Small Plastic Wastes in Soils: What Is Our Real Perception of the Problem?

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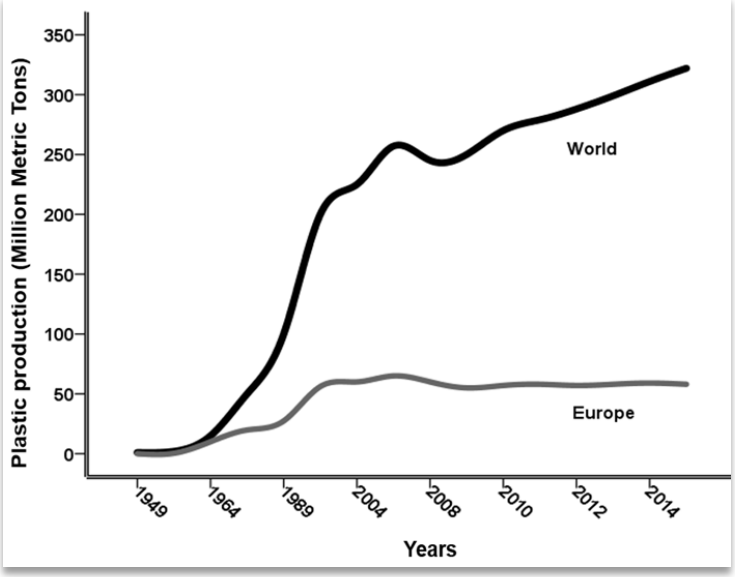
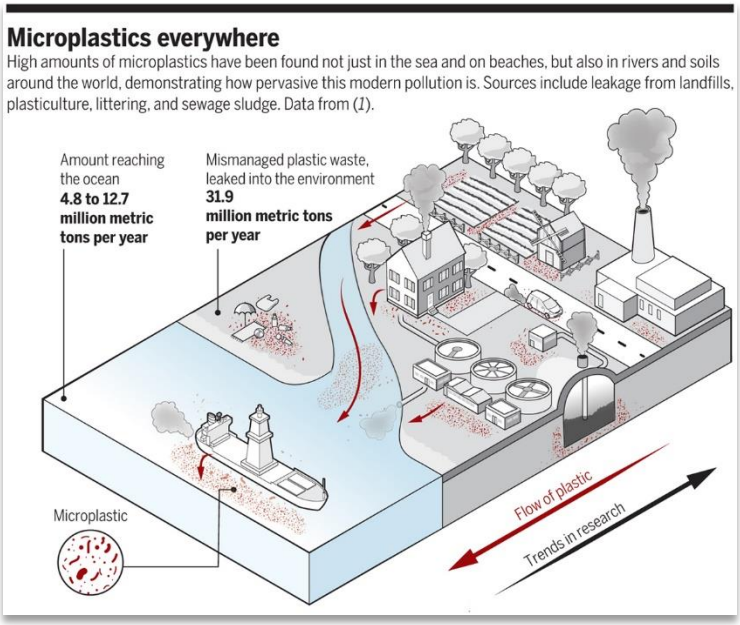
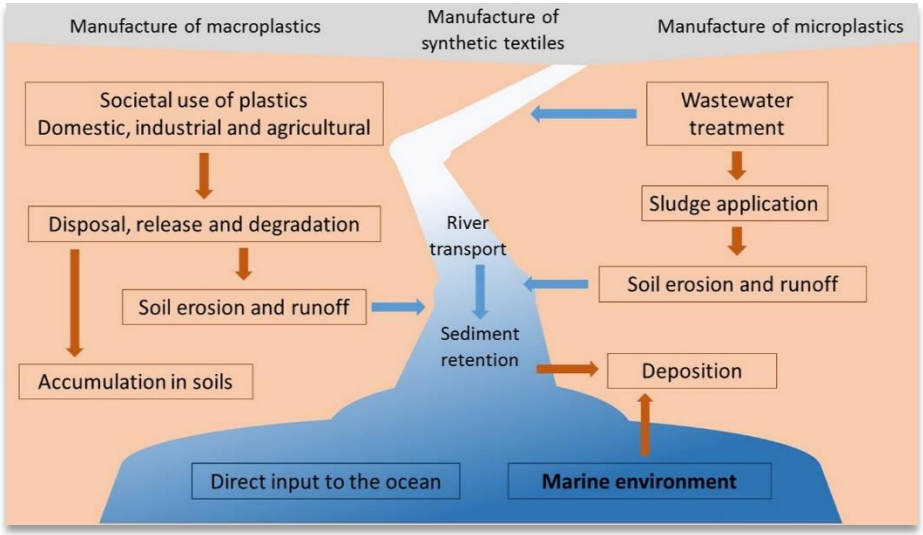
Introduction

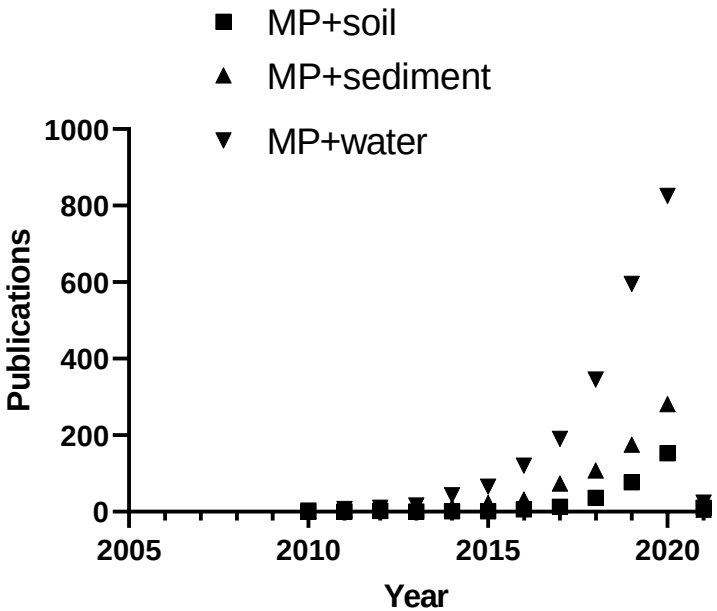




Microplastics in soils? The forgotten environment



Horton et al. (2017)



- The amount of plastic's release in land is estimated to be 4-23 times higher than the amount that goes to the oceans.
- The transference processes among environmental compartments are poorly studied.
- Only less than 15% of ISI WOS papers about environmental impacts of microplastics targeted soil and/or soil organisms (**90% publications last 6 years**)

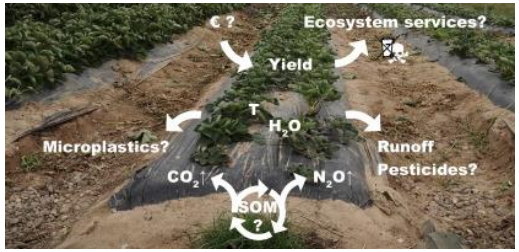
Agricultural, industrial uses and landfills as source of plastics

- Landfills
- Greenhouse films and plastic mulch
- Microplastics from sewer sludges (waste treatment plants)…
- Packaging/transport/industrial wastes…

Soil incorporation → Water streams, Lakes, Seas and oceans

↓ 30-50% can be retained within soil system

Liu et al. 2018



Steinmetz et al. 2016

→ Weathering of plastics wastes

↓

Microplastics incorporation into soils in agricultural lands

WHAT CAN YOU FIND IN THIS BOOK CHAPTER?

We do a short review about the microplastics on terrestrial ecosystems, with emphasis on how the presence of microplastics can affect the physical, chemical and biological properties of the soil, including ecotoxicology in the three main study groups: nematodes, springtails and earthworms.

Table 1 An overview of the effects of nanoplastics/microplastics on nematodes

Species testing	Type of plastic polymer	Particle size	Doses	Exposure conditions (test media and time of exposure)	Observed endpoints	References
Nematodes						
Caenorhabditis elegans (Maupas, 1900)	Fluorescently labelled PS	100–1000 nm	100 µL suspension of 1.0×10^9 mL^{-1} of 0.5 µm and 1.0×10^8 mL^{-1} of 1.0 µm microspheres in S-basal buffer	Agar plates 30 min	Uptake and accumulation in the intestine and pharynx	Kiyama et al. (2012)
	PA, PE, PP, PVC	~70 µm	MP suspension in K-medium (32 mM L^{-1} KCl, 51 mM L^{-1} NaCl) added to nematode growth medium at different concentrations (0.5, 1.0, 5.0 and 10.0 mg m^{-2})	Agar-padded slide 2 days	Inhibition of growth, survival and reproduction; decreased intestinal calcium levels, microplastic accumulation in the intestine, and oxidative stress (increased expression of Glutathione S-transferase 4)	Lei et al. (2018)
	Fluorescently labelled PS	0.1, 1.0 and 5.0 µm				
C. elegans	Nano-PS	50 and 200 nm	17.3 mg L^{-1} and 86.8 mg L^{-1}	Agar-padded slide 1 day	Inhibition of locomotion and reproduction Induction of oxidative stress (ROS production) Changes in energy metabolism (reduction on TCA cycle intermediates, lactic acid and glucose). Uptake and accumulation of nanoplastics in the intestine	Kim et al. (2019)
	TiO_2-Nano-PS	108.2 ± 4.5 nm	0.01, 0.1, or 1 µg L^{-1} by 1% solid suspension in water	Agar-padded slide 1 day	Inhibition of locomotion and induction of intestinal ROS production	Dong et al. (2018)

PA polyamides, *PE* polyethylene, *PP* polypropylene, *PVC* polyvinyl chloride, *PS* polystyrene. *NanoPS* nanopolystyrene, *TCA cycle* tricarboxylic acid cycle

Table 2 An overview of the effect of nanoplastics/microplastics on springtails species

Species testing	Type of plastic polymer	Particle size	Doses	Exposure conditions (soil type and time of exposure)	Observed endpoints	References
Springtails						
Folsomia candida (Willem, 1902)	Urea-formaldehyde and PET	<100 mm and 100–200 mm	2.5 mg of the <100 mm 5 mg of the 100–200 mm fraction	Direct exposure on petri dishes. without substrate 7 days	Ability to transport and distribute MP	Maaβ et al. (2017)
	PVC	80–250 µm	0 and 1 g MP kg^{-1} soil$_{dw}$	*OECD artificial soil* 56 days	Inhibition of growth and reproduction Changes in gut microbiota and in the carbon and nitrogen elemental absorption	Zhu et al. (2018a)
	PVC	80–250 µm	5000 particles	Direct exposure on petri dishes. Without substrate 7 days	Transport and distribution of MP up to 9 cm	Zhu et al. (2018b)
Lobella sokamensis (Deharveng and Weiner, 1984)	PE and PS	0.47–0.53 µm, 27–32 µm, and 250–300 µm	Several concentrations (4–1000 mg kg^{-1})	*LUFA soil type no. 2.2* <1 day	Inhibition of movement	Kim and An (2019)
Proisotoma minuta (Tullberg, 1871)	Urea-formaldehyde and PET	<100 mm and 100–200 mm	2.5 mg of the <100 mm 5 mg of the 100–200 mm fraction	Direct exposure on petri dishes. Without substrate 7 days	Ability to transport and distribute MP	Maaβ et al. (2017)

MP microplastics, *PET* polyethylene terephthalate, *PE* polyethylene, *PVC* polyvinyl chloride, *PS* polystyrene

WHAT CAN YOU FIND IN THIS BOOK CHAPTER?

We identified that it is necessary to increase the study on the biological properties of soil, especially on soil microbial activity and its role in nutrient cycles, which can negatively affect soil productivity as well as environmental quality.

Also, the introduction of new eco-friendly materials such as bioplastics opens up several questions about whether they are eco-friendly.

Table 4 An overview of the effect of nanoplastics/microplastics on soil microbial communities

Type of plastic	Particle size	Dose	Exposure conditions (soil type and time of exposure)	Observed endpoints	References
PAN fibres	3756 × 18 µm	0.05, 0.10, 0.20, 0.40% of $soil_{dw}$	Loamy sand soil 5 weeks	Inhibition of soil microbial activity through the assessment of FDA hydrolysis	de Souza Machado et al. (2018)
PA beads	15–20 µm diameter	0.25, 0.50, 1 and 2% of $soil_{dw}$			
PES fibres	5000 × 8 µm	0.05, 0.10, 0.20, 0.40% of $soil_{dw}$		Inhibition of soil microbial activity through the assessment of FDA hydrolysis	
HDPE fragments	±643 µm	0.25, 0.50, 1 and 2% of $soil_{dw}$		No clear effect on soil microbial activity	
PP	<180 µm	0, 7 and 28% of $soil_{dw}$	Calcaric *cambisol* 7 and 30 days	Increased activity of phenol oxidase and FDA hydrolysis	Liu et al. (2017)
Plastic film mulch (PVC) + contaminated with phthalate acid esters	20 mm × 20 mm	0, 67.5 and 337.5 kg ha^{-1}	*Luvisol* 60 days	Reduction of soil microbial C and N (measured by fumigation extraction method) Reduction of enzymatic activities (FDA and dehydrogenase activities) and functional diversity (community-level physiological profile)	Wang et al. (2016)
NanoPS	32.6 nm ± 11.9 nm	10, 100, and 1000 ng PS-NPs g^{-1} dry soil	*Stagnic-Luvisol* 28 days	Reduced microbial biomass carbon (measured by chloroform fumigation extraction) Inhibition of enzymatic activities (dehydrogenases, leucine-aminopeptidase, ß-cellobiohydrolase, ß-glucosidase, alkaline-phosphatase enzyme activities)	Awet et al. (2018)

FDA hydrolysis of fluorescein diacetate, *PAN* polyacrylic, *PA* polyamide, *PES* polyester, *HDPE* high-density polyethylene, *PP* polypropylene, *NanoPS* nanopolystyrene

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MATiSSe - Microplastics on AgriculTural SoilS: assessment of their impact on physical, chemical and biological soil properties. CNRS – OHM-Estarreja. **OHM-E/2018/Proj.4**

Microplastics in the environment: soil-water interactions and effects on soil properties. Fundação para a Ciência e a Tecnologia. **CEECIND/03794/2017**

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