

Long term effects of three different silver sulphide nanomaterials, silver nitrate and bulk silver sulfide on soil microorganisms and plants

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Silver nanomaterials (AgNMs) are subjected to various transformations along their way into the sewage treatment plant (STP). Hereby the AgNMs are mainly transformed to silver sulfides (Ag₂S) (Kaegi et al, 2011). Sparingly soluble Ag₂S is considered as none toxic to soil organisms. In the STP the AgNMs adsorb to sewage sludge (Schlich et al., 2013) and the arising biosolids will be applied in large quantities on agricultural land within the European Union.

The main goal of the present study was to determine, if different types of sulfidized AgNMs evoke a difference in the toxicity of the AgNMs. A realistic exposure scenario was chosen. The five test materials NM-300K, previously sulfidized NM-300K, a nanoparticulate Ag₂S, and bulk Ag₂S were added with an influent concentration of 1 mg/L and AgNO₃ with an influent concentration of 0.5 mg/L into the denitrification of a simulated STPs continuously for 10 days. The sewage sludge of each treatment was dewatered and the biosolids were mixed with soil. After 0, 60, 90, 140 and 180 days the effects on ammonium oxidizing bacteria (AOB, ISO 15685) and the substrate induced respiration (SIR, OECD 217) were observed. In addition, after 60 days of aging of the AgNM in the test soil a subsample was taken from each treatment and a chronic plant test was carried out with oat (*Avena sativa*) and both the roots and the shoots were examined for an uptake of the Ag.

We found an increasing inhibition of the ammonia oxidizing bacteria (AOB) from day 60 until day 140/180 in both tests. The inhibition due to the different nanosized AgNMs was mainly comparable throughout the test. In the first test the bulk Ag₂S had no effect on the activity of the AOB. Surprisingly, in the second test we found an effect of the bulk Ag₂S on the AOB, whereas all other results were in good agreement with the first test. The substrate induced respiration (OECD 217) occurred to be a less sensitive test system to determine the effect of the different test materials on the soil microorganisms. Effects were found only after 180 days of the test due to the silver nitrate (70% inhibition) and the nanosized Ag₂S (30% inhibition). There were no effects on the emergence or plant growth of *Avena sativa* over 8 weeks in the chronic plant test. An uptake of a low Ag concentration into the roots of the plants was observed.