

ABUNDANCE AND DIVERSITY OF BIOPLASTICS ON AGRICULTURE SITES



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Abundance and diversity of bio-based microplastics in agricultural sites



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Executive abstract

The use of plant-based plastic mulches has increased in recent years due to a desire to move away from the plastic mulches traditionally used in agriculture. Plant-based mulches were specifically developed to quickly degrade in soil. The aim of this study was to assess the concentration of bio-based microplastics in soils where bio-based mulches have been applied in two climates with different environmental conditions, the Mediterranean climate (Spain) and the Atlantic climate (Netherlands). Sediments and water from water bodies surrounding agricultural areas in these countries were also assessed. Soil, sediment and water samples were collected in Autumn 2022. Bio-based microplastics were dominant in sediments (53%) and 48 different types of plastics were found. Bio-based microplastics in the soils from the different climates (Spain vs The Netherlands) were not significantly different in number or size. There was a moderate correlation between microplastics in soils and ditch sediments ($r = 0.43$). Bio-based microplastics were abundant in water samples, and extremely high in ditch sediments from the Netherlands. Further studies are required to understand the behavior of bio-based microplastics in agricultural soils.

Introduction

The problem of microplastics in soil.

Previous studies have shown how the traditional use and disposal of plastic mulches has led to high concentrations of microplastics in agricultural soils (Figure 1). These microplastics are transported throughout the soil profile, horizontally and vertically. Microplastics have even been found in waterbodies near agricultural sites. Although microplastic contamination can come from many different sources, this study will focus on contamination resulting from the use of plastic mulches.

With the increasing amount of attention that plastic mulch use has received in recent years, there is a growing push to find solutions to current problems using more flexible and environmentally friendly materials. In this study, we analysed plastics found in soils where only mulches composed of plant-based materials have been used.

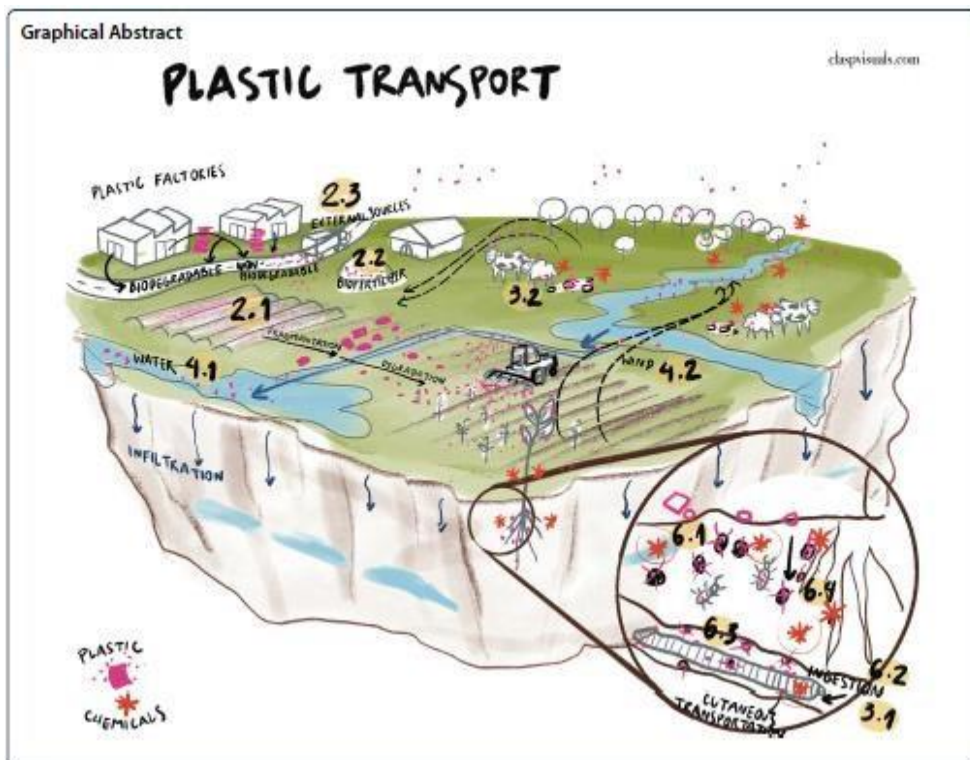


Figure 1. Transport of microplastics in agricultural areas (Huerta Lwanga et al., 2022).

Plant-based plastics as an alternative to fossil-based mulches.

In agriculture, plant-based mulches are viewed as a good alternative to plastic-based mulches since they were developed to rapidly degrade, allowing them to be quickly incorporated into the soil. Despite the fact that there is the standard EN 17033 stating that biodegradable plastic mulches should be incorporated (90%) into the soil within 2 years (European bioplastics and Europa bio, https://docs.european-bioplastics.org/publications/pp/EUBP_EuropaBio_PP_Fertilizer_Regulation), the concentration of microplastics of plant-based origin in the soil has been scarcely studied. If plant-based plastic mulches do in fact decompose completely after two years in agricultural soils, one would expect that after 20 years of using plant-based mulches, the concentration of microplastics would be close to zero or completely absent in soils from agricultural areas since the plant-based plastics should have completely degraded. There is a large diversity of plant-based plastics on the market. Some of these plastics are coated with a compound that makes them more fragmentable under environmental conditions. The PAC oxo mulch (fossil polyethylene based) sold and used intensively 20 years ago is a plastic mulch example. Even though this type of plastic had a coating that made it photodegradable, it is still found in soils 20 years after it was initially used.

Public opinion on the use of plant-based mulch.

At the end of 2022, the European Union hosted a round table discussion concerning the effects or impacts of using plant-based plastics. The round table included stakeholders as well as representatives from the agricultural, industrial and scientific sectors. One point of contention, especially for representatives of the industrial sector, was the lack of scientific reports studying plastics under environmental conditions. Scientists agreed that more studies conducted under field conditions are needed in order to better understand how fossil-fuel based and bio-based plastics behave under different soil conditions.

Recent research carried out in the southern part of the Netherlands in Brabant (Huerta Lwanga et al., 2023) has shown that microplastics are highly prevalent in agricultural soils. Different types of plastic particles were found in soils, sediments and water from this agricultural area, with soils under plastic mulch containing the highest concentration of microplastics.

Conditions that promote the degradation of plant-based plastic mulch.

Plant-based plastic mulches are usually made of Polylactic acid plastic (PLA) or Polybutylene adipate plastic (PBAT) which normally require high temperatures and high moisture levels to trigger a fragmentation or degradation reaction. However, under normal soil conditions, where temperatures reach around 20°C and moisture stays between 15 to 17%, microplastic degradation is very slow because optimal conditions needed for complete decomposition are not reached.

The aim of this study was to evaluate if residuals of bio-based plastic mulches were present in agricultural soils, surrounding water bodies and ditch sediments in different climatic zones within Europe.

Material and Methods

Sampling in the Netherlands and in Spain

Sampling was carried out at the end of September 2022 in the Netherlands and the beginning of November 2022 in Spain. Sixteen farms were sampled, 8 in the Netherlands and 8 in Spain (Table 1). The main crops in the Netherlands were flowers and in Spain the main crop was coriander. Details on sampling days are shown in Table A1. To maintain anonymity, the coordinates of sampling sites and the names of farmers are not presented in this report.

Table 1. Farm descriptions.

Country	Location	Farms	Crop	Soil type
Netherlands	Gelderland and South Holland	F1-F8	Flower	Sandy soil
Spain	Murcia	F9-F16	<i>Coriandrum sativum</i> , <i>Brassica oleracea</i> , vegetables	Karstic soil

Microplastic assessment of soils

Eight farms per country were selected and plots were chosen based on at least 2 to 5 years of plastic mulch application (same type of plastic mulch per country).

Soil sample collection

A transect of 20 meters was made and 4 quadrants of one square meter were established per field (Figure 2). Soil samples were taken for the determination of microplastics following the monitoring plan protocol established in MINAGRIS (www.minagris.eu, Figure 2 & 3). Four composite soil samples were collected for each farm. After discussions with Plastic Soup Foundation staff, we decided together with them to focus on microplastic determination.

In addition, we also estimated the abundance of soil invertebrates, mainly earthworms, as an indicator of soil quality (these results are not present in the current report).



Figure 2. A quadrant for macroplastic assessment in the Netherlands.



Figure 3. Collection of soil sample (0-15 cm) in Spain.

Microplastic assessment in sediments

Collection of sediment samples.

Sediments were collected from the bottom of the water bodies using glass jars. Two 200 g samples were collected per farm and immediately transported in cool boxes to the laboratory for further analysis. Once in the laboratory, sediments were dried at 40°C. Microplastics were extracted according to the protocol used in the MINAGRIS project (Deliverable 3.2, www.minagris.eu).

Microplastic assessment in water

Collection of water samples.

According to a previous study (Huerta Lwanga et al. 2023), microplastic concentrations in water are highest in Autumn and after or during the rainy season. Samples were collected from ditches and water bodies close to the agricultural sites. In both the Netherlands and Spain, two 500 ml water samples per farm were collected near the agricultural sites using glass jars. Samples were transported in cool boxes to the laboratory. Once the samples were in the laboratory, the extraction of microplastics took place following the protocol indicated in the annexes (Figure S1).

Microplastic determination

For assessing the sort and number of microplastics per type of matrix (soil, sediment and water), Laser direct infrared imaging (LDIR) was used. The advantage of using this method is the size of microplastic measurement. This instrument can measure microplastics smaller than 30 µm. The LDIR sample was obtained by collecting an aliquot from the laboratory sample. More LDIR samples were measured than laboratory samples since we measured several aliquots per sample. In this study, there were several problems with the LDIR and therefore, only soil samples had high numbers of LDIR samples.

LDIR detection limit

Two detection limits were used in this study, 0.9 and 0.78 ± 0.05 . In order to detect the highest amount of plant-based microplastics, the correlation between the library spectra present in the LDIR and the spectra detected per sample was 0.78 ± 0.05 . For indicating the number of microplastic particles present per gram of soil or sediment or per ml, the limit of detection used was 0.9, following Huerta Lwanga et al. (2023).

Results

In total, there were 208 samples analysed using LDIR including 26 samples from sediments, 32 samples from water and 150 samples from soil. For identifying the number of samples per farm and per matrix, please see Table S1 in the annexes.

Microplastics in soils.

Diversity of microplastics according to the limit of detection

Using a detection limit of 0.9 (0.9 correlation between the LDIR spectra library with the sample spectra of 0.9), 19 different types of microplastics were detected (see Annex, Table S2). When the detection limit was lower than 0.9, more microplastic types were detected. In total, we detected 31 types of microplastics (see Annex Table S3, figure 4) with a detection limit of 0.78 ± 0.05 according to the LDIR library (correlation between the LDIR spectra library and the sample spectra). When using the lower detection limit, 61% of the microplastics were fossil-based and 39% were bio-based (after analysing 68861 particles, Table 3). The concentration of bio-based microplastics per gram of soil was of 0.73 MPs.g^{-1} (Figure 5).

Table 3. Bio-based and fossil-based microplastic particles, detected with the lower detection limit, from agricultural soil where bio-based mulches were applied in the last 2 to 5 years.

Type of plastics	No. detected particles	%
Bio-based	26843	39
Fossil-based	42012	61
Total particles detected and analysed with >0.7 limit	68855	100

No significant differences were observed in the total concentrations of microplastics between fields in Spain and the Netherlands. However, soils in the Netherlands did have a higher number of plastic particles per gram of soil (Figure 5 & 6).

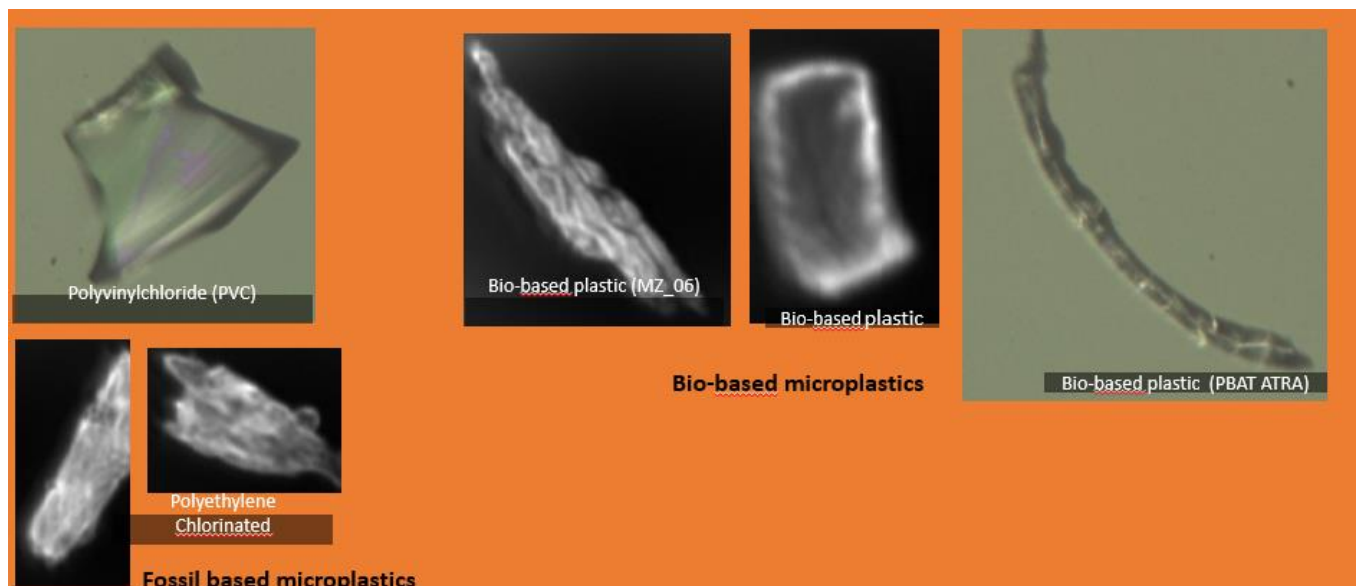


Figure 4. Examples of microplastics. Photos obtained from LDIR.

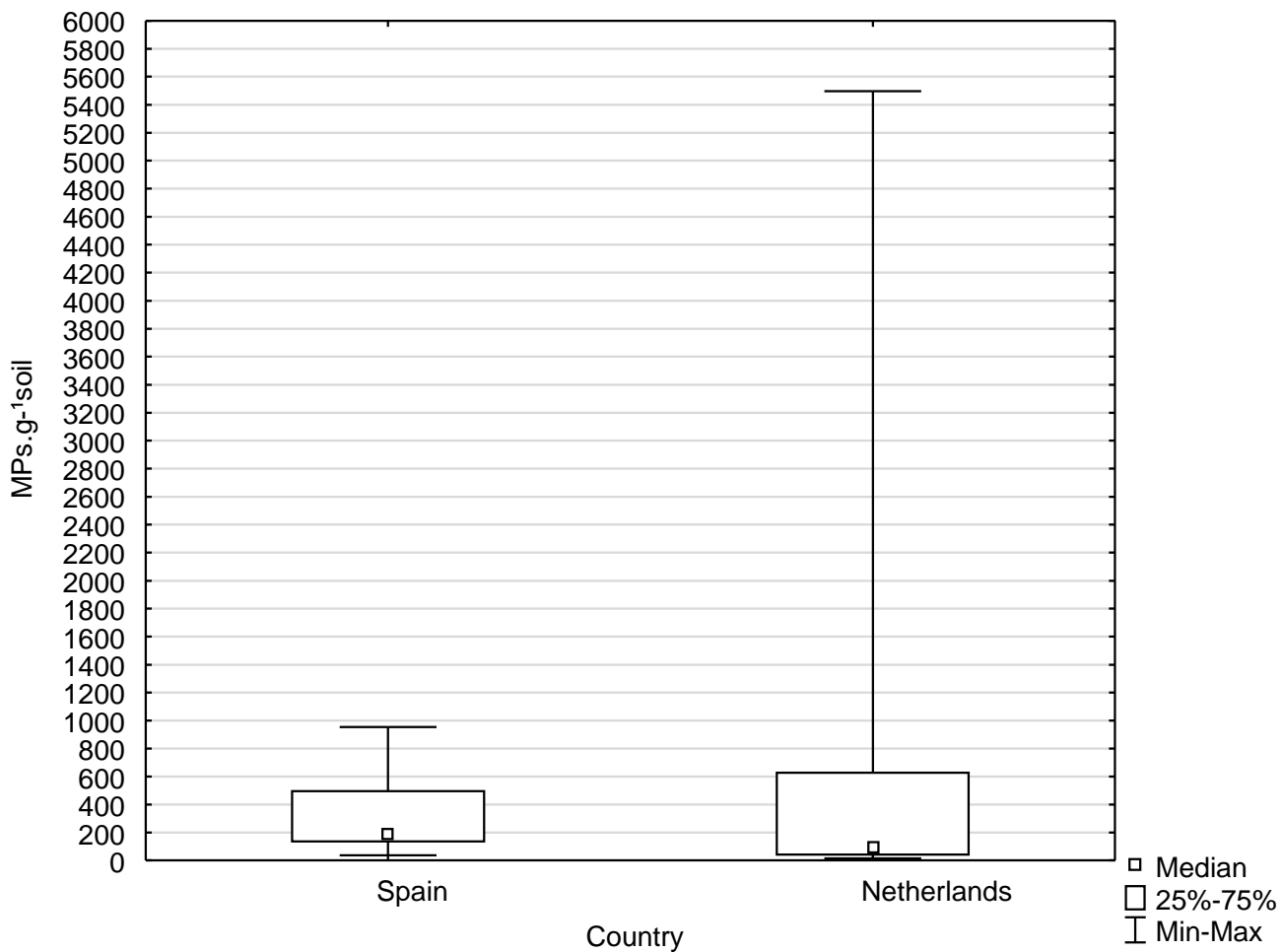


Figure 5. Microplastics per gram of soil from agricultural fields where bio-based mulch was applied.

Bio-based microplastics per gram of soil were also not significantly different between Spain and the Netherlands (Figure 6) since high standard deviations were present. The higher numbers were observed in the field samples from the Netherlands.

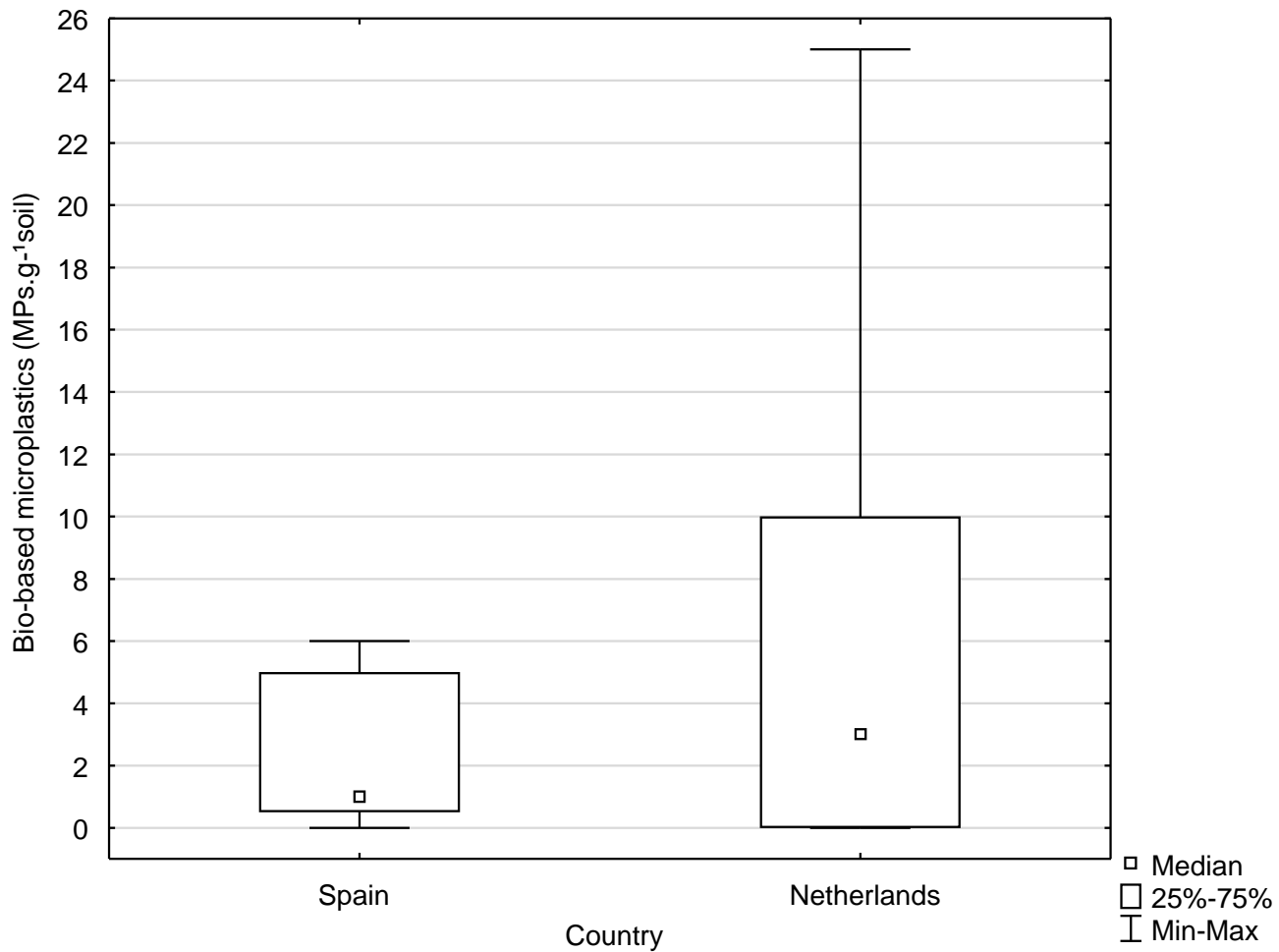


Figure 6. Bio-based microplastic concentrations (MPs.g⁻¹ soil) in soils from agricultural fields for each country where bio-based mulch was applied in the last 2 to 5 years.

Size of the microplastics in soil

In soils, the average size of bio-based microplastics was smaller than the average size of fossil-based plastics (Table 4, and Table S5), but not significantly different. There was also no significant difference between the sizes of the microplastics found in the two countries.

Table 4 . Microplastic sizes, bio-based and fossil-based, in soils per country. Std, standard deviation.

	Bio based plastic (μm^2)		Fossil based (μm^2)	
	mean	Std	mean	std
Spain	1795	20986	1817	20961
Netherlands	2217	50155	1648	16249

Movement of microplastics from soils to ditch sediments and water.

The Netherlands

Types of microplastics found in soil and sediments

Sediment samples were only collected from agricultural areas in the Netherlands since no ditches were present in Spain. Even though irrigation systems in Spain were present, the authorities didn't allow us to take sediments from the bottom of the water bodies due to security reasons. From all samples, 3995 particles were identified as microplastics from sediments using LDIR. 48 different types of microplastics (Figure S2) were found and 53% were bio-based (Figure 7).

The percentage of bio-based microplastics was higher in sediments than in soils. It seems that the quantities of bio-based microplastics varied according to the sampling point. More studies are required in order to verify this assumption. In the present study, bio-based microplastics were found along two different quantity ranges: high, with 2866 particles per gram of sediment (Figure 8a) and low, with 72 particles per gram of sediment (Figure 8b). In both cases, the quantity of bio-based microplastics in sediments were high compared with the quantities found in soils. When all the bio-based microplastics are grouped together in the category of bio-plastics, it is possible to find a significantly strong correlation between the microplastics found in sediments and the microplastics found in soils ($r: 0.91, p < 0.001$). However, when this correlation analysis is carried out with the different types of bio-based microplastics separately, then the correlation becomes moderate with a lower value ($r: 0.43, p < 0.05$). Among the fossil-based plastics, the

most abundant kinds found in soils and sediments were PAC mulch (Pro-oxidant additive containing plastics), Light density polyethylene (LDPE mulch), polyethylene chlorinate and polypropylene (Table S5). The sizes of the microplastics found in sediments were $1871 \pm 9864.7 \mu\text{m}^2$. Even though we saw no significant differences in sizes between bio-based and fossil-based microplastics, the largest particles found were fossil-based microplastics ($304100 \mu\text{m}^2$, Table 5).

Table 5. Size of microplastics in sediments (μm^2).

	N	Minimum	Maximum	Mean	Std. Deviation
Bio-based	2095	325	231675	1846	10395
Fossil based	1859	325	304100	1900	9233

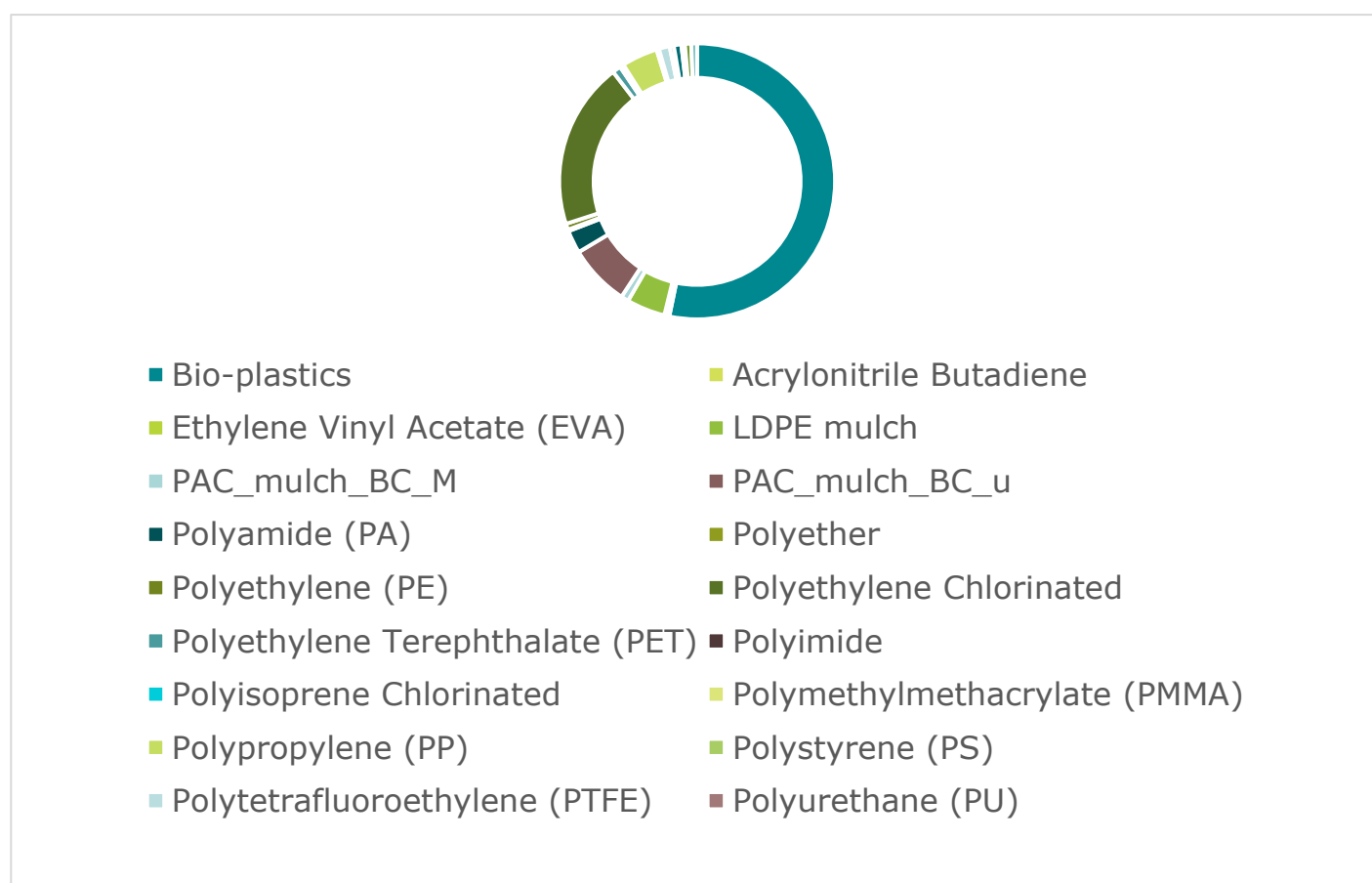


Figure 7. Diversity of microplastics in sediments. Bio-based plastic represents 53% of the total. Limit of detection >0.7.

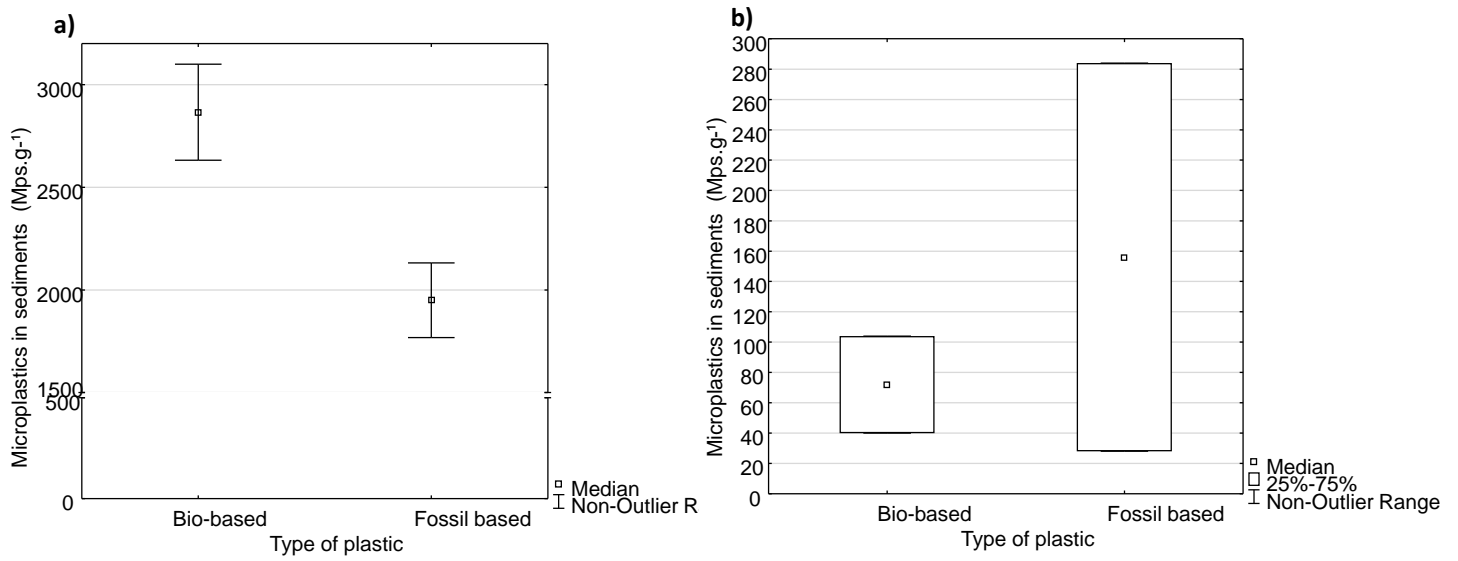


Figure 8. Bio-based microplastics in ditch sediments (Netherlands). Two ranges, a) high, b) low.

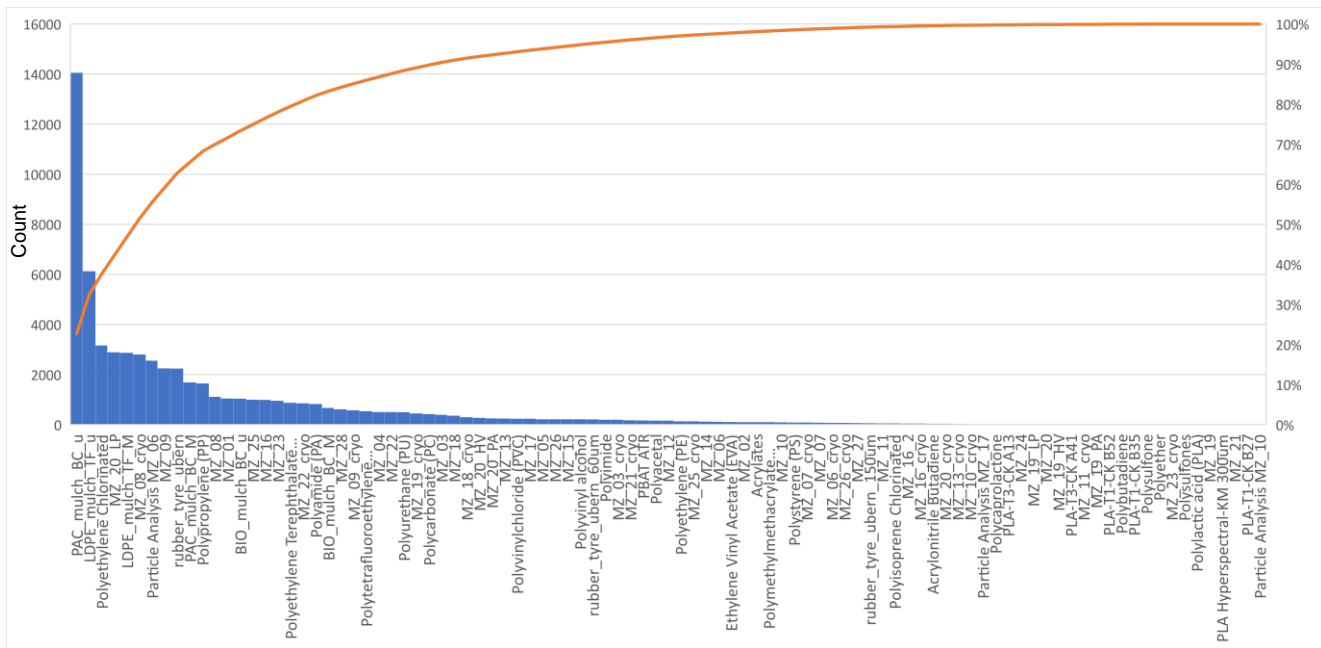


Figure 9. Abundance of microplastics in soils and sediments (detection limit of >0.7).

Microplastics in water

Since a low amount of water was present in the ditches near the agricultural areas in Brabant in the Netherlands in the autumn of 2022, most of the water samples used in this study were taken from the water bodies or irrigation systems near the agricultural areas in Spain. Forty four types of microplastics were detected with LDIR using the limit of detection of >0.7 . LDPE was the most abundant plastic found in Spain (Figure S4) and Bio mulch was the most abundant plastic found in the Netherlands (Figure S3). The size of the microplastics found in water was $1915 \pm 9902.5 \mu\text{m}^2$. The proportions of bio-based and fossil-based plastics found in Spain was 31 and 68.7%, respectively. In the Netherlands, these proportions were 42.1 and 57.9 %, respectively.

In the Netherlands, the number of bio-based microplastic particles found in water was higher than those found in sediments (4073 particles and 2095 particles, respectively). More studies are required in order to assess the number of particles per millilitre of water. In the current study, we were not able to carry out this measurement due to problems we experienced with the LDIR.

Table 6. Microplastics in water samples

Country	bio-based	fossil based
	1235	
Spain	(31.2%)	2718 (68.7%)
	2698	
Netherlands	(42.1%)	3716 (57.9%)

Discussion.

Microplastics are present in agricultural soils. The abundance and type of microplastic found depends on farming practices as well as environmental conditions at each site. According to this study, soils from Spain had lower amounts of microplastics compared to soils from The Netherlands. The particle size of plastics found in soils from Spain were smaller than those found in soils from the Netherlands, which presupposes more degradation due to warmer temperatures in Spain. However, the types of plastics seemed to be the same, and not statistical significant differences were obtained.

The diversity of microplastics appears to be dependent on physicochemical factors surrounding the plastic particles in each of the studied matrices (soil, water, sediments). In soils, the number of different microplastics found was lower (31 with the >0.7 limit, and 15 with the 0.9 limit) compared to the diversity of microplastics found in sediments and water (44-48 with the >0.7 limit in sediments and water).

The sampling point seems crucial for sediment samples. For those places with more accumulated sediment, the concentrations of microplastics seemed to be higher than in those places where the sediments were removed by the movement of water. With a detection limit of 0.9, we detected very high concentrations of microplastics (around 3000 particles per gram of sediment), and low concentrations of microplastics (around 200 particles per gram of sediment). In both cases, these concentrations were higher than the concentrations found in soils in this study, showing an accumulation of microplastics in sediments. Even though more studies are required to better understand this behaviour, there was a strong linear correlation between the percentage of bio-based microplastics in soils and sediments and a moderate correlation between the number of different bio-based microplastics in sediments and soils, being higher in sediments, as previously mentioned.

Bio-based microplastics were also more abundant in sediments (53% of the total microplastics in sediments) than in soils (39% of the total microplastics in soil) using the lower detection limit, and less than 1% using the highest detection limit. With regards to degradation, no significant differences were observed between the sizes of microplastics in soils and in sediments.

In this study, sediments were collected only in the Netherlands and not in Spain. Because of this, we were not able to determine how the degradation process of microplastics might occur in Spain. Further studies are required in order to properly assess the process of degradation in sediments in warm conditions.

In water, the number of bio-based microplastics was lower than in sediments. In the Netherlands, bio-based microplastics made up 42% of the total amount of the microplastics found, and in Spain, it was 31%.

In this study, fossil-based microplastics were the most abundant in soils and water in Spain, while in the Netherlands, these microplastics were the most abundant in sediments and soils. A high percentage of bio-based plastics was found. These results are similar to those found by Huerta Lwanga et. al.(2023) in agricultural soil from the Netherlands.

Challenges

One of the major limitations/challenges in this study was the LDIR which was out of order for more than 5 weeks. This caused a major delay in the analysis of the samples.

We decided to use different detection limits for different purposes. When reporting per gram of soil, per gram of sediment or per ml of water, we recommend using the higher detection limit (0.9 correlation between LDIR library spectra and sample spectra) because the measurements follow a quantitative analysis. When reporting on microplastic diversity, the lower detection limit (>0.7) is the most useful, and the analysis can be quantitative or qualitative. More studies are required to explore the use of different detection limits in microplastic studies.

Perspectives

The information obtained from this study helps to understand more about the dynamics of microplastic movement based on environmental conditions: in warmer conditions, high levels of degradation are expected resulting in smaller bio-based particles. In this study, due to high standard errors, we were not able to observe this phenomenon. It is important to establish a particle cycle, following a particle from the moment it arrives in the soil and watching how it moves to sediments and finally how it is transported to the water. More studies are required to understand this cycle for each type of fossil-based or bio-based plastic particle.

Acknowledgments

Thank you to all the farmers who allowed us to collect samples in The Netherlands and in Spain. Special thanks to CAMPOSEVEN, specially Javier Castillo, for the logistic help in Spain.

References

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Annexes

Total S1. Number and type of samples collected per farm from the Netherlands and Spain.

		Sampling day (2022)			Total samples
		22-sep	3-oct	27-oct	
Sampling description	no transects/farm	2	2	1	
Netherlands	no. soil and macroplastic samples/transect	4	4	4	
	no. water samples per farm	2	2	2	
	no. sediment samples per farm	2	2	2	
	no farms/day in Netherlands	2	2	4	
	macroplastic samples in soil	16	16	no	32
Netherlands	soil samples	16	16	16	48
	water samples	no	8	8	16
	sediment samples	no	no	16	16
			total		112
Spain		7-nov	8-nov	9-nov	
	soil samples	8 (2 farms)	16(4 farms)	8 (2 farms)	32
	water samples	4 (2 farms)	8(4 farms)	4 (2 farms)	16
	sediment samples	no	no	no	0
				total	48
				Total Netherlands & Spain	160
				Total without macroplastics	128

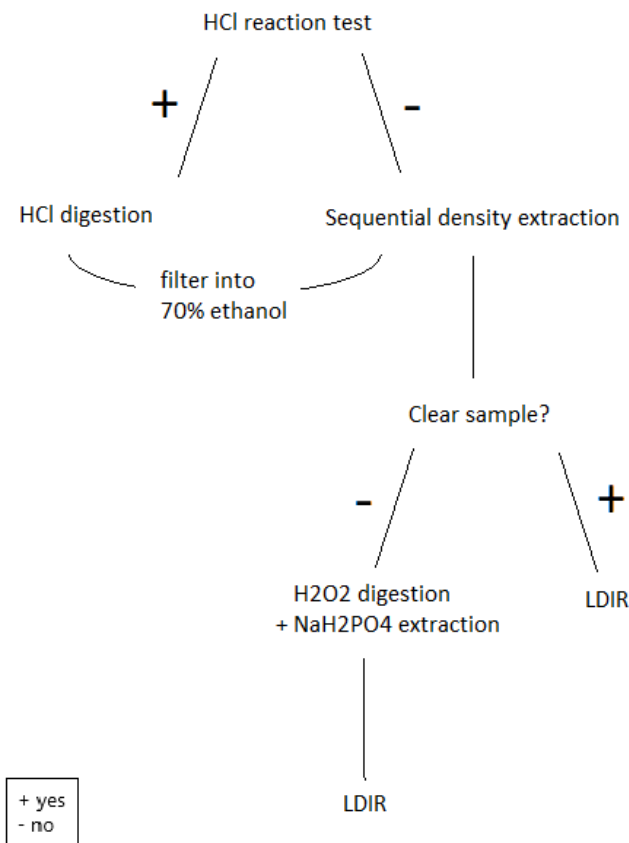


Figure S1a. Extraction procedure, taken from Raevel et al. (2021) (submitted), general view.

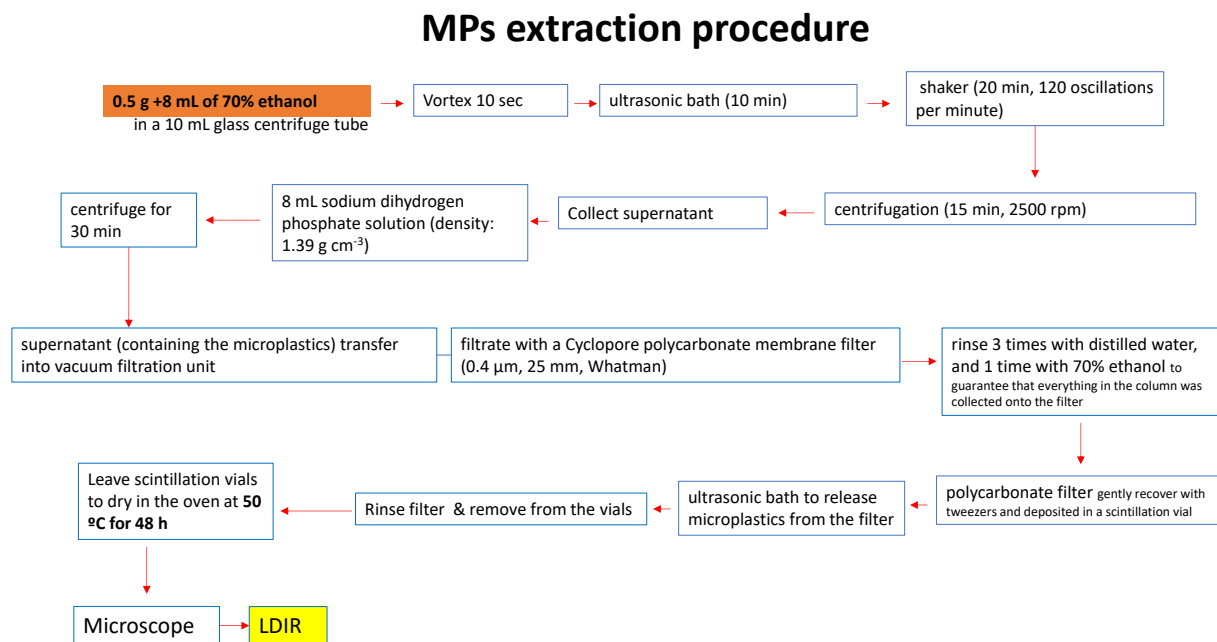


Figure S1b. Extraction procedure, taken from Raevel et al. (2021)(submitted), detailed.

- 1) Please measure first the total amount of water in the bottle with the help of a test-tube
- 2) Then with the help of a metal spoon, move the water to resuspend particles at the bottom of the bottle, move the water of the bottle in order that all particles move, also those that are in the bottom of the bottle, do that during a minute
- 3) Take an aliquot of 8 ml, and put it in a glass tube
- 4) Add 10 mL of H₂O₂ solution (30 % w/v)
- 5) Put the tubes in an ultrasonic bath for 30 seconds
- 6) Place the tubes in the oven to dry at 50 °C for at least 24h, and then filter the solution onto cyclopore polycarbonate filters
- Carefully recover the filter with tweezers and rinse it into a 10 mL glass tube with 70% ethanol, then place it again in the ultrasonic bath for 30 seconds
- And then prepare slide for the LDIR

Figure S1c. Extraction procedure for water samples. This adaptation was altered to obtain fewer particles per slide. Previously, all of the water was analysed by allowing complete evaporation. This led to problems during analysis so the correction was made by using only an aliquot.

Table S2. Adapted protocol for sediment samples.

Step	Change
Preparation of solutions	9.2:10 NaBr:H ₂ O ration for 1.52 g/mL that does not crystallise
Density separation I and filtration I	Use 1 g of dry sediment sample
Urea Steps 1, 4	Put 12.5 mL Urea because the sample is 5 times less, wash 8 times
Density separation II and filtration III step 2	Use 8.0 µm 25 mm polycarbonate(?) filter (Nuclepore Track-Etch Membrane)
Density separation II and filtration III steps 5-7	Sonicate 5-10 min before putting on slides. Otherwise particles stick to vials

Table S3. Total number of samples extracted and analysed by LDIR. Due to problems with the LDIR, only 208 samples were analysed; *sample aliquots were randomly chosen for LDIR analysis* .

Matrix	Country	Farm	Extracted	LDIR analysed
soil	Netherlands & Spain	F1-F16	80	150
Water	Netherlands & Spain	F1-F16	32	32
sediment	Netherlands	F1-F8	16	26
Total samples			128	208

Table S4. Diversity of microplastics (limit of detection 0.9) and concentration in agricultural soils where bio-mulch was applied in the last 2-5 years.

Plastic type	Valid N	Mean (Mp.g ⁻¹ soil)	Minimum	Maximum	Std.De v.
MZ28	1	1,0	1.0	1.0	0
Mz_06	7	1.1	0.0	2.0	1.1
Mz_08	6	0.2	0.0	1.0	0.4
Total Bio	14	0.73	0.0	2.0	0.5
PE	8	0.3	0.0	1.0	0.5
chlorinated					
LDPE mulch	11	61.6	0.0	258.0	86.6
Mz01	9	0.0	0.0	0.0	0.0
Mz09	16	3.0	0.0	14.0	4.2
PA	22	12,3	1.0	80.0	19.1
PMMA	19	6.4	0.0	40.0	10.3
BioMulch	17	5.0	0.0	25.0	6.4
Acrylates	19	0,2	0.0	1.0	0.4
PAC	19	28.9	0.0	205.0	55.0
PE	24	31.0	1.0	239.0	55.9
PET	17	0.1	0.0	1.0	0.2
Polyacetel	20	0.6	0.0	3.0	0.8
PP	31	476.6	12.0	4739.0	1002.8
PS	23	33.3	0.0	250.0	59.8
PU	22	17.4	0,0	125.0	30.4
PVC	22	1.2	0.0	8.0	2.1

Table S5. Size of microplastics in soils (limit of detection >0.7).

Type of plastics	Area (μm^2) Mean	N	Std. Deviation
Acrylates	11235.9	99	38749.9
Acrylonitrile Butadiene	2995.6	50	3526.9
BIO_mulch_ BC_M	10272.7	673	170139.8
BIO_mulch_ BC_u	1713.7	1080	4529.4
Ethylene Vinyl Acetate (EVA)	11657.7	106	47505.9
LDPE_mulch _TF_M	1112.4	2930	2356.3
LDPE_mulch _TF_u	1614.0	7426	12316.0
MZ_01	1403.9	1087	7036.8
MZ_02	1111.1	102	2022.0
MZ_03	2810.2	409	5971.2
MZ_03_cryo	2198.6	220	4537.8
MZ_04	49559.3	519	429020.7
MZ_05	2220.3	224	5005.6
MZ_06	3675.5	120	10386.7
MZ_06_cryo	2025.3	71	10937.3
MZ_07	2671.5	85	4938.3
MZ_07_cryo	741.8	89	895.1
MZ_08	5045.9	1136	89209.7
MZ_08_cryo	833.1	2988	2066.4

MZ_09	5452.6	2494	111888.7
MZ_09_cryo	1647.5	597	7114.6
MZ_10	893.7	88	1512.1
MZ_10_cryo	2536.3	25	9142.1
MZ_11	1804.8	55	4210.1
MZ_11_cryo	1460.1	9	3260.9
MZ_12	1814.6	163	4743.4
MZ_13	900.3	243	895.9
MZ_13_cryo	627.7	28	401.3
MZ_14	1631.7	118	2073.9
MZ_15	1320.7	218	5118.6
MZ_16	2684.7	1098	7016.3
MZ_16_2	1003.2	50	1751..4
MZ_16_cryo	903.1	44	748.5
MZ_17	2245.9	238	22159.4
MZ_18	1019.0	365	2249.4
MZ_18_cryo	2457.7	304	4936.7
MZ_19	458.3	3	92.1
MZ_19_cryo	1163.3	459	1434.9
MZ_19_HV	27309.3	10	82292.6
MZ_19_LP	862.4	14	488.0
MZ_19_PA	2757.8	9	4923.8
MZ_20	743.0	16	947.4
MZ_20_cryo	1823,8	94	3065.7
MZ_20_HV	854.0	275	856.2
MZ_20_LP	883.0	3055	5539.9
MZ_20_PA	779,4	255	1051.6
MZ_21	26062.5	1	
MZ_21_cryo	4166.5	212	20184.1
MZ_22	1213.1	519	2814.7

MZ_22_cryo	896.9	889	1633.1
MZ_23	838.3	1093	1532.2
MZ_23_cryo	1674.2	6	1481.0
MZ_24	4782.4	17	10809.8
MZ_25	889.7	1007	2778.5
MZ_25_cryo	2580.0	132	13611.5
MZ_26	1159.4	222	2352.1
MZ_26_cryo	2056.7	68	5630.9
MZ_27	2496.1	71	6237.1
MZ_28	2976,9	622	12440.0
PAC_mulch_ BC_M	1384.6	1711	7437.3
PAC_mulch_ BC_u	1114.5	15632	5188.1
Particle Analysis MZ_06	1670.2	2924	2199.5
Particle Analysis MZ_10	337.5	1	
Particle Analysis MZ_17	734.8	19	337.4
PBAT ATR	2130.3	198	4148.2
PLA Hyperspectra I- KM 300um	650.0	2	106,1
PLA-T1-CK B27	975.0	1	
PLA-T1-CK B35	1143.2	6	984.6

PLA-T1-CK B52	2272.2	9	3584.6
PLA-T3-CK A13	988.6	16	962.7
PLA-T3-CK A41	2686.6	10	6479.6
Polyacetal	1842.7	162	5675.7
Polyamide (PA)	1602.4	837	4727.6
Polybutadien e	648.4	8	283.1
Polycaprolact one	3331.9	18	7256.5
Polycarbonat e (PC)	2074.0	418	3408.8
Polyether	2475.0	5	4190.1
Polyethylene (PE)	3443.1	141	10720.4
Polyethylene Chlorinated	1546.0	3674	2534.5
Polyethylene Terephthalate (PET)	2209.3	958	20458.5
Polyimide	925.1	212	1700.7
Polyisoprene Chlorinated	2257.7	48	3764.4
Polylactic acid (PLA)	3042.0	5	5213.4
Polymethylm ethacrylate (PMMA)	2851.0	101	12274.7

Polypropylene (PP)	5055.6	1901	14697.6
Polystyrene (PS)	5474.7	93	15062.6
Polysulfone	1563.6	7	1403.4
Polysulfones	1080.2	4	730.9
Polytetrafluoroethylene (PTFE)	1547.3	564	2890.8
Polyurethane (PU)	3489.9	507	8389.7
Polyvinyl alcohol	2336.6	212	7217.5
Polyvinylchloride (PVC)	3187.2	242	5847.1
rubber_tyre_ubern	2142.6	3235	16167.9
rubber_tyre_ubern_150um	4753.8	148	33845,6
rubber_tyre_ubern_60um	972.8	226	1486.5
Total	2256.3	68855	48382.5

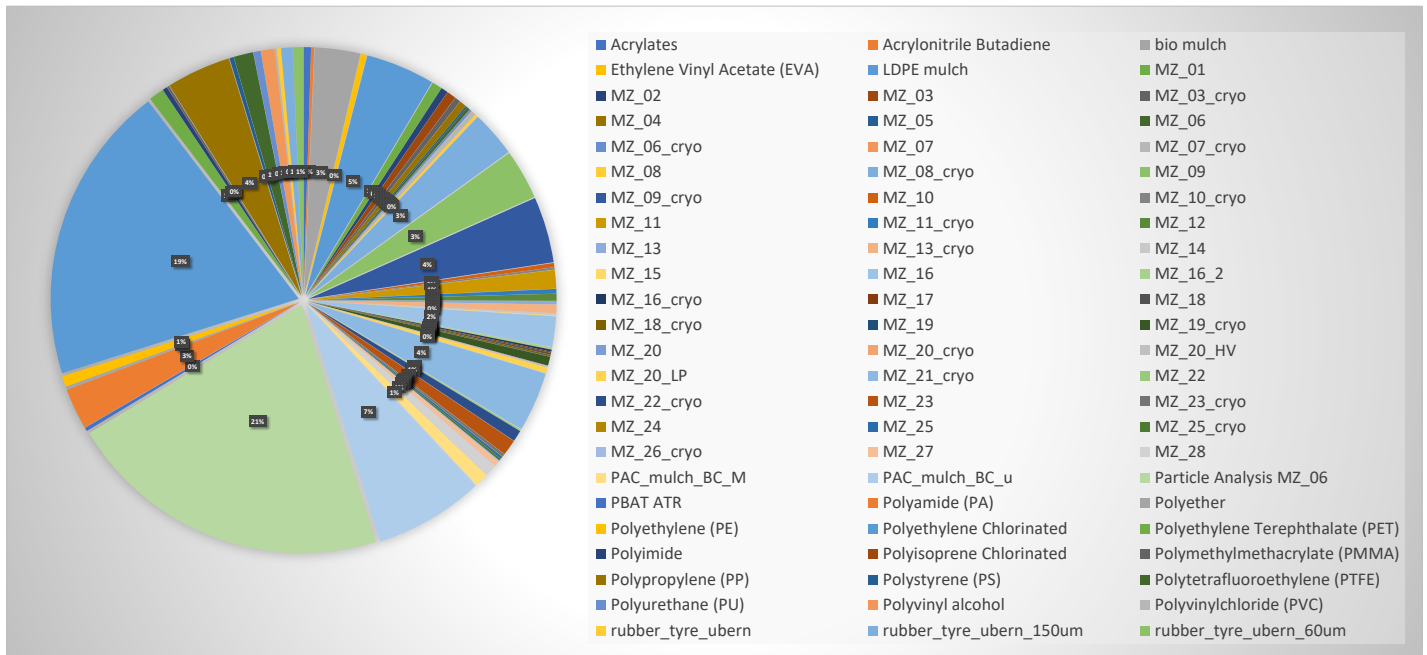


Figure S2. Diversity of microplastics in sediments (limit of detection >0.7).

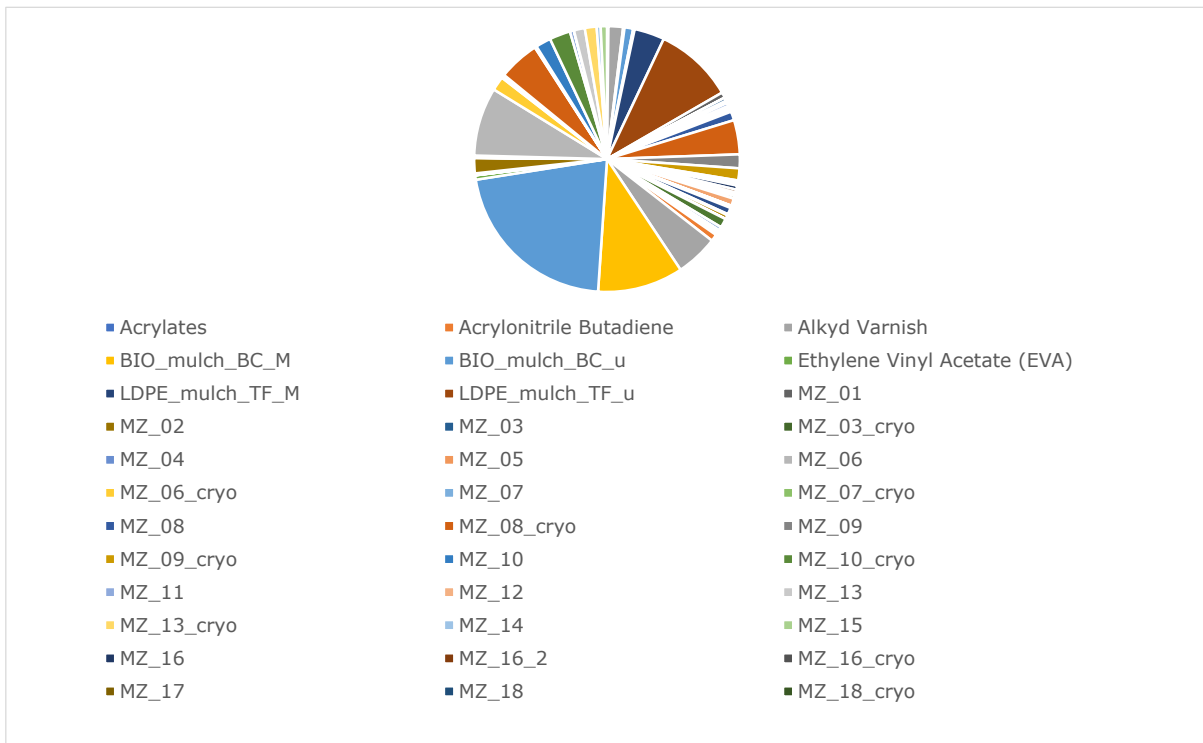


Figure S3. Diversity of microplastics in water samples from the Netherlands (limit of detection >0.67).

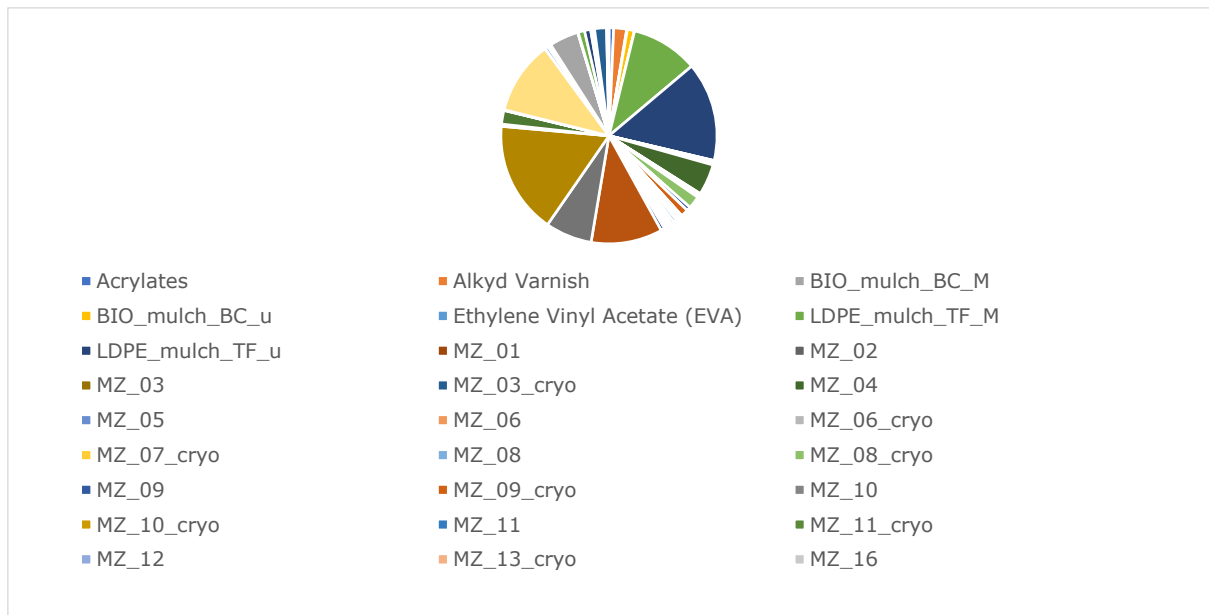


Figure S4. Diversity of microplastics in water samples from Spain (limit of detection >0.67)