Electronic Supplementary Material (ESI) for Environmental Science: Advances.

Supporting Information (SI)

Microplastics in the ecosystems: Their implications and mitigation pathway

Poritosh Roy[a,b], Amar K. Mohanty[a,b]*, and Manjusri Misra[a,b]*

[a]School of Engineering, Thornbrough Building, University of Guelph, 50 Stone Road East, Guelph, Ontario N1G 2W1, Canada.

[b]Bioproducts Discovery and Development Centre, Department of Plant Agriculture, Crop Science Building, University of Guelph, 50 Stone Road East, Guelph, Ontario N1G 2W1, Canada.

*Corresponding author: mmisra@uoguelph.ca (M. Misra); mohanty@uoguelph.ca (A. K. Mohanty)

Table SI-1 Common microplastics (MPs) assessment tools/methods

Type of ample/Product	Tools/Methods	Remarks/Findings	Reference
Bottled water	Fourier-transform infrared (FTIR) spectroscopy; Nile Red tagging with the microscope	325 MP/L; MP was observed in 93% of bottled water	(1)
Tap water	SEM and FTIR; coagulation	Polyaluminium chloride (PAC), coagulation was better than ferric chloride ($FeCl_3$) coagulation to removing polystyrene (PS) and polyethylene (PE) MPs	(2)
Municipal wastewater, sludge	FTIR, universal attenuated total reflectance accessory (ATR)	31.1±6.7 MPs/L; Fibres (65.6%), fragments (28.1%) and pellets (5.4%), rest is the combination of foam, granules, and sheets in water samples; 14.9 ± 6.3 MPs/g-sludge	(3)
Municipal wastewater	Density separation, trinocular microscopic identification, and polymeric analysis by FTIR spectroscopy	Fragment, film, bead, fibre, and foam were observed	(4)
Large reservoir water (3700 L/s)	µFTIR (micro-FTIR), µRaman (micro-Raman), coagulation-flocculation and sand filtration	1473 ± 34 MPs/L	(5)
Small reservoir water (100 L/s)	µFTIR, µRaman; coagulation-flocculation, sedimentation, sand, and activated carbon filtration	1812 ± 35 MPs/L	(5)
River water	µFTIR, µRaman; coagulation-flocculation, flotation, sand, and activated carbon filtration	3605 ± 497 MPs/L	(5)
Contaminated water	Pyrolysis-Gas chromatography, time of flight mass spectrometry (Py-GCToF) in combination with PTFE membranes	241.8 µg/L	(6)
Marine sediment	Microplastic sediment separator; FTIR	42−6595 MP/kg; 18 different polymers were	(7)

	and µFTIR spectroscopy	detected, 80% of them were ≤25 µm	
River-bank sediment	SEM-EDS (energy-dispersive spectroscopy)	161–432 MPs/kg dry sediment	(8)
Aquatic samples (sediments)	Raman and FTIR spectroscopy	For a smaller particle, Raman is noted to be a better option	(9)
River-basin sediment	Visual extraction, flotation along with Raman spectroscopy	~660 MPs/kg, 91% were fragments	(10)
Agricultural soil (mulched/irrigated)	Stereomicroscopy and micro-FTIR (µ-FTIR)	571 MP/kg and 263 MP/kg in mulched soil and non-mulched soil, respectively	(11)
Floodplain soil	FTIR and Raman spectroscopy; density separation and oxidation of organic matter	~593 MPs/kg; MP concentration was correlated with the population of the catchment	(12)
Farmland and greenhouse soil	A camera connected with a microscope visual extraction, flotation, and heating	~320 MPs/kg	(13)
Municipal soil (industrial area)	Microscope and FTIR, pressurized fluid extraction	500–6900 mg/kg	(14)
Garden soil	Microscope	~2770 MPs/kg; MP and macroplastics (5–150 mm) can enter in food chains	(15)
Soil	µ-FTIR	420–1290 MPs/kg	(16)
Sewage sludge	µ-FTIR	5553–13460 MPs/kg	(16)
Contaminated soil	Pyrolysis-gas chromatography/mass spectrometry (Py-GC/MS).	Simplified and sped up sample handling reduced the risk of contamination	(17)
Table salt	FTIR	50–280 MPs/kg	(18)
Fish	ATR-FTIR	0.054 ± 0.099 MP/g; MP ingested by fish resulted in higher lipid peroxidation levels in the brain, gills, dorsal muscle, and increased brain acetylcholinesterase activity	(19)
Tadpoles	SEM coupled with an EDAX detector for X-Ray microanalysis systems	MPs were observed in gills, gastrointestinal tract, liver, muscle tissues, and in the blood, which indicates the accumulation of MP in tadpoles and can affect the health of amphibians	(20)

Reference

1. Mason SA, Welch VG, Neratko J. Synthetic polymer contamination in bottled water. Front Chem. 2018;6:407.

2. Zhou G, Wang Q, Li J, Li Q, Xu H, Ye Q, et al. Removal of polystyrene and polyethylene microplastics using PAC and FeCl3 coagulation: Performance and mechanism. Sci Total Environ. 2021;752:141837.

3. Gies EA, LeNoble JL, Noël M, Etemadifar A, Bishay F, Hall ER, et al. Retention of microplastics in a major secondary wastewater treatment plant in Vancouver, Canada. Mar Pollut Bull. 2018;133:553–61.

4. Bayo J, López-Castellanos J, Olmos S. Membrane bioreactor and rapid sand filtration for the removal of microplastics in an urban wastewater treatment plant. Mar Pollut Bull. 2020;156:111211.

5. Miranda MN, Silva AMT, Pereira MFR. Microplastics in the environment: A DPSIR analysis with focus on the responses. Sci Total Environ. 2020;718:134968.

6. Sullivan GL, Gallardo JD, Jones EW, Hollliman PJ, Watson TM, Sarp S. Detection of trace sub-micron (nano) plastics in water samples using pyrolysis-gas chromatography time of flight mass spectrometry (PY-GCToF). Chemosphere. 2020;249:126179.

7. Bergmann M, Wirzberger V, Krumpen T, Lorenz C, Primpke S, Tekman MB, et al. High quantities of microplastic in Arctic deep-sea sediments from the HAUSGARTEN observatory. Environ Sci Technol. 2017;51(19):11000–10.

8. Blair RM, Waldron S, Phoenix VR, Gauchotte-Lindsay C. Microscopy and elemental analysis characterisation of microplastics in sediment of a freshwater urban river in Scotland, UK. Environ Sci Pollut Res. 2019;26(12):12491–504.

9. Käppler A, Fischer D, Oberbeckmann S, Schernewski G, Labrenz M, Eichhorn K-J, et al. Analysis of environmental microplastics by vibrational microspectroscopy: FTIR, Raman or both? Anal Bioanal Chem. 2016;408(29):8377–91.

10. Horton AA, Svendsen C, Williams RJ, Spurgeon DJ, Lahive E. Large microplastic particles in sediments of tributaries of the River Thames, UK–Abundance, sources and methods for effective quantification. Mar Pollut Bull. 2017;114(1):218–26.

11. Zhou B, Wang J, Zhang H, Shi H, Fei Y, Huang S, et al. Microplastics in agricultural soils on the coastal plain of Hangzhou Bay, east China: Multiple sources other than plastic mulching film. J Hazard Mater. 2020;388:121814.

12. Scheurer M, Bigalke M. Microplastics in Swiss floodplain soils. Environ Sci Technol. 2018;52(6):3591–8.

13. Zhang S, Yang X, Gertsen H, Peters P, Salánki T, Geissen V. A simple method for the extraction and identification of light density microplastics from soil. Sci Total Environ. 2018;616:1056–65.

14. Fuller S, Gautam A. A procedure for measuring microplastics using pressurized fluid extraction. Environ Sci Technol. 2016;50(11):5774–80.

15. Lwanga EH, Vega JM, Quej VK, de los Angeles Chi J, Del Cid LS, Chi C, et al. Field evidence for transfer of plastic debris along a terrestrial food chain. Sci Rep. 2017;7(1):1–7.

16. Li Q, Wu J, Zhao X, Gu X, Ji R. Separation and identification of microplastics from soil and sewage sludge. Environ Pollut. 2019;254:113076.

17. Steinmetz Z, Kintzi A, Muñoz K, Schaumann GE. A simple method for the selective quantification of polyethylene, polypropylene, and polystyrene plastic debris in soil by pyrolysis-gas chromatography/mass spectrometry. J Anal Appl Pyrolysis. 2020;147:104803.

18. Iñiguez ME, Conesa JA, Fullana A. Microplastics in Spanish table salt. Sci Rep. 2017;7(1):1–7.

19. Barboza LGA, Lopes C, Oliveira P, Bessa F, Otero V, Henriques B, et al. Microplastics in wild fish from North East Atlantic Ocean and its potential for causing neurotoxic effects, lipid oxidative damage, and human health risks associated with ingestion exposure. Sci Total Environ. 2020;717:134625.

20. da Costa Araújo AP, de Melo NFS, de Oliveira Junior AG, Rodrigues FP, Fernandes T, de Andrade Vieira JE, et al. How much are microplastics harmful to the health of amphibians? A study with pristine polyethylene microplastics and Physalaemus cuvieri. J Hazard Mater. 2020;382:121066.