Microplastics effects on evaporation dynamics and cracking morphology in drying porous media

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Introduction

- Global production of plastics has increased exponentially over the past few decades
- Soil represents a large reservoir for plastics disposal. The improperly disposed plastics could serve as a major and long-term source of contamination
- Microplastics (MPs) with particles less than 5 mm enter the soil through different pathways ranging from plastic mulching and irrigation to soil amendment with sewage sludge affecting soil properties and processes

Objective: To quantify the effect of type and concentration of MPs on the soil water evaporation dynamics and desiccation cracking patterns

Materials & methods

- Two classes of experiments were conducted using mixture of porous media and MPs to investigate how evaporation dynamics and drying-induced cracking patterns are influenced by MPs
- Sandy media was used for the evaporation experiments and Bentonite clay for the analysis of drying-induced cracking
- Two types of microplastics were used:
  - **Polyethylene (PE)** with 34-50 μm particles and density of 0.94 g/m^3
  - **Polyvinylchloride (PVC)** with 80-200 μm particles and density of 1.4 g/m^3
- The concentration of MPs varied as:
  - **Evaporation experiment:** 0%, 0.75%, 1.5% and 4.5%
  - **Cracking experiment:** 0%, 0.75%, 1.5%, 4.5%, 6%, 8%, 10%
- A customized code was developed in MATLAB to quantify crack patterns based on binarized and skeletonized images

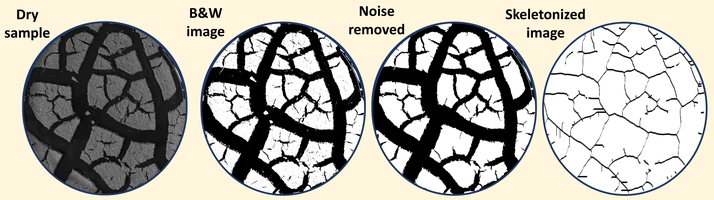

Figure 1. Image processing

Evaporation dynamics

- MPs modified soil characteristics and decreased saturated water content (θ_s)
- Mean pore size changed from 80 μm for the reference sample (without MPs) to 70 μm for the PE and 65 μm for the PVC samples

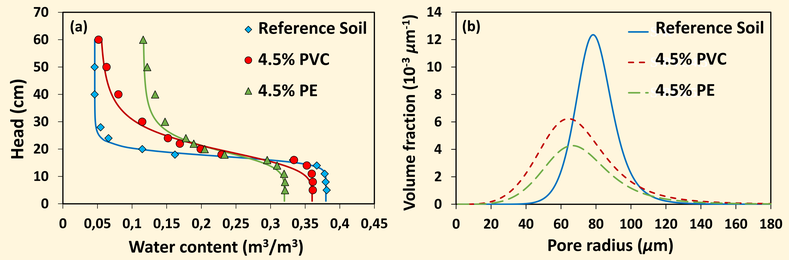

Figure 2. Water retention curve and volumetric pore size distribution

- Presence of MPs increased evaporative mass loss from sand samples with more pronounced effects at low concentrations (i.e., 0.75 and 1.5%)
- MPs increased the extent of stage 1 evaporation

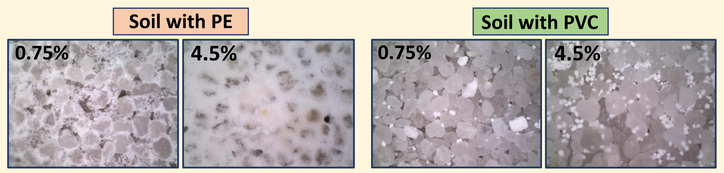

Figure 3. Surface microscopic images at the end of evaporation experiments

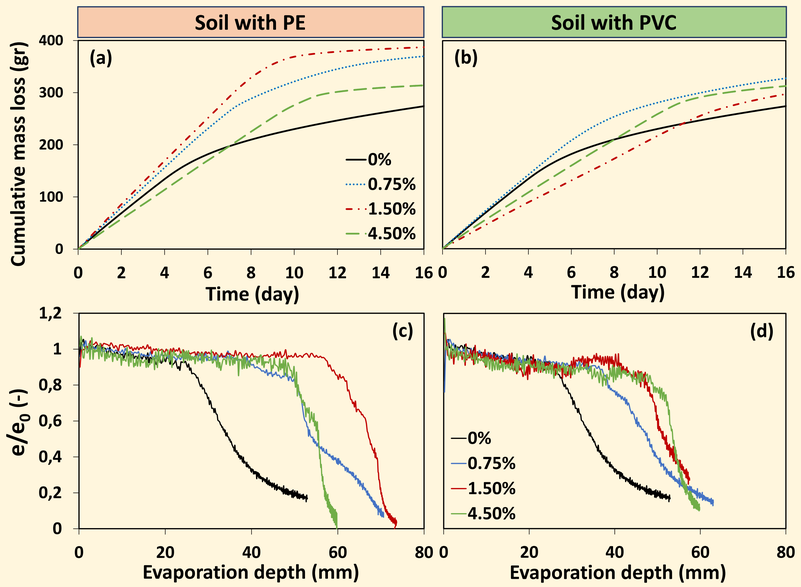

Figure 4. Cumulative mass losses vs. Time (top); normalized evaporation rate vs. evaporation depth (bottom)

Cracking patterns

- Presence of PE and PVC slightly affected cracking patterns in our tests
- Variation of MP concentrations did not significantly change the crack area and length; however PE samples showed lower crack area than PVC samples

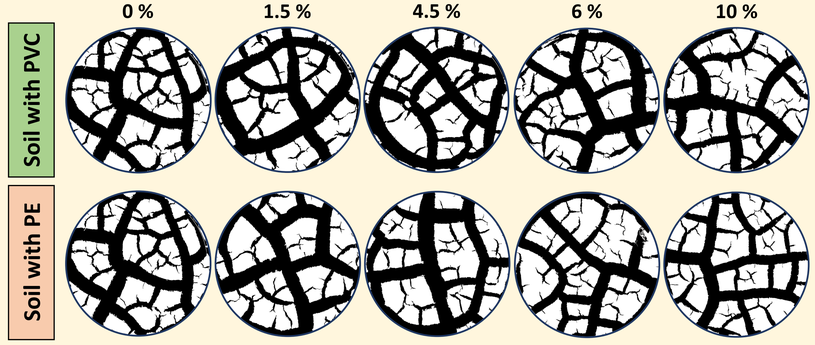

Figure 5. Crack patterns in samples with different concentrations of MPs

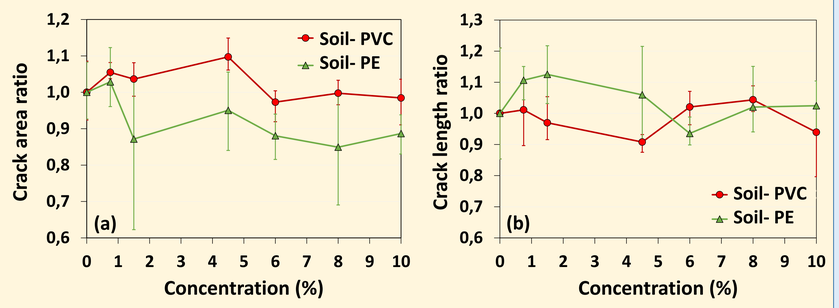

Figure 6. Crack area ratio & crack length ratio

Conclusions

- Microplastics affected soil characteristics and pore structure and thus changed water holding characteristics with reduction of saturated water content and increase of residual water content
- The presence of MPs in sand sample increased cumulative mass loss and the extent of stage 1 evaporation relative to the reference sample
- We observed less nuanced differences in cracking patterns in the presence of MPs. The findings showed a decrease in crack area and a concurrent increase in total crack length at low concentrations of PE

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