Soil and land research funding platform for Europe

Project MISSOURI

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

Final report
November 2021

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SOILveR in brief
The SOILveR platform strongly believes in the need for integrated soil and land research and knowledge exchange in Europe. We acknowledge the added value of coordinating, co-funding and disseminating cross-border soil and land management research. SOILveR is a self-financed platform. The platform members have a common interest in sharing and implementing integrated multidisciplinary research. SOILveR builds on the experiences from other funding networks such as SNOWMAN and address knowledge needs identified by e.g. the Horizon 2020 project INSPIRATION and other initiatives as well as those proposed by the members of SOILveR.

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ABSTRACT

The one-year European project MISSOURI focuses on microplastics (MP) in soil and groundwater and aims at conducting a state-of-the-art review along a “sources-transfer-exposure” continuum and at participating in a European-scale interlaboratory study (ILS) in order to provide recommendations on separation and analytical methods in an idea of harmonization.

This work aims at proposing a harmonized definition for microplastics, a set of laboratory methods for the separation and analysis of microplastics in soil and at identifying priorities for future projects. It also aims at giving first recommendations for decision-making and management of soil quality regarding the potential risks associated with microplastics in soil and groundwater.

This final report recalls each objective and the project and presents the used methodology and the main outcomes.

Abbreviations and acronyms

ADEME	Agence de l’Environnement et de la Maîtrise de l’Énergie (France)
ILS	Interlaboratory study
Ineris	Institut national de l’environnement industriel et des risques (France)
ISSEP	Institut Scientifique de Service Public (Belgium)
MP	Microplastics
PMMA	poly methyl methacrylate
PE	polethylene
PS	polystyrene
pyr-GC-MS	Pyrolyse Gazeous chromatography- Mass spectrometer
VU	Vrije Universiteit of Amsterdam, department Environment & Health (The Netherlands)

1 Context and objectives of the project

The MISSOURI project is the acronym for **MIcroplasticS in Soil and grOUndwateR: sources, transfer, metrology and Impacts**, and focuses on these anthropogenic pollutants in terrestrial media.
Microplastics in marine and surface waters have been studied for many years whereas soil and groundwater are emerging environmental compartments for undergoing studies.
"Microplastic" is a catch-all phrase for plastic particles spanning six orders of magnitude in particle size (from 0.1 to 5000 µm) and a gigantic variety of chemical compositions: (co)polymers, chemical additives, residual monomers, fillers, catalysts, non-intentionally added substances (NIAS).

This project aims at conducting a state-of-the-art review and at organizing a European-scale interlaboratory study on the determination of microplastics in soil, in order to provide recommendations on separation and analytical methods. It will also provide guidelines for policy making and future projects.

This document is the final report of the MISSOURI project that details the tasks performed from January 2021 to November 2021. All WPs but WP1 is then described in terms of methodology and outcomes.

2 Project description

2.1 Tasks and work packages

The following table and graphic representation (Figure 1) show the MISSOURI project 4 work packages with internal links and status:

Work packages (WP)			
No. of WP	**Title**	**Lead organisation acronym**	**Status**
1	Project Management and Coordination	Ineris	All project duration
2	State-of-the-art review	Ineris	Start in July 2020, delivered the 26^{th} of October 2021
3	Interlaboratory study: Microplastics in soil - Preparation and analyses of microplastics in soil	ISSEP & VU	Start in July 2020, presented during the final meeting the 15^{th} of October 2021, report to be delivered
4	Dissemination and Exploitation	Ineris	Ended

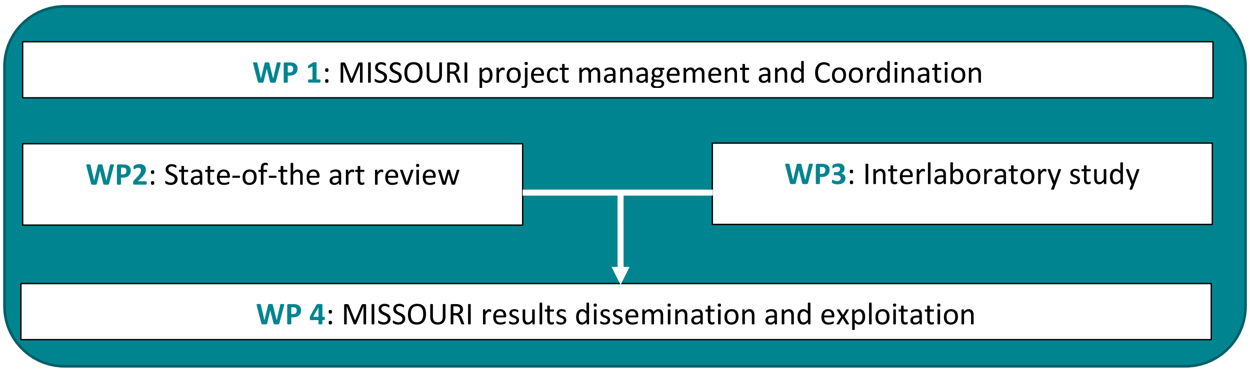


Figure 1 : Work packages in the MISSOURI project

2.2 Technical meeting

A technical meeting was organized the 24^{th} of March 2021. During this meeting, the Mid-term report was discussed followed by exchanges on the methodology to be used for making the state-of-the-art report and a presentation of the first results of the survey. Karen Perronnet (Ineris) informed the partners about her departure of the project and her replacement by Florence Carré as new coordinator of the project.

3 Main outcomes of WP2

3.1 Objectives of WP2

The objectives of WP2 were to make a state-of-the-art review along a "sources-transfer-exposure" continuum as illustrated in the following figure (Figure 2).

Figure 2 : Source-transfer-exposure continuum

The topics that had to be tackled were:

- For soil:
    - The ways to collect, characterize and quantify microplastics in soil;
    - The microplastic occurrence in soil;
    - The main sources of microplastics;
    - The main transfer processes
    - The main impacts of microplastics on terrestrial ecosystems (soil functions and properties, microbial communities, fauna and flora)
- For groundwater:
    - The occurrence of microplastics in groundwaters
    - The main sources of microplastics;
    - The main transfer processes;
    - The main impacts of microplastics on groundwater ecosystems (fauna and flora)
- For humans:
    - The main exposure pathways;
    - The main impacts at molecular, cellular and organ levels

This state-of the art review had to be completed by : (1) a review about the knowledge of stakeholders involved either in plastic production, either in plastics and microplastics management, in research and development, legislation; (2) an identification of research and development gaps for a better knowledge about the topics listed previously, (3) proposals of a definition of microplastics, (4) proposals of management actions and policies for limiting microplastic terrestrial contamination.

3.2 WP2 methodology

The state-of-the-art was produced by collecting validated scientific papers on microplastics in soil and groundwaters, the way to analyze and characterize them and on their sources, transfers and impacts on soil ecosystems and human health. The scientific papers were grouped according to the following matters:

- The ways to collect, characterize and quantify microplastics in soil and their occurrences;
- The main sources, transfer processes of microplastics in soil and their impacts on terrestrial ecosystems (soil functions and properties, microbial communities, fauna and flora);
- Microplastics in groundwater: their occurrence, sources, transfers and impacts on groundwater organisms;
- For humans, the main exposure pathways and impacts.

For each matter, the methodology presented in Figure 3 was used.

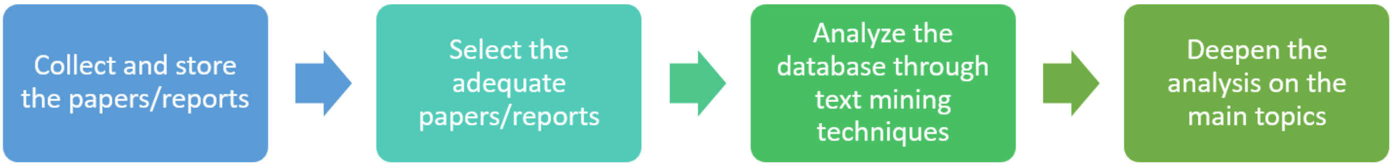


Figure 3: The general methodology for making the state of the art

For each matter, the scientific papers were first collected, then selected and referenced according to the first author, the year of publication and a subtopic label. The two steps were followed by text mining techniques which allowed for the identification of topics which were then deeply analyzed based on comparison criteria of the related research outcomes.

The survey was done by identifying main stakeholders from scientific papers and from documents on standardization protocols and legislation. Among the hundreds of people contacted in Europe, the 23 answers were received from 1 association, 4 decision-makers, 1 analysis laboratory, 9 companies and 8 researchers. People were interviewed by using open and closed questions about their knowledge on microplastics, about the regulations and about proposals for management actions, regulations and research and development. The closed questions were analyzed by using distribution frequencies whereas the open questions were analysis by using the same text mining techniques as for publication analysis.

3.3 WP2 outcomes

The main WP2 outcomes have been described in the deliverable L2 (report : *State of the art on soil and groundwater microplastics*). About 650 scientific papers were analyzed and resulted in the following synthesis.

- **On the definition of microplastics**

Regarding the size, microplastics are generally defined as fragments of plastic having a size less 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, ISO / TR 21960: 2020 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.

Regarding the shape, the debate over the size 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 clothes washing, foams 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.

- **On the way to characterize soil microplastics**

Besides the question of what to characterize, how to do it involves different chain procedure techniques that are already tested:
- sampling, separation and extraction (e.g. drying and sieving, density separation, removal of organic matter, filtration);
- identification and quantification (e.g. 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.

- **On abundance of microplastics in soil**

The abundance of microplastics in soil depends on the soil use (farmlands, industrial site, wetlands, roadsides ..), soil types and locations. However, comparing soil microplastic abundances is not an easy task since different reporting units are currently used. These are mainly items per kg, particles per kg, MPs per kg, and pieces per kg. 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 impact on the fauna, flora and functions of terrestrial ecosystems.

- **Impact of microplastics on soil ecosystems**

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, POP, 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. Common biodegradable microplastics such as polylactic acid or polybutylene succinate have a greater affinity for hydrophobic contaminants (heavy PAHs, PCBs, PBDEs ...) 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 capacity and the functional relationship between microbial activity and stable aggregates in water. In addition, by being able to modify the microbial communities of the soil, microplastics can have an impact on the enzymatic activities related to carbon degradation which in turn affect the state of nutrients available to plants and more generally the cycles. carbon and nitrogen.

- **Microplastics and groundwaters**

Few studies specifically report microplastics in groundwaters. 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 microplastic abundance correlated with the concentrations of triclosan, phosphate and chloride (components of wastewater). The most common microplastics in groundwater are polyethylene, polyethylene terephthalate and propylene, compounds also present in 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 almost non-existent. 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.

- **Impacts of microplastics and soil fauna and flora**

Most studies reporting the impact of microplastics on terrestrial flora and fauna focus on microplastic concentration levels corresponding to reality (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 influence plant growth, plant tissue composition, root physiology and symbiotic formations at the root level.
All these observations are nevertheless variable depending on the characteristics of the soil, fauna and flora, types (forms and compounds) and concentrations of microplastics considered. 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.

- **Impacts of soil microplastics on health**

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.

- **Stakeholders' knowledge and recommendations**

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. than 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, most stakeholders agree with the general definition. Some of them, however, wanted to distinguish between small microplastics (less than

1 mm) and large (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 to limit the releases of microplastics into the environment are in addition to the proposed restriction on intentionally added microplastics, a better knowledge of plastic waste management and of the product life cycle. containing microplastics as well as 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 on 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.

4 WP3 – European interlaboratory study (ILS)

4.1 WP3 Objectives

The objective of the ILS is to respond to the need for quality controls at microplastics analysis laboratories and more specifically, to:

- validate a test method and determine the uncertainty of results, via the determination of the standard deviations of repeatability and reproducibility;
- determine the characteristics of a product intended for be used as a reference material;
- assess the reliability of the test results of the participating laboratories.

The detailed information related to the ILS can be found in the L3 report produced by VU and ISSEP.

4.2 WP3 methodology

The ILS was done in collaboration with the 2nd round of WEPAL-QUASIMEME (https://www.wepal.nl/en/wepal.htm) on microplastics. The methodology is in 3 steps presented in Figure 4.

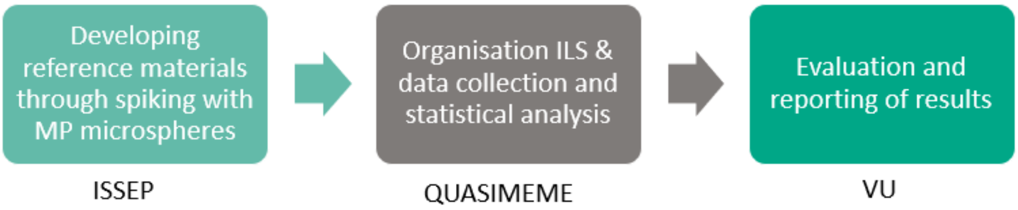


Figure 4: The 3 steps of the ILS

The first step, done by ISSEP, was the development of the reference materials through soil spiking with MP microspheres.

The soil spiking was realized by ISSEP during summer 2020. Two types of soils were individually mixed with white MP microspheres to provide 2 levels of difficulty for the MP separation (see Appendix 4 for more information on the composition).

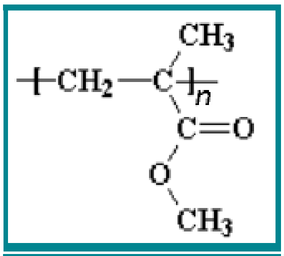
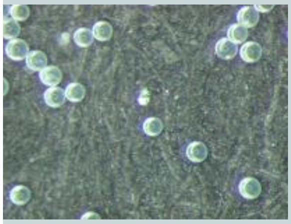
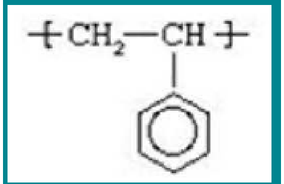
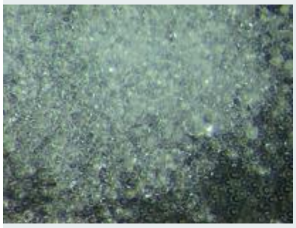
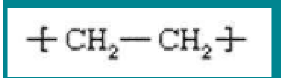
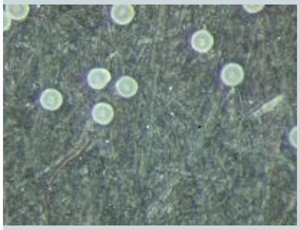
- Soil A is a synthetic silica: technical Fontainebleau Sand provided by Filter Service. This sand contains no organic matter or other natural compounds that would adsorb MP on their surface. Grains size is below 350 µm, 3 times larger than microspheres. This material[1] will be used as a reference compared to soil B. The composition is described in Appendix 4.
- Soil B is a real sandy soil collected on an industrial Walloon site which is currently referenced at ISSEP (no further sampling was then organized for a sake of simplicity). The table in Appendix 4 gives its physical and chemical parameters including the organic matter level that is considered as medium to high. The sandy soil was sieved to deliver 2 fractions:
  - 250 µm in order to simplify the MP separation as soil grain size is closer to the MP size (sample more homogeneous);
  - 2 mm (fraction usually analyzed by laboratories for the analyses of chemical compounds) and should be more difficult to handle for the MP separation.

The MP microspheres used were selected based on 1) the presence in the environment, 2) used in earlier interlab studies by WEPAL-QUASIMEME, and 3) the availability to buy a specific size class. The microspheres were provided by Cosphere (USA). They are detailed in
Table 1.

Table 1: description of the microplastic microspheres used for the ILS

Microplastics	**Type** **Resine code**	**Main uses**	**MP size** **Pictures (electronical microscopy- ISSEP)**
PMMA – Polymethyl-methacrylate	***Polysacrylics*** -others plastics	glasses (lenses), glazing, ruler, optical fiber, neon signs. Also called plexiglass	White microspheres 1.2g/cc . **90-106µm**

[1] Provision by **Cospheric Customer Service – Quotes (**quotes@cospheric.com; 805-687-3747)

			
Polystyrene PS 	***Polystyrenics***	CD cases, yogurt containers, cups, plates, cutlery, hinged takeout containers (clamshells), electronic housings, building isolation, medical products, packing, foamed coolers	White microspheres 1.07g/cc . **85-105µm** 
Polyethylene PE 	***Polyolefines*** for HDPE for LDPE	LDPE (low density) : bottles for shampoo, bags, films HDPE (high density) : rigid storage containers	White microspheres 0.96g/cc. **90-106µm** 

An attempt was done to get PP (polypropylene) and PET (Polyethylene Terephtalate) microspheres since these polymers are highly encountered in terrestrial media but the forms and size of polymers that could be used were highly different from the ones used. The microspheres used for soil spiking were also those used for the other environmental samples in this ILS.
The samples were afterwards prepared by using the distributor Resch. First 200 g of soil were distributed in 10 small glass bottles. Then MP solely or mixes of MP were distributed in the same bottle. At the end, each bottle was mixed one hour in a flipper mixer. Regarding the 90 small bottle sampling stage, this protocol was made nine times to obtain 90 bottles by batches. VU performed the homogeneity tests of the samples.

The second step, done by QUASIMEME, was the organization of the ILS, data collection and statistical analysis. The ILS included the five samples of soil prepared by ISSEP (from the MISSOURI project) and other "environmental matrices" (sediments, aquatic organisms, etc.) that were prepared by WEPAL-QUASIMEME. QUASIMEME launched the ILS towards potential interested laboratories, sent the soil samples and collected the results.

The third step, done by VU, was the evaluation and report of the results. VU received the different results obtained by ILS and evaluated the data.

4.3 The WP3 outcomes

- ***Soil spiking***

In total, 5 types of spiked soils were prepared as presented in Table 2.

For each batch (1 to 5), 90 bottles were prepared by ISSEP, resulting in 450 bottles in total which were sent in October 2020 to VU, collecting all QUASIMEME spiked samples before their dispatch to ILS participating laboratories. For the 1st batch, the goal was to get easy-to-measure sample. Differences between batch #1 and batch #3 are due to the small quantity of PS.

Table 2: The reference materials used for the ILS

Batch number	ILS name	Matrix	Quantity of matrix in each bottle	MP microspheres	Quantity of MP in each bottle
1	QMP005SL	Sand (soil A)	20 g	PE	40 mg
2	QMP006SL	Sand (soil A)	20 g	PE	10 mg
				PMMA	15 mg
				PS	1.5 mg
3	QMP007SL	Real sandy soil 250 µm (soil B)	20 g	PE	25 mg
4	QMP008SL	Real sandy soil 250 µm (soil B)	20 g	PE	10 mg
				PMMA	15 mg
				PS	1.5 mg
5	QMP009SL	Real sandy soil (soil B) (25% 250 µm + 75% 2 mm)	20 g	PE	10 mg

- ***Interlaboratory study organization***

Twenty-five laboratories participated: 19 reported on particle number basis (number of particles / kg) and 10 on mass basis (mg/kg). The detection methods used were: µFTIR, ATR-FTIR, Pyr-GC/MS, microscopy (Manual counting) and gravimetric.

- ***Interlaboratory study analysis results***

An overview of the results on mass basis of the total polymers for all samples is given in Table 3. Results on number of particles / kg values, are given in Table 4.

Table 3: Assigned total mass polymers values (mg/kg) obtained for each sample and associated criteria (SD: Standard deviation; SRST: Relative Standard Deviation)

Sample	N labs	Assigned Value	Robust SD of study	Robust RSD of study
QMP005SL	10	1281	707	55%
QMP006SL	10	609	485	80%
QMP007SL	10	1029	703	68%
QMP008SL	10	478	251	51%
QMP009SL	10	502	204	41%

Table 4: Assigned total polymer particle number values (nb particles/kg) obtained for each sample and associated criteria (SD: Standard deviation; SRST: Relative Standard Deviation)

Sample	N labs	Assigned Value	Robust SD of study	Robust RSD of study
QMP005SL	19	3.6E+05	5.6E+05	157%
QMP006SL	18	5.0E+05	6.5E+05	132%
QMP007SL	19	8.0E+05	1.0E+06	128%
QMP008SL	17	3.6E+05	5.9E+05	162%
QMP009SL	17	7.5E+05	1.0E+06	135%

Results show that :

- Analysis of MPs in spiked sand was as difficult as spiked real soil samples
- There were similar coefficients of variation (relative standard deviations) for spiked single or mixtures of MPs
- Quantification on mass basis had lower coefficients of variation than on particle basis.
- Indications were found that not all MP polymers behave equally in glass bottle

The comparison between assigned and spiked values for each polymer is presented in Figure 5.

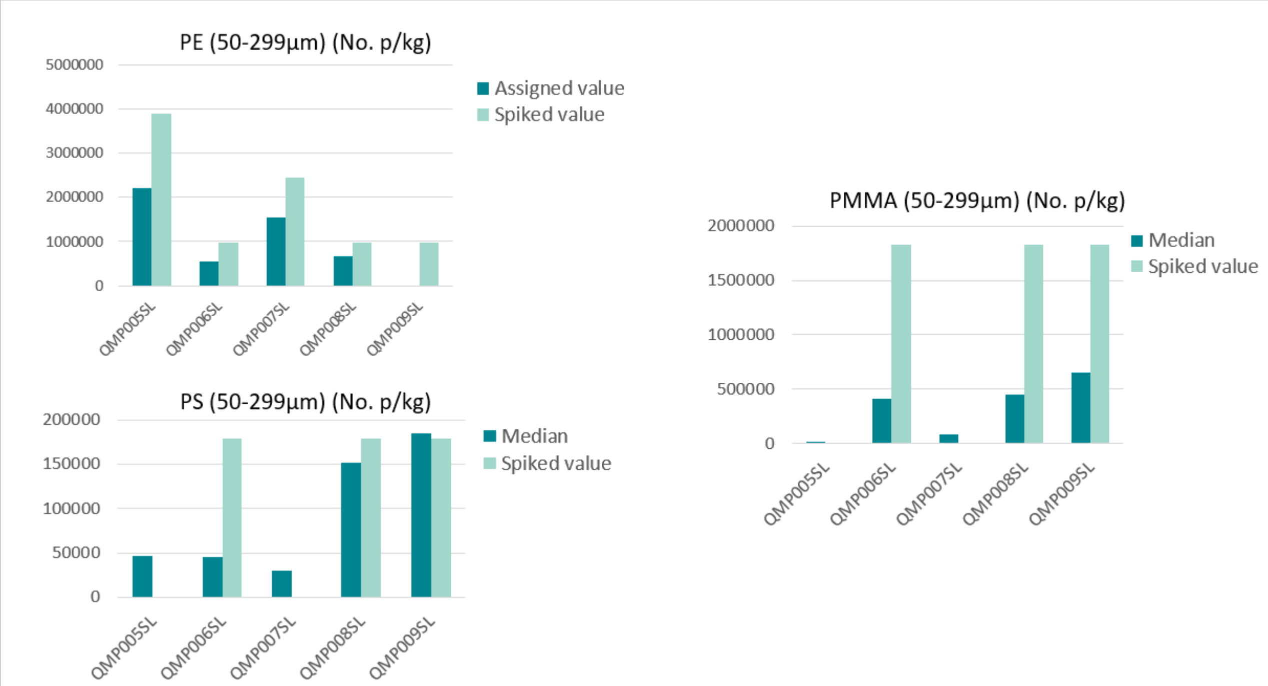


Figure 5 : comparison between assigned and spiked values for each polymer

For individual polymers similar variations as for the total polymer particles were found for both the sand and a real soil samples. A large variation in MP levels is found between the laboratories for all samples. In general, the reported values per laboratory showed large deviations from the spiked values. The results show that PMMA particles behave differently than PE and PS in glass bottles. This could be interpreted by potential interactions between glass bottles and PMMA due to different physico-chemical behavior of these particles, and this could cause unequal behavior of PMMS in glass bottles. It was recommended to make wet soil materials in next interlaboratory studies to generate more homogeneous samples. It was also recommended to perform additional soil and/or sediment ILS studies using lower concentrations of MPs.

5 WP4 – Dissemination and exploitation

5.1 WP4 objectives

The aim of this workpackage was to communicate and disseminate the MISSOURI outcomes. Communication tasks related to the start of the MISSOURI project were conducted by Ineris, VU and ISSEP using social networks, web pages and national and international workshops presented in §3.3.3.

5.2 WP4 methodology

Different tools were used for the dissemination:

- Webpages dedicated to communication;
- Social networks;
- Workshops;
- Scientific papers.

5.3 WP4 outcomes

- **Webpages dedicated to communication**

Regarding the webpages dedicated to communication, Ineris, as coordinator of the project, made two pages, one in French, the other in English to present the MISSOURI project:

- The link towards the presentation in French can be found at: https://www.ineris.fr/fr/ineris/actualites/microplastiques-ineris-pilote-projet-europeen-missouri
- The link towards the presentation in English can be found at: https://www.ineris.fr/en/ineris/news/microplastics-ineris-leads-european-missouri-project

ISSEP, as a partner made also a specific webpage dedicated to MISSOURI project (in French):

https://www.issep.be/events/event/enjeux-lies-a-la-presence-de-microplastiques-dans-les-sols-et-les-eaux-souterraines/

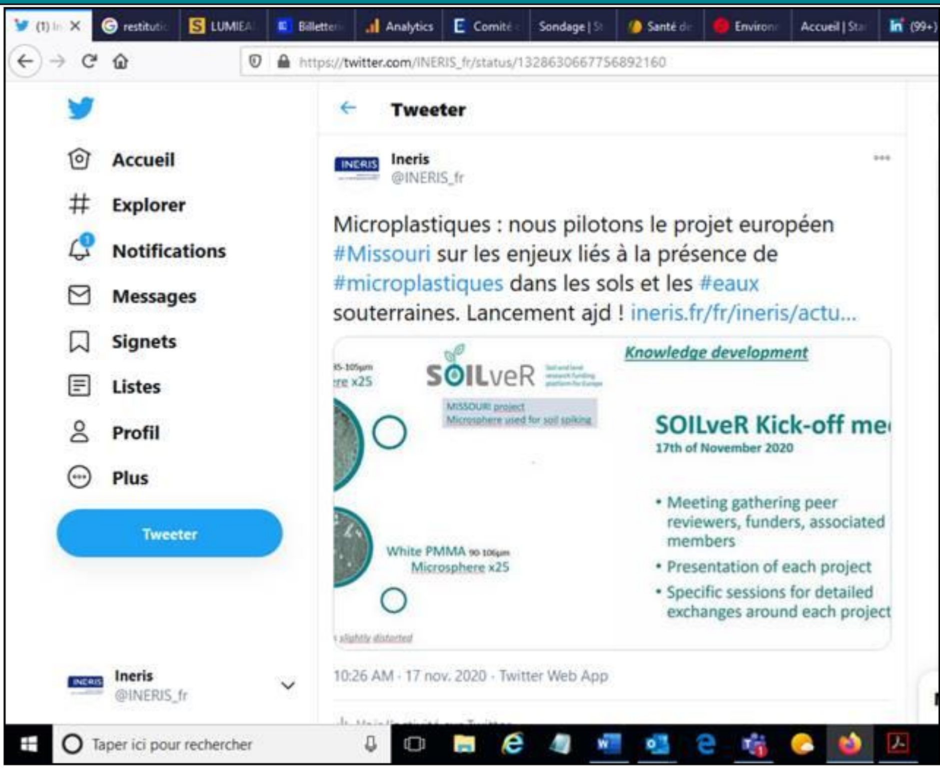
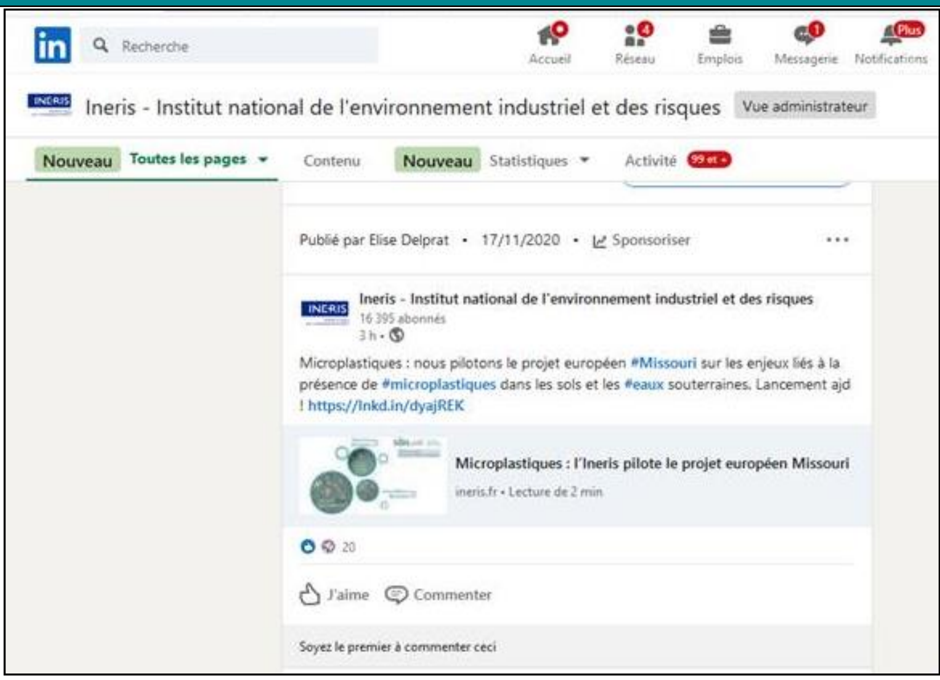
Furthermore, a digital pedagogic brochure presenting the main scientific outcomes of the MISSOURI project was made in three languages: French, Dutch and English. A first draft of the brochure was made at the end of October and sent to the Science and Expertise orientation Committee of Ineris for revision. This Committee is composed by representatives of industries, policy entities, environmental NGOs and scientific organisations. Its aim is to brings society expectations and knowledge into the scientific challenges and issues faced by Ineris experts, in order to strengthen the Institute's strategy development. In total, 8 persons participated to the revision. Some recommendations were made to better emphasize the scientific objectives and outcomes, identify where are the main scientific debates and the potential actions that can be done in terms of policies and soil microplastics management. Heavy structural changes were proposed.

- **Social networks**

The

Table 5 shows the pushes done on Tweeter and LinkedIn social networks to disseminate the start of the project

Table 5 : The social network pushes dedicated to the MISSOURI project

<table>
<tr><td rowspan="4">November 2020 : SOILveR Kick-off meeting</td><td>• Tweeter</td></tr>
<tr><td>
</td></tr>
<tr><td>• LinkedIn</td></tr>
<tr><td>
</td></tr>
</table>

- **Workshops**

The project was presented to:

- The 3rd international workshop on Emerging policy challenges on New SOil contaminants (ENSOr), online event, May 6th & 7th, 2021. A video was made by Ineris and ISSEP and presented during the workshop. Questions by the audience were then answered by Ineris and ISSEP.
- The online NORMAN-QUASIMEME workshop held the 20th and 21st of May 2021, presenting the interlaboratory study outcomes regarding microplastics analysis on different matrices (pellets, water, fishes, soils and sediments). VU presented the MISSOURI outcomes on soil samples. The results are presented in the following document: https://www.norman-network.net/sites/default/files/files/QA-QC%20Issues/Second%20MICROPLASTICS%20ANALYSIS%20WORKSHOP%20Fiinal%20210719pdf%20%281%29.pdf

The project will also be presented by ISSEP and Ineris, the 30th of November, in Lorient (France), during the Technical day workshop on nano / microplastics in solid media. The communication will be focused on the interlaboratory outcomes.

Initially, the project had to be presented during the French Technical day dealing with polluted soil, forecasted in June 2021 and then postponed in November 2021, organized by Ineris on behalf for the French Ministry of Environment (Paris, France). However, due to several organisational issues, the microplastics topic was not anymore part of the workshop.

Regarding the final restitution of the MISSOURI results, Ineris organized an online workshop of two-days sessions the 14th and 15th of November 2021. The first session was dedicated to the impacts of soil microplastics on terrestrial ecosystems and human health, the second session was on soil and groundwater processes related to microplastics and the way to analyse them (see Appendix 1). Researchers and stakeholders involved in relevant scientific issues were first identified and then invited to participate to the workshop. In total, 90 participants were registered. There were 6 MISSOURI presentations:

(1) The impacts of microplastics on human health
(2) The impacts of microplastics on terrestrial ecosystems
(3) The outcomes of the survey
(4) Microplastics and groundwaters
(5) The state of the art regarding soil microplastics analysis and quantification
(6) The interlaboratory study outcomes

At the end of the workshop, as part of the conclusion, scientific and policy recommendations were presentations. They are listed below.

There are a lot of experiments regarding the characterization and quantification of microplastics in soil, the impacts of microplastics in terrestrial ecosystems and on human health but it is currently impossible to rule on the effects of the microplastics since there is no clear definition of microplastics and standardized testing methods, reference materials which to work on. Furthermore, many studies focus on lab experiments and extrapolation from lab to fields is not an easy task. Regarding health impacts, only few studies look at the environmental exposures to microplastics. Most of the studies deal with characterizing the hazards of some microplastics in vitro or in vivo, usually with high doses of microplastics which, for some, are not representative of bioavailable concentrations. Assessing health risks related to microplastics deserve further studies. Other studies are also needed on chronic low-dose exposure of microplastics to different aged populations. The characterization, quantification and impacts of additives should be also more studied as it is the case with co-transfer of pollutants by microplastics, more globally, their environmental behavior and their effects on terrestrial ecosystems and human health.

Regarding intentional plastic use, we need safe-by-design approach combined with socio-economic assessment and research on materials for optimizing relevant substitutes to microplastics and their additives. This could be emphasized by more cross-sectoral policies and by promotion the FAIR approach[2] and an increased involvement of scientists for the dissemination of results.

Regarding unintentional plastics spread in the environment, there should be policies and incentives for limiting the spread of plastics in the environment and more research on remediation techniques once in the environment.

Furthermore, during the break session, it was asked to the participants to vote regarding the most relevant size to characterize microplastics that should be included in the European REACH restriction.

All presentations that were not associated to pending scientific publications were distributed to people registered to the workshop using the following link: https://1drv.ms/u/s!AlfHSsGsLI_1aHbCJZDCNwCmWDA?e=Ohxm5k

- **Scientific papers**

[2] https://www.go-fair.org/fair-principles/

The project was the opportunity to draft 4 scientific papers as main outcomes of the state of the art (WP2). The one on analytical methods and global occurrence of microplastics in soil was sent to Chemosphere, then redirected to the Journal of Environmental Chemical Engineering, where it has been reviewed and the principal authors are now addressing the major revisions. An executive summary of the manuscript is included in Appendix 2.The three others on, based on text mining, analysing effects of microplastics on terrestrial ecosystems, on health and on groundwaters are currently under submission. They should be submitted by the end of the year 2021. That is why, the state-of-the-art report should be disseminated once these scientific papers edited.

6 Deliverables

Table 6 shows all the deliverables of MISSOURI project.

Table 6 : List of deliverables and dates of delivery

Deliverables (D)			
No. of D	**Title**	**Work package No.**	**Date**
L1	Project mi-term report	WP1	January 2021, accepted in July 2021
L2	Workshop summary *(cancelled and replaced by survey)*	WP4	/
L3	Pedagogic Brochure including further scientific and policy action recommendations	WP4	November 2021
L4	French Polluted sites management technical day (oral presentation)	WP4	Cancelled but replaced by the ADEME Day November 2021
L5	Final report including the state-of-the-art review and the interlaboratory study (soil samples)	WP2 & 3	November 2021

7 Conclusion

This project of one-year duration had ambitious objectives regarding the vast amount of scientific publications. However, all objectives were reached. The MISSOURI project provides proposals for a harmonized definition, standardized protocol for characterizing the soil microplastics and for studying their behavior and effects on terrestrial ecosystems and human health. However, there are still a lot of research that should be done. This research should be transdisciplinary for developing safe-by-design materials composed of microplastics. This transdisciplinarity should also serve for building cross-sectoral policies in order to limit the spread of microplastics in the environment.

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Table 2: The reference materials used for the ILS
Table 3: Assigned total mass polymers values (mg/kg) obtained for each sample and associated criteria (SD: Standard deviation; RSD: Relative Standard Deviation)
Table 4: Assigned total polymer particle number values (nb particles/kg) obtained for each sample and associated criteria (SD: Standard deviation; SRST: Relative Standard Deviation)
Table 5 : The social network pushes dedicated to the MISSOURI project
Table 6 : List of deliverables and dates of delivery

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Figure 1 : Work packages in the MISSOURI project
Figure 2 : Source-transfer-exposure continuum
Figure 3: The general methodology for making the state of the art
Figure 4: The 3 steps of the ILS
Figure 5 : comparison between assigned and spiked values for each polymer .

10 Appendices

Appendix 1: Agenda of the final MISSOURI workshop
Appendix 2: Executive summary of the Journal of Environmental Chemical Engineering paper

Appendix 1 : Agenda of the final MISSOURI workshop

Day 1: 14th of November 2021

Soil and underground microplastics, their environment and health effects & societal needs		
Introduction and objective of the workshop	13.30-13.45	F. Carré (Ineris)
Effects of microplastics on humans and environmental systems		
State of the art on microplastics and human health	13.45-14.05	A. Hoarau-Belkhiri (Ineris)
Microplastics and health	14.05-14.20	Mikko Herrala (UEF)
Impact of MP additives on soil and water ecosystems	14.20-14.40	A. Barrick (Cawthron Institut)
Effect and toxicity of Micro- and Nanoplastics combined with environmental contaminants on the risk of allergic diseases – IMPTOX Project	14.40-15.00	T. Cirkovic Velickovic (University of Belgrade)
Detection, counting and identification of nanoplastics in bioindicators: is this the way to go ?	15.00-15.20	A. Valsesia (JRC)
Coffee Break (vote)	15.20-15.35	
The Science-Society Bridge on microplastics		
Economic Valuation of Benefits From the Proposed REACH Restriction of Intentionally Added Microplastics	15.35-15.55	P. King (University of Bath)
The need of research and legislation on microplastics	15.55-16.15	J. Albrecht (Ineris)
Multiple Ways to Convey Microplastic-Related Science to Stakeholders and the Interested Public	16.15-16.35	C. Rummel (UFZ)
Microplastic Regulation Should Be More Precise to Incentivize Both Innovation and Environmental Safety	16.35-16.55	D. Mitrano (USYS, ETHZ)
Conclusion of Day 1	16.55-17.00	F. Carré (Ineris)

Day 2: 15th of November 2021

Soil and underground microplastics & their characterization		
Introduction and objective of the workshop	09.00-09.15	F. Carré (Ineris)
Microplastics and soil and groundwater processes		
State of the art on soil and microplastics	09.15-09.30	F. Carré (Ineris)
State of the art and gaps on soil and microplastics	09.30-09.45	V. Geissen (WUR)
Improving bioturbation models	09.45–10.00	W.M. Heinze (SLU)
Microplastics and groundwater	10.00-10.15	A. Hoarau (Ineris)
Soil microplastic characterization		
Robust Ultra-Fast Analysis of Microplastics in Large µFTIR Imaging Datasets using Machine Learning	10.15-10.30	B. Hufnagl (Purency)
Coffee break	10.30-10.45	
Characterization and Identification of Microplastics by QC-IR Imaging	10.45- 11.00	C. Perier (Agilent)
State of the art on soil microplastics analysis	11.00-11.15	C. Perez (VU)
Soil MP inter-comparison analysis	11.15-11.30	P.Leonards (VU), A. Jorris (ISSEP)
Plastic pollution assessment and monitoring - standardising the methods EUROqCHARM	11.30-11.45	Bert Van Bavel (NIVA)
Science-Society Bridge on Microplastics		
Roundtable on expectations for future research and legislation - Companies association: Plastics Europe - Vision of the European Commission: DG JRC - Environmental association: Plastic Soup Foundation	11.45-12.20	Animated by F. Carré
Conclusion of the workshop	12.20-12.30	F. Carré

Appendix 2: Executive summary of the Journal of Environmental Chemical Engineering paper

Summary of manuscript
'Microplastics in soil: A review of analytical methods and global occurrence' for SOILveR report

Carolina N. Perez[1], Florence Carré[2], Amélie Hoarau-Belkhiri[2], Audrey Joris[3], Pim E.G. Leonards[1], Marja H. Lamoree[1*]

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[3] Department of Inorganic Chemistry Laboratory, Institut Scientifique de service Public, Rue du Chéra 200, B 4000 Liège

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Introduction

Plastics are widely used in daily human activities and globally in various sectors, including agricultural production, packaging, building and construction, electronics, transportation, and automotive manufacturing (Okoffo et al., 2021). The extensive use of plastics has increased the production rates, contributing to an alarming accumulation rate of plastics in the environment (Boyle and Örmeci, 2020; Wang et al., 2020). Once in the environment, exposure to ultraviolet (UV) radiation, mechanical abrasion, wind or water erosion, and other physical and chemical wear may progressively fragment plastic into smaller plastic particles, including microplastics (MPs, with a size ranging from 1µm to <5 mm) (Frias and Nash, 2019; Gewert et al., 2015; Hartmann et al., 2019; Rillig, 2012; Steinmetz et al., 2016). MPs are present in different morphologies, i.e., fragments, filaments and fibers, granules, and pellets (Boyle and Örmeci, 2020). They are released into the environment in different ways from primary sources where MPs are used directly as raw material. Secondary sources originate from the fragmentation of large pieces of plastics (Bläsing and Amelung, 2018; Guo et al., 2020; Steinmetz et al., 2016). In recent decades, many studies have focused on the MPs' source, occurrence, and fate in aquatic ecosystems. However, fewer studies have focused on MPs in soil, their impact on terrestrial ecosystems, and their effects on human health (Horton et al., 2017; Prata et al., 2020). Since 2012, attention to MPs in soil ecosystems has increased (Rillig, 2012), yet the research findings are still relatively limited compared to studies of MPs in aquatic environments (Bläsing and Amelung, 2018; Corradini et al., 2019b; de Souza Machado et al., 2018; Huerta Lwanga et al., 2017). There is an urgent need to investigate the adverse effects of MPs in soil under environmental concentrations. Since there is still no standardized method for soil sampling or the analysis of MPs, the results depend on the applied methods, causing difficulty in comparing the results obtained by different groups. The method development and implementation for collecting, analyzing, and characterizing MPs in soil, followed by proper Quality Assurance/Quality Control (QA/QC), is also challenging (Duarte, 2020; Prata et al., 2021). This report summarizes the manuscript '**Microplastics in soil: A review of analytical methods and global occurrence**' by Carolina N. Perez, Florence Carré, Amélie Hoarau-Belkhiri, Audrey Joris, Pim E.G. Leonards, and Marja H. Lamoree (submitted to Journal of Environmental Chemical Engineering, which is an Open Access journal freely accessible for everyone). The manuscript extensively summarizes the analysis and characteristics of

MPs in soil of different land uses from 31 research papers published between 2019 and 2021 and briefly highlighted and summarized the frequently reviewed (8) research papers published between 2016 and 2018. Thus, this report focuses on summarizing the extensive overview provided in the review article on the existing and most recently developed analytical methods used for the analysis of MPs in soil, comparing the results from different experimental studies, and highlighting challenges together with suggestions for future studies.

Sample collection

Analysis of MPs in soil generally involves sampling, separation, sample treatment, identification, quantification, and confirmation. The sampling design of the soil matrix must be well planned and modified to the specific research question to achieve reliable results (Möller et al., 2020). The reviewed studies analyzed various land uses, e.g., soils of agricultural lands, natural and urban lands (e.g., roadsides, dumping sites). Various studies also had multiple sampling locations. MPs are not homogeneously distributed in the soil of, e.g., agricultural lands. Therefore, the composite sampling method is commonly applied to those types of land uses. Composite samples are samples from various discrete sites of the same size and sampling area combined and homogenized into one sample (Möller et al., 2020). Other sampling methods included using quadrat sampling, grid and belt sampling, random sampling, drilling down boreholes to different depths, and different measuring sampling plots (Chen et al., 2020; Choi et al., 2021; Harms et al., 2021; Zhang et al., 2020; Zhou et al., 2020a). Various types of sampling equipment were utilized to collect soil samples, mainly (stainless) steel material equipment. Soils are a three-dimensional medium, making the soil sampling at different depths important. Many research studies sampled a single layer or multiple layers, with depths ranging from 0-40 cm, and collected various sampling amounts.

Separation and extraction

The complex composition and the heterogeneous soil sample make it challenging to separate MPs from the soil matrix. In addition, plastic particles in soils are associated with soil aggregates and can interfere with the analysis (Bläsing and Amelung, 2018; Zhang and Liu, 2018). Currently, no unified standard method exists to separate and identify MPs in the soil, which is essential for comparing and monitoring MP pollution between different ecosystems (Kumar et al., 2020; Qi et al., 2020). After field sampling, the MPs are extracted from the soil for further analysis. Generally, the extraction methods for MPs in soil include drying and sieving, density separation, organic matter (OM) digestion, and filtration.

Drying and sieving – The collected soil samples are typically stored at 4°C in the laboratory and air-dried before analysis to minimize the effect of soil humidity on the analysis. The reviewed studies commonly allowed the soil samples to air-dry naturally, while a few oven-dried the samples instead. Sieving the soil MPs sorts the particles by specific size classes. While the selected sieve mesh size determines MPs' quantitative size range, it is dependent on the research objective. The reviewed studies often visually classified and removed residues and large particles (>5 mm), used mesh sizes between 1 mm and 5 mm, or utilized multiple sieves in smaller size ranges.

Density separation – In density separation, MPs are extracted or preconcentrated from the soil by floating the MPs in salt solutions with a higher density than the plastics (ρ=0.9-1.6 g cm^{-3}) (Thomas et al., 2020). Saline solutions with different densities varied for the targeted MPs. Saturated sodium chloride (NaCl) solution and distilled water were commonly applied but are limited to low-density MPs. For the extraction of high-density MPs, such as polyvinylchloride (PVC), polyethylene terephthalate (PET), and polyamide (PA), alternative salt solutions such as calcium chloride ($CaCl_2$), zinc chloride ($ZnCl_2$), and sodium iodide (NaI) were used in several studies. However, each comes with its limitations (Li et al., 2020a). Therefore, recent studies consider other alternatives, such as sodium bromide (NaBr), castor oil, olive oil, and canola oil (Liu et al., 2019; Mani et al., 2019; Radford et al., 2021; Scopetani et al., 2020). The extraction efficiency of the floatation technique relies on sample mass, sample to volume (floatation solution) ratio, and the mixing method used (Han et al., 2019).

Organic matter removal – Some components (e.g., soil organic matter (SOM) and other organic materials) in complex heterogeneous soils and MPs have similar densities, allowing them also to be extracted by density separation, and may then interfere with the MPs' visual and spectral analysis (Bläsing and Amelung, 2018;

Li et al., 2020a; Scheurer and Bigalke, 2018). The reviewed studies applied oxidant, strong acid, or alkali solution as SOM digestion technique to remove these components, with hydrogen peroxide (H_2O_2, 30%) and Fenton's reagent (30% H_2O_2 and iron (II) sulfate ($FeSO_4$) catalysts) being most frequently used.

Filtration – Filtration is a solid-liquid separation technique that allows the separation of MPs from the supernatant floating solution (Zhou et al., 2020b). This step is performed mainly before visual sorting and MPs identification. Filter size selection is essential to retain the preferred MPs on the filter surface. Several filter materials and porosity sizes were applied in the reviewed studies.

Other extraction methods – As an alternative extraction procedure, pressurized fluid extraction with dichloromethane (DCM) was utilized (Fuller and Gautam, 2016), and more recently, pressurized liquid extraction with a less toxic solvent than DCM and more volatile tetrahydrofuran (THF) was used (Dierkes et al., 2019).

Identification and quantification of MPs

After separating MPs from the soil samples, several analytical techniques are applied to determine MPs particle size and morphology, polymer type (chemical composition), and to identify and quantify the polymers. Generally, the MPs are identified and quantified by visual sorting, spectroscopic techniques, and thermo-analytical techniques.

Visual identification – To determine the size and quantity of MPs after extraction and distinguish MPs from other impurities, they are visually sorted by the naked eye or microscopic techniques (Zhang et al., 2018). The reviewed studies commonly used a stereomicroscope or microscope to determine the morphological characteristics (shape, surface texture, and color). Additionally, some studies applied scanning electron microscopy (SEM) to examine the MPs' surface morphologies further.

Vibrational spectroscopy – Spectroscopic techniques such as FTIR and Raman (micro)spectroscopy are the most common methods for identifying and quantifying MPs, applied by 20 and 4 research studies, respectively.

Thermal analysis – For the identification and quantification of MPs, three mass spectrometry (MS) analysis techniques are efficient, even though the number and morphological information of the particles cannot be obtained (Wang et al., 2020). The use of thermal analysis such as pyrolysis-gas chromatography-mass spectrometry (Py-GC-MS) (Dierkes et al., 2019; Steinmetz et al., 2016), thermogravimetric analysis-mass spectrometry (TGA-MS) (David et al., 2018), TGA coupled to a soil universal model method (SUMM) (David et al., 2019), and thermal extraction and -desorption-GC-MS (TED-GC-MS) (Dümichen et al., 2015; Elert et al., 2017; Müller et al., 2020) has demonstrated its efficiency in identifying and quantifying MPs in soil, by analyzing the thermal degradation products of MPs (Peñalver et al., 2020).

Chromatography – Other studies developed straightforward approaches to analyze MPs in soil, including methods coupled to a chromatographic unit for separation. Such methods included liquid extraction with size-exclusion chromatography (SEC) (Elert et al., 2017) and alkaline extraction followed by liquid chromatography with UV detection (LC-UV) (Müller et al., 2020).

Other techniques – In recent years, several analytical methods have been developed by combining techniques to provide fast analysis of MPs in soil samples, including time-of-flight secondary ion mass spectrometry (TOF-SIMS) (Du et al., 2020a, 2020b), hyperspectral imaging technology combined with chemometrics (Shan et al., 2018), visible-near infrared (vis-NIR) (Corradini et al., 2019a), NIR spectroscopy combined with chemometrics (Paul et al., 2019), vis-NIR with convolutional neural network (CNN) model (Ng et al., 2020), resonance microwave spectroscopy with a mathematical model (Malyuskin, 2020) and terahertz (THz) spectroscopy with Least Squares Support Vector Machine (LS-SVM) model (Li et al., 2020c).

QA/QC – To prevent and monitor the possible contamination during sampling, processing, and analyzing MPs, QA/QC procedures are required (e.g., blank control, standard control, dust-free laboratory, rinse out materials before use, avoiding the use of plastic materials and synthetic clothes). Besides this, other QA/QC requirements for the analysis of MPs in soil research are lacking, such as the limited availability of certified reference materials for soil, certified MP particles standards (with different polymer types, sizes, shapes, and in different stages of MP), and labeled standards with chemical groups (including both absorbed and additive chemicals), which are essential for analytical measurements and method validation processes. In addition to applying more and improved interlaboratory protocol comparisons.

Characterization and Occurrence of MPs in soil

MP polymer type – Identifying the polymer types is crucial to identify the source of MP pollution. Polyethylene (PE), polypropylene (PP), and polyester (PES/PET) were dominantly present in the soils of different land uses (Figure 1).

MP particle size – The reported size fractions varied widely across the reviewed studies. MPs size is defined as plastic particles smaller than 5 mm (Frias and Nash, 2019). However, the minimum particle size is determined by the sieve mesh size used after sampling, during sample pretreatment, and the membrane pore size of the filters used, resulting in a wide range of MPs particles sizes (Figure 1B).

MP particle shape – The most common classified shapes of MPs in the soil reported in the reviewed studies are fibers, fragments, films, and foams (Figure 1C).

Abundance – The abundance of MPs in soils have varied significantly between different land uses, soil types, and locations, with potential sources consisting of inputs of anthropological activities, littering, atmospheric deposition, plastic mulching, compost, sewage sludge, irrigation, and street runoff (Bläsing and Amelung, 2018; He et al., 2018). The most frequently used abundance units were items per kg, particles per kg, MPs per kg, and pieces per kg. However, this report assumes they are the same unit (MPs per kg) and are comparable (Figure 2). Other abundance units were particles per gram, particles concentration per kg, items/m_2, mg/kg, and mg/g. A wide range of MP concentrations, five orders of magnitude, has been reported, and no correlation was found with the different soil sources or soil types in the studies.

Conclusion and future perspective

Various analytical methods were recently reported to analyze MPs in soil, and depending on the specific research objectives, the specific analytical methods can be applied to identify and quantify the MPs. Thermal techniques such as TGA-MS, TED-GC-MS, or Py-GC-MS provide good selectivity and sensitivity for MPs characterization but are destructive methods and can only provide a total mass of plastic particles of an MP type. While FTIR and Raman spectroscopy can detect small particle sizes down to >20μm and 1μm, respectively, they only provide the chemical composition of the MPs. The number of research studies, available global monitoring data, and knowledge on MPs in the soil is still minimal, resulting in many knowledge gaps. Several areas require attention in future work to achieve a more reliable assessment of the occurrence of MPs in soil, such as:

1. There is an urgent need for a standardized analytical method and to organize interlaboratory studies to analyze MPs in soil.
2. There is an urgent need for standard validation processes, certified reference materials for soils, certified MP particles standards, and labelled standards with chemical groups essential for analytical measurements and production stimulation for these reference materials.
3. Further research on contamination control and ways to avoid MPs contamination during the analysis is needed.
4. Promoting the automation of laborious purification protocols.
5. Promoting in situ techniques to rapidly detect MPs in soil
6. Large-scale monitoring research is needed to evaluate MPs' distribution in different soil environments globally.

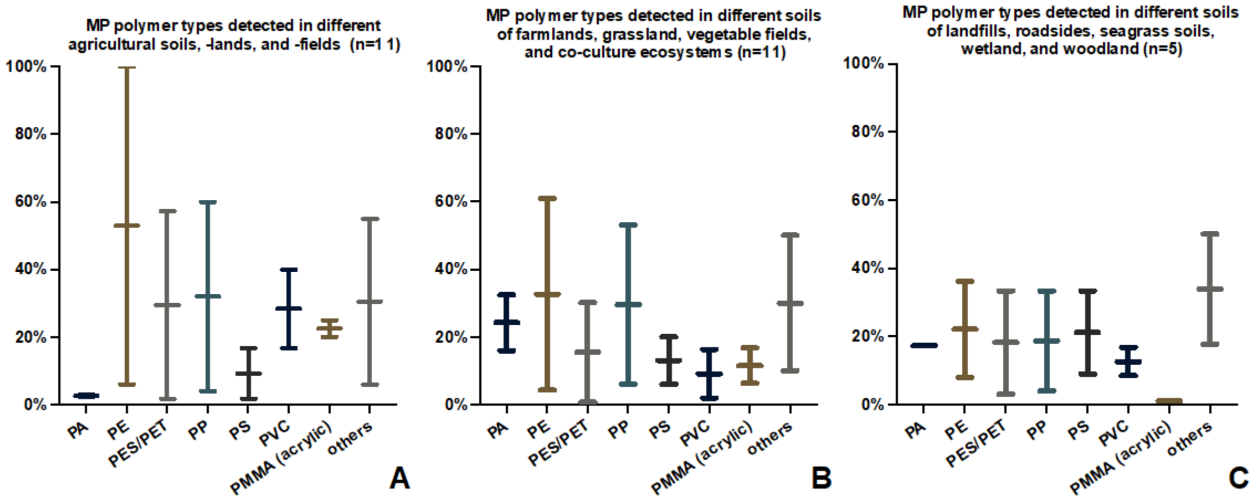

*Figure 1 A summary of MP polymer types (PA, PE, PES/PET, PP, PS, PVC, PMMA, and others) in soil analysis of different classes of land uses (**agricultural soils, -lands, and -fields (A)***(Choi et al., 2021; Corradini et al., 2021, 2019b; Crossman et al., 2020; Ding et al., 2020; Harms et al., 2021; Li et al., 2019; Li et al., 2020b; van den Berg et al., 2020; van Schothorst et al., 2021; Yang et al., 2021)*, **farmlands (B)***(Chen et al., 2020; Ding et al., 2021; Du et al., 2020b, 2020a; Fakour et al., 2021; Feng et al., 2021, 2020; Lv et al., 2019; Wang et al., 2021; Zhang et al., 2020; Zhou et al., 2020a)*, **and urban lands (C)***(Dahl et al., 2021; Dierkes et al., 2019; Helcoski et al., 2020; Puthcharoen and Leungprasert, 2019; Zhou et al., 2019)*. The range (min-max) of each MP polymer type reported in the reviewed literature summarized per different classes of land uses.*

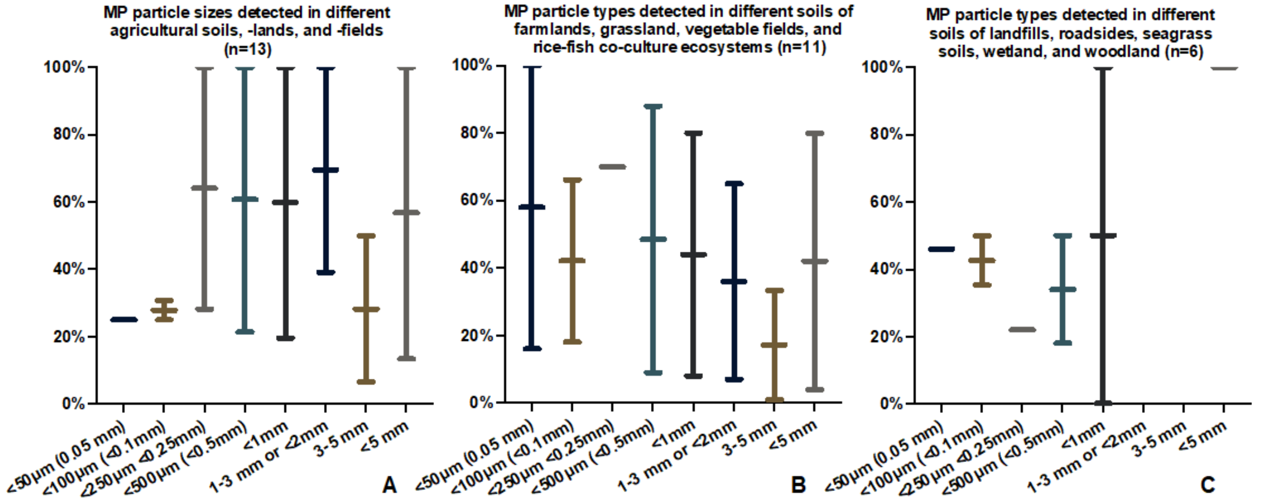

*Figure 2 A summary of MP particles size (<0.05-, <0.1-, <0.25-, <0.5-, <1-, 1-3- or <2-, 3-5-, and <5-mm) in soil analysis of different classes of land uses (**agricultural soils, -lands, and -fields (A)**(Beriot et al., 2021; Choi et al., 2021; Corradini et al., 2021, 2019b; Crossman et al., 2020; Ding et al., 2020; Harms et al., 2021; Li et al., 2019; Li et al., 2020b; Rafique et al., 2020; van den Berg et al., 2020; van Schothorst et al., 2021; Yang et al., 2021), **farmlands (B)**(Chen et al., 2020; Ding et al., 2021; Du et al., 2020b, 2020a; Fakour et al., 2021; Feng et al., 2021, 2020; Lv et al., 2019; Wang et al., 2021; Zhang et al., 2020; Zhou et al., 2020a), **and urban lands (C)**(Álvarez-Lopeztello et al., 2021; Dahl et al., 2021; Dierkes et al., 2019; Helcoski et al., 2020; Puthcharoen and Leungprasert, 2019; Zhou et al., 2019). The range (min-max) of each MP particle size reported in the reviewed literature summarized per different classes of land uses.*

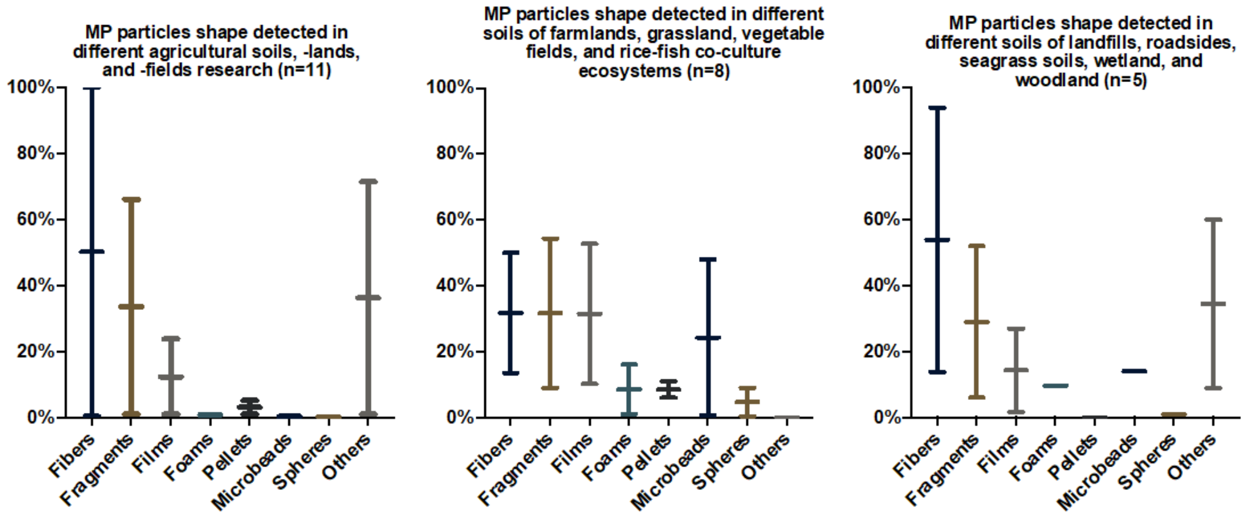

*Figure 3 A summary of MP particles shape (fibers, fragments, films, foams, pellets, microbeads, spheres, and others) in soil analysis of different classes of land uses (**agricultural soils, -lands, and -fields (A)** (Choi et al., 2021; Corradini et al., 2021, 2019b; Crossman et al., 2020; Ding et al., 2020; Harms et al., 2021; Li et al., 2019; Li et al., 2020b; Rafique et al., 2020; van den Berg et al., 2020; Yang et al., 2021), **farmlands (B)**(Chen et al., 2020; Ding et al., 2021; Fakour et al., 2021; Feng et al., 2021, 2020; Lv et al., 2019; Wang et al., 2021; Zhou et al., 2020a), **and urban lands (C)**(Álvarez-Lopeztello et al., 2021; Dahl et al., 2021; Helcoski et al., 2020; Puthcharoen and Leungprasert, 2019; Zhou et al., 2019). The range (min-max) of each MP particle shape reported in the literature summarized per different classes of land uses.*

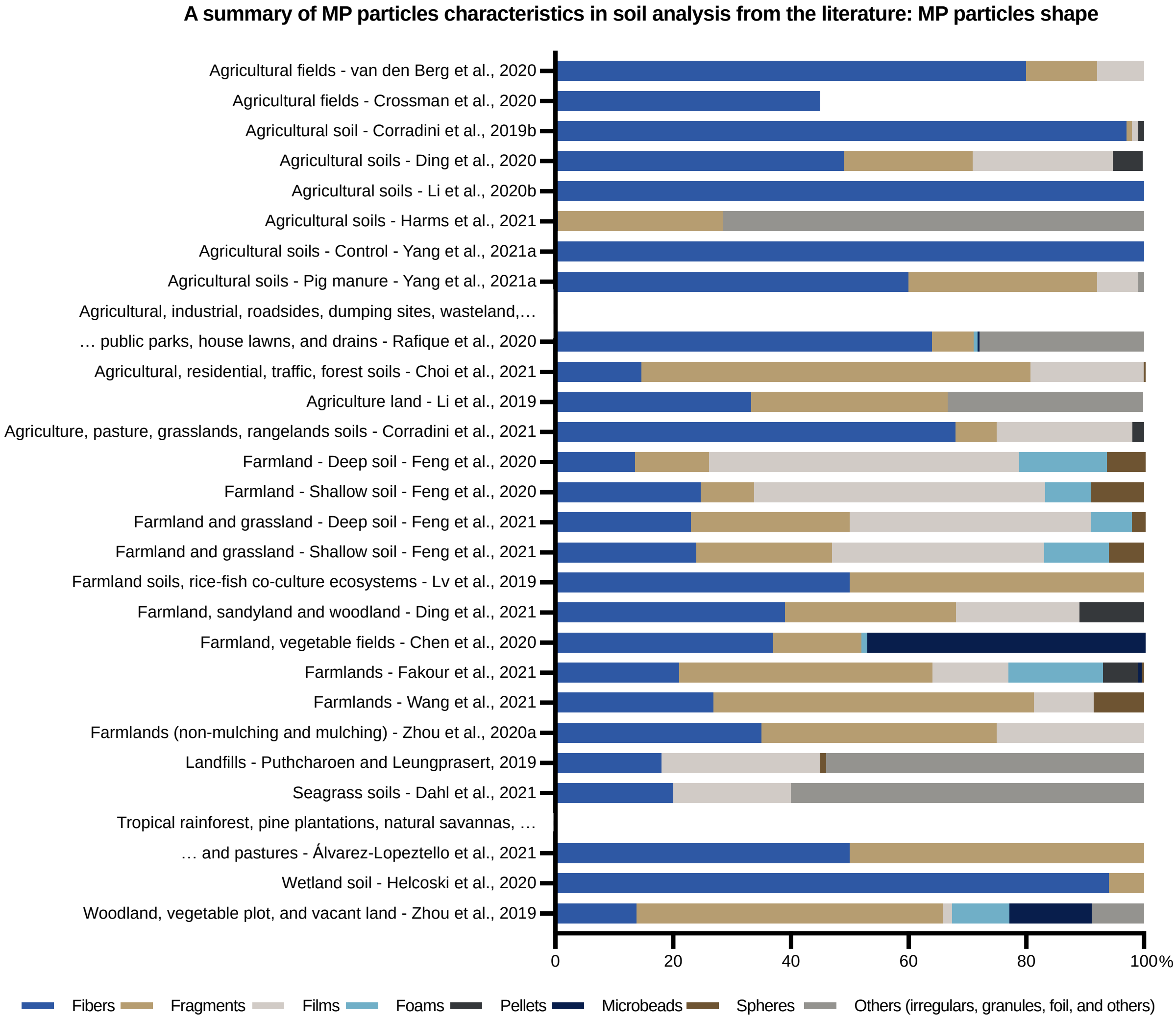

Figure 4 A summary of MP particles abundance (given in particle per kg, items per kg, MPs per kg, and pieces per kg) in soil analysis from the literature, corresponding to their location (right y-axis) and soil source(s)/ type(s) (left y-axis) of the study.

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Abstract

The one-year European project MISSOURI focuses on microplastics (MP) in soil and groundwater and aims at conducting a state-of-the-art review along a “sources-transfer-exposure” continuum and at participating in a European-scale interlaboratory study (ILS) in order to provide recommendations on separation and analytical methods in an idea of harmonization.

This work aims at proposing a harmonized definition for microplastics, a set of laboratory methods for the separation and analysis of microplastics in soil and at identifying priorities for future projects. It also aims at giving first recommendations for decision-making and management of soil quality regarding the potential risks associated with microplastics in soil and groundwater.

The MISSOURI project provides proposals for a harmonized definition, standardized protocol for characterizing the soil microplastics and for studying their behavior and effects on terrestrial ecosystems and human health. However, there are still a lot of research that should be done. This research should be transdisciplinary for developing safe-by-design materials composed of microplastics. This transdisciplinarity should also serve for building cross-sectoral policies in order to limit the spread of microplastics in the environment.

Soil and land research funding platform for Europe