-ecco-la-circolare-ministeriale-intepretativa.

ciations and elected officials have signed a statement[4] Ellen MacArthur Foundation's New Plastics Economy initiative that proposes a ban on oxo-plastic packaging (Ellen MacArthur Foundation, 2017).

Taxes and charges – Taxes and charges are market-based instruments which provide incentives to reduce the use of certain materials, products or specific applications.

Landfill tax: 20 EU Member States currently have landfill taxes on waste disposal encourages alternative waste management strategies such as recycling, composting and reuse (CEWEP, 2017). In Poland, a tax is applied on the landfilling of selectively collected plastics waste (OECD, 2018).

Waste legislations – As part of the Circular Economy package (COM/2015/0614 final) adopted in 2015, legislative proposals have been put forward to revise the Waste Framework Directive (2008/98/EC), the Landfill Directive (1999/31/EC) and the Packaging and Packaging Waste Directive (94/62/EC) – these proposals include revised waste management targets.

Increased recycling and re-use targets for plastic packaging encourage better management of plastics, reducing leakage to the environment.

The *EU Strategy for Plastics* aims to improve the economics and quality of plastics recycling, one of the objectives being all plastic packaging to be reusable and recyclable by 2030. Ambitious targets of this kind have an important impact on future investments in waste management infrastructure (European Commission, 2018c).

Regulations on fertilisers – Regulations can help to determine how fertilisers are manufactured, handled and applied. The European Regulation (EC) No 2003/2003 relating to fertilisers ensures a common market for mineral fertilisers in the EU, however it does not address specific contaminants (such as plastics) or waste-based fertilisers in general. National legislation in some cases provide specific guidelines on contaminants. For example, Germany has one of the stricter regulations on fertiliser quality allowing a maximum of 0.1 weight % of plastics. Yet, particles smaller than 2mm are not taken into account (Weithmann et al., 2018).

The *proposed revision of the EU Fertiliser Regulation* (COM(2016) 157 final) aims at addressing the issue of contamination by fertilisers of soil as well as of inland waters, sea waters and food but also aims at facilitating the use of organic fertilizers in the spirit of circular economy. The regulation introduces new harmonised requirements for all CE marked fertilizing products on the quality, labelling and safety, including limits for heavy metals such as cadmium, for microbial contaminants and impurities specific to each fertiliser category (European Commission, 2016). The Annexes[5] to the Communication provides the detailed requirements for the 11 Component Material Categories (CMC), 3 of these specifically refer to plastics in their requirements:

- CMC 3: Compost
- CMC 5: Other digestate than energy crop digestate
- CMC 10: Other polymers than nutrient polymers

For CMC 3 and 5 a limit of "no more than 5g/kg of dry matter of macroscopic impurities in the form of glass, metal and plastics above 2mm". For CMC 10, this refers to the biodegradability of polymers included as well as a testing procedure (p.29). The Staff Working Document and Impact Assessment for the proposal (SWD/2016/64) refers to plastics in some detail. It proposes limit values for plastics in organic fertilisers of 0.5% (per kg of dry matter). It also refers to the benefits and risks associated with plastic mulching and their current use in the EU (p.19).

4 https://newplasticseconomy.org/assets/doc/Oxo-paper-13.03.18.pdf
5 https://ec.europa.eu/docsroom/documents/15949/attachments/3/translations/en/renditions/native

Regulations on sewage sludge applications to land – Sewage sludge is commonly used as a fertiliser on agricultural land; however, concerns over the potential environmental and human health impacts has led to the introduction of regulations. While these regulations include limits on pollutants, microplastics contamination is hardly taken into account.

The *EU Directive (EU 86/278/EEC)* on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture sets rule on how sewage sludge can be used by farmers. In particular, limits are set on the concentration allowances for 7 heavy metals. Microplastic concentrations are not mentioned.

The *40 Code of Federal regulations (CFR), part 503 "Standards for the Use or Disposal of Sewage Sludge"*, promulgated by the US EPA, set the general requirements, including pollutant limits, applied to the use of sewage sludge on land (US EPA, 1994).

The Common Agricultural Policy (CAP) – The use of plastics in agriculture is not addressed explicitly by the CAP, it does offer considerable opportunities to influence farming practices. These can take a variety of forms including conditions farmers must comply with in order to receive direct payments (cross compliance and greening), as well as the more flexible tools available through rural development Regulation (EU 1305/2013) that can be used to provide training and capacity building, test and develop new approaches, and enable a transition to alternative and more sustainable farming practices, amongst others. Providing such support requires sufficient financial and operational resources to be made available at the EU, national and regional level, and well as effective accounting and monitoring frameworks. In addition, it requires the will and commitment of Member States to enable these changes in their territories.

The Communication on the future CAP (COM(2017) 713 final) and its upcoming legislative proposals insist on the need for the future policy to increase environmental ambition's levels and focus on results. It additionally highlights the need for the whole policy to support a transition to sustainable agriculture.

Conclusions and way forward

The problem of plastic pollution in terrestrial environments and more specifically in the soil has only recently been receiving attention. In addition to representing an important source of marine litter, plastics are produced, consumed and disposed of on land, highlighting the presence of plastics in the terrestrial environment as well.

Moreover, research shows that plastics are increasingly being used for agricultural purposes, further evidencing the potential of plastics contamination in the soil. While a number of measures are being implemented with the aim of tackling marine plastic litter, further emphasis is needed to address the inadequate treatment of plastics and the leakage of both macro and micro plastics on land.

In order to include this within the current policy mix on plastics, a greater knowledge and consideration of the issue of land-based plastic pollution is necessary. In addition, current trends in plastics applications in agriculture and the associated environmental risks explored so far call for further investigation on the potential harms to humans and the environment as well as possible solutions.

In order to directly tackle plastic pollution in soil, a greater consideration of the issue and its implications is needed in the policies and regulations already addressing or with unexplored potential to address the use of agricultural plastics, limits to soil contaminants and fertiliser quality. In the context of circular economy transition, the evidence discussed here demonstrates that discussions around ensuring the quality and purity of secondary materials are as relevant to biological loops as to technical ones.

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