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Chemistry of Analysis and Determination of Microplastics and Nanoplastics in Humans, Air, Water and Soil: A Comprehensive Review of Previous Studies

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Abstract

Environmental pollution caused by plastics has become one of the most pressing global challenges of the 21st century. The rapid pace of industrial and technological advancement—often driven by human convenience and economic priorities—has intensified the accumulation of plastic waste in the biosphere, posing severe threats to both human and ecosystem health. Despite extensive global efforts to address legacy contaminants and pollutants, the continual introduction of new and complex plastic-derived substances, including microplastics (MPs) and nanoplastics (NPs), remains a persistent and evolving concern. These emerging contaminants have triggered worldwide initiatives focused on risk evaluation, toxicological assessment, and regulatory control, highlighting the urgent need for improved analytical and monitoring strategies. This study aims to present a comprehensive overview of the chemistry, analytical techniques, and methodological approaches used in the identification, characterization, and quantification of microplastics and nanoplastics in environmental media. Data and relevant literature were systematically retrieved from reputable scientific databases including Scopus, PubMed, Royal Society of Chemistry Publishing, SpringerLink, Google Scholar, Magiran, and Taylor & Francis Online. The search employed keywords such as *microplastics*, *nanoplastics*, *analysis*, *determination*, and *environmental monitoring*. The review identified a range of analytical techniques employed for the determination of MPs and NPs. These include particle-based methods, thermal degradation techniques (such as pyrolysis–GC/MS), and non-destructive spectroscopic approaches such as Fourier-transform infrared (FTIR) spectroscopy, Raman spectroscopy, scanning probe microscopy coupled with spectroscopy, and Raman-based analysis of nanoplastics enabled by optical tweezers. Each method varies in its detection limits, resolution, selectivity, and sample preparation requirements, influencing its suitability for specific environmental matrices such as water, air, and soil. The study concludes that while remarkable progress has been made in the development of analytical tools for MPs and NPs, significant challenges persist in achieving standardized, reproducible, and high-sensitivity measurements—particularly at the nanoscale. Future research should therefore focus on the harmonization of analytical protocols, development of integrated multi-technique frameworks, and the advancement of real-time detection systems to better understand the fate, transport, and ecological implications of micro- and nanoplastics in the environment.

Keywords
Strength Prediction,
Optimization,
Orange Peel ash,
Eggshell powder
Cement blends

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INTRODUCTION

Emerging contaminants, microplastics and nanoplastics are substances of synthetic origin that are not typically regulated in the environment (Goukeh et al., 2025). These environmental pollutants are a significant emerging research interest that can be established in a variety of environmental systems (Dirtu et al., 2012; Albero et al., 2017; Barroso et al., 2019; Liu et al., 2021a, 2021b; Bayabil et al., 2022; Pakdehi et al., 2023; Goukeh et al., 2025). Several hundreds of emerging contaminants, microplastics and nanoplastics have been found in the environment at low concentrations (Glüge et al., 2020; Goukeh et al., 2025; Wang et al., 2024a).

Microplastic and nanoplastics pollution has led to severe environmental problems. Microplastics and nanoplastics have been established on the world's highest mountain (Dong et al., 2023) and in the deepest trench of the Pacific Ocean. Microplastics and nanoplastics are widely distributed throughout the hydrosphere, pedosphere, atmosphere and biosphere (Dong et al., 2023). Figure 1 presents an overview of the sources of microplastics and nanoplastics, implications and migration pathways. Figure 2 shows a schematic diagram of the degradation process of waste plastic. Figure 3 shows a schematic of the sources of waste plastics and their transportation routes. Figure 4 presents the atmospheric deposition of microplastics and nanoplastics in the terrestrial ecosystem, their effect on soil properties and feedbacks to the atmosphere. Figure 5 shows an adsorption mechanism between microplastics and chemicals. Figure 6 shows the role of microplastics in an aquatic environment.

Humans are exposed to nanoplastics and microplastics through the air, water and food. nanoplastics and microplastics have been frequently detected in food samples, such as salt, sugar, beer, honey, eggs and seafood (Dong et al., 2023). In addition, microplastics and nanoplastics have been found in biological samples from humans, such as colectomy specimens, saliva, sputum, the lungs, liver, breastmilk and faeces (Dong et al., 2023). These microplastics, nanoplastics and smaller polymers can be transported throughout the human body through the blood circulation system and can penetrate the blood–brain barrier, possibly leading to oxidative damage and immunological stress, which could threaten human health (Dong et al., 2023). Figure 7 shows the cycling of microplastics in the multi-sphere system. Figure 8 presents the potential health effects and impacts of microplastics and nanoplastics. Figure 9 presents changes in the properties of microplastics and nanoplastics.

Figure 10 shows the bioaccumulation phase of the microplastics and nanoplastics life cycle. Figure 11 presents the impacts of microplastics and nanoplastics on seafood organisms. Figure 12 shows the impacts of microplastics and nanoplastics on human health. Figure 13 shows the sources, potential pathways and routes of exposure to microplastics and nanoplastics and potential toxic effects on humans. Figure 14 presents the interaction between microplastics, nanoplastics and the human body. Further readings on nanoplastics and microplastics, effects, movement and fate can be established in the literature, such as Parida et al. (2021); Akhbarizadeh et al. (2020); Nika et al. (2023); Mojiri et al. (2021); Rout et al. (2021); Wang et al. (2021a; 2021b); Saravanan et al. (2022); Yatoo et al. (2024); Mojiri et al. (2021); Wijekoon et al. (2022); Chen et al. (2022); Dong et al. (2023; Ghosh et al., 2023).

Figure 1 An overview of the sources of microplastics and nanoplastics, implications and migration pathways (Source: Roy et al., 2022).

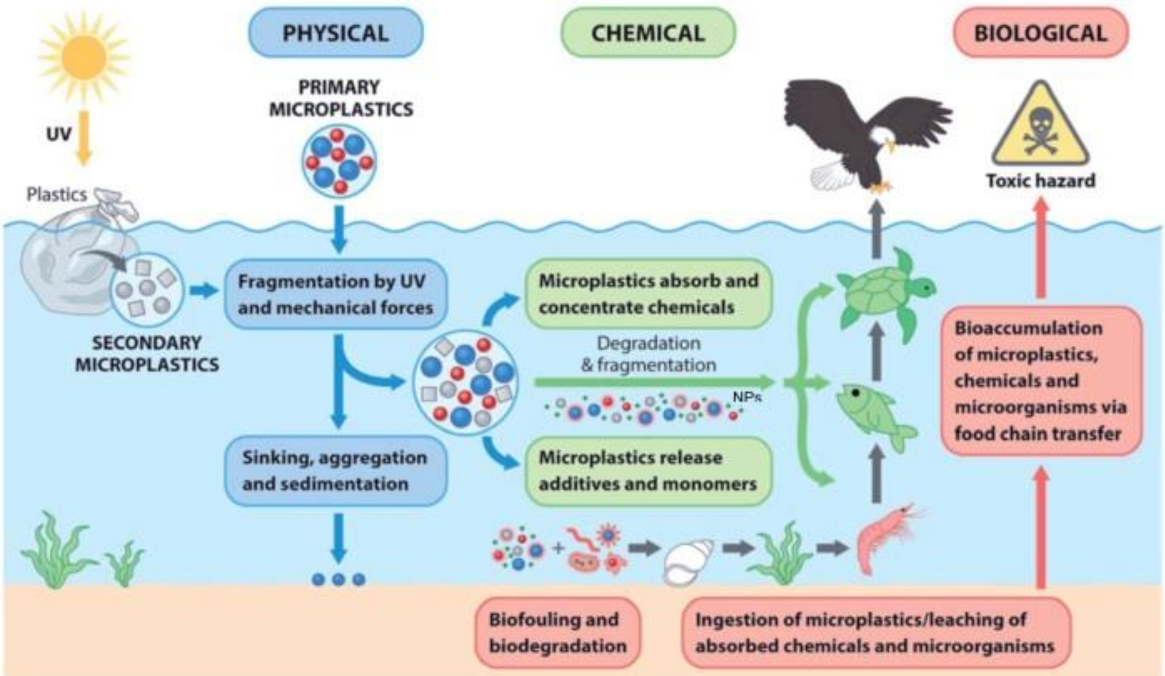

Figure 2 A schematic diagram of the degradation process of waste plastic (Source: Roy et al., 2022).

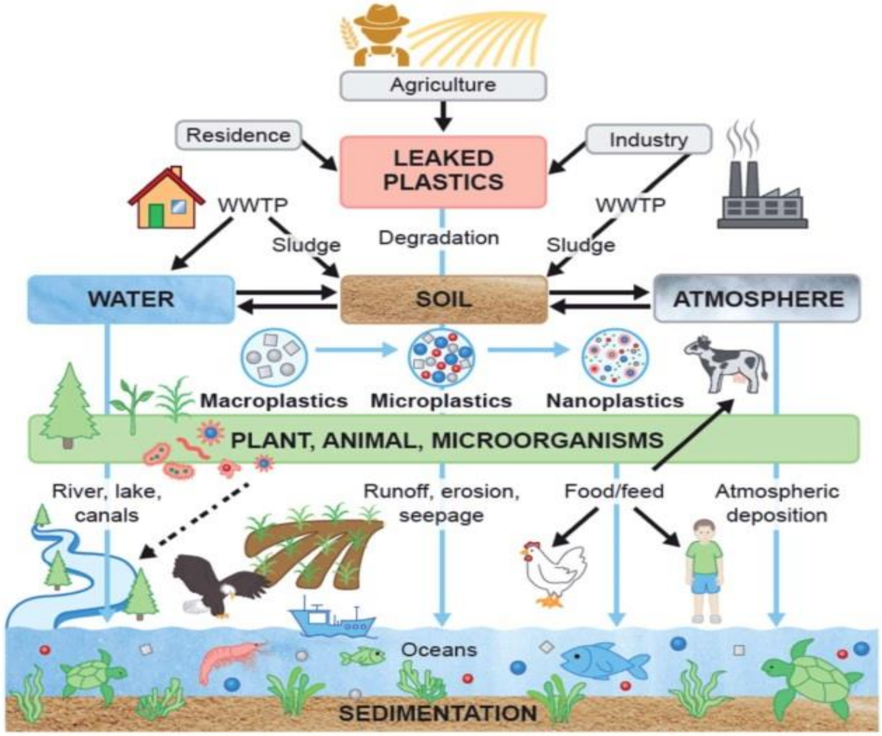

Figure 3 A schematic of the sources of waste plastics and their transportation routes (Source: Roy et al., 2022).

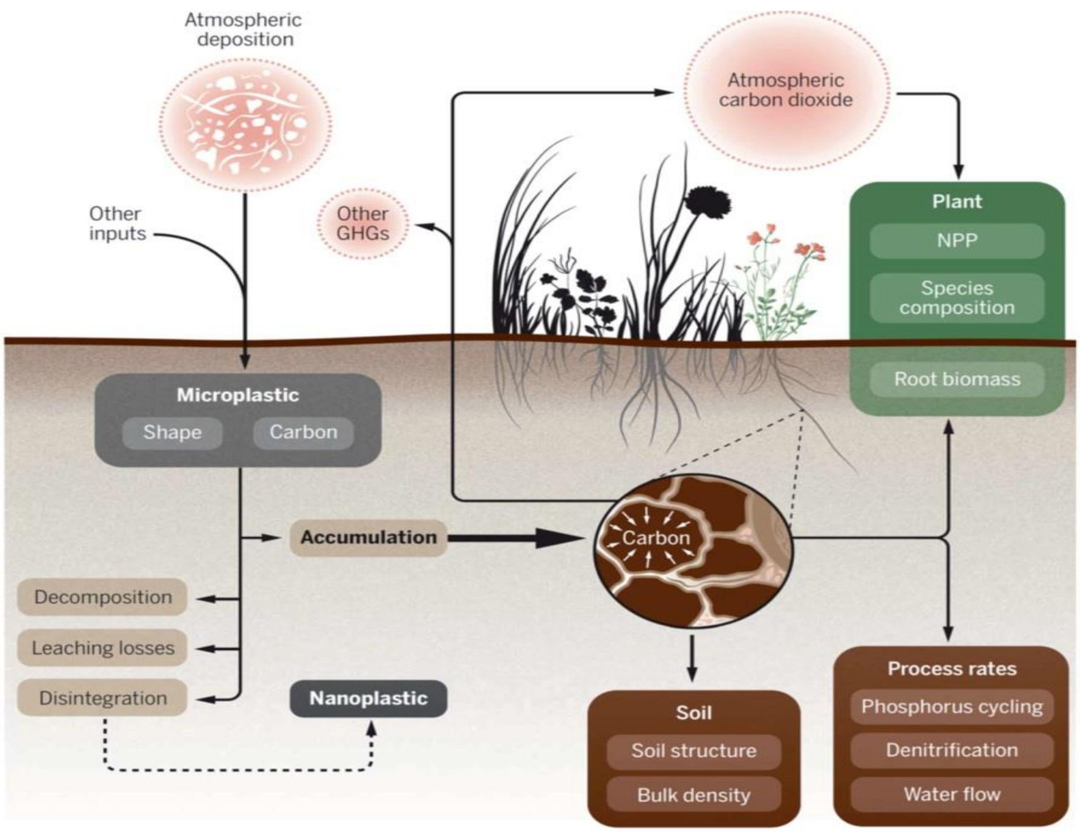

Figure 4 the atmospheric deposition of microplastics and nanoplastics in the terrestrial ecosystem, their effect on soil properties and feedbacks to the atmosphere (Source: Roy et al., 2022).

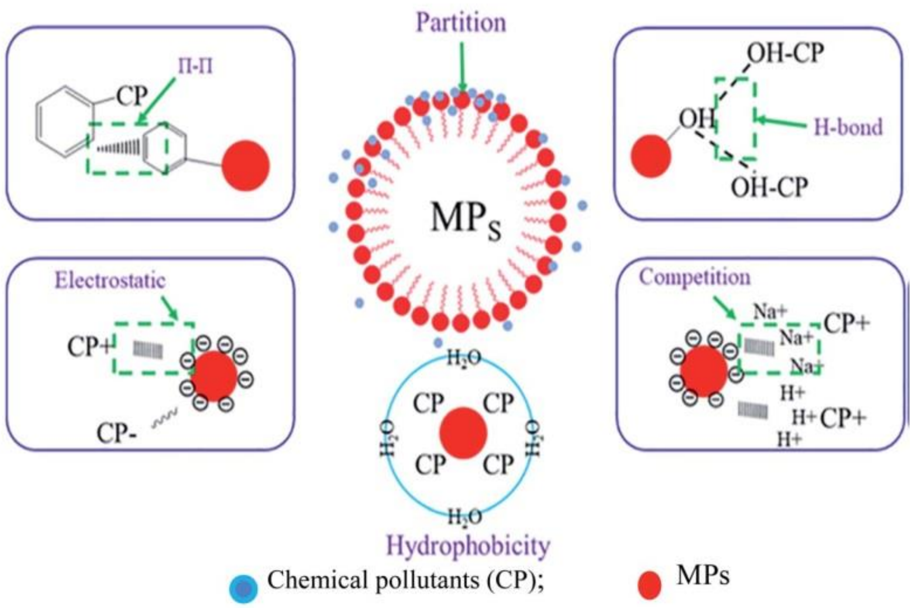

Figure 5 An adsorption mechanism between microplastics and chemicals (Source: Roy et al., 2022).

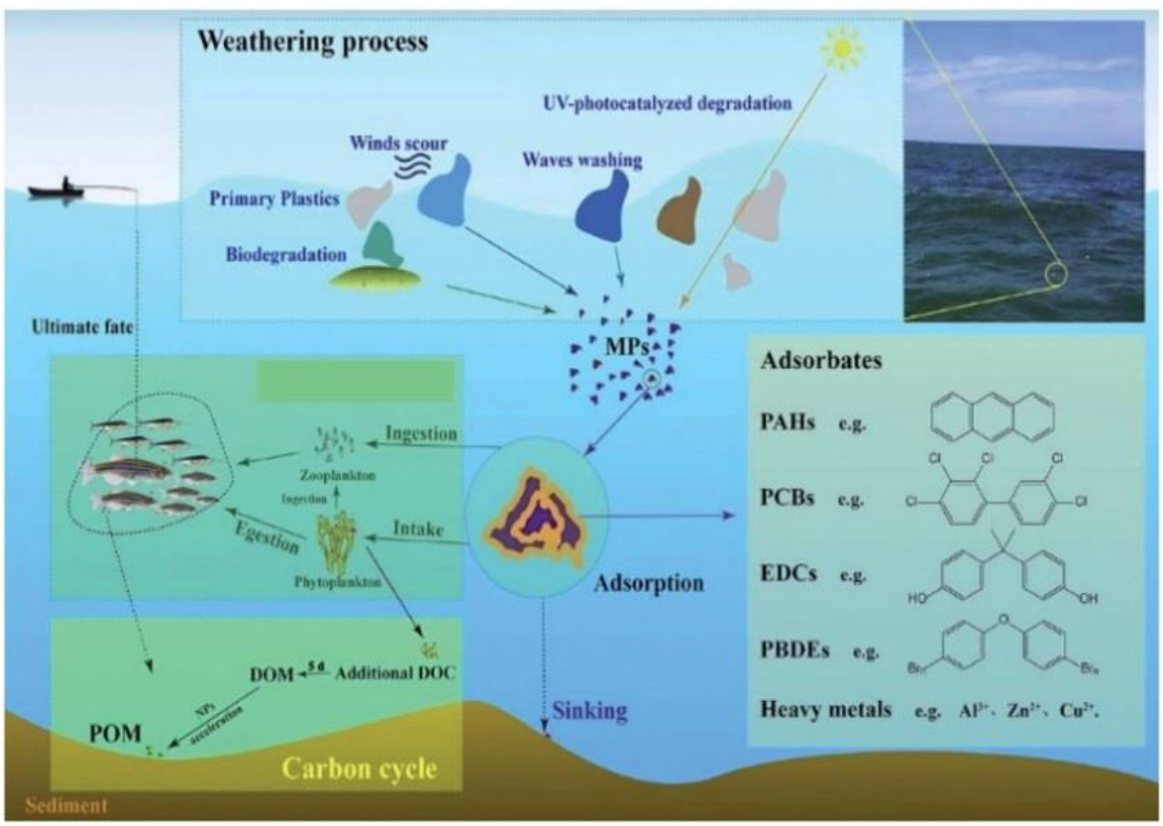

Figure 6 The role of microplastics in an aquatic environment (Source: Roy et al., 2022).

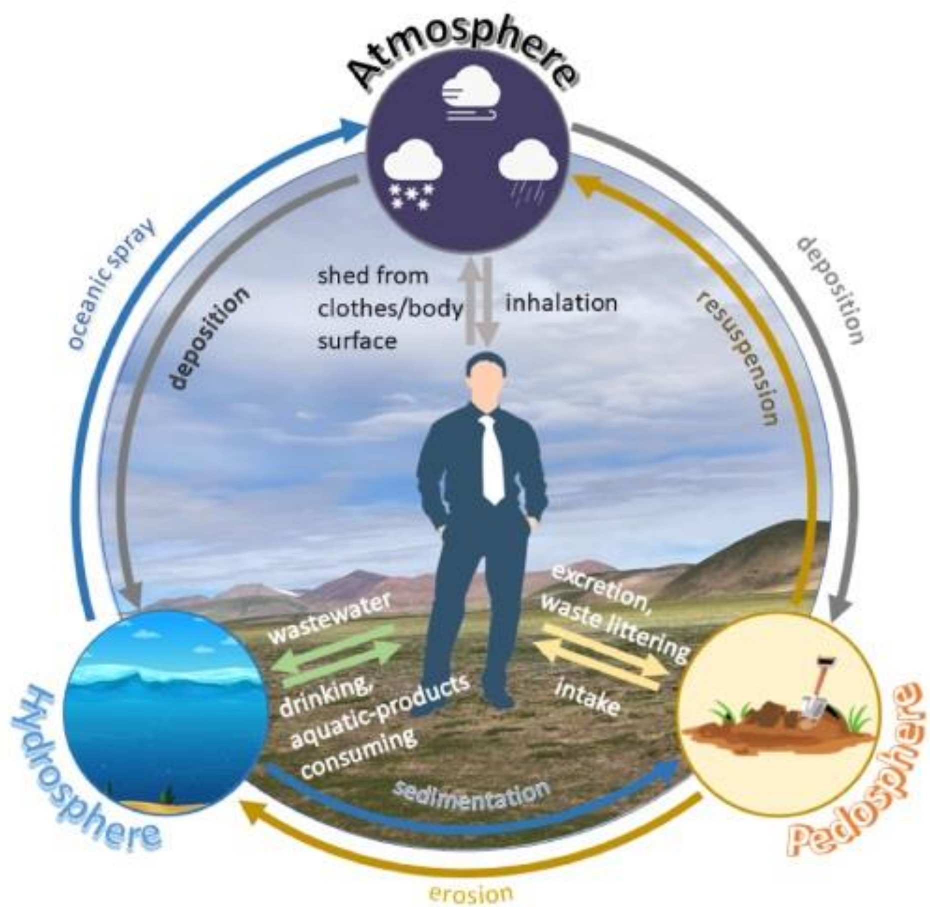

Figure 7 the cycling of microplastics in the multi-sphere system (Source: Dong et al., 2023).

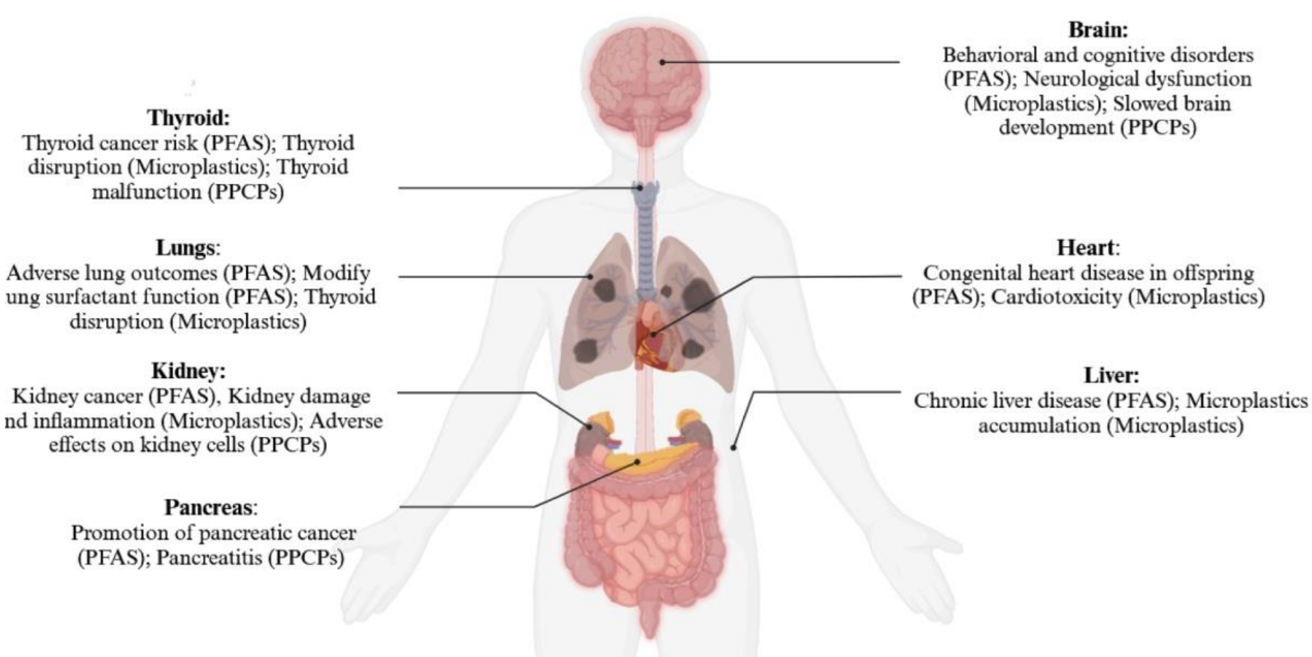

Figure 8 the potential health effects and impacts of microplastics and nanoplastics (Source: Goukeh et al., 2025).

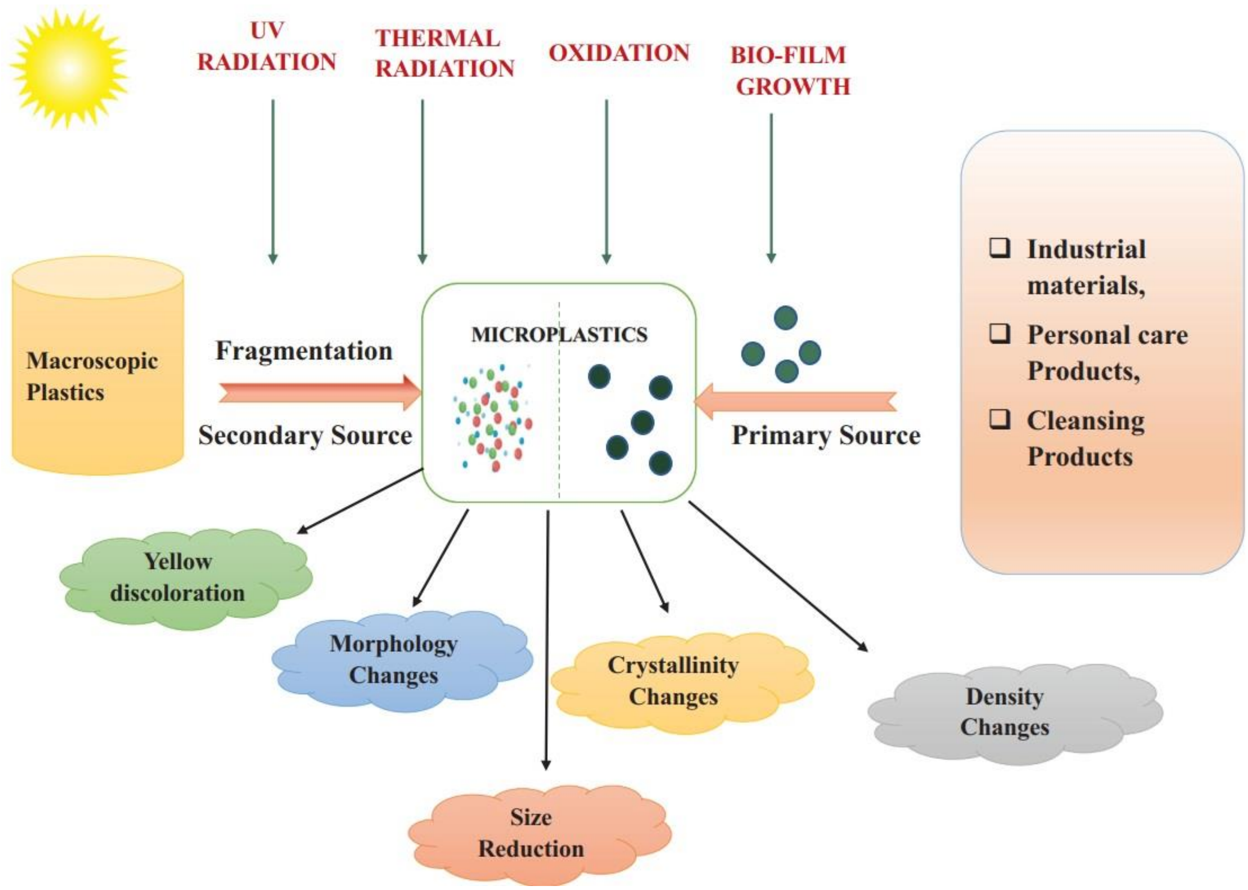

Figure 9 The changes in the properties of microplastics and nanoplastics (Source: Kushwaha et al., 2024).

Figure 10 The bioaccumulation phase of the microplastics and nanoplastics life cycle (Source: Kushwaha et al., 2024).

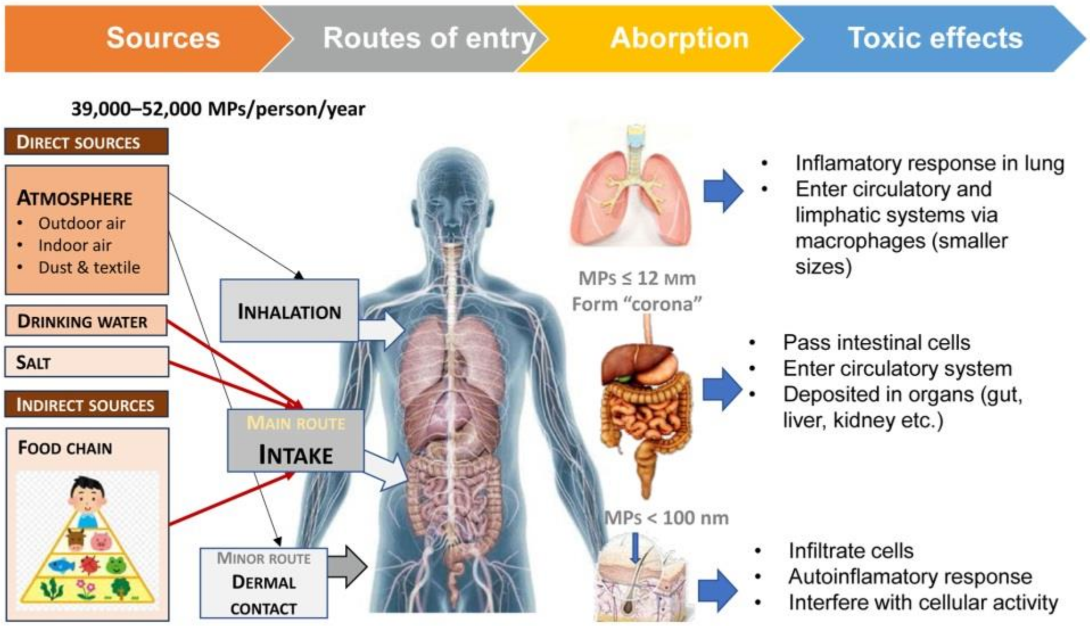

Figure 13 the sources, potential pathways and routes of exposure to microplastics and nanoplastics and potential toxic effects on humans (Source: Barcelo et al., 2023).

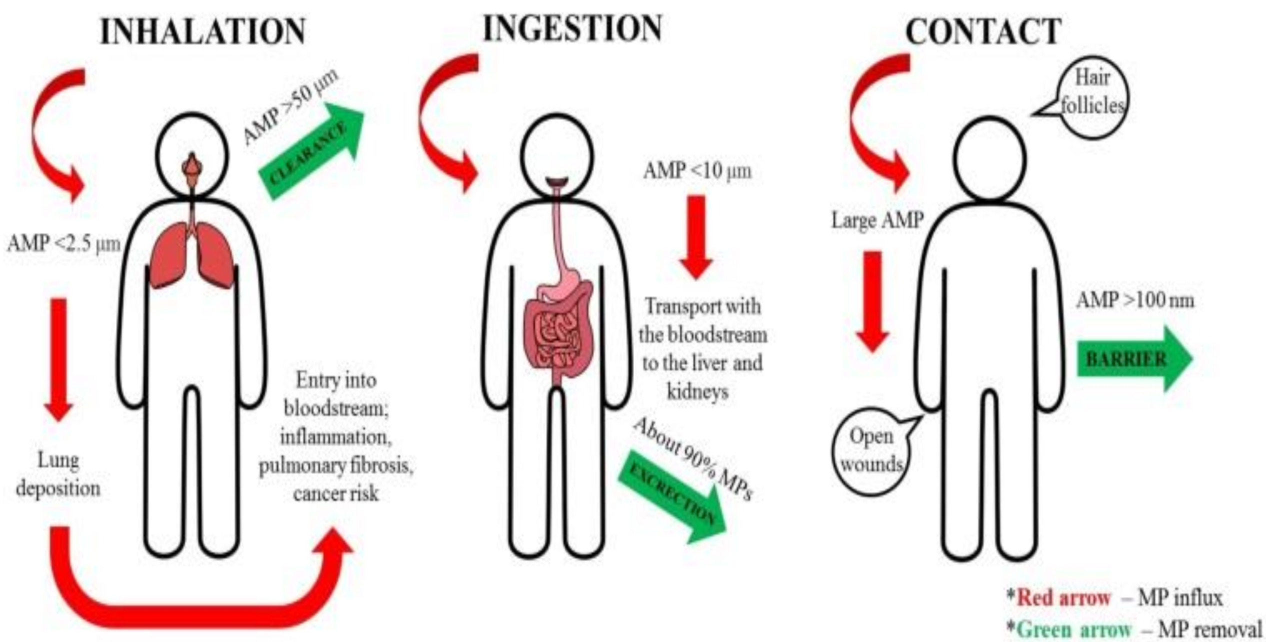

Figure 14 the interaction between microplastics, nanoplastics and the human body (Source: Rednikin et al., 2024).

These observations and findings revealed that there is a need to accurately assess microplastics and nanoplastics in the environment to prevent ecological risks and the health risks posed to humans by these pollutants. The main focus of this study is to provide information and data on methods and techniques utilised in the analysis and determination of microplastics and nanoplastics, with challenges in each of these detection techniques.

MATERIALS AND METHODS

In this dynamic and vital study on the creative methods for cleaning up soil contaminated by microplastics, the evaluation of the literature based on accomplished information on microplastic and nanoplastic particles presence in the soils, the sampling, examination, evaluation and laboratory analysis of microplastic and nanoplastic in soil samples, and the environment utilising various techniques. The essential information and relevant data (figure and numerical values) were collected and extracted from published databases such as PubMed link (https://www.pubmed.ncbi. nlm.nih.gov), Taylor and Francis Online link (http://www.tandfonline.com/), ScienceDirect link (http://www.sciencedirect.com/), Google Scholar link (https:// scholar.google.com/), Scopus link (https:// www.scopus.com/), Web of Science link (https://webofknowledge.com/), Elsevier link (https://www.elsevier.com/), Wiley Online Library link (http://onlinelibrary.wiley.com/), SpringerLink (http://link.springer.com/), American Chemical Society (ACS) Publications link (http://pubs.acs.org), Magiran link (https://www.magiran.com/), MDPI link (https://www.mdpi.com/), Frontiersin link (https://www.frontiersin.org), and Royal Society of Chemistry (RSC) Publishing link (http://pubs.rsc.org) using the keywords: microplastics, microplastics - nanoplastics , methods for nanoplastics determination, creative methods for microplastics determination, analysis of microplastics, analysis of nanoplastics, pretreatment of microplastics and nanoplastics, digestion of microplastics and nanoplastics. Figure 15 presents the flow chart of the methodology used. The outcome of the literature search was analysed using Microsoft Excel.

Literature Review on techniques for the analysis and determination of microplastics and nanoplastics in human, air, water and soil.

Literature Review and Research Findings on techniques for the analysis and determination of microplastics and nanoplastics in human, air, water and soil are presented as follows:

a. **General Techniques for the Determination of Microplastics and Nanoplastics**

Shi et al. (2024) reviewed methods to analyse microplastic ageing with a focus on the ageing process, qualitative identification, quantitative characterisation, and chemometrics. It was concluded that changes in mechanical and thermal properties allow for the differentiation of aged microplastics. Infrared and Raman spectroscopy are rapid and sensitive for chemical identification of microplastics in complex environmental samples. Combining two techniques is preferable for accurate detection and categorisation. Figure 16 shows the Methods for the qualification and quantification of aged microplastics. Ivleva (2021) reviewed advanced methods for the representative mass-based and particle-based determination and analysis of microplastics and nanoplastics, with a focus on the sensitivity and lower-size limit for detection. The disadvantages, advantages and limitations of these methods and techniques, with their complementarity of the methods and techniques for the comprehensive characterisation of microplastics and nanoplastics, were discussed.

b. **Methods for the Analysis and Determination of Microplastics and Nanoplastics in Human.**

Barcelo´ et al. (2023) reported that the techniques and methods that have been used for analysis and determination of microplastics and nanoplastics in human samples fall into three classes as follows:

I Microscopy (stereo microscopes, optical microscopes, scanning electron microscope (SEM), fluorescence microscopes after Red Nile Stainning),

Spectroscopy (Raman, FTIR), and Separation (Chromatography coupled with mass spectrometric detection, such as pyrolysis gas chromatography. mass sepctrometry (py–GC–MS), high performance liquid chromatography with tandem mass spectrometry (HPLC–MS/MS)). Table 1 presents a brief description of sample treatment and analysis techniques used for the detection of microplastics and nanoplastics in human matrices. Figure 17 shows the features and limitations of the techniques used to characterise and quantify microplastics and nanoplastics in human samples. Figure 18 shows a scheme of the different steps and procedures followed in the studies on microplastics and nanoplastics in human matrices.

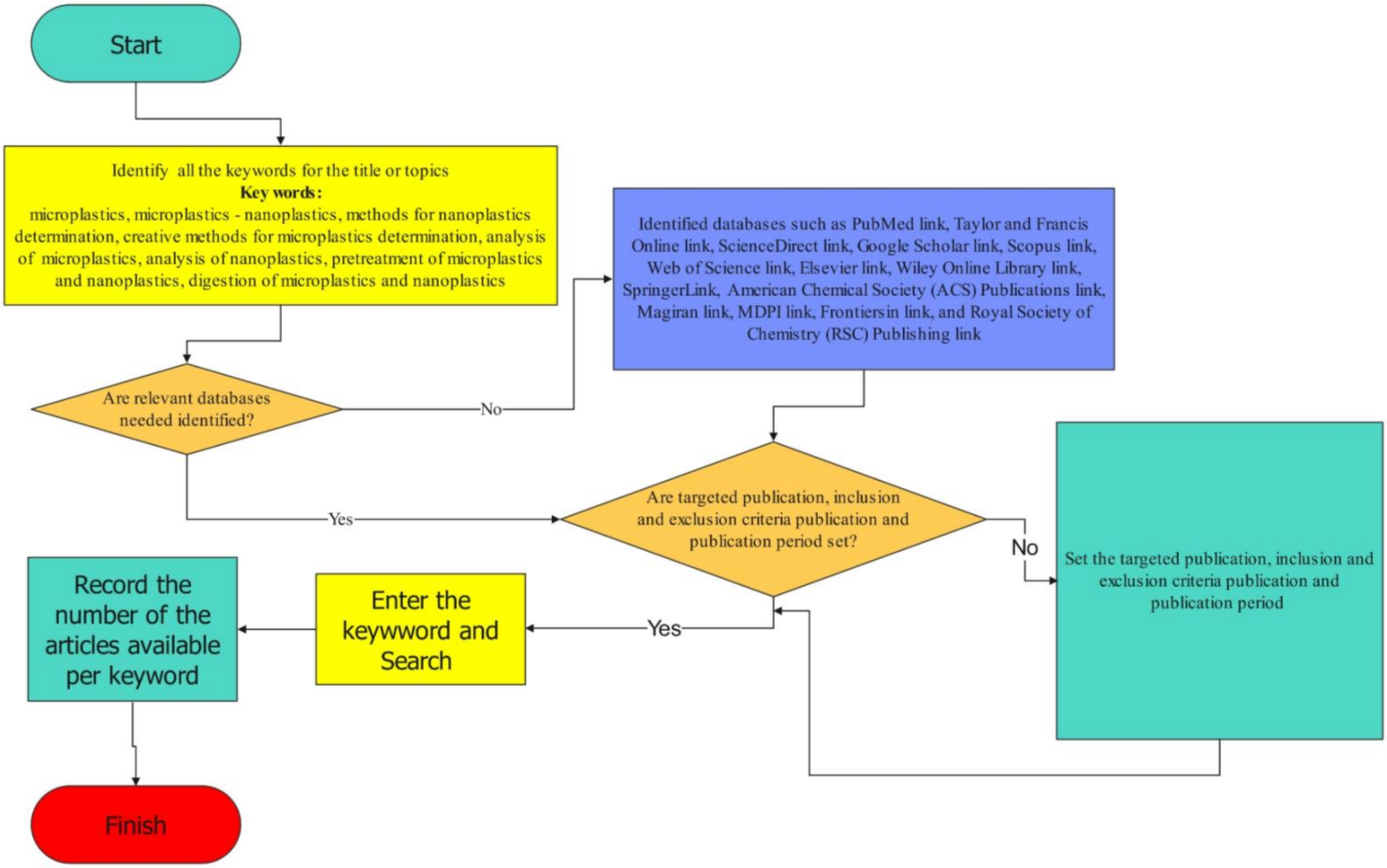

Figure 15 The flow chart of the methodology used

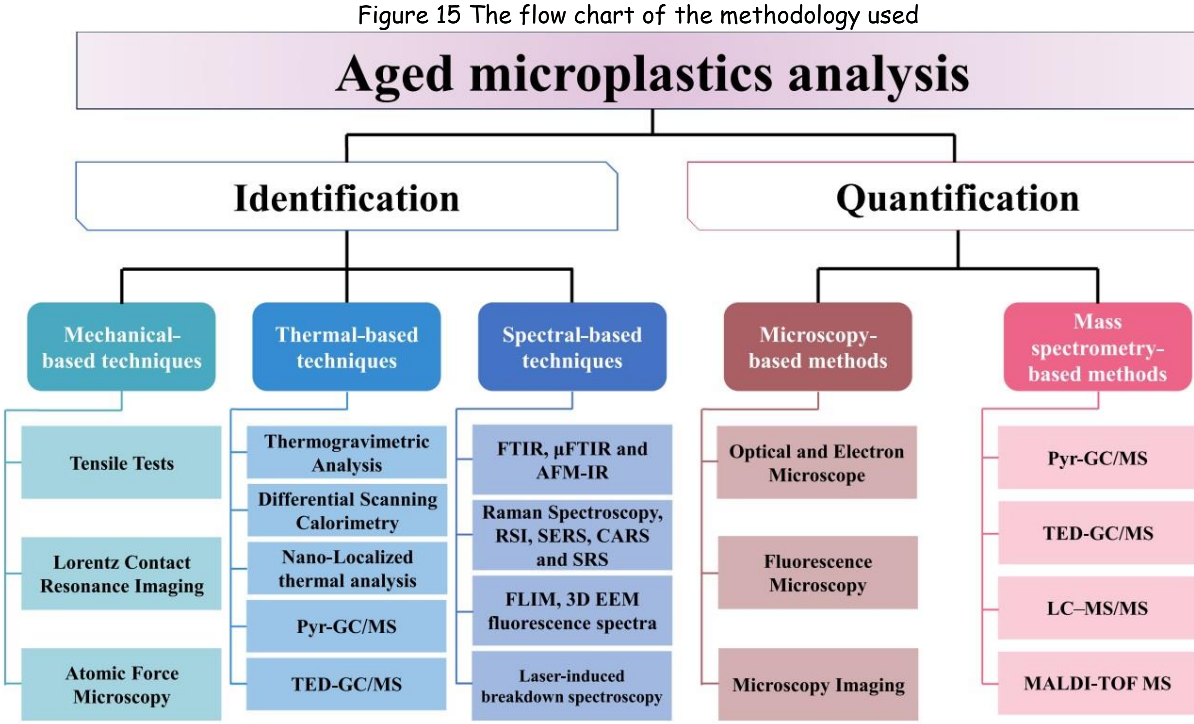

Figure 16 The Methods for the qualification and quantification of aged microplastics (Source: Shi et al., 2024).

Table 1 A brief description of sample treatment and analysis techniques used for the detection of microplastics and nanoplastics in human matrices (Source: Barcelo´ et al.2023)

Matrix	Sample pretreatment	Analysis	Reference
Filtered washes of the hand and face skin, head hair and saliva	**For hand, face or hair samples that appeared turbid:** Reduction of volume by heating , Removal of organic matter by adding 35 mL of 35% H_2O_2 for 2–10 days. Elimination of residual H_2O_2 heating . Addition of 50 mL of $ZnCl_2$ (1.6 g/cm^3), shaking for 5 min, and allowed to settle for 90 minutes. Centrifugation of the remaining supernatants and vacuum filtration through 2.0 x 10 ^{6} m filter paper. **Samples without visible contamination:** Vacuum filtration filters were air-dried at room temperature in a glass cabinet for a few days and then transferred to Petri dishes for counting.	Binocular microscopy at up to 200 × magnification, Polarized light microscopy, fluorescence microscopy x 10^{6,} Raman Spectra 400–800 cm^{-1} Size determined equal or greater than 10.0 x 10^{6}m	Abbasi and Turner (2021)
Urine	Digestion with KOH 10% at a ratio of sample/ solution of 1:2 (v/v) for 48 h at 40 °C and filter through 1.2 μm pore size glass fiber filter	Binocular microscopy using × 10 and x100 objectives μRaman Spectral range 200–1800 cm^{-1} Size determined 4.0 –15.0 x 10^{6}m	Pironti et al. (2023)
BALF 44 healthy volunteers	Rinse with bidestillated water and dry overnight at 60 °C	Binocular microscopy SEM-EDX μFTIR – Transmission mode Spectral range 550–4000 cm^{-1} Size determined greater than 50.0 x 10^{6}m	Baeza-Martínez et al. (2022)
Sputum	Digestion with nitric acid , density separation with $ZnCl_2$ (1.7–1.8 g/ cm^3), Filtration in a silver membrane, rinsing and soaking in ethanol and drying in a Petri dish	Optical microscope, μFTIR -Reflection Size determined greater than 0.1 mm, LDIR imaging -Reflection Size determined between 20.0 and 500.0 x 10^{6}m	Huang et al.(2022)
Breast milk	KOH, ratio sample /solution 1:10 (w/v) at 40 °C for 48 h • Filtration on a glass fibre membrane and dry in a Petri dish	μRaman Spectral range 200–1800 cm^{-1} Size determined between 2.0 and 12.0 x^{6}m	Ragusa et al. (2022)
Blood	Denaturing of proteins at 60°C for 1 h • Digesting proteins with Proteinase K and CaCl2at 50°C for 2 h • Filtration and rinsing with 30% H2O2 solution	Double shot Py–GC–MS (First 100 –300 °C at 50°C/min, second 600 ° C) MPs total mass determined	Leslie et al. (2022)
Placentas, Breast milk and Meconium Infant feces	Digestion with HNO3 for 48 h at room temperature, then for 3 h at 95°C • Filtration to 13.0 x 10^{6}m stain steel sieve and rinse with water and ethanol	LDIR imaging -Reflection Size determined 20–500 μm	Liu et al. (2023); Liu et al. (2022)
Feces	Treatment with H2O2, Keeping samples for 2 weeks to reduce the amount of natural stool constituents • Separation of solids into 2 fractions 0.05–0.5 and > 0.5 mm r• Additional treatment of 0.05–0.5 mm fractions using chemical/ enzymatic procedures	Fractions > 0.5 mm by ATR- FTIR • 0.05–0.5 mm fractions by FTIR imaging • Transmission mode	Schwabl et al.(2019)

Table 1 Continued

Matrix	Sample pretreatment	Analysis	Reference
Feces	Digestion of 3 g sample with 25 mL of 30% H_2O_2 for 20 days • Freeze drying • Sieving of particles > 5 mm • Filtration	μFTIR Reflection mode Spectra 4000–750 cm^{-1} 4000–750 cm^{-1} Size determined 20–800 μm	Zhang et al. (2021)
Feces	Digestion using Fenton's reagent • Filtration • Digestion with HNO_3 • Dilution and filtration	Raman Spectra 500–2750 cm^{-1} Size determined not reported	Luqman et al.(2021)
Feces	Digestion using Fenton's reagent • Filtration • Incubation with 65% HNO_3 at 50 ◦ C for 30 min	μRaman: Spectra 200–1050 nm Space resolution: < 0.5 μm Size determined: 1.7–393.8 μm	Yan et al. (2022)
Feces	Dilution and filtration Drying • Digestion using Fenton's reagent • Filtration	Raman Spectra 500–2750 cm–1 Size determined not reported	(Wibowo et al., 2021)
Human placenta	• Digestion with 10% KOH solution in a ratio with the sample of 1:30 (w/v) for 72 h at 50 °C and 120 rpm • Filtration to 10 μm stain steel sieve and rinse with water and ethanol	LDIR imaging –Reflection Spectra 900–1800 cm–1 Size determined 20–500 μm	Zhu et al. (2023)
Human placenta and meconium	Sieving through a 50 μm stainless steel sieve • Rinsing out into a beaker with H_2O_2 30% at 25 ◦ C keeping it ca. 5 weeks for meconium and 7 weeks for placenta. • Sieving residuals using a 50 μm filter and placing carefully into NaOH 0.05 M at 25 ◦ C • Transfer onto a 50 μm stainless steel sieve and flushed out with ultrapure water into a pre- cleaned beaker. • Vacuum filtration using membrane • Placing filters in lidded Petri dishes and dried at 60 ◦ C overnight	FTIR imaging system Transmittance mode Spectra 4000–1250 cm–1 Spectral resolution of 16 cm–1 Pixel size 25 μm Size determined > 50 μm	(Braun et al., 2021)
Human placenta	Digestion with 10% KOH solution in a ratio with the sample of 1:8 (w/v) • Sealing and incubating the containers at room temperature for 7 days • Filtration of digestates • Drying filter papers and storing in glass Petri dishes.	Binocular microscopy using × 10 and x100 objectives μRaman Spectral range 160–2000 cm–1 Size determined 5–10 μm	(Ragusa et al., 2021)
Pulmonary tissue samples	Digestion of tissues using enzymatic mixture for 12 h at 60 ◦ C • Density separation by $ZnCl_2$ solution (1.5 g cm– 3) • Filtration by silver membrane • Drying of membrane filters	Binocular microscopy using × 10 and x100 objectives μRaman Spatial resolution of 0.5 μm Size determined Particles < 5.5 μm Fibres from 8.12 to 16.8 μm	(Amato-Lourenço et al., 2021)
Lung tissues	Digestion with 100 mL of 30% H_2O_2 at 50°C for ca. 11 days • Filtration onto Al_2O_3 membranes	μFTIR – transmittance mode Spectral range of 4000–1250 cm–1, High spectral resolution 8 cm–1 Size determined 20 – 500 μm	Jenner et al., 2022)
Human colectomy specimens	Digestion: 10% KOH at 60 ◦ C for 7–10 h. • Filtration cellulose filter • Drying at room temperature for 2 days	Stereomicroscope (hot needle test) μFTIR -ATR mode Spectral range of 4000–400 cm–1 SEM -EDX Size determined not reported	Ibrahim et al., 2021)
Liver tissues, kidney, and spleen	Digestion with 10% KOH and NaClO 2:1 ratio at 40 °C for 72 h • Filtration silver filter • Second digestion with 30% H_2O_2 • Filtration silver filter	Fluorescent microscopy and Red Nile staining μRaman Size determine 3.3–30.1 μm	Horvatits et al., 2022)
Saphene vein tissue	Digestion with 200 mL H_2O_2 (30%) for 168 h at 65 °C and 85 rpm • Filtration with AlO_3 filters of 0.02 μm	μFTIR – transmittance mode Spectral range of 4000–1250 cm–1 Spectral resolution 8 cm–1 Size determined > 5 μm	Rotchell et al., 2023)

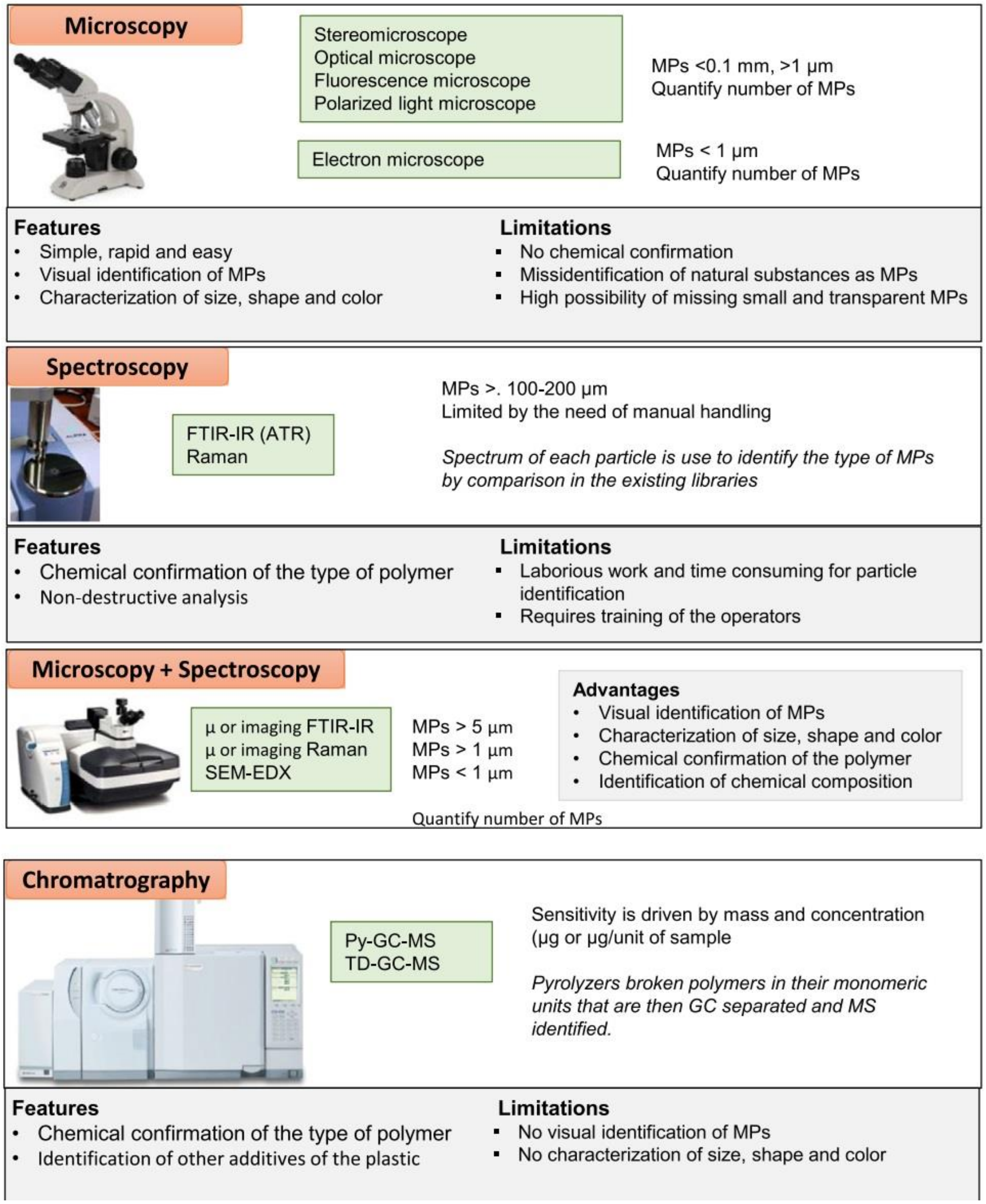

Figure 17 The features and limitations of the techniques used to characterise and quantify microplastics and nanoplastics in human samples (Source: Barcelo et al. 2023)

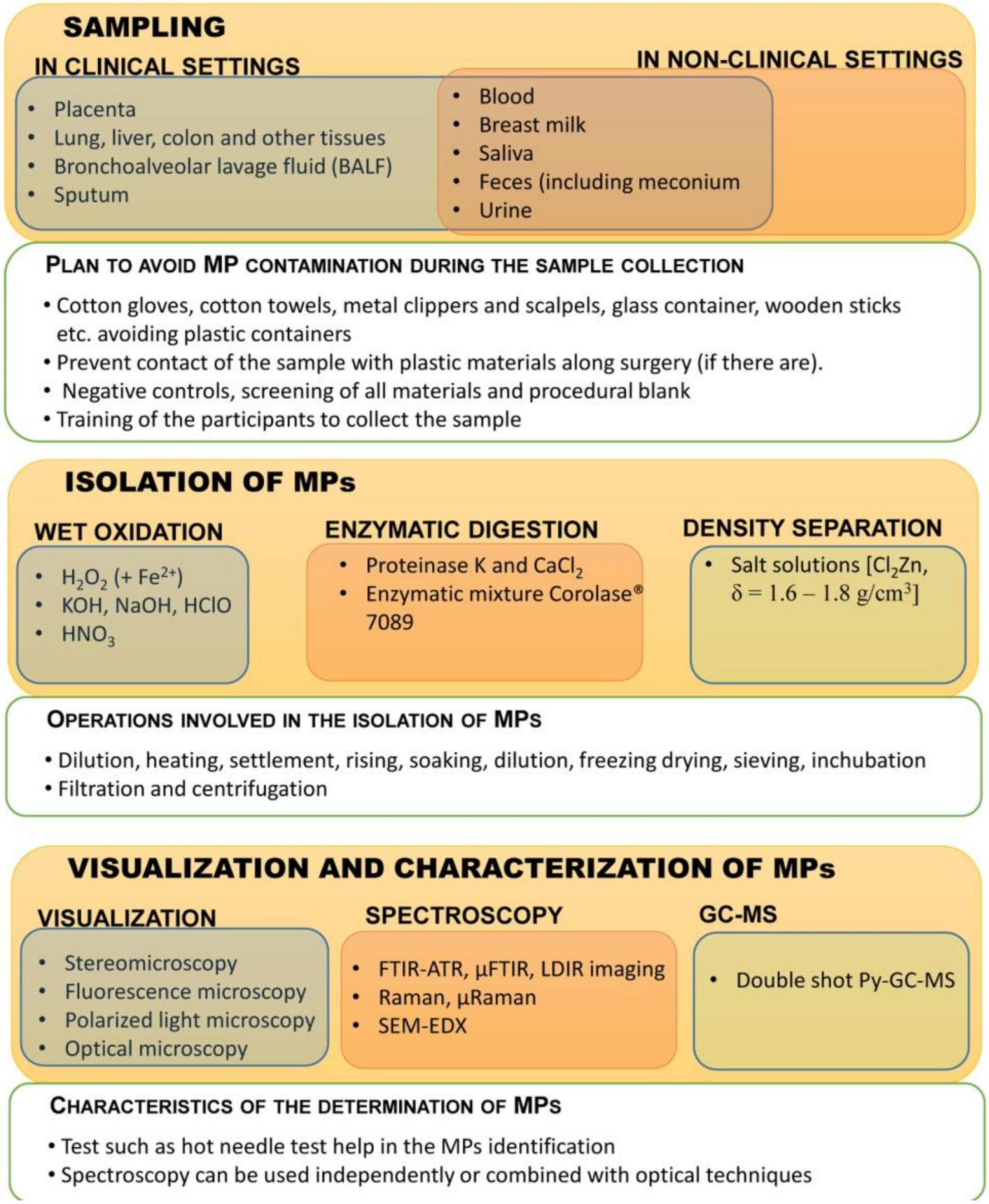

Figure 18 A scheme of the different steps and procedures followed in the studies on microplastics and nanoplastics in human matrices (Barcelo et al. 2023).

c. Methods for the Analysis and Determination of Microplastics and Nanoplastics in Water

Caldwell et al. (2022) summarised research and studies generated on multiple facets of the micro- and nanoplastics field, ranging from size and shape definitions to detection and characterisation techniques to generating reference particles, in order to provide a more complete understanding of the current strategies for the analysis of plastic particles. This information is then used to provide generalized recommendations for researchers to consider as they attempt to study plastics in analytically complex environments; including method validation using reference particles obtained through the presented creation methods, encouraging efforts towards method standardization through the reporting of all technical details utilized in a study, and providing analytical pathway recommendations depending upon the exact knowledge desired and samples being studied. Table 2 shows a summary of which techniques can be used to gain information about various particle properties.

d. Methods for the Analysis and Determination of Microplastics and Nanoplastics in Air

Rednikin et al. (2024) critically summarise the existing body of literature on airborne microplastics, including their distribution, identification, and safety assessment. Dong et al. (2023) reviewed the current sample pretreatment and analytical methods used to determine microplastics in water, soil, air and biological matrixes and found many challenges, especially in the pretreatment of human tissue samples. The study summarize here the rescaling methods used to correct the incompatibilities in data caused by differences in the type of microplastic and the quality assurance and control strategies used to obtain more accurate and comparable results. We recommend frameworks for research into microplastics in water, soil, air and biological samples. Micro-Raman spectrometry and time-of-flight secondary ion mass spectrometry are considered to be ideal techniques for the determination of the number and mass concentrations of microplastics.

e. Methods for the Analysis and Determination of Microplastics and Nanoplastics in Soil

Möller et al. (2020) provided a critical review on the different published methods for sampling, extraction, purification, and identification/quantification of microplastics in complex environmental matrices, with the main focus on their applicability for soil samples. It was concluded that none of the published methods seems ideally suitable for the analysis of smaller microplastics in soil samples, but slight modifications and combinations of methods may prove promising and need to be explored.

Research Findings on the chemistry of analysis and determination of microplastics and nanoplastics in humans, air, water and soil

The summary of the articles on the keywords based on the links are PubMed link (3829), Taylor and Francis Online link (6017), ScienceDirect link (12581), Google Scholar link (51965), Web of Science link (3282), Elsevier link (8205), Wiley Online Library link (6564), SpringerLink (7658), American Chemical Society (ACS) Publications link (1641), MDPI link (547), Frontiersin link (2188) and Royal Society of Chemistry (RSC) Publishing link (1094), which indicates that google scholar has a lot of articles in it database than other links. Figure 19 presents the growth of the cumulative articles on the keywords. In addition, classification of articles availability based on the keywords chemistry of micro- and nano-plastics in soil-water and a bibliometric analysis and a literature review on chemistry analysis of micro-and nano-plastics in humans, air, soil, and water revealed that chemistry of micro- and nonaplastic in humans, (20890), soil and sediment of river (10965), water (19675), air and related environment such as in (3170).

Further literature on the chemistry of analysis and determination of microplastics and nanoplastics in humans, air, water and soil

- Abidin et al. (2024) in innovative solutions for the removal of emerging microplastics from water by utilizing advanced techniques, Acarer (2023) in a review of microplastic removal from water and wastewater by membrane technologies, Akhbarizadeh et al. (2020) in worldwide bottled water occurrence of emerging contaminants: a review of the recent scientific literature, AL Falahi et al. (2022) in occurrence of pharmaceuticals and personal care products in domestic wastewater, available treatment technologies, and potential treatment using constructed wetland: a review and Albero et al. (2017) in application of matrix solid-phase dispersion followed by GC–MS/MS to the analysis of emerging contaminants in vegetables.
- Allred et al. (2014) in orthogonal zirconium diol/C18 liquid chromatography–tandem mass spectrometry analysis of poly and perfluoroalkyl substances in landfill leachate, Anger et al. (2018) in raman microspectroscopy as a tool for microplastic particle analysis, Arismendi et al. (2019) in simultaneous determination of multiresidue and multiclass emerging contaminants in waters by rotating-disk sorptive extraction–derivatization-gas chromatography/mass spectrometry, Arminini Neto et al. (2024) in the role of membrane technology in addressing pharmaceutical pollution in water, Atugoda et al. (2021) in interactions between microplastics, pharmaceuticals and personal

Table 2: A summary of which techniques can be used to gain information about various particle properties (Source: Caldwell et al., 2022)

Property	Techniques
Size	AFM, SEM, TEM, Optical Tweezers coupled with Raman, DLS, DDLS, Dissecting and Stereo Microscopy, NMR, NTA, TDA, AFM-IR, MALDI-ToF-MS, Diascopic microscopy, Dark Field Microscopy, Hyperspectral Imaging, AF4-MALS, Particle- Impact Electrochemistry, SP-ICP-MS, ToF-SIMS Imaging
Size Distribution	SEM, TEM, Dissecting and Stereo Microscopy, Diascopic microscopy, Dark Field Microscopy, NTA, TDA, AFM, AFM-IR, AF4-MALS, SP-ICP-MS
Shape	AFM, SEM, TEM, Diascopic microscopy, Dissecting and Stereo Microscopy, Fluorescence microscopy, AFM-IR, Hyperspectral Imaging, Dark Field Microscopy
3D Visualization	Fluorescence microscopy, AFM, AFM-IR
Surface Characteristics	SEM, AFM, AFM-IR
Chemical Fingerprint	EDS/EDX, FTIR, Raman, SERS, Optical Tweezers coupled with Raman, XPS, NMR, AFM-IR, Hyperspectral Imaging, Pyr-GC- MS, TED-GC-MS, MALDI-ToF-MS, SP-ICP-MS, ToF-SIMS
Colloidal Stability Concentration	DLS, DDLS NTA, TDA, SP-ICP-MS
Mass Quantitation	DSC, Pyr-GC-MS

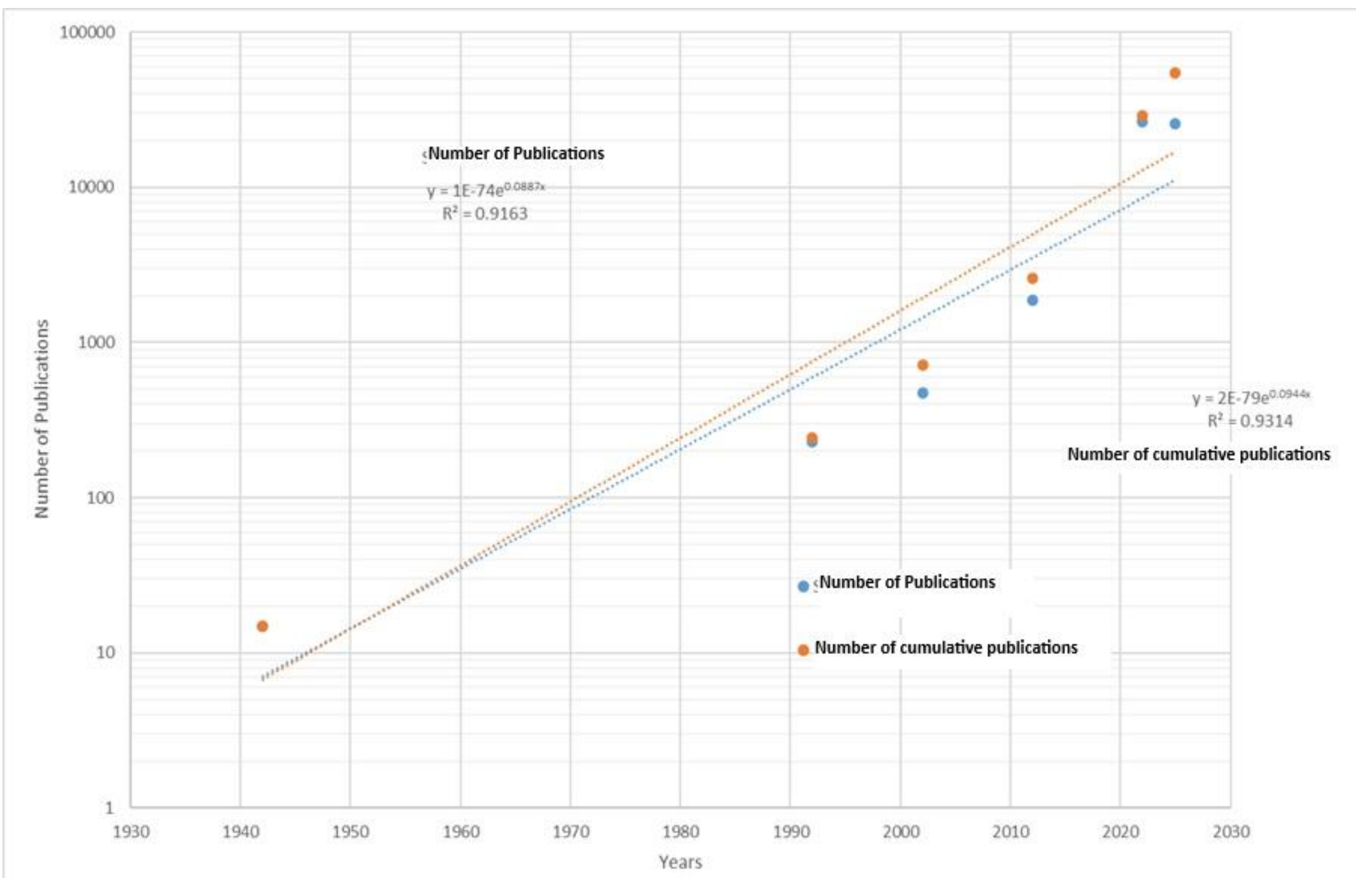

Figure 19 the growth of the cumulative articles on the keywords care products: implications for vector transport, Aydin et al. (2019) in monitoring the release of anti-inflammatory and analgesic pharmaceuticals in the receiving environment, and Baderna et al. (2011) in a combined approach to investigate the toxicity of an industrial landfill's leachate: chemical analyses, risk assessment and in vitro assays.

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CONCLUSION

It can be concluded that techniques can be used to gain information about various plastics particle properties are as follows:

- Size: Particle- Impact Electrochemistry, Dark Field Microscopy, Hyperspectral Imaging, and Diascopic microscopy
- Size Distribution: Dissecting and Stereo Microscopy, Diascopic microscopy, Dark Field Microscopy,
- Shape: , Diascopic microscopy, Dissecting and Stereo Microscopy, Fluorescence microscopy, AFM-IR, Hyperspectral Imaging, Dark Field Microscopy,
- 3D Visualization : Fluorescence microscopy, AFM, AFM-IR,
- Surface Characteristics: SEM, AFM, AFM-IR and
- Chemical Fingerprint: EDS/EDX, FTIR, Raman, SERS, Optical Tweezers coupled with Raman, XPS, NMR, AFM-IR, Hyperspectral Imaging, Pyr-GC- MS, TED-GC-MS, MALDI-ToF-MS, SP-ICP-MS, ToF-SIMS..

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Abbreviations

(HD)PE	High-density polyethylene
(LD)PE	Low-density polyethylene
3D EEM	Three-dimensional excitation–emission mode
ABS	Acrylonitrile–butadiene–styrene copolymer
ABS	Acrylonitrile butadiene styrene
AF4	Asymmetric Flow Field-Flow Fractionation
AF4-MALS	Asymmetric flow field-flow fractionation multi angle light scattering
AFM	Atomic force microscopy
AFM-IR	Atomic force microscopy coupled with infrared spectroscopy

ATR Attenuated total reflection
CARS Coherent anti-Stokes Raman scattering
DDLS Depolarized dynamic light scattering
DLS Dynamic light scattering
DOSY 2D diffusion ordered spectroscopy
DSC Differential scanning calorimetry
EDS/EDX Energy dispersive x-ray spectroscopy
ESEM Environmental SEM
FFF Field Flow Fractionation
FPA Focal plane array
FTIR Fourier transform infrared spectroscopy
HDC Hydrodynamic chromatography
HDPE High-density polyethylene
HPLC–MS/MS High-performance liquid chromatography–tandem mass spectrometry
HQI Hit quality index
ICA Independent component analysis
ILC Interlaboratory comparison
IR Infrared
JRC Joint Research Centre
LC-HRMS Liquid chromatography–high-resolution mass spectrometry
LDIR Laser direct infrared imaging
LDPE Low-density polyethylene
LIBS Laser-induced breakdown spectroscopy
LOD Limit of detection
LOQ Limit of quantification
MALDI-TOF MS Matrix-assisted laser desorption/ionization time-of-flight mass spectrometry
MALDI-ToF-MS Matrix assisted laser desorption/ionization time of flight mass spectrometry
MALS Multi-angle light scattering
MCR-ALS Multivariate curve resolution-alternating least squares
MP(s) Microplastic(s)
MS Mass spectrometry
NMR Nuclear magnetic resonance
NTA Nanoparticle tracking analysis
OT Optical tweezers
PA Polyamide
PB Poly(1-butene)
PBAT Polybutylene adipate terephthalate
PBT Polybutylene terephthalate
PC Polycarbonate
PDI Polydispersity index
PE Polyethylene
PEG Poly(ethylene glycol)
PES Polyethersulfone
PET Poly(ethylene terephthalate)
PET Polyethylene terephthalate