European Commission

Science for Environment Policy

Risk of silver nanoparticles to terrestrial plants is low, but increased by chlorine

Silver nanoparticles are used in a range of household products. This study investigated the risk to plants of these nanoparticles in soil, showing that risk was overall low but increased when soils contained high levels of chlorine. The researchers, therefore, suggest that the risk of silver nanoparticles to plants may increase in salty soils or those irrigated with poor-quality water. These findings could be important for future risk assessments.

09 February 2017
Issue 482

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Source: Wang, P., Menzies, N., Dennis, P., Guo, J., Forstner, C., Sekine, R., Lombi, E., Kappen, P., Bertsch, P. & Kopittke, P. (2016). Silver Nanoparticles Entering Soils via the Wastewater–Sludge–Soil Pathway Pose Low Risk to Plants but Elevated Cl Concentrations Increase Ag Bioavailability. *Environmental Science & Technology*, 50(15): 8274–8281. DOI: 10.1021/acs.est.6b01180.

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Nanotechnology is one of the major scientific developments of recent years, expected to address major societal challenges such as climate change and renewable-energy development. Although nanotechnologies are at various stages, nanoparticles made of silver have already found a range of applications, from catalysts to anti-microbial agents, and are increasingly used in common household products, such as cleaning products, textiles, home appliances, nutritional supplements and even toothpaste. In fact, silver is the most common element in consumer nanotechnology products in Europe[1].

While nanoparticles are generating useful products, they also raise concern for the environment. This is because after they are used and disposed of, they can be released into the natural environment where they may have unexpected effects; this could happen, for example, through wastewater treatment plants (WWTPs) (the main objective of which is to protect the environment from the adverse effects of organic and nutrient pollution). Such effects, whenever harmful, would reveal the importance of the preventive action in the production and use of the aforementioned household products, also considering that it is, in general, difficult and expensive to fully remove nanoparticles from wastewater through treatment.

This study focused on nanoparticles in sewage sludge (which can be applied in some countries to agricultural land as a fertiliser), and is the first to investigate the behaviour and risk of silver nanoparticles across the complete chain — from wastewater to sludge, then soil and eventually plants — over the long term.

This study assessed the stability and bioavailability of silver (i.e. how likely it is to be absorbed by plants) along this pathway, using environmentally relevant concentrations and a realistic exposure route (application of sewage sludge to land).

Sewage sludge was produced from three reactors, each receiving a different treatment: silver nanoparticles; silver nitrate; and control (no silver). The sewage sludge was then collected and applied to soil from agricultural land in Queensland, Australia; this is a single type of soil, usually characteristic of tropical regions. In total, 25 different incubation experiments were set up to investigate the effect of soil properties on the behaviour of silver, with incubation periods of up to 400 days.

The mass of sludge applied to the soil was equivalent to a realistic rate reported by the US Environmental Protection Agency (870 grams per square metre), resulting in soils with final silver concentrations of either 1 or 10 milligrams per kilogram. The researchers say this represents the addition of 'high silver sludge' (a worst-case scenario) to soils for either 1 or 10 years. The researchers assessed the amount, form and availability of silver in the samples and also performed a plant-growth experiment (using wheat) at the end of the incubation.

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1. According to the Nanodatabase: http://nanodb.dk/en/

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Risk of silver nanoparticles to terrestrial plants is low, but increased by chlorine *(continued)*

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To cite this article/service: "Science for Environment Policy": European Commission DG Environment News Alert Service, edited by SCU, The University of the West of England, Bristol.

The results showed that almost all of the silver added to the sludge reactors stayed in the sludge, with most being converted to silver sulphide — a form of silver that is stable for long periods. The researchers investigated its stability and bioavailability in soils, confirming that silver sulphide is stable in soil and has low availability to plants. Availability further decreased over time, reducing risk.

Although the bioavailability of silver in the soil was overall low, it increased considerably in soils with higher levels of chlorine; the addition of sodium chloride resulted in a 2.3–160-fold increase in the availability of silver. The authors suggest this is likely because silver forms soluble complexes with chlorine. Importantly, although availability to plants increased, plant growth was not reduced in any of the treatments.

Overall, the results suggest that silver nanoparticles entering soils via sewage sludge pose a **low risk** to plants, as they are converted to a stable form of silver during wastewater treatment. However, bioavailability (and, therefore, risk) might increase in saline soils (which includes over 20 million hectares in Europe) or those irrigated by poor-quality water (which might include chlorine).

It would be interesting to replicate the experiment using soils that are more typical of European conditions, so that findings could help in the development of better risk-assessment frameworks for silver nanoparticles, which are used in more consumer products than any other type of nanomaterial.