Investigating the role of microplastics as potential PFAS Vectors in Landfill Soil-Groundwater Systems

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Driving impact through **collaboration**

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Why This Study Matters?

- PFAS are persistent contaminants with complex transport behaviour in landfill soil-groundwater systems.
- Microplastics (MPs) have recently been proposed as potential vectors for PFAS mobility, but field-based subsurface evidence remains limited.
- Understanding whether MPs materially influence PFAS mobility is important for:
  - Landfill monitoring programs;
  - Groundwater Risk Assessment;
  - Conceptual Site Development (CSM) development; and
  - Long-term management of PFAS-impacted sites.

This Phase II study builds on preliminary findings presented at Ecoforum 2025, and applies refined QA/QC and phase-specific analytical approaches to better isolate MP-PFAS interactions.

Study Objectives and Key Research Questions

Primary Objective:

Determine whether MPs materially influence PFAS mobility in landfill soil-groundwater systems.

Key Research Questions:

- Can dissolved-phase PFAS be differentiated from particle-associated PFAS in groundwater?
- Do MPs show evidence of vertical migration through the unsaturated zone toward groundwater?
- Are specific polymer types associated with elevated PFAS occurrence?
- Do MPs behave primarily as:
  - passive carriers,
  - temporary sinks, or
  - potential secondary PFAS sources?

Study Design and Sampling Program

Site Context

- Landfill site located in Western Australia.
- Semi-arid Mediterranean climate with seasonal winter rainfall.
- Sandy to silty soils with shallow groundwater conditions.
- Potential for vertical migration of contaminants through the vadose zone.

Why the Site is Relevant?

- Seasonal recharge may influence PFAS transport.
- Low organic carbon soils may reduce PFAS retardation.
- Weathered MPs may influence contaminant mobility.

Sampling Program

Soil Investigation

- Surface and subsurface soil samples collected to 2 m bgl.
- Discrete depth intervals used to assess vertical transport pathways.

Groundwater Investigation

- Low-flow Hydrasleeves™ groundwater sampling.
- Filtered and unfiltered PFAS fractions analyzed.

QA/QC Measures

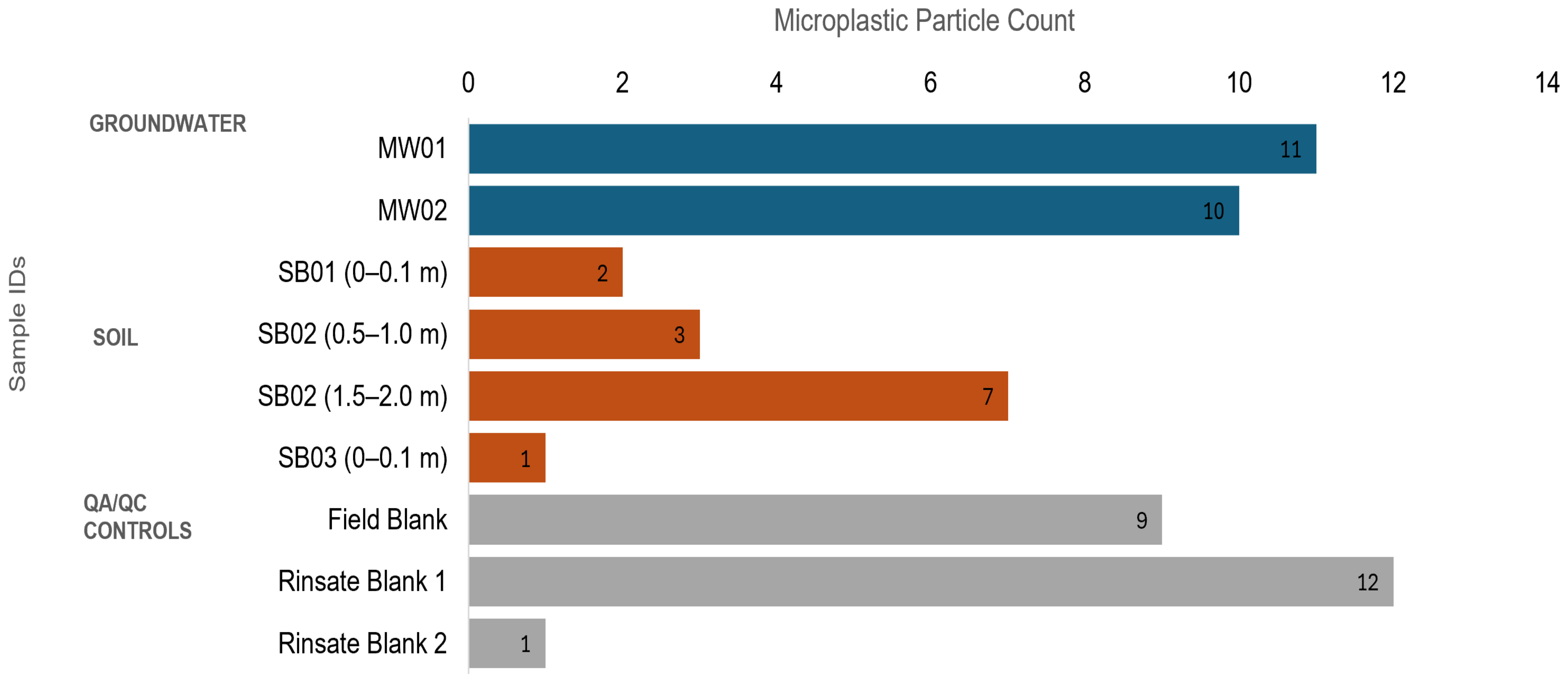
- Field blanks and rinsate blanks included.
- PFAS-free laboratory supplied water.

Analytical Scope

- PFAS phase differentiation.
- Polymer identification and MP quantification.

Microplastic Abundance Across Sample Types

Graph 1. Total Microplastic Particle Abundance Across Environmental and QA/QC Samples



Detection limit = 20 µm. Particle identification based on >80% spectral match confidence.

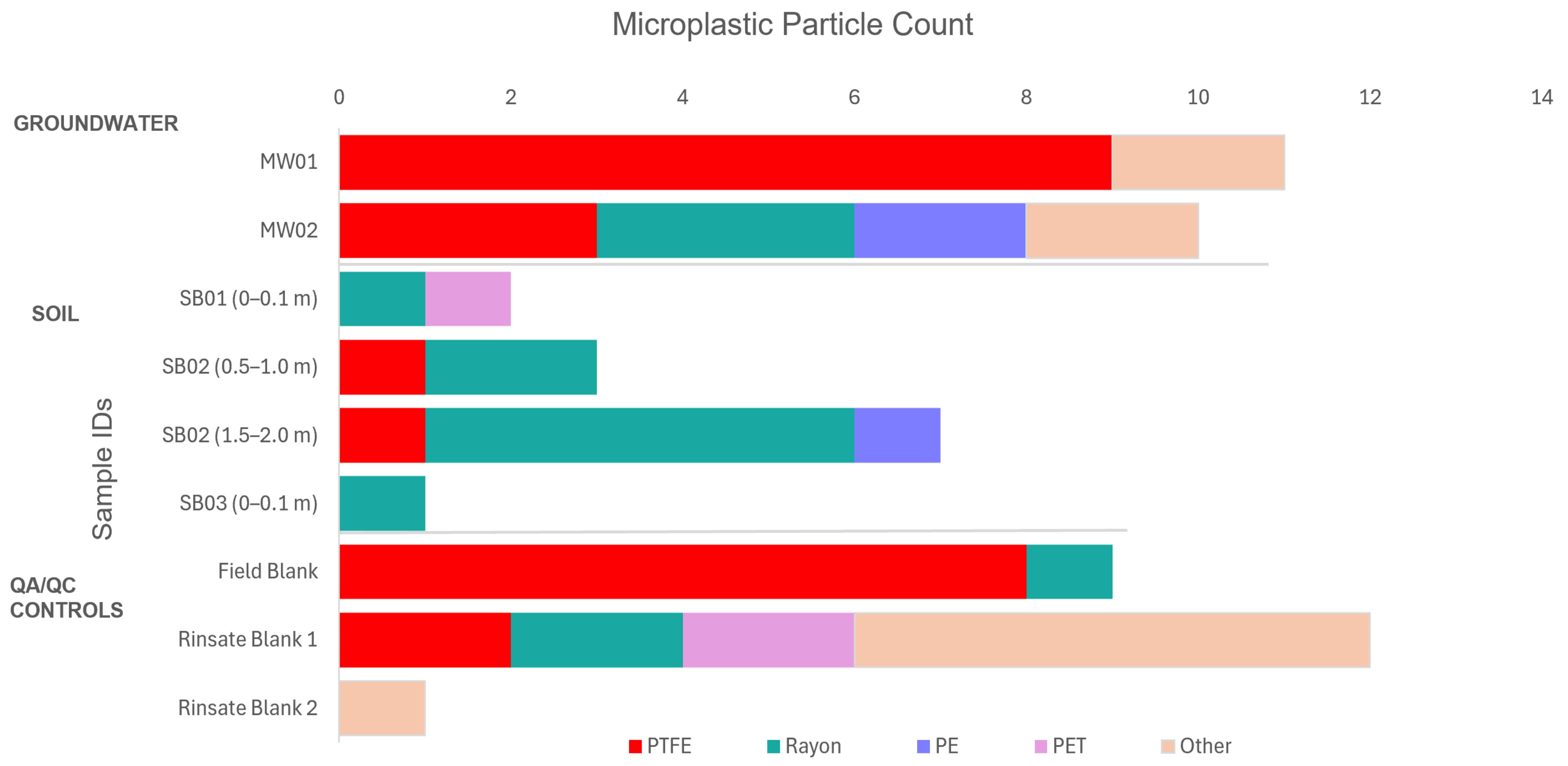
Key Observations

- Groundwater samples showed the highest particle count (10-11 particles).
- Soil samples exhibited lower and variable abundances (1-7 particles).
- Elevated PTFE detections in QA/QC blanks suggest potential procedural contamination and may impact interpretation of environmental detections.

PTFE (Polytetrafluoroethylene) is a common lab contaminant associated with laboratory clothing and sampling equipment.

Polymer Composition by Matrix

Graph 2. Polymer Composition of Microplastics Across Environmental and QA/QC Samples

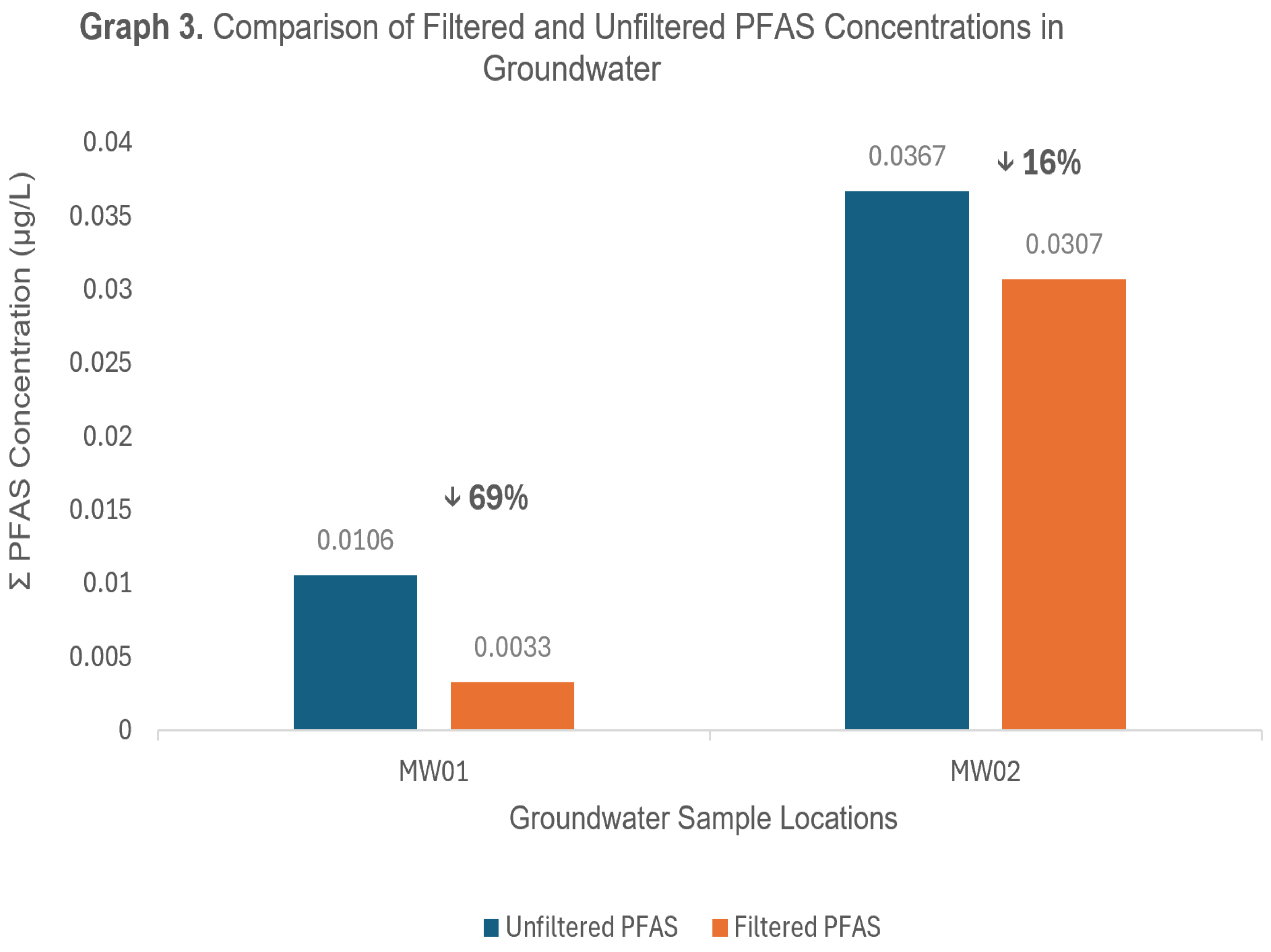


Only polymers detected above 80% spectral match confidence are presented.

Key Observations

- ❖ PTFE was the dominant polymer detected in groundwater and QA/QC samples.
- ❖ Soil samples showed more variable polymer composition.
- ❖ Significant PTFE presence in blanks suggests possible contamination artefacts.

Evidence for Particle-Associated PFAS

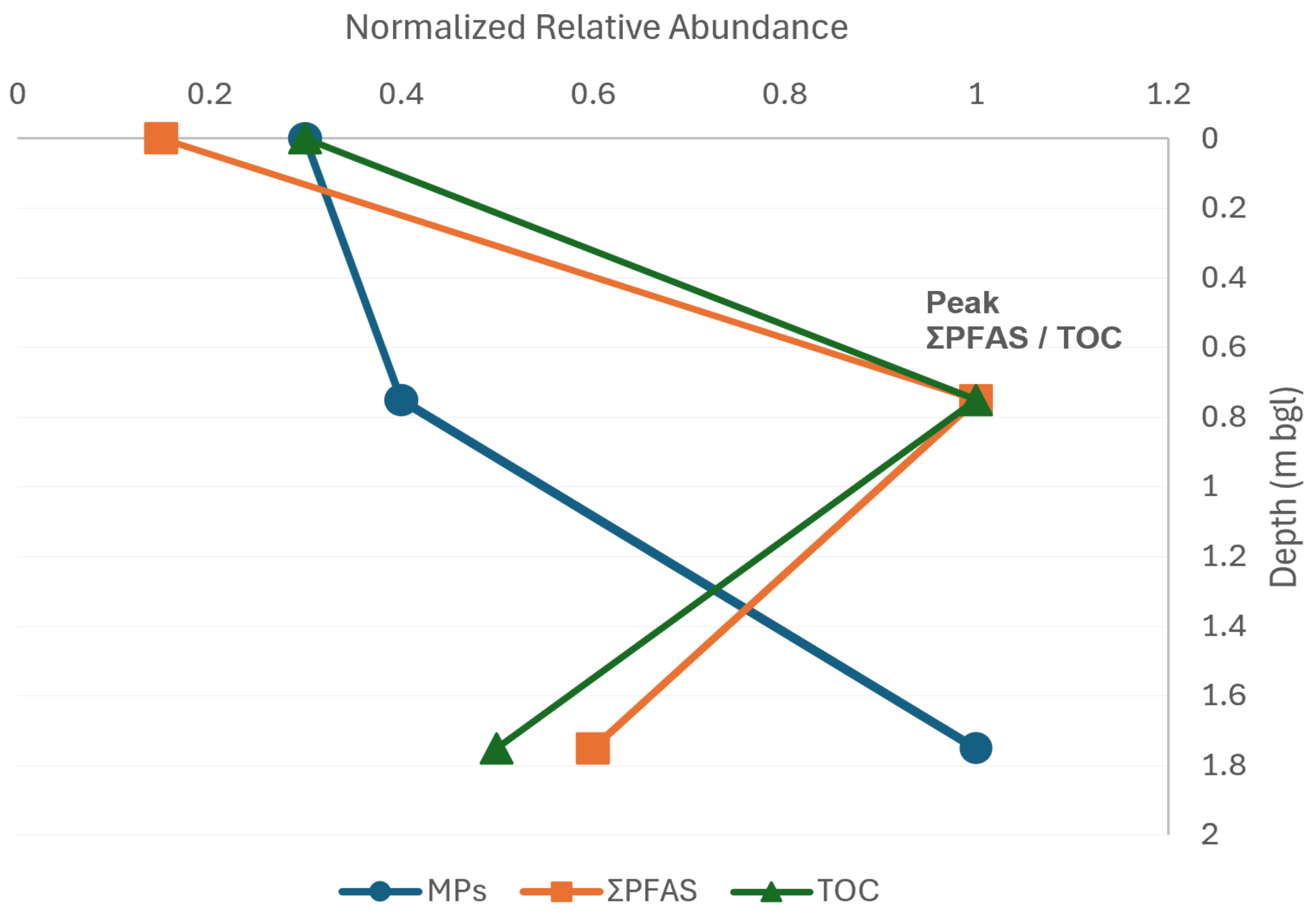


Key Observations

- PFAS concentrations decreased after filtration at both sites.
- MW01 exhibited the largest reduction (69%).
- Results suggest a particulate-associated PFAS fraction in groundwater.

Depth Trends in MPs, TOC and PFAS

Graph 4. Vertical Profiles of Normalized MP Abundance, ΣPFAS and TOC in Soil

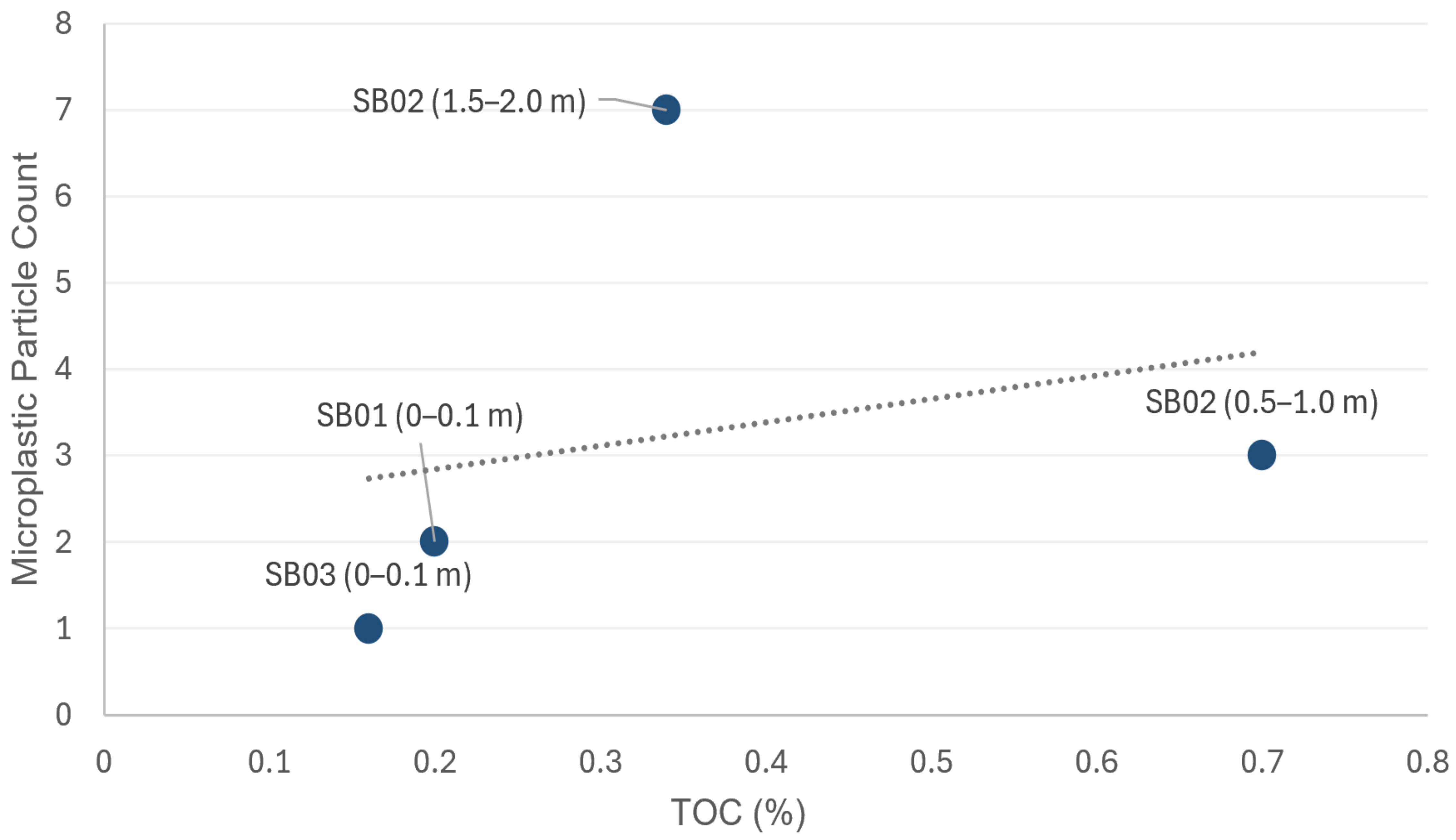


Key Observations

- ❖ MP abundance increased with depth.
- ❖ ΣPFAS and TOC peaked at intermediate depth.
- ❖ Divergent profiles may indicate differing transport or retention mechanisms.

Exploratory Relationship Between TOC and MP Abundance

Graph 5. Exploratory Relationship Between TOC and MP Abundance



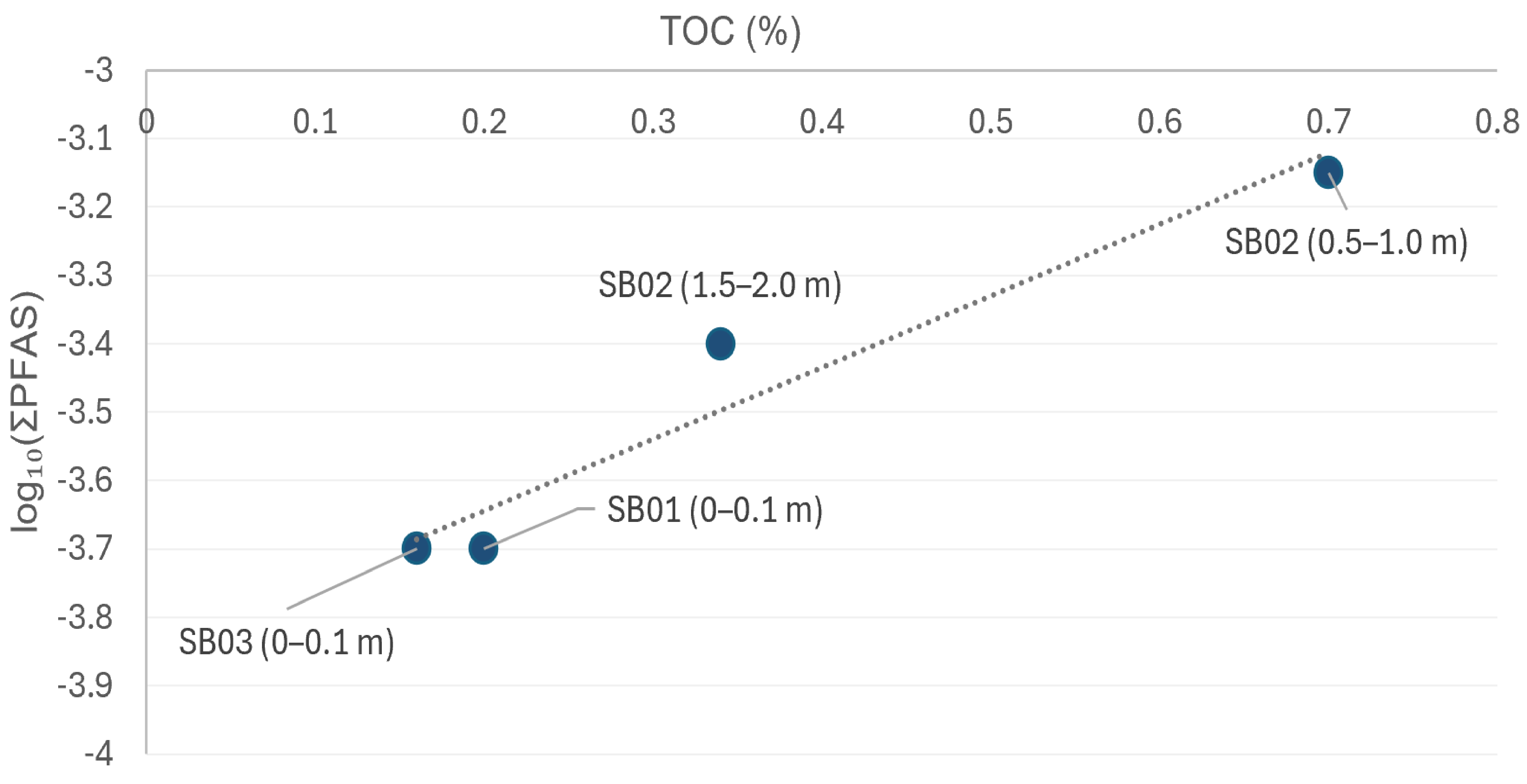
Exploratory comparison only; limited sample size precludes robust statistical interpretation.

Key Observations

- ❖ A weak positive exploratory relationship was observed between TOC and MP abundance.
- ❖ The intermediate-depth sample (SB02; 1.5–2.0 m) exhibited the highest MP abundance.
- ❖ Variability across samples suggests TOC alone may not fully explain MP distribution.
- ❖ Limited sample size precludes robust statistical interpretation.

Exploratory Relationship Between TOC and log$_{10}$(ΣPFAS)

Graph 6. Exploratory Relationship Between TOC and log$_{10}$(ΣPFAS)



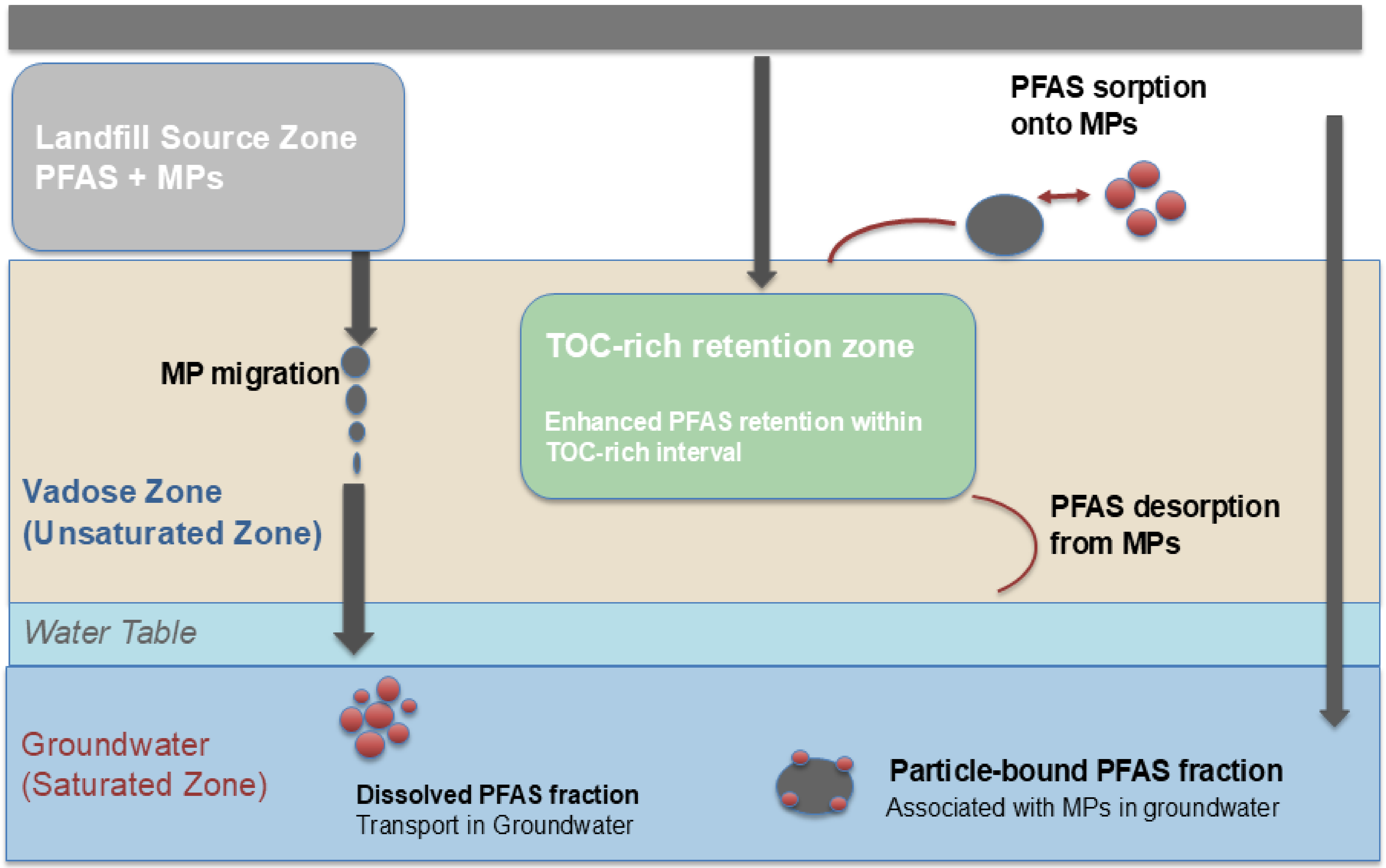
Non-detect PFAS values plotted at half the reporting limit for visualization purposes only.

Key Observations

- A positive exploratory trend was observed between TOC and log-transformed ΣPFAS concentrations.
- Samples with higher TOC generally corresponded with elevated ΣPFAS concentrations.
- Results may indicate an association between organic carbon content and PFAS retention.
- Exploratory analysis only; limited sample size precludes robust statistical interpretation.

Conceptual Site Model

Proposed PFAS–microplastic transport and retention mechanisms



Conceptual interpretation based on exploratory Phase II field observations and phase-specific PFAS analysis.

Key Conceptual Interpretation

- ❖ MPs may facilitate vertical PFAS transport through the vadose zone.
- ❖ TOC-rich intervals may promote PFAS retention within soil profiles.
- ❖ PFAS sorption and desorption from MP surfaces may influence contaminant mobility.
- ❖ Both dissolved and particle-bound PFAS fractions may occur in groundwater systems.

Key Findings and Future Research Priorities

Key Findings

- Results support the presence of particle-associated PFAS in groundwater.
- Filtered versus unfiltered PFAS analysis provides a practical framework for phase differentiation.
- QA/QC controls remain critical because MP contamination artefacts can materially influence interpretation.

Future Research Priorities

- Expanded spatial and seasonal sampling.
- Controlled PFAS desorption experiments.
- Improved differentiation of MP-associated PFAS from other particulate-bound fractions.
- Evaluation of polymer-specific sorption and transport behaviour.

Broader Implications and Future Applications

- Particle-associated PFAS transport may extend beyond landfill systems to wastewater, biosolids and urban stormwater environments.
- Microplastics generated from consumer products, textiles, packaging, tyres and industrial materials may influence contaminant mobility across diverse environmental settings.
- Conventional dissolved-phase monitoring may underestimate total PFAS transport in particulate-rich systems.

Key Takeaway

This study provides preliminary field evidence that particulate-associated PFAS transport may occur in landfill vadose zone and groundwater systems, warranting further investigation in PFAS monitoring frameworks.

Study Limitations

- Limited sample size.
- PTFE contamination artefacts.
- Explanatory relationships only.