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Risk model suggests nanomaterials could reach toxic levels in San Francisco Bay area

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Although nanomaterials are already in widespread use, their risk to the environment is not completely understood. Researchers in the US have developed a next-generation risk-assessment model to better understand nanomaterials' environmental impact. Applied to the San Francisco Bay area, the model predicted that even soluble nanomaterials could accumulate at toxic levels.

Nanomaterials have many useful features and are already used in a wide range of products, from paints and batteries to air purifiers and medicines. However, they may also pose a risk to the environment, for example by affecting the growth of plants and microbes or toxicity to aquatic species. As their use and production increases, it is important to better understand these risks.

Because it is not yet possible to accurately measure concentrations of nanomaterials in the environment, scientists rely on lab-based measurements and computational models to predict the activity of nanomaterials and their associated risks. Although several such models are available, they have significant limitations, including considering only one type of environment (such as water) and one specific location (such as a particular river).

The authors of this paper, therefore, developed a new model called nanoFate, which predicts the accumulation of nanomaterials over time. The model accounts for the release, transport and fate of nanomaterials in the atmosphere, water and on land.

Unlike similar models, nanoFate considers a wide range of ways in which nanomaterials could enter the environment and predicts the concentration of nanomaterials released into the atmosphere (including air and aerosols), soil (including urban, natural and agricultural land), water (including freshwater and coastal water) and sediments at the bottom of water, and also considers their re-suspension, conversion into other compounds, and long-term accumulation.

In order to estimate nanomaterials' risk to ecosystems, the model compares their predicted concentration to species sensitivity distributions (SSDs, estimated toxic ranges for several species) for freshwater and soil systems where available. It also considers toxicity to individual species using the no observed adverse effect level (NOAEL) and the concentration required to kill 50% of the population (LC50) — together used to calculate the '5% hazardous concentration'.

The researchers applied the model to 10-year release for four metallic nanomaterials (cerium dioxide, copper oxide, titanium dioxide and zinc oxide) in the San Francisco Bay area of the United States. The Bay was selected as a case study due to the availability of release predictions for a range of nanomaterials. It contains a range of environmental compartments where nanomaterials could accumulate, including freshwater, marine water and urban, agricultural and natural land.

The researchers found that, even under a low-release scenario, nanomaterials could transfer to all environmental compartments within just a few weeks. The highest concentrations of nanomaterials were found in agricultural areas (where biosolids are applied to the land) or in sediment at the bottom of water (both marine and freshwater).

Even soluble nanomaterials could accumulate, and in some cases at concentrations high enough to be toxic to freshwater and soil organisms. In freshwater, cerium dioxide and copper oxide were unlikely to cause toxicity, even under the highest-release scenario, but titanium dioxide and zinc oxide exceeded toxic levels in all scenarios, with zinc oxide posing the greatest risk.

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In soil, none of the nanomaterials reached toxic levels (although titanium dioxide and zinc oxide were close to toxic levels in the highest-release scenario for agricultural soil). The researchers note that titanium dioxide, which is commonly used in paints, and zinc oxide, which is also used in paints and as an antibacterial agent, are produced in large quantities.

The researchers say that if the production and release of nanomaterials continues to rise they are likely to reach toxic levels. They warn that, in combination with a spike in concentration, caused by a spill, for example, this could generate significant toxic effects for both humans and animals. Importantly, given the changing climate, fluctuations in weather (such as changes in rainfall) could also make it more likely for nanomaterials to reach toxic levels in the environment.

The nanoFate model considers a wide range of chemical processes and environments and could be applied to other nanomaterials and areas. Although it represents an improvement over previous risk-assessment frameworks, it is important to recognise the limitations of the model, such as uncertainty in some chemical process rates and a lack of spatial considerations, which limits the accuracy of its short-term exposure estimates. It is also important to note that the model has not yet been validated due to a lack of experimental data.

Environment