Science for Environment Policy

Nanoparticles’ ecological risks: effects on soil microorganisms

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Nanotechnology is a key enabling technology predicted to have many societal benefits, but there are also concerns about its risks to the environment. This study reviewed the effects of nanoparticles on soil microorganisms, showing that toxicity depends on the type of particle. The researchers make recommendations for improving environmental risk assessment, including performing experiments in soil and over longer time periods.

Nanoparticles are tiny particles under 100 nanometres in size — around 1 000 times smaller than the width of a human hair. Due to their large surface area-to-volume ratios, they can be used to produce materials with new functions and properties (compared to their conventional forms), such as very thin films, tubes, wires and coatings. Engineered nanoparticles are already widely used in the electronics, food technology, energy and pharmaceuticals sectors and have an estimated global market value of €20 billion[1].

Although nanoparticles have many beneficial applications, there is concern about what might happen if they are released into the environment (their ecological risk). Laboratory studies have shown that many nanoparticles — specifically those made of silver, copper and zinc — have anti-microbial properties. While these may be beneficial for medical applications, the introduction of such particles into the natural environment could pose a threat to beneficial microbial communities (bacteria, fungi and archaea), such as those found in soil.

This is a growing concern, as models suggest that soil is a major receptor of nanoparticles — more so than air or water. Nanoparticles can enter the soil through industrial spills, landfill sites or when sewage sludge is used as a fertiliser. They can also be used intentionally to clean the soil. Nanoscale zerovalent iron (nZVI) particles, for example, have been used to remove a range of pollutants from soil (in a process known as bioremediation).

It is important that any potential adverse effects are detected early, as soil microorganisms provide essential ecosystem services, including nutrient cycling, crop production and climate regulation.

To assess the effects of engineered nanoparticles on soil microbial communities, the researchers performed a comprehensive literature review. They noted the effects of three major types of nanoparticles — metal and metal oxide nanoparticles, carbon-based nanoparticles and nZVI — on the number of microorganisms (abundance), number of different species of microorganisms (diversity) and their activity.

Overall, they found that toxic effects depend on the type of nanoparticle, with metal nanoparticles generally being more toxic than organic (carbon-based) nanoparticles. Metal and metal oxide nanoparticles can have toxic effects on activity, abundance and diversity even at concentrations below 1 milligram per kilogram (mg per kg). For example, silver nanoparticles have been shown to reduce some enzyme activities in microorganisms (which are important for their ability to break down organic matter in soil and contribute to crucial biogeochemical cycles), while copper- and zinc-based nanoparticles can reduce bacterial growth and biomass.

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1. http://ec.europa.eu/research/industrial_technologies/policy_en.html

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Metal nanoparticles can also affect the entire bacterial community; in one study, sewage sludge containing 0.14 mg per kg of silver nanoparticles changed the bacterial community structure, despite only a short-term exposure. However, very high concentrations of carbon nanoparticles, much higher than those predicted to be found in the environment (over 250 mg per kg), are required to have negative effects.

Surprisingly, nZVI (which is widely used to restore polluted soils) can have detrimental effects on the ability of microorganisms to biodegrade pollutants — the essence of soil bioremediation. The researchers say more work is needed to understand how nZVI treatments may be affecting these non-target populations and, therefore, soil functions.

As well as the type of nanoparticle, soil properties are also important in determining the toxic effects of nanoparticles. Organic matter content, pH and texture, for example, all influence the type of microorganisms living in the soil and the ability of pollutants to have toxic effects on them (bioavailability).

The researchers say that most studies to date have only analysed the impact of nanoparticle contamination using high concentrations and in a single type of soil. They recommend that future studies should use concentrations of nanoparticles that are likely to be found in natural settings (and over longer time periods) and should compare the toxicity of the same nanoparticles in different soils. This could facilitate the identification of the soil properties that influence the bioavailability and toxicity of nanoparticles, which they say is 'fundamental' for environmental risk assessment.

Further recommendations for risk assessment include studying nanoparticles in natural conditions (which is currently technically challenging) and investigating how nanoparticles interact with other pollutants in soil, such as heavy metals and pharmaceutical residues.