Fate and effect of doped and non-doped microplastic particles under environmental relevant conditions in an outdoor lysimeter study

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Introduction and aims

Plastics in the environment are considered one of the key challenges of the 21st century. The application of sludge to agricultural soils as fertilizer will lead to microplastic (MP) contamination of soils. There is a lack of information for the terrestrial environment, because detection and speciation of MP in soil is extremely challenging. For a comprehensive risk assessment, information on the fate and effect of MPs in soil is needed. Thus, the use of model particles is inevitable. Our aim was to investigate the fate and effect of polystyrene particles (PS-P) and polystyrene particles with a core of silver nanoparticles (Ag-PS-P) in a sewage treatment plant (STP) and a subsequent outdoor lysimeter study.

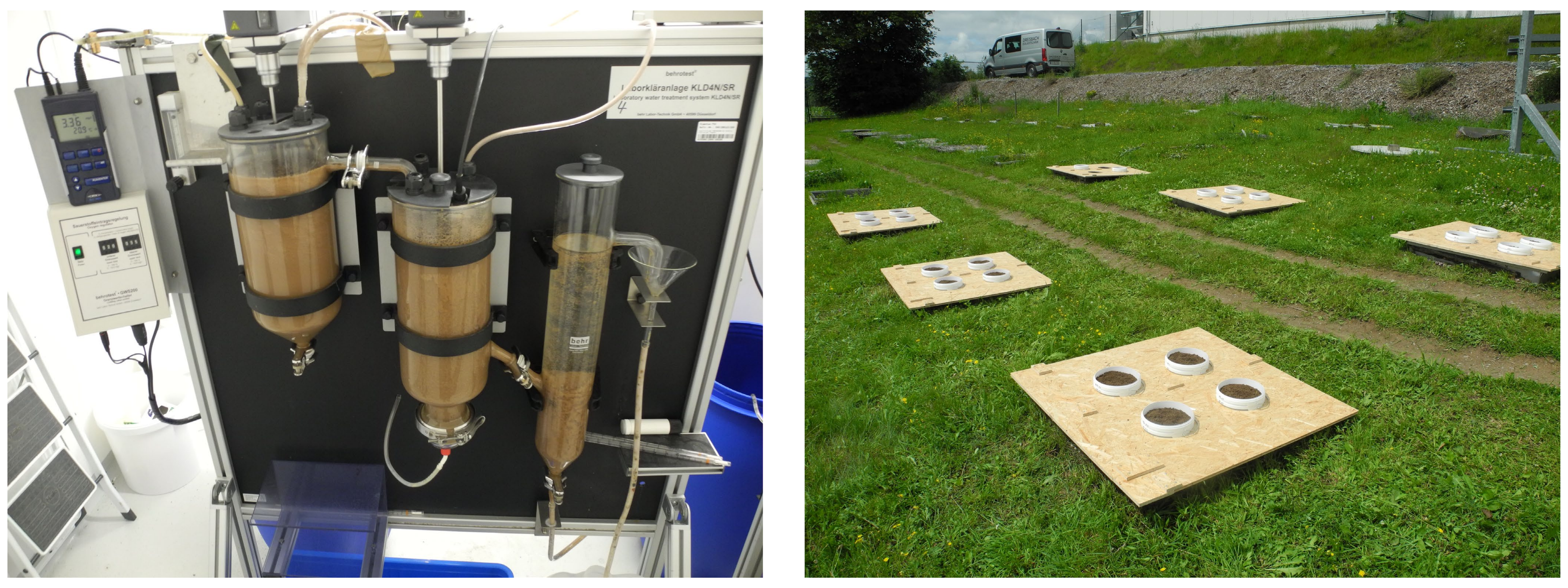

Figure 1: Test performance on fate and effect of MPs using a model sewage treatment plant (left picture) followed by an outdoor lysimeter experiment with soil-sludge mixtures (right picture).

Material and Methods

- Both particles were synthesized by emulsion polymerization and characterized by scanning electron microscopy (SEM) and dynamic light scattering (DLS).
- The particles were added into single STPs for twelve days following the OECD 303A. Samples were taken from sludge and effluent to determine the fate of the MPs. In addition, the effect on the microorganisms in the STP was investigated by measurements of the DOC elimination.
- After twelve days, the sludge was dewatered. To achieve three consecutive test concentrations, the sludge of the two treatments (PS-P, Ag-PS-P) was mixed with control sludge (1:2, 1:10). Afterwards, 1.67 g dry matter sludge of each treatment were added per kg dry soil. Three replicates of 5 kg dry matter soil were prepared for each treatment.
- For the control (with control sludge) and for each treatment with PS-P and Ag-PS-P three single replicates were prepared.
- The replicates were incubated outdoor and wheat was sown on each lysimeter. Over four month leachate samples were taken at regular intervals and the effect on soil microorganisms (substrate induced respiration (SIR), Ammonium oxidizing bacteria (AOB)) was examined.

Results

- After dialysis and dilution, all particles were present as single particles, which was confirmed by DLS. The SEM pictures showed that one silver core particles was centrally located in most of the PS-P.

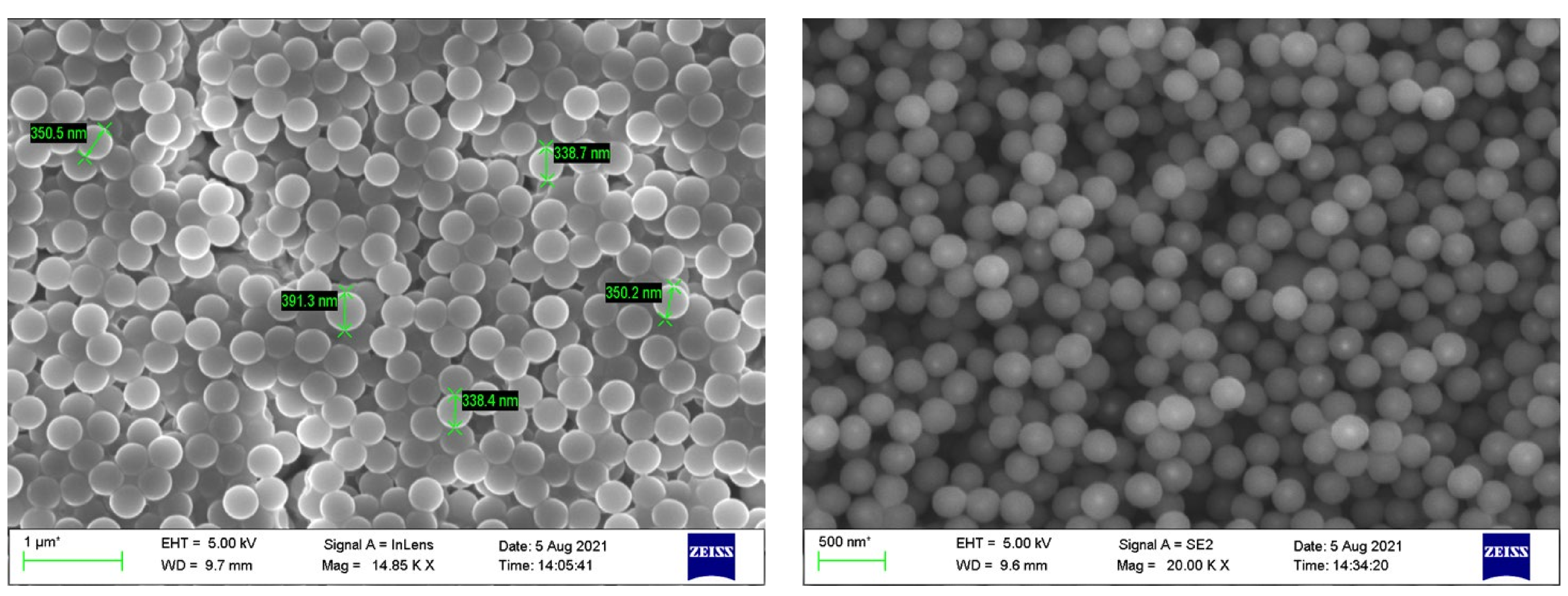

Figure 2: PS-P (left picture) and Ag-PS-P (right picture) synthesized at BGR (a: dilution 1:10, b: dilution 1:8). The figures shows uniform size distribution and individual particles. The measured particle diameters was in agreement with the hydrodynamic diameter (a: HDD = 354 nm; b: HDD = 255 nm). For the images, the particles were deposited on an Al carrier and sputtered with C..

Results

- No impact on the DOC elimination of the STP due to the MPs. The DOC elimination was above 95% in all treatments (control, Ag-PS-P and PS-P).

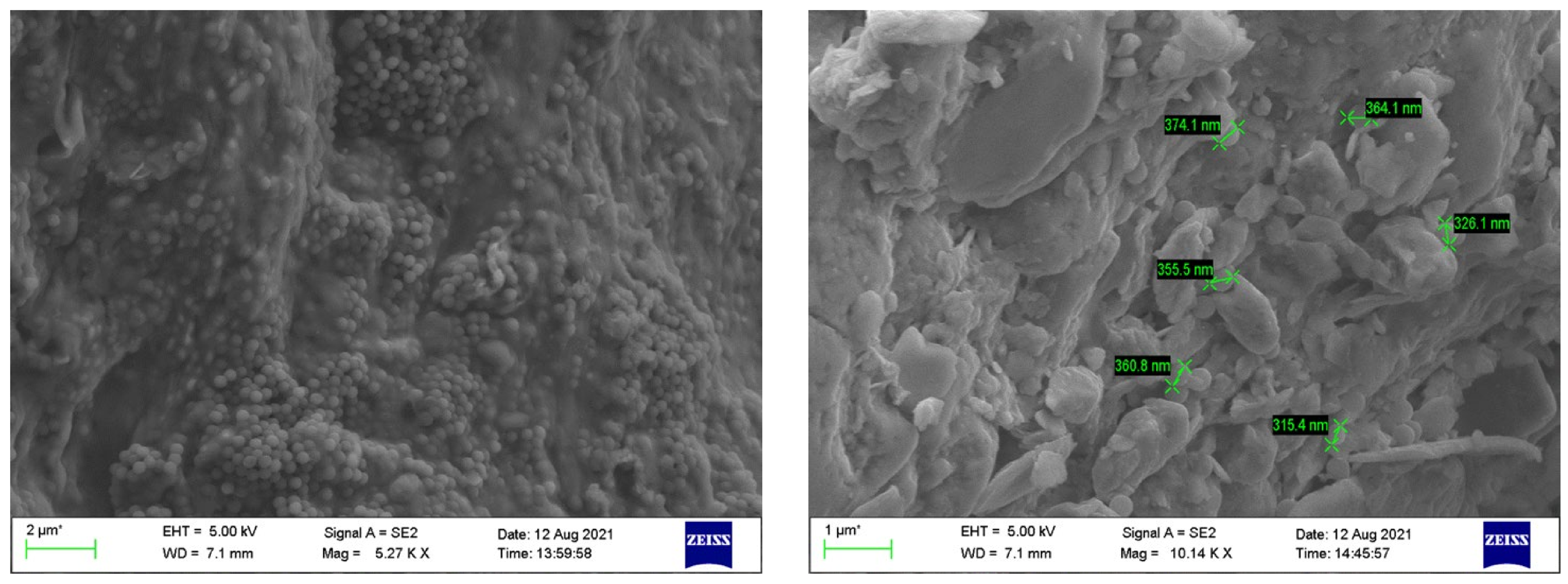

Figure 3: PS-P in sewage sludge (left picture) and in soil-sludge mixture (right picture). The figures shows uniform size distribution and individual particles. The measured particle diameters was in agreement with the hydrodynamic diameter (HDD = 354 nm). For the images, the particles were deposited on an Al carrier and sputtered with C.

- There were no PS-P detected in the effluent samples by SEM, indicating that most of the particles were retained by the sewage sludge. This could be verified by analysis of the pure sewage sludge and soil samples. Single particles were detected non-aggregated in the sewage sludge and soil (Figure 3).
- Determining the effect on AOB after 30 days incubation ANOVA ($\alpha = 0.05$) indicated that treatments are significantly different from each other. However, only the stimulation found at the two highest concentrations of Ag-PS-P were statistically significant different from the sludge control. After 60 days incubation the ANOVA ($\alpha = 0.05$) showed no statistically significant difference between the treatments and the sludge control. At the end of the test, after 90 days incubation, the treatments were statistically significant different (ANOVA, $\alpha = 0.05$). Effects on the AOB of 15.1% and 12.3% were found.

Table 1: Observed effects of PS-P and Ag-PS-P on AOB in an outdoor lysimeter study.

Nominal concentration [w/w%]	Inhibition to sludge control [%]		
	30 days	60 days	90 days
PS-P 1:10	5.2	4.3	-12.6
PS-P 1:2	3.8	0.1	3.1
PS-P pur	21.7*	-2.9	3.3
Ag-PS-P 1:10	6.2	5.9	4.5
Ag-PS-P 1:2	-26.6*	13.4*	15.1*
Ag-PS-P pur	-15.6*	18.4*	12.3*

** Statistically significant different compared to control. Student t-test, Alpha = 0.05.*

- Neither basal respiration nor substrate induced respiration (glucose, L-Alanine) were negatively affected by PS-P or Ag-PS-P after 30, 60 and 90 days incubation in the outdoor lysimeters.

Conclusion

No effect of observed MPs on STP (DOC elimination). PS-P and Ag-PS-P mainly adsorb to sewage sludge.

The PS-P and Ag-PS-P are evenly distributed in the sludge after the STP experiment. Moreover, non-aggregated particles were found in the soil after the sludge application to the lysimeters.

The Ag-PS-P affected the AOB (inhibition mainly <20%) after long-term incubation indicating a slight toxic effect.