Effects of Ag NM-300K on *Folsomia candida* (Collembola) in different standard soils and in long-term aged sludge-treated soils

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Introduction

Soils are considered a major sink of AgNP, because AgNP enter these by application of sewage sludge from waste water treatment plants to agricultural soils. Due to the rising use of AgNP, long-term emission to soils and long-term accumulation are expected.

The aim of the present study was to determine the toxic effect of AgNP on *Folsomia candida* reproduction to illustrate potential impact on terrestrial ecosystems.

Methods

The effect of AgNP (NM-300K) on *F. candida* reproduction in two standard soils (RefeSol 01-A, Lufa 2.2) at concentrations from 12,5 to 50 mg Ag kg^{-1} soil was determined. $AgNO_3$ was used as a metal salt reference.

In addition, to simulate realistic exposure pathways, effects on *F. candida* reproduction after AgNP application to soil via sewage sludge and after aging this treatment in the soil for up to 140 days were studied using environmentally relevant concentrations of AgNP.

The miniaturised form of the OECD collembola reproduction test was used (ISO 11267:2001; OECD TG 232:2009). The test is based on the reproduction of *F. candida* in the soil within 28 days. The toxicological endpoint is the number of juvenile per adult (Figure 2)

Results

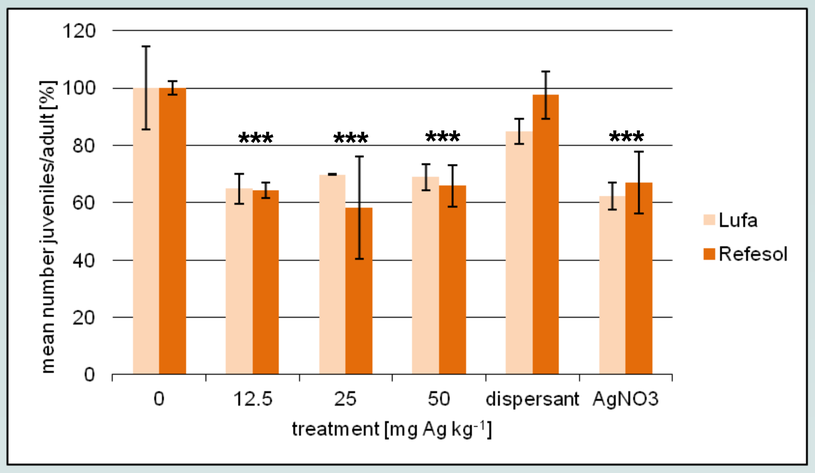

Figure 1: : Inhibition of *F. candida* reproduction compared to control (mean ± SE) in LUFA 2.2 and RefeSol 01-A. The $AgNO_3$ treatment contained 50 mg Ag kg^{-1}. The solvent control contained the equivalent amount of NM300K dispersant as the highest NM300K treatment. Statistical significances to the respective control: *** $p \leq 0.001$. (n=2; 5 replicates each)

Figure 2: *F. candida* reproduction test

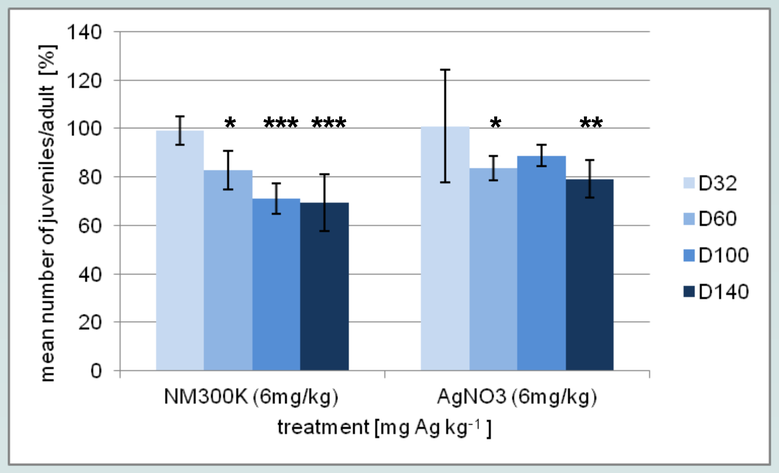

Figure 3: Inhibition of *F. candida* reproduction compared to the corresponding sludge control (mean ± SD). The sewage sludge was applied to soil and incubated for 32, 60, 100 or 140 days before the tests. Statistical significances to the respective control: * $p \leq 0.05$, ** $p \leq 0.01$; *** $p \leq 0.001$.

The generated data demonstrate that the presence of AgNP in soil in the low mg Ag kg^{-1} concentration range results in significant, but concentration independent inhibition of the *F. candida* reproduction in RefeSol 01-A and LUFA 2.2. Significant inhibition of *F. candida* reproduction due to AgNP was also observed for soils amended with AgNP treated sludge. An increase in inhibition with aging of the AgNP in the soil was evident, and indicates that toxic effects depend on exposure duration of NM-300K in soil.

Conclusion

The results demonstrate that, at environmentally relevant concentrations, AgNP adsorption to sludge and subsequent aging in soil lead to a toxic effect on soil invertebrates. The consideration of transformations and the implementation of aging tests when performing environmental risk assessment of AgNP (and other nanoparticles) are essential.

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