Microplastic water repellency impacts water flow and microplastic transport in soils

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Soils are considered the largest sink of microplastic particles (MP) in terrestrial ecosystems. However, there is little knowledge on the implications of MP contaminating soils. In particular, we do not know the extent of and conditions under which MP are transported through porous media and, if they are deposited, how they affect soil hydraulic properties and soil moisture dynamics. We hypothesize that: 1) hydrophobic MP enhance soil water repellency; 2) isolated MP are displaced and transported by the air-water interface; 3) clusters of MP impede water flow and are retained in air-filled pores.

We tested these hypotheses in mixtures of MP ($\mu$m range) and sands (mm range) in a series of experiments. The Sessile Drop Method (SDM) was applied to measure the average contact angle (CA) of the mixtures for MP and model porous media in the same size range, ranging from 0 - 100 % MP content. Based on the specific surface and shape factor of MP and soil particles, the results are extrapolated to different MP and soil particle sizes. Capillary rise experiments were performed to measure the impact of MP on water infiltration. The applied MP contents of 0.35 % and 1.05 % reflect an average CA of 60° and 90° from the SDM extrapolation. Capillary rise of water and ethanol were carried out to estimate the apparent CA. Additionally and with the same MP content, we simultaneously imaged in three-dimensions the movement of deuterated water and MP during repeated drying / wetting cycles using X-Ray and Neutron tomography (at the beamline ICON, PSI). The different neutron attenuation coefficients of deuterated water and MP allows for estimating their distribution in the sand packing.

Already at MP contents of 5 % the CA measured with the SDM exhibited a steep increase and reached 59° to 81°, depending on the grain size of MP. The capillary rise experiments showed that MP reduce capillary rise. The apparent CA (43° and 53°) were smaller compared to the average CA from the SDM (60° and 90°), but the added MP increased air entrapment during capillary rise leading to a reduced saturation of the pore space (18 % and 16.5 %). Accumulation of MP at the advancing air-water interface was visible. Neutron and X-ray imaging showed at high resolution that regions with major MP content are water repellent and, are bypassed by water flow, and remain in air-filled pores.

Extrapolation of these results to soils suggests that in microregions with high MP contents, water
infiltration is hindered. The low water content in these microregions might limit MP degradation due to reductions in: hydrolysis, coating of MP by e.g. dissolved organic substances, and colonization by microorganisms.