Fraunhofer IME

MULTIPLE SEWAGE SLUDGE APPLICATIONS INTO SOIL – FATE AND EFFECT OF NANOSILVER IN AN OUTDOOR LYSIMETER STUDY OVER 5 YEARS

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Introduction & objectives

Nanomaterials (NM) will enter the environment via diverse pathways. Sewage sludge is repeatedly applied as fertilizer on farmland due to its high nutrient content.

Our aim was to investigate the accumulation, plant uptake and additive effects on soil microorganisms after a 2nd sludge application for two years (2018/2019). The 1st sludge application was carried out in 2014.

Test setup

- Artificially filled lysimeters (~ 1 t of dry matter soil)
- Nanomaterial: NM-300K; OECD Sponsorship Programm
- **2014: 1st application** of 1.8 (Lysimeter 2; L2) and 7.0 (Lysimeter 6; L6) mg Ag/kg dry matter (dm) soil applied via sewage sludge into top 20 cm soil to simulate ploughing
- Control (Lysimeter 1; L1) received pure sewage sludge
- Series of agricultural crops relevant for sewage sludge fertilized fields (wheat, canola, barley; 2015 - 2017)
- **2018: 2nd application** of AgNM.
  L1 and L6: Only uncontaminated pure sewage sludge
  L2: Sludge with an AgNM content to achieve 7.0 mg/kg dm soil
- Agricultural crop relevant for sewage sludge fertilized fields (wheat) followed by bare fallow
- Leachate was permanently collected, the volume was determined and Ag was measured frequently
- Regular determination of effects on ammonium oxidizing bacteria (AOB, ISO 15685)

Results 2014 – 2017

- No detectable vertical displacement very low remobilization → NM remained nearly immobile in the pathway between soils and leachate.
- Ag uptake in the roots of wheat, canola and barley → chemical conditions in the rhizosphere induce AgNM remobilization.
- Constant inhibition of the soil microflora at 7.0 mg/kg dm soil (L6). No effect at the lower AgNM concentration (L2).



Results 2018 – 2019

- L2: Comparable effects on AOB four months after the 2nd application as found for L6 in 2014 (Sept. 2014: 31% vs. Aug. 2018: 49%; Figure 1).
- L6: Increasing toxicity on AOB after 2nd application of uncontaminated sewage sludge.
  - ➢ pH drift below pH 5 → higher toxicity
    → November 2018: Liming to achieve pH 5.5
- Increasing toxicity with increasing exposure time.

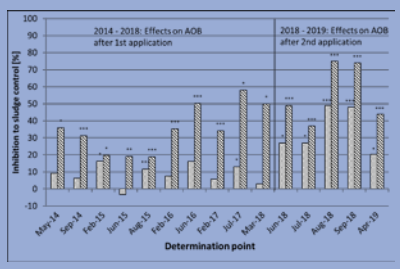

Figure 1: Effect of AgNM applied via sludge on the AOB. First bar L2: 1.8 mg/kg dm soil until May 2018, afterwards 7.0 mg/kg dm soil. Second bar: 7.0 mg/kg dm soil (L6). Lysimeters were limed to reach a pH of ~5.5 in November 2018. p<0.05; ** p<0.01; *** p<0.001 (Student t-test).

- Previous results (2014-2017) were confirmed, the Ag introduced via AgNM-300k remains in the upper soil layers (0-20 cm) (Figure 2).

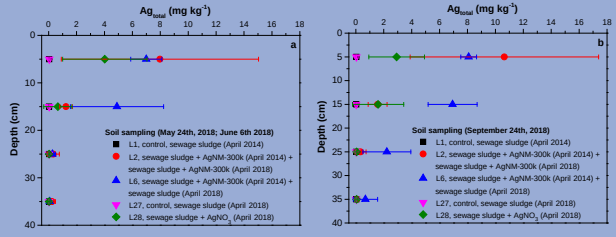

Figure 2: Silver content of the field lysimeters after application and incorporation of the soil-sewage sludge mixtures in May and June 2018 (left) and after the harvest of wheat (right).

- The Ag availability is highest in L6 (≈ 10.000 µg Ag/kg; Figure 3), comparable values were already found in the roots of the wheat during the first measurement (2014).

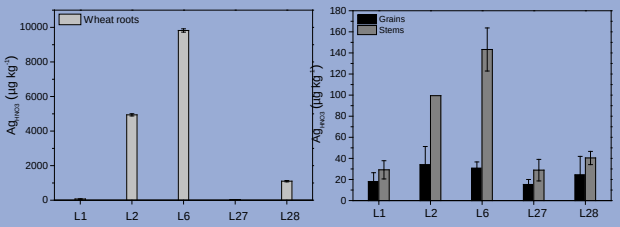

Figure 3: Silver content in the roots (left) and grains/stems (right) of wheat from the lysimeters (LOQ = 40 µg Ag/kg dry matter) in 2018.

Conclusion

- AgNM remain in the topsoil for >5 years. Repeated sludge applications will lead to increasing Ag concentrations.
- A synergistic effect due to an additional application of AgNM via sewage sludge was found.

Session: The environment as a reactor determining fate and toxicity of nanomaterials (P)
Poster, Exhibition hall, ID WE085
Wednesday May 29th, 2019, 8:30 AM

Multiple sewage sludge application into soil – Fate and effect of nanosilver in an outdoor lysimeter study over 5 years.

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Nanomaterials (NM) will enter the environment via diverse pathways. Sewage sludge is repeatedly applied as fertilizer on farmland due to its high nutrient content. This may lead to a significant increase of NMs in soil over years. Our aim was to investigate the accumulation, plant uptake and additive effects due to multiple sewage sludge applications into soil for two years after a second application of Ag-NM via sewage sludge.

In 2014, two concentrations of 1.8 and 7.0 mg Ag-NM/kg dry matter (dm) soil were applied via sewage sludge into the top 20 cm of lysimeter soil. The sludge was mixed into the top 20 cm to simulate ploughing. Over 3 years, the lysimeters were cultivated according to good agricultural practice. The effect on soil microorganisms was investigated as well as the fate of the NM in soil and the potential uptake into wheat, canola and barley (Schlich et al., 2017). No detectable horizontal displacement in combination with very low remobilization for both tested NM over 3 years was found indicating that the sludge applied NM remained nearly immobile in the pathway between soils and leachate. However, Ag uptake in the roots of wheat, canola and barley indicated that the chemical conditions in the rhizosphere induce Ag-NM remobilization from the incorporated sewage sludge even after three harvesting cycles.

A constant inhibition of the soil microflora (ammonium oxidizing bacteria and substrate-induced respiration) was observed over 3 years at 7.0 mg/kg dm soil, while there was no effect at the lower Ag-NM concentration.

Then, the experiment was continued for further 2 years. In accordance to the German Sewage Sludge Ordinance 5 tons of dry matter sludge can be applied on a hectare in 3 years. Therefore, after 3 years a new application of Ag-NM onto the lysimeter with an Ag-NM content of 1.8 mg/kg dm soil via sewage sludge was performed aiming in an Ag-NM content of 7.0 mg/kg dm soil. Only uncontaminated sludge was applied on the lysimeter, which already had an Ag-NM content of 7.0 mg/kg and onto the control lysimeter. After the application in April 2108, wheat was cultivated followed by bare fallow after the wheat harvest in October 2018. In regular intervals, the effect of the Ag-NM on soil microorganism was observed. In addition, the wheat plants were investigated for their Ag content in roots, shoots and ears. Once per month the leachate was collected and the Ag concentration was determined. Results until April 2019 will be presented.