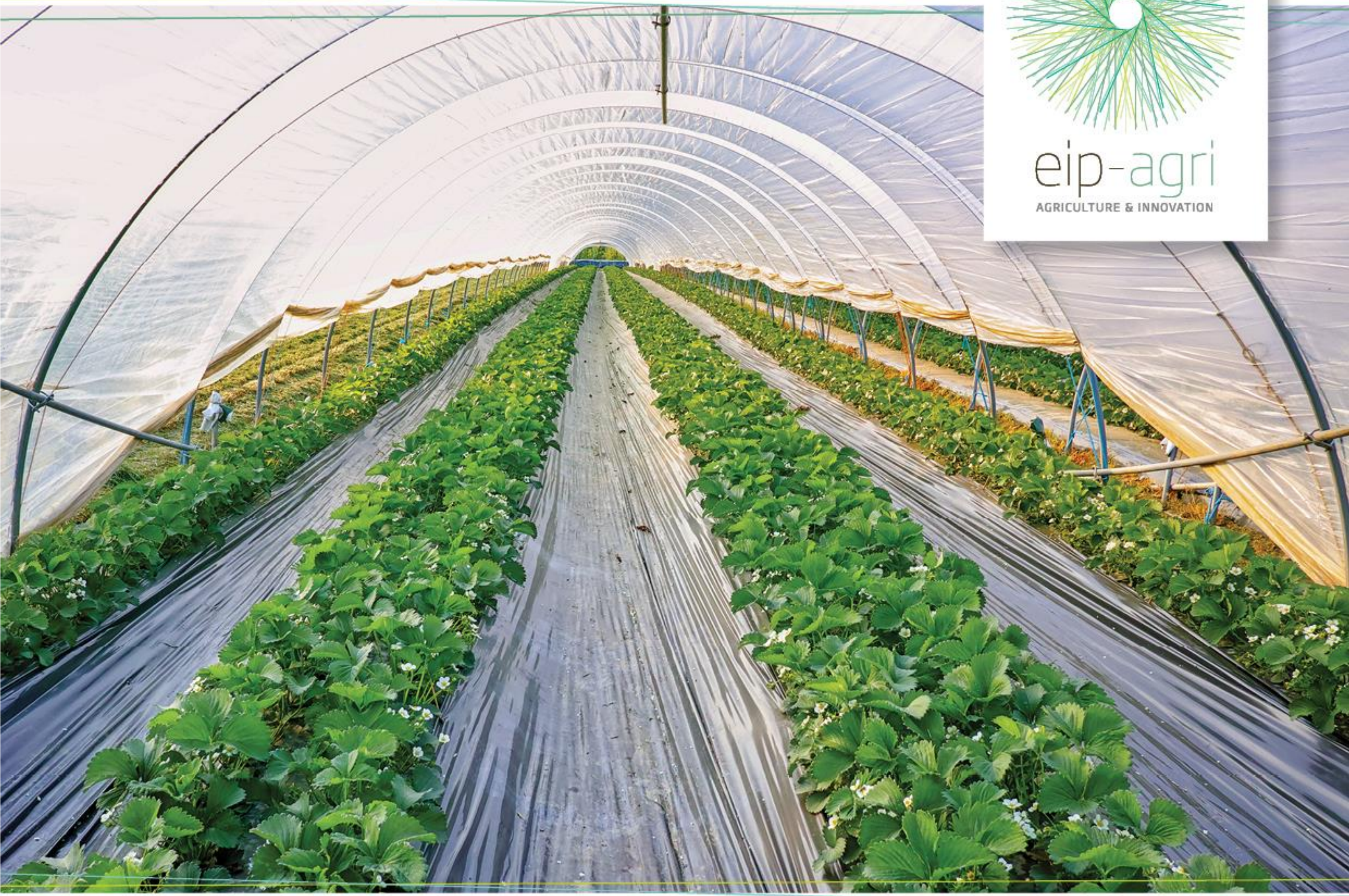


EIP-AGRI Focus Group
Reducing the plastic footprint of agriculture

February 2021

Minipaper E: Secondary sources of plastic contamination

Authors: Geert Cornelis, Cesare Accinelli, Francis Rayns, Karl Fonteyene, Vesna Miličić

funded by European Commission

Table of contents

funded by European Commission

Introduction

Involuntary secondary plastic contamination in agriculture occurs when soil additives containing a significant concentration of plastics are used on land and agricultural fields. Examples of important additives include cattle manure, urban compost, crop residues (agricultural composts), wastewater treatment plant (WWTP) sludges, biodigestates and irrigation water. All of these additives, except irrigation water, have in common that they are relatively cheap ways to add crop nutrients and carbon to soils and can thus be collectively termed biofertilizers, bio-based fertilizers or bio-based amendments. They are in many cases essential to improve crop yields and soil structure. Moreover, applying biofertilizers and soil amendments on land plays an important role in Europe's goal of promoting bio-based societies, that entails recycling carbon and nutrients back to land rather than discarding them in landfills or burning them (Chojnacka et al., 2020).

At the same time, biofertilizers (and possibly also irrigation water) may contain significant concentrations (Table 1) of plastic particles called microplastics (MPs) - plastic fragments smaller than 5 mm. Primary MPs are plastic particles produced and used in the same size as they are when emitted into the environment. Primary MPs include microfibers from clothing, microbeads added to cosmetics as exfoliants and microgranules added to detergents as foam suppressants. Secondary MPs emerge from macroplastics because of physical and chemical processes such as abrasion and photodegradation.

Environmental pollution stemming from plastics, particularly MPs, is coming under increasing scrutiny. The focus was initially primarily on aquatic environments, particularly marine pollution, but the attention to soils has increased more recently. Some authors have claimed that agricultural soils are receiving orders of magnitude more plastic inputs than our oceans, precisely because of the widespread use of soil additives (Nizzetto et al. 2016 a,b; Horton et al., 2017). At the same time, there are indications that relatively high concentrations of MPs impair micro- and macro biological functioning of soils and eventually decrease yields (Moore-Kucera et al., 2014; Brodhagen et al., 2017; Ghimire et al., 2020). Moreover chemical substances used in agriculture, especially those with low water solubility, tend to sorb to MPs, a phenomenon that potentially elevates the environmental impact both within soils or after run-off to aquatic environments (Velzeboer et al., 2014; Hodson et al., 2017; Huerta Lwanga et al., 2016).

The combined influx of MPs from soil additives and the suspected effects on soil organisms and functions has led to proposed or even enacted bans on the use of WWTP sludge on agricultural soil in some countries. Sweden, for instance, suggests a full ban on the use of WWTP sludge on land partly based on the microplastic content. The ban proposes, as an alternative, to extract phosphorus from incinerated WWTP sludge (Swedish Ministry of the Environment, 2018). In addition, the European Urban Waste Water Treatment Directive has publicly been deemed to insufficiently prevent environmental pollution, amongs others because of a lack of consideration of the MP content (European Commision, 2019).

In this mini-paper, we seek to provide more information and raise awareness about soil additives as potential sources of MPs to agricultural systems. While the resulting risk of MPs are detailed in other EIP-AGRI contributions, we specifically focus here on practical issues associated with individual additives and what measures potentially can be taken to minimize contamination while at the same time maximizing the benefit of biofertilizers and irrigation water. As MP measurement, fate and their effects in soils are all relatively unexplored research areas, there are many knowledge gaps that we will briefly summarize.

funded by European Commission

1 Plastic concentrations in secondary plastic sources

Anecdotal measurements of the plastic content of soil amendments confirm that these can indeed contain elevated concentrations of plastics (Table 1) but, as described further in this minipaper, plastic concentrations are not being measured routinely in soil additives, because a validated, standard measurement method does not exist. Moreover, while different measurement techniques have shown great promise, they have different capabilities in terms of the size range of plastics that can be detected. The concentrations in Table 1 are expressed in particles per g of dry biofertilizer when they were measured using a particle counting technique such as µFTIR and they are expressed in mg per g of dry biofertilizer when they were measured using a mass-sensitive technique such as Py-GC-MS. While counting techniques are able to distinguish macroplastics (fragments > 5 mm) from MPs, they are not capable of detecting the even smaller nanoplastics (size < 1 µm). Moreover, interpreting concentration levels expressed in number concentrations is not an easy task, because environmental legislation and ecotoxicological effect levels of chemicals tends to be expressed in terms of mass units such as mg kg^{-1}.

A mass-sensitive approach reflects, if properly optimized, the total content of plastics in a sample. Interpreting these results, e.g. by comparing them to effect levels obtained in standard ecotoxicological tests, may seem more straightforward, but measurement methods that determine the total mass of plastic are not capable of distinguishing macroplastics, MPs and nanoplastics. Such a distinction is likely important because both the environmental mobility and associated effects on the environment and agricultural yield are assumed to increase in the order macroplastics << MPs < nanoplastics (Bellasi et al., 2020). Ideally we would have separate information on the mass concentration of MP and the mass concentration of nanoplastics that can each be compared to the specific effect concentrations for these two size classes obtained in lab tests. This information is difficult to obtain, currently.

It appears that the plastic concentrations in the amendments shown in Table 1 lead to soil concentrations that are lower than the effect levels obtained thus far in ecotoxicological studies. In some cases, other more diffuse plastic contamination sources, such as atmospheric deposition, may be more important (Kawecki et al., 2020). However, we still do not have a complete picture of the hazards posed by plastics on soil functions. Currently known effect levels of MPs in soils are relatively high (Bradney et al., 2019; Zhou et al., 2020), but these were obtained for short-term exposures of single organisms including crops. Agreed-upon effect levels of other chemicals have decreased as more information is gathered on more subtle, longer-term effects on soil functions and the same trend is showing for plastic particles. At the same time, we know that plastics are very persistent and their continuous addition to soils will thus gradually increase their concentration.

funded by European Commission

2 Description of key issue(s)

Table 1. Overview of concentrations and plastic-related issues associated with using different additives

Additive	Plastic Source	Plastic content	Other contaminants	Possible solutions
Urban Compost	Bags and packaging.	~1 p*.g^{-1} [a] 0.01 to 1 p.g^{-1} [b] ~ 2.4 p.g^{-1} [c]	Glass and metal fragments	Better monitoring, certification, Better sorting, Adapt compost processes for the biodegradation to fully happen
Crop residues / agricultural compost	Agricultural plastics	0-0.01 p.g^{-1} [b]		Use biodegradable plastic, including paper, for agriculture, have segregated compost plants.
Sewage sludge	Laundries, road and tyres abrasion	~34 p. g^{-1} [d] ~50 p. g^{-1} [e]	Heavy metals, nutrient excess, pharmaceuticals	Stop applying in fields, pre-treatments, burning
Biodigestate	Agricultural plastics	Expected similar to compost		Better sorting of green and food waste
Manure	Animal ingestion, oversight	~ 1 p.g^{-1} in sheep faeces [f]	Nutrient excess, pharmaceuticals	Avoid the use of contaminated feed
Irrigation water	rivers, canals, groundwater, WWTP effluent	~3.9 p.L^{-1} in irrigation water [g] 0.1 to 10 p.L^{-1} in wastewater effluents [h] 1-1000 p.L^{-1} in surface water [i] 0-60 p.L^{-1} for drinking water [i] from 0 to 1000 p L^{-1} [j]	Pesticides, pharmaceuticals	Be more selective on the e.g. water that is used - boreholes preferable to rivers
Seed coatings	Film-coating formulations	1-5% per seed mass	Pesticides, antimicrobials	Replacing with natural and biodegradable polymers

*"p" = „number of particles"

a (Watteau et al., 2018)
b (Weithmann et al., 2018)
c (Gui et al., 2021)
d (Corradini et al., 2019)
e (van den Berg et al., 2020)
f (Beriot et al., 2020)
g (Zhou et. al., 2020)
h (Zhou et al., 2020)
i (Shen et al., 2020)
j (Koelmans et al., 2019)

funded by European Commission

2.1 Microplastics in manure

Large amounts of food waste (particularly items such as biscuits and bread that have passed their sell-by dates) are used as ingredients for animal feed. In the UK alone, this amounts to 650 000 tonnes per year. Although the food items are de-packaged before discarding them as waste food, a considerable quantity of residual plastic is included in the product. The UK Food Standards Agency has set a limit of 0.15 % plastic in animal food, below this such contamination is legal (ABP Control Regulations (UK), 2015). The European Union has, in principle, a zero tolerance for plastic in animal food (Reg. EC 767/2009), but as discussed earlier, the plastic concentration is rarely measured routinely so it is unclear how this legal limit can be enforced. This plastic may eventually be found in the manure.

Secondly, domesticated animals left to roam on contaminated fields also ingest plastics (Figure 1). A recent study found plastics in faeces of sheep left to graze on fields close to agricultural areas where plastics have been used intensively as mulching films (Beriot et al., 2020). If left unattended, plastic residues are displaced towards the grazing areas, probably via run-off or via wind erosion. This links direct use of agriplastic use (plastic mulch) with the secondary plastic contamination (microplastic in the sheep manure).

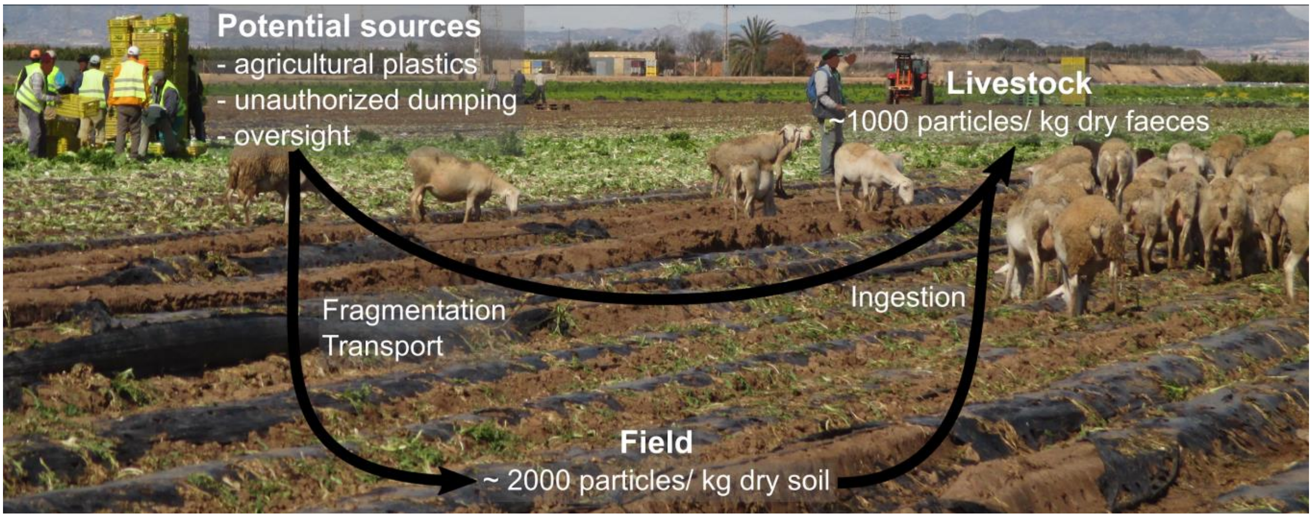


Figure 1: Sheep are brought to eat the plant residues in a lettuce field where plastic mulch was applied in south east Spain. The manure from these sheep was contaminated with plastic, probably because of the plastic contamination in the field.

2.2 Microplastics in compost

Compost is commonly used to improve soil properties (e.g.. soil structure) especially in organic farming. The massive use of plastics and improper sorting by consumers, however, generates a significant plastic concentration in urban food and garden waste. Moreover, in many European countries, organic waste is collected using bags that are designed to be compostable under industrial composting conditions along with organic waste. Sometimes, bags of bioplastics or soil-biodegradable plastics are used. While bioplastics are made from renewable materials, they are not always compostable (as certified by e.g. ISO standard 17088:2008). Soil-biodegradable plastics (as certified by e.g. the N17033:2018 standard) are designed to biodegrade in a soil environment, but they also appear to be "compostable", i.e. they also biodegrade in a composting plant (Sintim et al., 2020). However, the composting process is usually very short (2-3 months) and sometimes this period is insufficient to fully degrade even certified compostable plastics (Weithmann et al., 2018; Accinelli et al., 2019). Finally, most countries allow a certain amount of foreign matter such as plastics in fertilizers; for example, Germany allows up to 0.1 % plastics and particles smaller than 2 mm are not even considered (Figure 2), probably because a standard measurement method is not available (Accinelli et al., 2019, 2020). Physical processes, e.g. during handling and transport of the compost, in combination with light-driven fragmentation processes cause macroplastics to start degrading into MPs. In this way, most composts contain an appreciable

funded by European Commission

concentration of macro- and microplastics and when the compost is spread on land and mixed in, soils are exposed to plastics that may fragment further into MPs and nanoplastics.

In the last decade there has been increasing interest in using compost from biological wastes in agriculture as a soil organic matter amendment, especially in countries with an increased interest in building circular economies. Compost is commonly applied at yearly rate of 20-35 t ha^{-1}. Although MP concentration in compost can vary (Table 1), based on recent studies, compost application can result in an annual spread of MP ranging from 0.016 to 6.3 kg ha^{-1} (Chojnacka et al., 2020). Whilst it is unknown whether these concentrations are high enough to generate observable effects on yields, it is known that MPs tend to accumulate in the soils. Continued accumulation of plastics from compost may thus, in the long term, become unsustainable.

Figure 2. Fractions collected after the first composting and sieving cycle of urban organic waste and close up picture. Many plastic debris are visible and are removed with the sieving cycle but sieving cannot eliminate microplastics (van der Zee, M. & Molenveld, K., 2020).

2.3 Microplastics in WWTP sewage sludge

Plastics are used in various consumer products and many of these inadvertently end up in municipal wastewater. It has been verified that > 90% of the MPs is removed from the wastewater and remains in the WWTP sludge (Lapointe et al., 2020). Much of the plastics are secondary MPs, but many consumer products such as toothpastes or cosmetics contain primary MPs. However, a European wide ban on the use of MPs in cosmetic products, which has already been enacted in several European countries, is bound to reduce the latter group (ECHA, 2018). Moreover, WWTP sludge is applied to agricultural fields with more precautions than for compost or other soil additives. WWTP sludges indeed can contain many other potential contaminants such as toxic metals (e.g. Cd) or pharmaceuticals (Kirchmann et al., 2017).

The use of WWTP sludge is thus strictly regulated in many EU member states and subject to a lot of scrutiny The percentage of WWTP sludge that is put on land varies widely among EU member states from 0 % (e.g. the Netherlands) to 80 % (Ireland). Although the occurrence of plastic in WWTP sludge is neither regulated nor monitored, concentration of up to 24,000 MP particles per kg of dried sludge can be expected (Nizzetto et al., 2016). Considering conventional application rates of sewage sludge in the EU (e.g. in Germany sewage sludge can be applied at the rate of 5 t dry mass of sewage sludge per ha within 3 years) and the plastic concentrations found in WWTP sludge (Table 1), a potential source of up to 430,000 MP particles ha^{-1} per year could be expected. When applied to agricultural fields, sewage sludge is thus a relevant source of MPs in soil (Figure 3). Sweden has recently proposed a ban on the use of WWTP sludge on land and this is partly motivated by the known concentrations of MPs (Swedish Ministry of the Environment, 2018).

funded by European Commission

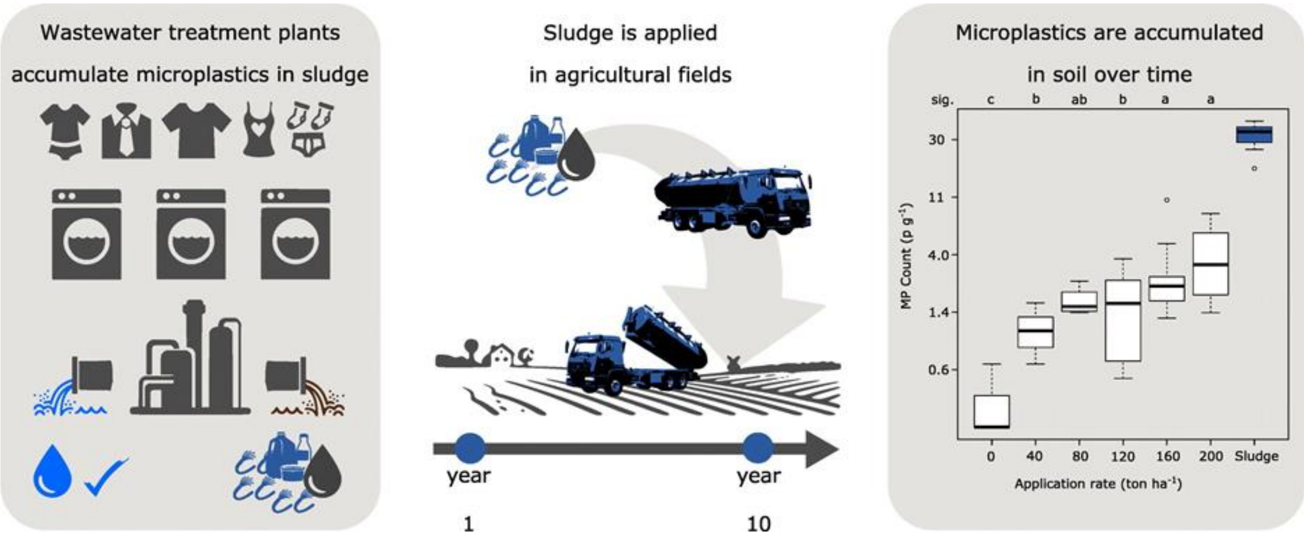


Figure 3, Study showing how the consecutive application of sewage sludge on agricultural fields led to an accumulation of microplastic in the soil (Corradini et al. 2019)

2.4 Microplastics in biogas production residues

Biodigestate is produced from fermenting urban biowaste anaerobically, rather than composting it aerobically. The gases produced in this process can be used to generate. electricity and/or heat. The volumes of biodigestate produced are significantly lower than compost or WWTP sludges, but biodigestate is similarly applied to land, even in countries such as Switzerland where application of WWTP sludge to land has been banned. The same urban biowaste can be used used as during composting. Biodigestate thus similarly contains plastics, because most of them do not decompose anaerobically either (Dümichen et al., 2017) and this adds to the plastic content of soils (Kawecki et al., 2020). Biodigestate produced only from energy crops (such as maize) is much less likely to be contaminated.

2.5 Irrigation water

Irrigation water reaches agricultural soils via lengthy lines of irrigation pipes that are generally made out of polyethylene or other non-biodegradable polymers. These pipes may release MPs because of shear but very little information is available. The quantity released may be low as a study on MPs release from drink bottles found MPs to be generated mainly by physical abrasion while opening and closing the bottle cap and much less by shear. More research is needed to confirm that MP release from irrigation water is indeed limited.

2.6 Seed coatings

Application of pesticides to seeds has become a widely accepted method for improving seed germinability and overall seedling health by protecting against many diseases and early-season insect pests. Despite advancements in seed film-coating technologies, abrasion of the seed coating can occur during handling and mechanical planting operations, resulting in variable amounts of detached fragments entering the soil. Studies have shown that detached seed-coat fragments are characterized by having dimensions not exceeding 5 mm (Foquè et al., 2014; Accinelli et al., 2018), and thus they resemble microplastics. Under some circumstances, these plastic fragments can persist in the soil, having the potential to affect soil quality and soil function. Replacing plastic-based film-coating formulation with biobased and biodegradable formulation would reduce these risks.

funded by European Commission

3 Possible solutions

Below are some suggestions for how the quality of soil additives can be improved, but it should be noted that more technical solutions, e.g. at industrial composting plants, may also provide solutions.

- A more accurate **source separation** is required for reducing indirect MP contamination of soil. However, different sorting procedures and composting technologies result in differences in compost quality as measured by factors such as total organic carbon content, C/N ratios, pH values, etc. Compost quality is also affected by contaminant levels, including glass, metal and plastic particles, which are routinely assessed by sieving the compost through 4 and/or 2-mm sieves, then sorting and weighing unpassed material (Khalid et al., 2017). Although thresholds for physical contaminants larger than 4 or 2 mm have been established in various countries, the content of smaller-sized impurities, such as plastic and compostable plastic particles, is not regulated or measured. Alternatively, different sorting lines can be set up for less contaminated vegetable waste versus more contaminated urban waste.
- A longer **duration of the composting process** is required for reducing indirect MP contamination of soil. At least, certified compostable plastics degrade completely.
- **More defined standards** are required to establish compost quality to avoid excessive concentration of MPs.
- **Monitoring plastic content in soil amendments or grazing areas**, which requires development of routine standard methods.
- **On-site composting** for agricultural compostable plastic (such as biodegradable and compostable twine used for fixing the hops, as illustrated by the LIFE BioTHOP project www.biothop.eu)
- Burning the WWTP sludge and **recycling phosphorus** from the ashes, as proposed in Sweden (Kirchmann et al., 2017)

4 Raising awareness

In addition to the solutions suggested above, the sustainable use of biofertilizers can also be improved with increased awareness. An important piece of information is correct terminology. Table 2 shows different types of plastic in terms of their compostability in different environments and the terms that are often confused with compostable plastics: "oxo-biodegradable", "oxo-degradable", "compostable", "biodegradable" and "bioplastics" (US Federal Trade Commission, 2010).

Knowing what these terms mean is important, e.g. when agricultural plastics are to be composted on-farm to produce high quality compost or when more efficient sorting schemes are designed. A common confusion is that all biobased plastic are also bio-degradable and compostable. While some biobased plastic indeed fit that description, there are plastics produced from fossil fuels such as the PBAT-based plastics that are equally biodegradable (and compostable) whereas there are bioplastics/biobased plastic (e.g bio-PE) that are not biodegradable at all.

The location where biodegradation is supposed to occur (soil, industrial compost plant, home (small-scale) composting plant) and different certificates guarantee biodegradation in different locations. Finally, compostable plastics do not necessarily decompose in a landfill, which again implies that these plastics should be disposed of correctly, i.e. in a composting plant.

funded by European Commission

Table 2. Terminology for different types of plastic that are confused with compostable or biodegradable plastics, including examples of different certificates

Material	Meaning	Bio-degradable in soil	Biodegradable during composting	Anaero-bically degradable	Examples	Certificate examples
Soil-biodegradable plastics	biodegrade fully in soil	Always	Probably yes	Probably yes	Ecovio (BASF) Mater-BI (Novamont)	EN 17033 OK biodegradable SOIL (Tüv Austria)
Bioplastics Biobased plastic	produced from renewable biomass sources	Not always	Not always	Not always	INGEO (Natureworks) BioPE (Solvay)	EN 16785-1
Compostable plastics	biodegrade fully in an industrial and/or home composting plant	Not always	Yes	Probably yes	LIFE BIOTHOP (compostable twines for hop production)	EN 13432 (Industrial) EN 14995 ISO 17088 ISO 18606 ASTM D6400 OK compost home (Tüv Austria)
Oxo-degradable (oxo-biodegradable) plastics	Conventional polymers mixed with additives intended to initiate degradation	No	No	No	Oxo-degradable plastic mulch	N/A

Oxo-biodegradable plastics rarely meet the standard for biodegradability or compostability (Deconinck et al., 2013). It is increasingly being claimed that these plastics only partially biodegrade and when doing so generate microplastic residues in the soil, whereas oxo-biodegradable plastic producers state that the only difference with other biodegradable plastics is the initial non-biological degradation process (Meereboer et al., 2020; https://www.biodeg.org/)). Oxo-biodegradable plastics are nevertheless increasingly being restricted (ECHA, 2018).

Table 2 only gives the most important examples of certificates for compostability or biodegradability. A complete list is discussed elsewhere (Hilton et al., 2020). The many different certificates are produced in different regions (e.g. USA, EU) or different member states and thus add to the confusion. Moreover, certification of the plastic residues in biofertilizer would help farmers to choose one product or another. For certification, the plastic content in the biofertilizers needs to be measured and communicated to the farmer using it. Therefore the implementation of certifications and norms goes hand in hand with the development of fast, cheap and accurate monitoring protocols. The same applies to verifying whether regulatory or other actions improve the quantity of compost. We generally lack data on the plastic concentration in soil amendments and can thus currently not assess risks associated other than via mass-flow analyses (Kawecki et al., 2020).

funded by European Commission

5 Conclusions

It has to be stressed that field applications of biofertilizer should be implemented and promoted to improve the nutrients cycle. However many biofertilizers are also vectors for MPs into agricultural systems. It is clear that biofertilizers are frequently contaminated by plastics and bioplastic fragments and using them is consequently expected to contaminate the soil. The concentration especially of non-biodegradable plastics will thus gradually increase over time. However, despite the growing concern about terrestrial contamination by MPs, many aspects of the phenomenon remain unclear or unexplored, particularly for MPs generated from biodegradable and/or compostable plastic packaging products. It is thus very unclear at which concentration MPs really exert negative effects on soils. Laboratory studies seem to suggest that much higher concentrations are needed to generate observable negative effects on soils than are found there currently.

While most soils likely contain plastic concentrations much lower than these effect levels, we actually have very little information available on plastic content of biofertilizers. This constrains both the risk assessment of biofertilizer use as well as verification of the success of better waste management actions such as sorting or on-farm composting. A mass-flow analysis showed that using biodigestate or compost on soils, despite their plastic content, will contribute relatively little to the overall plastic concentrations of soil in the short term (Kawecki et al., 2020). Routine measurement tools are thus urgently needed to ensure a safe use of biofertilizers on land.

6 Ideas for operational groups

While routine standardised measurement techniques for plastic in soils or biofertilizers do not exist, such techniques can be expected to be developed in the relatively short term. A collaboration between academic partners developing such a technique, industrial composting plants and a farmer collective could explore whether different management actions such as better sorting, allowing only certified compostable plastics in composting plants and/or on-farm composting can indeed lead to observable decrease in plastic plastic fluxes to agricultural soils.

funded by European Commission

References

ABP Control Regulations (UK), 2015. The Animal Feed:Composition, Marketing and Use *UK Statutory Instruments*, England, n. 255.

Accinelli C., Abbas H. K., Sheir W. T., 2018. A bioplastic-based seed coating improves seedling growth and reduces production of coated seed dust. *Journal of Crop Improvement*, **32**: 318-330. https://doi.org/10.1080/15427528.2018.1425792

Accinelli C., Abbas H. K., Shier W. T., Vicari A., Little N. S., Aloise M. R., Giacomini S., 2019. Degradation of microplastic seed film-coating fragments in soil. *Chemosphere*, **226**: 645-650. https://doi.org/10.1016/j.chemosphere.2019.03.161.

Accinelli C., Abbas H. K., Bruno V., Nissen L., Vicari A.,Bellaloui N., Little N. S., Shier, W. T., 2020. Persistence in soil of microplastic films from ultra-thin compostable plastic bags and implications on soil *Aspergillus flavus* population. *Waste Management*, **113**: 312-318. doi:10.1016/j.wasman.2020.06.011

Bellasi A., Binda G., Pozzi A., Galafassi S., Volta P., Bettinetti R., 2020. Microplastic contamination in freshwater environments: a review, focusing on interactions with sediments and benthic organisms. *Environments*, **7**: 30. https://doi.org/10.3390/environments7040030

Beriot N., Zomer P., Zornoza R., Geissen V., 2020. A laboratory comparison of the interactions between three plastic mulch types and 38 active substances found in pesticides. *Peer J*, **8**: E9876. https://doi.org/10.7717/peerj.9876

Bradney L., Wijesekara H., Palansooriya K. N., Obadamudalige N., Bolan N. S., Sik Y. O., Rinklebe J., Kimg K. H., Kirkhamh M. B., 2019. Particulate plastics as a vector for toxic trace-element uptake by aquatic and terrestrial organisms and human health risk. *Environment International*, **131**: 104937. https://doi.org/10.1016/j.envint.2019.104937

Brodhagen M., Goldberger J., Hayes D., Inglis D. A., Marsh T., Miles C., 2017. Policy considerations for limiting unintended residual plastic in agricultural soils. *Environmental Science & Policy*, **69**: 81-84. doi:10.1016/j.envsci.2016.12.014

Chojnacka K., Moustakas K., Witek-Krowiak A., 2020. Bio-based fertilizers: A practical approach towards circular economy. *Bioresource Technology*, **295**: 1222234. doi:10.1016/j.biortech.2019.122223

Corradini F., Meza P., Eguiluz R., Casado F., Huerta-Lwanga E., Geissen V., 2019. Evidence of microplastic accumulation in agricultural soils from sewage sludge disposal. *Science of the Total Environment*, **671**: 411-420. https://doi.org/10.1016/j.scitotenv.2019.03.368

Deconinck S., De Wilde B., 2013. Recent developments in standardization and certification of oxo-degradable plastics: Do they bring more clarity? *8th European Bioplastics Conference,* Berlin, Germany. https://www.ows.be/wp-content/uploads/2014/05/Recent-developments-in-standardisation-certification-of-oxo-degradable-plastics.pdf

Dümichen E., Eisentraut P., Bannick C. G., Barthel A. K., Senz R., Braun U., 2017. Fast identification of microplastics in complex environmental samples by a thermal degradation method. *Chemosphere*, **174**: 572-584.

European Commission, 2009. Regulation (EC) No 767/2009 of the *European Parliament and of the Council of 13 July 2009* on the placing on the market and use of feed.

European Chemicals Agency ECHA, 2018. to consider restrictions on the use of oxo-plastics and microplastics.

European Commission, 2019. Evaluation fo the Urban Waste Water Treatment Directive. *Commission staff working document*.

Foquè D., Davarrewaere W., Verboven P., Nuyttens D., 2014. Characterization of different pneumatic sowing machines. *Aspect of Applied Biology,* **99**: 77-84.

Ghimire S., Flury M., Scheenstra E. J., Miles C. A., 2020. Sampling and degradation of biodegradable plastic and paper mulches in field after tillage incorporation. *Science of the Total Environment,* **703**: 135577. doi:10.1016/j.scitotenv.2019.135577

Gui J., Sun Y., Wang J., Chen X., Zhang S., Wu D., 2021. Microplastics in composting of rural domestic waste: abundance, characteristics, and release from the surface of macroplastics. *Environmental Pollution, **274***: 116553. doi.org/10.1016/j.envpol.2021.116553

Hilton M., Hann S., Scholes R., Molteno S., Favoino E., Jakobsen L.J., 2020. Relevance of biodegradable and compostable consumer plastic products and packaging in a circular economy. Framework Contract n. ENV.B.3/FRA/2017/005, *European Commission*. doi:10.2779/497376

Hodson M. E., Duffus-Hodson C. A., Clark A., Prendergast- Miller M. T. Thorpe K. L., 2017. Plastic bag derived- Microplastics as a vector for metal exposure in terrestrial invertebrates. *Environmental Science and Technology*, **51**: 4714-4721. doi:10.1021/acs.est.7b00635

Horton A. A., Walton A., Spurgeon D. J., Lahive E., Svendsen C., 2017. Microplastics in freshwater and terrestrial environments: evaluating the current understanding to identify the knowledge gaps and future research priorities. *Science of the Total Environment*, **586**: 127-141. doi:10.1016/j.scitotenv.2017.01.190

Huerta Lwanga E., Gertsen H., Gooren H., Peters P., Salánki T., van der Ploeg M., Besseling E., Koelmans A. A., Geissen V., 2016. Microplastics in the terrestrial ecosystem: implications for *Lumbricus terrestris* (*Oligochaeta, Lumbricidae*). *Environmental Science & Technology*, **50**: 2685–2691. https://doi.org/10.1021/acs.est.5b05478

ISO 17088:2012, Specifications for compostable plastics.

Kawecki D, Goldberg L, Nowack B., 2020. Material flow analysis of plastic in organic waste in Switzerland. *Soil Use Manage*, **00**: 1-12. https://doi.org/10.1111/sum.12634

Khalid S., Shahid M., Niazi N. K., Murtaza B., Bibi I., Dumat C., 2017. A comparison of technologies for remediation of heavy metal contaminated soils. *Journal of Geochemical Exploration*, **182**: 247-268.

Kirchmann H., Börjesson G., Kätterer T., Cohen Y., 2017. From agricultural use of sewage sludge to nutrient extraction. *A soil science outlook*, **46**: 143-154. https://doi.org/10.1007/s13280-016-0816-3

Koelmans A. A., Nor N. H. N., Hermsen E., Kooi M., Mintenig S. M., De France J., 2019.
Microplastics in freshwaters and drinking water: Critical review and assessment of data quality. *Water Research*, **155**: 410-422. doi: 10.1016/j.watres.2019.02.054u

Lapointe M., Farner J. M., Hernandez L. M., Tufenkji N., 2020. Understanding and Improving Microplastic Removal during Water Treatment: Impact of Coagulation and Flocculation. *Environmental Science & Technology*, **54**: 8719-8727.

Meereboer K. W., Misra M., Mohanty A. K., 2020. Review of recent advances in the biodegradability of polyhydroxyalkanoate (PHA) bioplastics and their composites. *Green Chemistry,* **22**: 5519-5558. doi: 10.1039/D0GC01647K

Moore-Kucera J., Cox S. B., Peyron M., Bailes G., Kinloch K., Karich K., Miles C., Inglis D. A., Brodhagen M., 2014. Native soil fungi associated with compostable plastics in three contrasting agricultural settings. *Applied Microbiology and Biotechnology,* **98**: 6467-6485. doi:10.1007/s00253-014-5711-x

Nizzetto L., Bussi G., Futter M. N., Butterfield D., Whitehead P. G., 2016a. A theoretical assessment of microplastic transport in river catchments and their retention by soils and river sediments. *Environmental Science: Processes & Impacts,* **18**: 1050-1059. doi:10.1039/c6em00206d.

Nizzetto L., Futter M., Langaas S., 2016b. Are agricultural soils dumps for microplastics of urban origin? *Environmental Science & Technology,* **50**: 10777-10779. https://doi.org/10.1021/acs.est.6b04140

Shen M., Ye S., Zeng G., Zhang Y., Xing L., Tang W., Wen X., Liu S., 2020. Can microplastics pose a threat to ocean carbon sequestration? *Marine Pollution Bulletin*, **150**: 110712. https://doi.org/10.1016/j.marpolbul.2019.110712

Sintim H. Y., Bary A. I., Hayes D. G., Wadsworth L. C., Anunciado M. B., English M. E., Bandopadhyay S., Schaeffer S. M., DeBruyn J. M., Miles C. A., Reganold J. P., Flury M., 2020. In situ degradation of biodegradable plastic mulch films in compost and agricultural soils. *Science of The Total Environment*, **727**: 138668.

Skog K., 2018. Inquiry shall propose a ban on the spread of sewage sludge in fields and requirements for recycling of phosphorus. *Swedish Ministry of the Environment*.

US Federal Trade Commission, 1010. Guides for the Use of Environmental Marketing Claims; Proposed Rule. *Federal Trade Commission*, Washington, 2010.

van den Berg P., Huerta-Lwanga E., Corradini F., Geissen V., 2020. Sewage sludge application as a vehicle for microplastics in eastern Spanish agricultural soils. *Environmental Pollution*, **261**:114198. https://doi.org/10.1016/j.envpol.2020.114198 0269-7491

van der Zee, M. & Molenveld, K., 2020, Wageningen: Wageningen Food & Biobased Research. 100 p. (Report / Wageningen Food & Biobased Research; no. 2020)
https://edepot.wur.nl/514397

Velzeboer I., Kwadijk C. J. A. F. , Koelmans A. A., 2014. Strong sorption of PCBs to nanoplastics, microplastics, carbon nanotubes, and fullerenes. *Environmental Science & Technology,* **48**: 4869-4876. https://doi-org.ezproxy.unibo.it/10.1021/es405721v

Watteau, F., Dignac M. F., Bouchard A., Revallier A., Houot S., 2018. Microplastic detection in soil amended with municipal solid waste composts as revealed by transmission electronic microscopy and pyrolysis/GC/MS. *Frontiers in Sustainable Food Systems*, **2**: 81. https://doi.org/10.3389/fsufs.2018.00081

Weithmann N., Möller J. N., Löder M. G. J., Piehl S., Laforsch C., Freitag R., 2018. Organic fertilizer as a vehicle for the entry of microplastic into the environment. *Science Advances,* **4**: EAAP8060. doi:10.1126/sciadv.aap8060

Zhou Y., Wang J., Zou M., Zhenyi J., Zhou S., Li Y., 2020. Microplastics in soils: A review of methods, occurrence, fate, transport, ecological and environmental risks. *Science of The Total Environment*, **748**: 141368. https://doi.org/10.1016/j.scitotenv.2020.141368

https://www.life-biothop.eu/project/about-the-project

https://www.biodeg.org/

You can contact Focus Group members through the online EIP-AGRI Network.
Only registered users can access this area. If you already have an account, you can log in here
If you want to become part of the EIP-AGRI Network, please register to the website through this link

funded by European Commission

eip-agri
AGRICULTURE & INNOVATION

The European Innovation Partnership 'Agricultural Productivity and Sustainability' (EIP-AGRI) is one of five EIPs launched by the European Commission in a bid to promote rapid modernisation by stepping up innovation efforts.

The **EIP-AGRI** aims to catalyse the innovation process in the **agricultural and forestry sectors** by bringing **research and practice closer together** – in research and innovation projects as well as *through* the EIP-AGRI network.

EIPs aim to streamline, simplify and better coordinate existing instruments and initiatives and complement them with actions where necessary. Two specific funding sources are particularly important for the EIP-AGRI:

- ✓ the EU Research and Innovation framework, Horizon 2020,
- ✓ the EU Rural Development Policy.

An EIP AGRI Focus Group* is one of several different building blocks of the EIP-AGRI network, which is funded under the EU Rural Development policy. Working on a narrowly defined issue, Focus Groups temporarily bring together around 20 experts (such as farmers, advisers, researchers, up- and downstream businesses and NGOs) to map and develop solutions within their field.

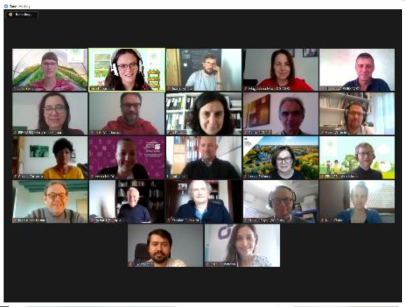
The concrete objectives of a Focus Group are:

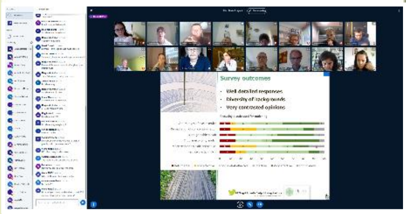
- ✓ to take stock of the state of art of practice and research in its field, listing problems and opportunities;
- ✓ to identify needs from practice and propose directions for further research;
- ✓ to propose priorities for innovative actions by suggesting potential projects for Operational Groups working under Rural Development or other project formats to test solutions and opportunities, including ways to disseminate the practical knowledge gathered.

Results are normally published in a report within 12-18 months of the launch of a given Focus Group.

Experts are selected based on an open call for interest. Each expert is appointed based on his or her personal knowledge and experience in the particular field and therefore does not represent an organisation or a Member State.

*More details on EIP-AGRI Focus Group aims and process are given in its charter on:
http://ec.europa.eu/agriculture/eip/focus-groups/charter_en.pdf





funded by European Commission

Join the EIP-AGRI network & register via www.eip-agri.eu

servicepoint@eip-agri.eu | +32 2 543 73 48 | Koning Albert II laan 15 | Conscience Building | 1210 Brussels | Belgium