Soil and land
research funding
platform for Europe

Project MISSOURI

Microplastics in soil and groundwater:
sources, transfer, metrology and impacts

The European project MISSOURI (MIcroplasticS in Soils and GROUndwater: sources, transfer, metrology and Impacts) took place from November 1, 2020 to October 31, 2021. It was partially funded by the European platform SOILveR. This project was coordinated by the National Institute for Industrial Environment and Risks (Ineris), with, as partners, the Environment & Health Department of the Dutch Vrije Universiteit (VU) and the Walloon Scientific Institute of the Public Service (Issep).

Summary

Plastics are globally used in various urban and industrial sectors and in everyday human activities. Their global production increased from 1.5 million tons in 1950 to 322 million tons in 2015, of which only 5% would be recycled. Plastic waste entering the environment can fragment into smaller particles such as microplastics which accumulate considerably in the environment. In order to better understand the transfers and impacts of microplastics on terrestrial ecosystems (the aquatic compartment being the most studied) and on humans, it is necessary to be able to characterize them and quantify their occurrence. This step can only be done in conjunction with a consensual definition of microplastics that does not exist today.

The objectives of the European project MISSOURI (MIcroplasticS in Soils and GROUndwater: sources, transfer, metrology and Impacts) were thus to:

(1) propose a definition of microplastics ;

(2) compare laboratory methods for the separation and analysis of microplastics in soils through a state-of-the-art review as well as through participation and analysis of the results of a study between several laboratories ;

(3) establish a state of the art of scientific knowledge on microplastics in soils and groundwater as well as their impacts on the terrestrial ecosystem and on humans ;

(4) collect the findings and opinions of stakeholders related to microplastics (analysis laboratories, manufacturers, users of microplastics for research and development, researchers in environmental science and toxicologists, etc.) ;

(5) identify management actions and priorities for future research projects on microplastics.

This educational brochure aims to explain the various debates on the proposals for the definition and protocols regarding analysis and quantification of microplastics, to summarize the state of the art on microplastics in soils and groundwater, their impacts on terrestrial ecosystems and humans and the opinions of the stakeholders.

Definition and harmonization protocol

The debate over the size of microplastics

Microplastics are generally defined as plastic fragments having a size lower than 5 mm and greater than 100 nm. However the size limits are still debated to distinguish them respectively from macro- and nano-plastics.

Regarding the upper limit size, the ISO / TR 21960: 2020 standard stipulates 1 mm while those dealing with wastewater and fertilizer treatment consider the size of 2 mm. This is the size for which wastewater filtration is maximum and the limit that a compost or digestate can contain.

Regarding the lower size limit, the ISO / TR 21960: 2020 standard sets it at 1 µm while (eco) toxicologists set it at 100 nm, the size allowing a particle to cross biological barriers.

The debate over the shape of microplastics

The debate over the definition is accentuated by the fact that there are microplastics of different shapes: microbeads mainly used in personal care products, plastic granules from pellet making, fibers (most common type) generated from clothing, foam used for food containers and beverage cups, and (smaller) fragments derived from degradation of larger plastic products. For a microbead, the size would correspond to its diameter while for a fiber, it could be its length or its width.

The debate over the identification techniques

Besides the question of what to characterize, how to do it involves different chain procedure techniques that are already tested:

- sampling, separation and extraction (eg drying and sieving, density separation, removal of organic matter, filtration);

- identification and quantification (visual identification, vibrational spectroscopy, thermal analysis, chromatography).

These techniques differ depending on the environmental matrix studied and there is currently no standardized analytical method for monitoring soil microplastics. Research and technical developments should focus on this standardization protocol associated with quality assurance / quality control processes, microplastic reference materials. These efforts will allow large-scale monitoring of soil contamination by microplastics, identification of the most polluting human activities and a better understanding of the fate and impacts of soil microplastics.

State of the art on soils and groundwater

Sources of microplastics in agricultural soils

The main sources of microplastics in European agricultural soils are sewage sludge (estimated between 125 and 850 tons per million inhabitants). Sludge from wastewaters contains microplastic fibers from textile abrasion in washing machines, microplastic beads from cosmetics and / or coating substances. In addition to sludge composting, microplastics can also be introduced by pig manure from farmed pigs, plastic mulch used for market gardening, irrigation with treated and untreated wastewaters, as well as fertilization from coated fertilizer granules for slow diffusion. The additional sources come not only from atmospheric transport of particles resulting from abrasion of tires and brakes of road vehicles but also from floods, surface water runoff or transfers by terrestrial organisms (ingestion / excretion, cutaneous adhesion). Since most microplastics are deposited on the surface of soils, their concentration is greater at the surface than at depth.

Different microplastics depending on the type of soil and its use

In urban, agricultural and coastal soils, polyethylene is the main type of microplastics, followed by polypropylene and polystyrene. Urban soils also contain polyvinyl chloride. In terms of shapes, fragments, fibers and films are the most common. To these data must be added those of the additives contained in microplastics, used for their properties of plasticizers, flame retardants, stabilizers, antioxidants or pigments. Little data exists today on their type and concentration in soils and even less on their potential impacts on the fauna, flora and functions of terrestrial ecosystems.

Impacts of microplastics on soils

Due to their large specific surface, their polarity, their hydrophobicity and their persistence in the environment, microplastics have the capacity to interact with soil contaminants (pesticides, heavy metals, PAHs[1], POP[2], etc.) and to promote their dispersion in thus playing the role of «Trojan horse». This capacity depends on the type, size, shape, aging (in relation to the rate of degradation) of the microplastics combined with the soil conditions and the properties of the contaminants. Certain biodegradable microplastics such as polylactic acid or polybutylene succinate have a greater affinity for hydrophobic contaminants (heavy PAHs, PCBs[3], PBDEs[4]...) compared to conventional non-degradable synthetic microplastics. These biodegradable microplastics would thus be more harmful than conventional synthetic microplastics. However, these results need to be supported by further studies.

These different properties give microplastics the power to affect bulk density, water retention

[1] PAH: Polycyclic Aromatic Hydrocarbons
[2] POP: Persistent Organic Pollutant
[3] PCB: Polychlorinated Biphenyls
[4] PBDE: Polybrominated diphenyl ethers

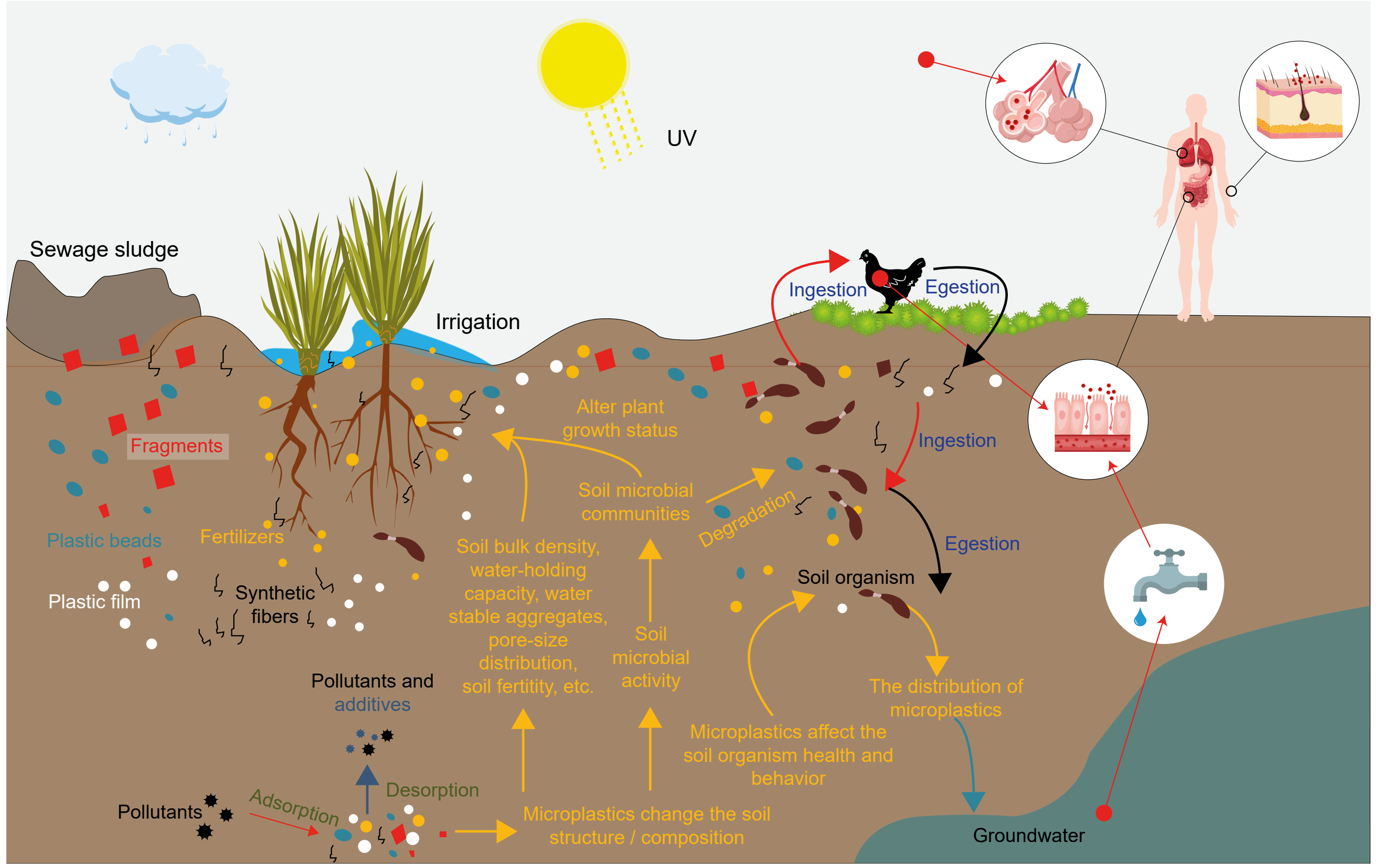
capacity and the functional relationship between microbial activity and stable aggregates in water. In addition, by being able to modify the soil microbial communities, microplastics can impact the enzymatic activities related to carbon degradation which in turn affect the state of nutrients available to plants and more generally the carbon and nitrogen cycles.

Microplastics and groundwater

Few studies specifically report microplastics in groundwater. These would come from their migration from soil to depth, including leaching of soils, surface runoff, landfill leachate, wastewater effluents, septic effluents and sewage sludge. A study on karstic groundwater revealed concentrations between 6 and 15 particles of microplastics / L, correlated with the concentrations of triclosan, phosphate and chloride (components of wastewaters). The most common microplastics in groundwater are polyethylene, polyethylene terephthalate and propylene, compounds also present in drinking water, drinking water and tap water, mainly in the form of fibers and fragments.

Soil factors influencing the transfer of microplastics from soil to groundwater are soil pH, ionic strength, freeze-thaw cycle, temperature, microbial and macrofauna activity (through bioturbation), soil texture and structure including porosity and soil cracks. These transports also depend on the physicochemical characteristics (density, solubility and hydrophobicity), the size, shape, composition and aging of the microplastics.

Regarding the impact of microplastics on groundwater ecosystems, studies are very seldom. However, there is a study on the impact of microplastics on Daphnia Magna, a species found in groundwater. This study demonstrates a decrease in the rate of growth, reproduction, inhibition of mobility as well as an increase in mortality. However, more studies are needed to support these findings.



Transfers of microplastics in terrestrial ecosystems (soils and groundwater) and to humans

Environmental and health exposure and effects

The impacts and challenges of microplastics in soils for flora and fauna

Most studies reporting the impact of microplastics on terrestrial flora and fauna consider microplastic concentrations compliant with the reality (sometimes up to 1000 mg / kg of soil). In some cases, ingestion of microplastics by invertebrates such as earthworms and gastropods can lead to reduced food intake and excretion, damage the gastrointestinal walls, alter the microbiota and induce toxic oxidative stress. Some microplastics can adhere to the outer surface of organisms representative of springtails, directly impeding their mobility and therefore influencing their behavior. Microplastics can also alter the structure of microbial communities in soils and impact the ecological functions of soils.

Regarding the effects of microplastics on higher plants, few studies exist on their absorption and translocation by the root system. However, some show that microplastics can decrease plant growth, increase plant tissue composition, and change root physiology and symbiotic formations at the root level.

All of these observations are nevertheless variable depending on the characteristics of the soil, fauna and flora, types (forms and compounds) and concentrations of considered microplastics. Efforts to harmonize test methods are required in order to be able to compare the results and rule on situations of microplastic contamination having real effects on terrestrial ecosystems.

The impacts and challenges of microplas-tics in soils for humans

Regarding exposure to microplastics, no published study has yet directly examined the effects of microplastics on humans. These are usually laboratory experiments involving exposing human cells, tissues or rodents to different (often very high) concentrations of microplastics. Ingestion of large amounts of microplastics by rodents causes inflammation in their small intestine. In vitro studies on human cells or tissues suggest potential oxidative stress, immune response, lipid metabolism disorders, neurotoxic response, however variable depending on the quantity and type of microplastics as well as the targets tested. Other studies focus on certain additives that make up microplastics, such as bisphenol A and phthalates. They reveal potential effects on the endocrine system and reproduction.

However, these studies do not make it possible to extrapolate the effects in humans, especially as exposure data, in the absence of standardized measurement protocols, are scarce.

Findings and opinions of stakeholders

All the stakeholders interviewed shared the **regulations** aimed at limiting plastic pollution, mentioning European directives 1994/62 / EC relating to packaging, 2015/720 on lightweight plastics and 2019/904 relating to single-use plastics as well as the proposed restriction on intentional microplastics, carried by the European Chemicals Agency (ECHA) within the framework of the REACH regulation and part of the European Green Deal action plan. In France, a ban is already in place for microbeads in cosmetic products as well as for new washing machines sold which must be fitted with filters limiting the release of microplastics during washing (from January 1, 2025). In the Netherlands, a political strategy aims to reduce the amount of microplastics in water. All parties recognize policies that are too sectorized and the need to develop intersectoral policies.

Regarding the **definition** on the size of microplastics, the majority of stakeholders agree with the general definition. Some of them, however, wanted to distinguish between small microplastics (less than 1 mm) and large ones (1 mm to 5 mm). Regarding the shape of microplastics, most stakeholders want fibers to be the most studied.

Regarding the **sources of microplastics,** for the actors questioned, the needs are to limit the releases of microplastics into the environment in addition to the proposed restriction on intentionally added microplastics, to get a better knowledge of plastic waste management and of the life cycle of the products containing microplastics as well as the remedial techniques.

Concerning research on the **behavior of microplastics** in soils, in addition to the need to assess the biodegradability of microplastics, the actors also wish to increase knowledge on the impact of additives on the terrestrial environment. For transfers, stakeholders want more studies to better identify the level of contamination of the various terrestrial compartments in order to better assess the possible transfers of microplastics in crops and human food, as well as from groundwater to the environment, drinking water and atmospheric transfers of inhaled microplastics.

Associated with these studies of transfer and **exposure** of ecosystems and humans, research on threshold values of (eco)toxicity for ecosystems, organs and the human body at different stages of development is essential.

The MISSOURI project mainly focused on microplastics in soils and groundwater as well as their possible effects on terrestrial ecosystems and human health. This state of the art consisted of an in-depth analysis of existing characterization protocols, studies related to microplastics in soils and groundwater and their potential effects. General hypotheses relating to the transfer mechanisms of microplastics in soils and groundwater as well as the identification of research subjects have been drawn from this review. This results in a global contamination of microplastics in all environments, whether or not they are anthropized, as well as potential effects on ecosystems or humans linked to the physicochemical characteristics of microplastics, their aging as well as their ability to damage in association with other contaminants or their additives. However, for the time being, it is impossible to draw a clear conclusion on these effects due to a lack of standardized protocols both in terms of measurements and impact studies. It is therefore necessary to develop them.

Soil and land research funding platform for Europe

What is SOILveR?

The SOILver platform strongly believes in the need for integrated soil and land research and knowledge exchange in Europe. It recognizes the added value of coordinating, co-financing and disseminating cross-border research on soil and land management. SOILver is a self-funded platform. Members of the platform have a common interest in sharing and implementing integrated multidisciplinary research. SOILver builds on the experiences of other funding networks such as SNOWMAN and responds to the knowledge needs identified eg. the Horizon 2020 INSPIRATION project and other initiatives as well as those proposed by SOILveR members.

Institutions involved in MISSOURI:

Ineris: The National Institute for the Industrial Environment and Risks (Ineris) is a public industrial and commercial establishment, placed under the supervision of the Ministry responsible for the environment. It conducts research programs aimed at better understanding the phenomena likely to lead to situations of risk or damage to the environment and to health, and to develop its expertise capacity in prevention.

www.ineris.fr/en

ISSEP: The Scientific Institute of Public Service (ISSeP) is subject to the authority of the Walloon Government, which holds the management powers. Its functional Minister is the Minister of the Environment. The ISSeP carries out scientific and technical activities in the environmental field, it is also recognized as a reference laboratory for Wallonia.

www.issep.be

VU: VU Amsterdam (Netherlands) is a unique university with faculties in the humanities, natural sciences, social sciences and medical sciences. Education and research are outspoken multidisciplinary. It is a real campus university in the heart of the Zuidas Knowledge District that offers excellent national and international position and accessibility. The mission of the Environment & Health (E&H) department of the VU is to better assess the impact of environmental pollutants on human health and the environment understanding through top-quality scientific research and teaching.

www.vu.nl/en

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