

Analysis of airborne Nano- and Microplastics using Pyrolysis-Gas Chromatography-Mass Spectrometry

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Introduction and Motivation

- Nano-and-micro-plastics (NMPs) are increasingly concerning due to their widespread occurrence and potential environmental impacts, especially given their small size, which can be easily transported to various environmental compartments.
- Environmental aging processes such as light exposure, wind erosion, and water abrasion contribute to the fragmentation of larger plastics into microplastics (MPs), leading to a significant increase in both secondary and primary MPs in the environment¹.
- There is a lack of research on the mass concentration of MPs in the atmosphere, with most studies focusing on their number concentration, leaving the impact of airborne submicron particles (PM₁₀ and PM_{2.5}) on human exposure underexplored^{2,3}.
- The current study introduces a routine measurement method for analyzing NMPs in airborne particulates using pyrolysis-gas chromatography coupled with mass spectrometry (Py-GC-MS).

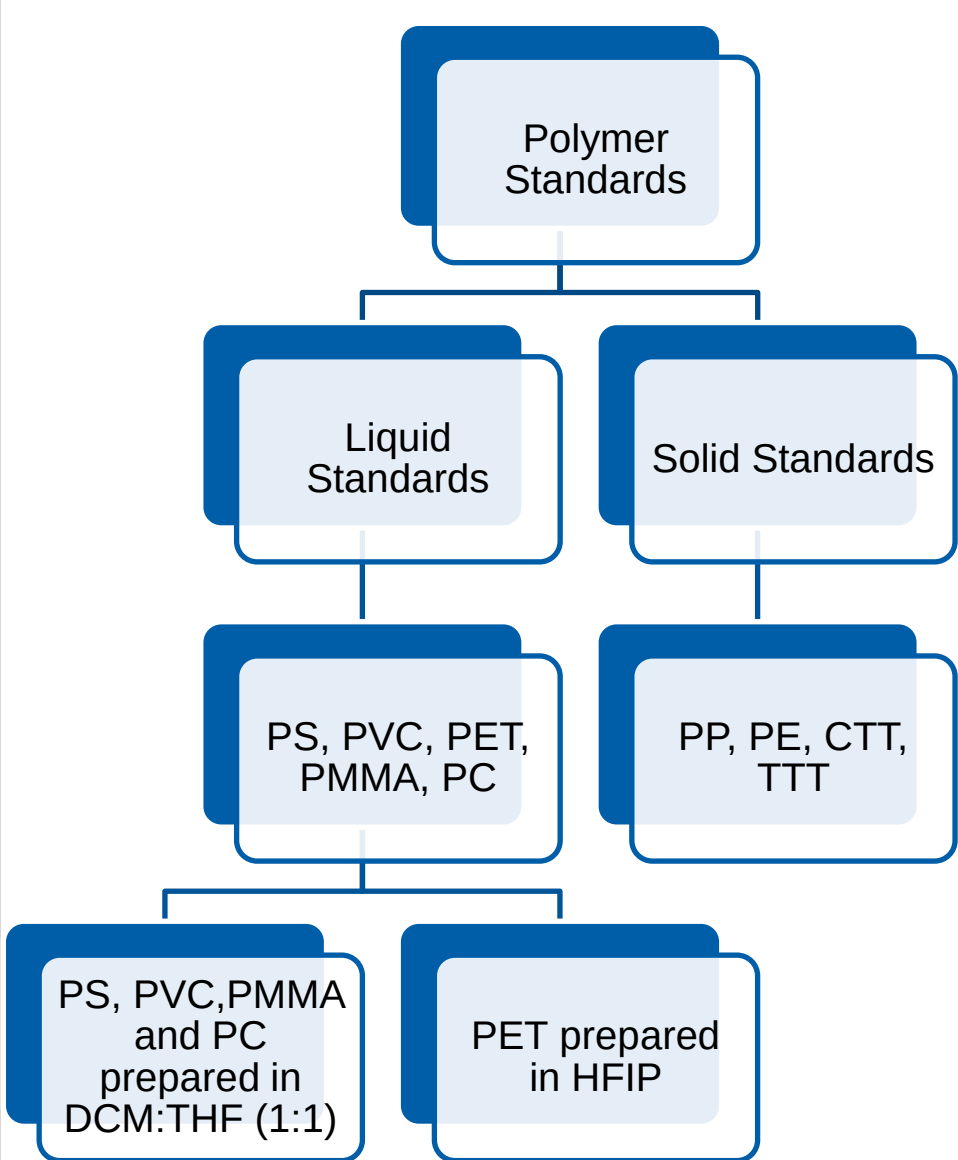
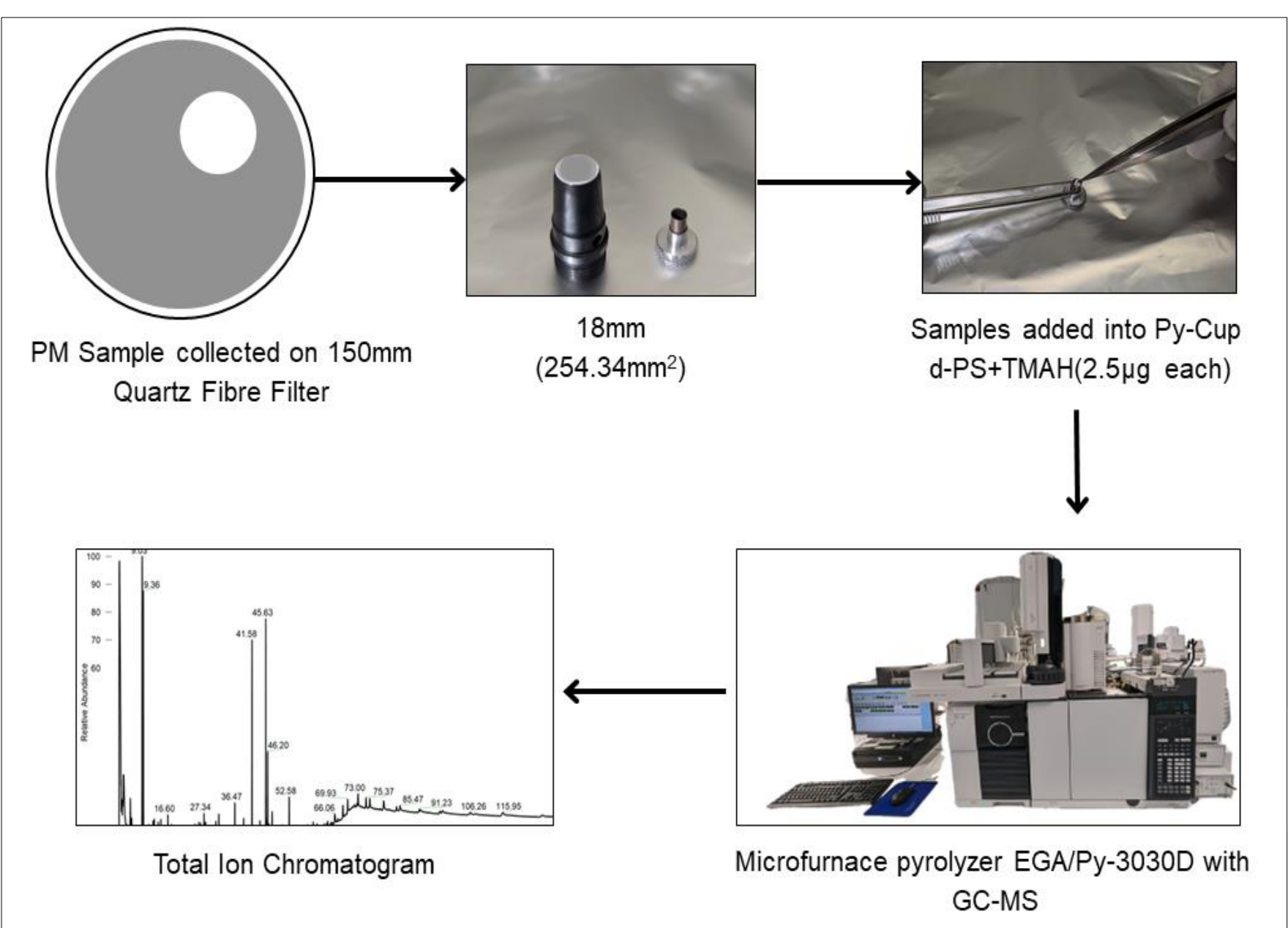
Objective

Investigation of synthetic polymers in atmospheric submicron particles (PM_{2.5} and PM₁₀) using Pyrolysis-Gas Chromatography-Mass Spectrometry (Py-GC-MS).

Methodology

24-hour PM₁₀ and PM_{2.5} samples were collected at Torgauerstraße, Leipzig, Germany in September 2022, using high-volume DHA-80 samplers equipped with 150 mm quartz fiber filters.

Methodology for simultaneous polymer analysis



Overview of Polymer Identification and Calibration Measurements

Polymer	Pyrolyzates	Ions (m/z)	RT (min)	Linear Equation	R ²
Polystyrene (PS)	2,4,6-triphenyl-1-hexene (Styrene trimer)	91, 117, 194, 207, 312 [M]	53.31	y = 0.7545x + 0.0039	0.99
Polyvinyl Chloride (PVC)	Naphthalene	51, 64, 102, 128 [M]	19.92	y = 0.0602x + 0.0386	0.97
Polyethylene Terephthalate (PET)	Dimethyl terephthalate	103, 135, 163, 194 [M]	30.45	y = 0.7474x - 0.0281	0.99
Polymethyl Methacrylate (PMMA)	Methyl methacrylate	69, 85, 99, 100 [M]	4.05	y = 0.6761x + 0.0464	0.98
Polycarbonate (PC)	2,2-Bis(4'-methoxyphenyl) propane	77, 133, 149, 241, 256 [M]	45.42	y = 7.6117x - 0.1245	0.98
Car Tire Tread (CTT)	Cyclohexenylbenzene	104, 115, 129, 158 [M]	24.94	y = 0.0014x + 0.0016	0.99
Truck Tire Tread (TTT)	2,4-Dimethyl-4-vinylcyclohexene	68, 93, 121, 136 [M]	11.39	y = 0.0092x - 0.0039	0.99
Polyethylene (PE)	Avg Alkadienes from C16 to C26	e.g: C17: 41, 55, 67, 82, 95, 109, 236 [M]	30.73	One-point calibration	-
Polypropylene (PP)	2,4, Dimethyl-1-heptene	43, 70, 83, 126 [M]	7.48	One-point calibration	-
D ₈ -PS (IS)	D ₈ -PS Trimer	98, 126, 208, 222, 336 [M]	52.33	-	-

Results and Discussion

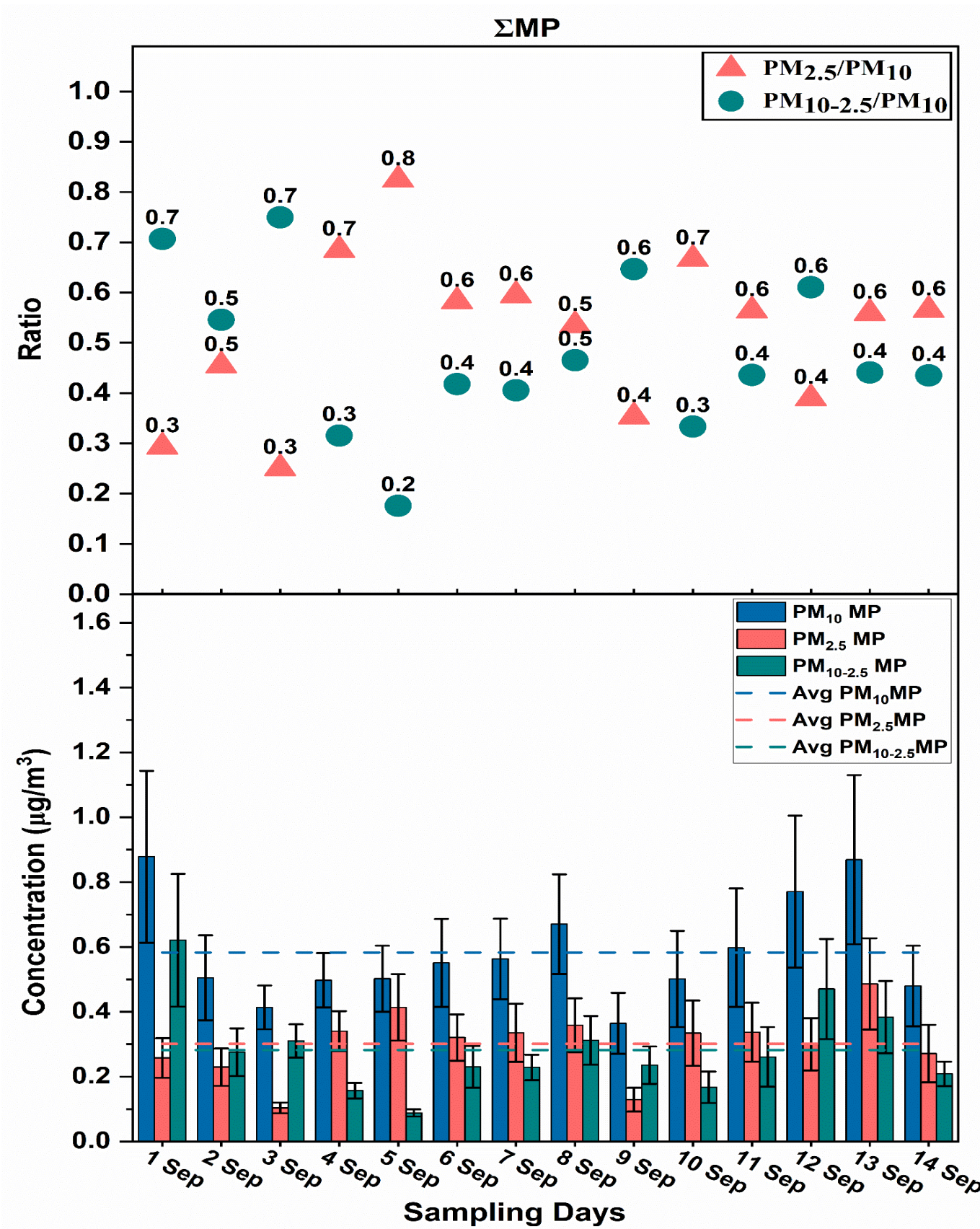


Figure 1. Ambient Concentration of ΣMP

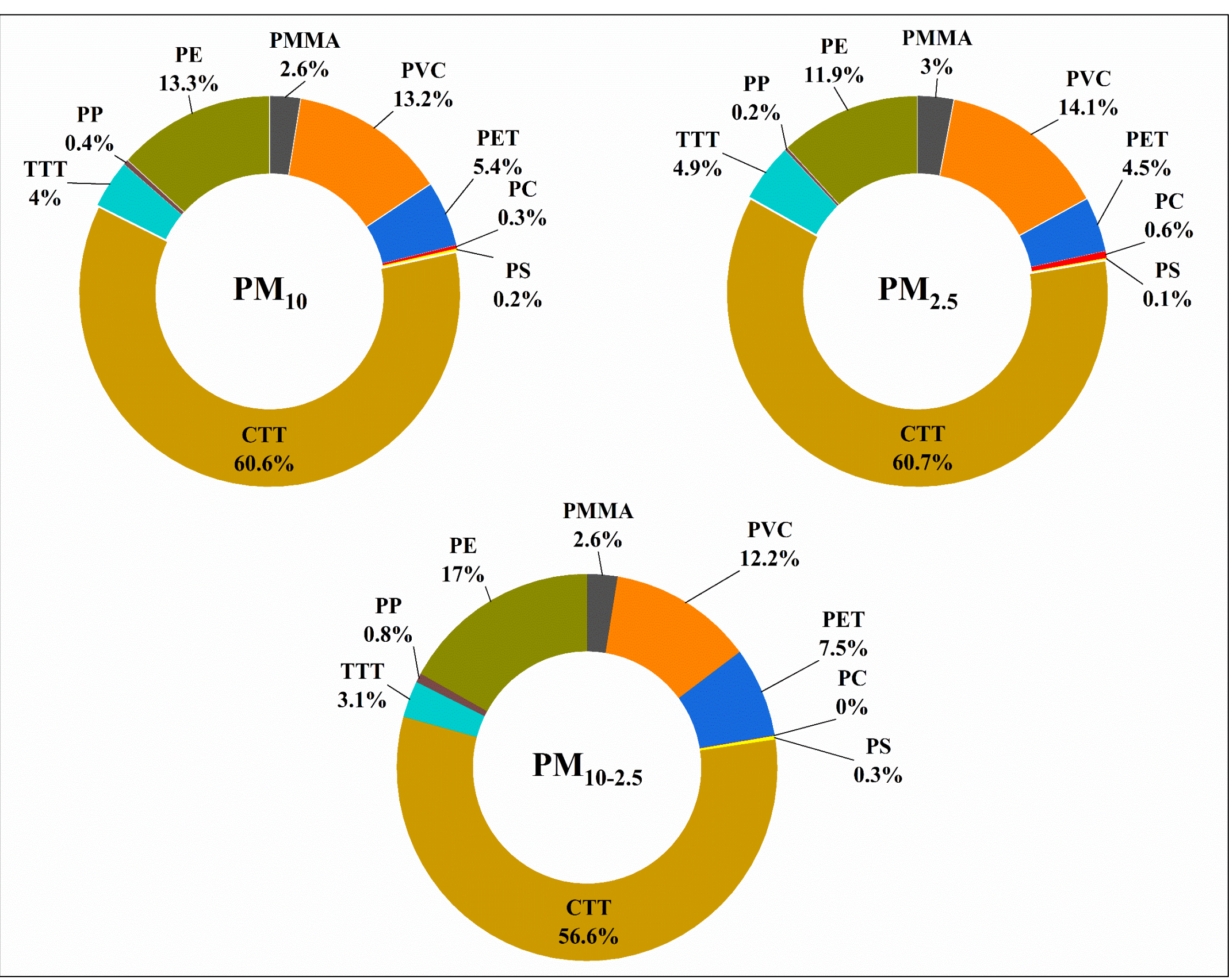


Figure 2. The percentage contribution of polymers in PM₁₀, PM_{10-2.5} and PM_{2.5} samples

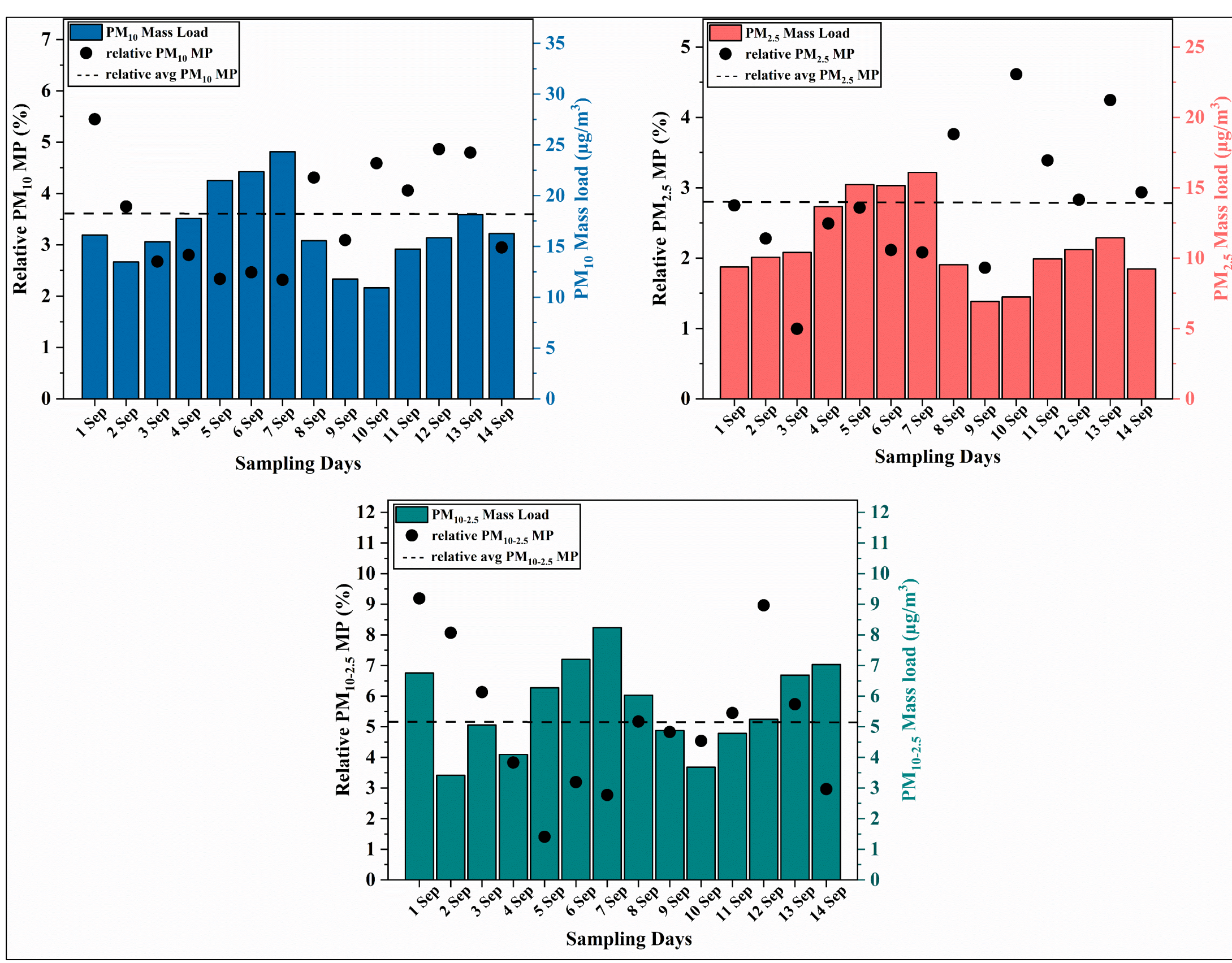


Figure 3. PM-MP relative contribution

- The average total atmospheric microplastic (MP) concentration was determined to be $0.64 \pm 0.16 \mu\text{g}/\text{m}^3$ in PM₁₀, $0.33 \pm 0.11 \mu\text{g}/\text{m}^3$ in PM_{10-2.5}, and $0.33 \pm 0.11 \mu\text{g}/\text{m}^3$ in PM_{2.5}.
- On average ΣMP exists equally in coarse mode particles (CMP: PM_{10-2.5}) and Fine mode particles (FMP: PM_{2.5}).
- MP contributes 3.6% to the total PM₁₀ mass load, 2.8% to the total PM_{2.5} mass load, and 5.2% to the total PM_{10-2.5} mass load.
- Tire wear particles (TWP : sum of CTT and TTT) contributed approximately 70% to the MP composition in PM₁₀ samples, followed by PVC and PE, each contributing around 13%.
- FMP had a higher contribution from TTT, PMMA, PVC, and PC, whereas CMP showed higher contributions from PP, PE, PET, and PS.
- The results indicate a higher contribution of TWPs, predominantly from urban traffic activities.

Summary and Future Outlook

- The proposed method, which requires no tedious sample pretreatment, helps for routine analysis of MPs in airborne particulates.
- Ongoing chamber studies on the ageing of airborne NMPs and TWPs.
- Modelling for mobilization and atmospheric spread will be developed.

Acknowledgement

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References

¹Song et al., 2020, ES&T, 2017, 51, 8, 4368-4376 ; ²Chen et al., 2024 ES&T, 2024, 58,10, 4691-4703; ³Goßmann et al., 2023 ES&T, 57, 43, 16541-16551