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Silica nanoparticles flow in (and out of) waste

New research highlights some of the issues swirling around nanomaterials in wastewater, but no answers are forthcoming.

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As nanomaterials continue to enter the market embedded in fabrics, medicines, and more, researchers are watching where these particles might surface. One place they will pop up is in the waste stream, washing out in laundry, flowing down the drain along with cosmetics, and coming from other domestic uses. Researchers publishing in *ES&T* (**2009**, DOI 10.1021/es901399q) examined silica-shelled nanoparticles, and their preliminary results show that these might pass through some stages of traditional wastewater treatment, depending on their outer coatings.

The laboratory-based experiments highlight how “changes in surface chemistry will have an important effect on where these materials go in nature,” comments Mark Wiesner, an environmental engineer at Duke University and director of the Center for the Environmental Implications of NanoTechnology. Wiesner, who says the new work is interesting colloidal chemistry, also notes that the team has adopted tracking methods for tracing nanomaterials quantitatively that will be of future use for environmental research. But he and other outside experts say that much work remains to elucidate what might happen to these and other nanoparticles in the real world.

The experiments were jointly led by Helen Jarvie of the U.K.’s Natural Environment Research Council’s Centre for Ecology and Hydrology and Stephen King of the U.K. government’s Science and Technology Facilities Council, along with researchers from King’s College London and the University of Oxford (U.K.). The team used lab-synthesized silica-shelled nanoparticles with iron-oxide cores; the iron centers made the particles easy to track with small-angle neutron scattering. This well-established detection technique was recently introduced to environmental nanocolloid research because of its aptness for quantifying the various characteristics of nanoparticles in liquids.

The researchers added their particles—around 56 nanometers in diameter—to both raw and lightly filtered wastewater from a local utility serving communities in south central England. They determined that all of these particles stayed suspended in the waste effluent for several hours. However, after introducing a commercial surfactant to coat or “functionalize” the silica nanoparticles, the team found that the nanoparticles settled out alongside particles of waste within seconds.

The researchers hypothesize that the coated nanoparticles will not pass through to the next stage of the waste-treatment process if they are allowed to settle out. The “naked” nanoparticles, however, seem to remain in sewage effluent, and the team has plans to test what will happen once the materials go to the next level of treatment, which usually involves microbes.

Jarvie notes that previous research has shown the effects of nanoparticles on microbes, but she says that it is impossible to speculate on outcomes at the moment with their particular nanoparticles. Either way, the authors say, these results hint at possible management solutions, such as modifying the step in which the solids in wastewater are allowed to settle out to optimize the removal of nanoparticles.

Bernd Nowack of the Swiss Federal Laboratories for Materials Testing and Research (Empa) comments that the team used very high starting concentrations of nanoparticles, more than 2000 milligrams per liter. In "real-world conditions," Nowack says, concentrations are not likely to exceed more than a few micrograms per liter of nanoparticles in wastewater; this has been shown in previous modeling of other nanomaterials such as titanium dioxide. But one possible scenario in which such high concentrations of nanomaterials might be found is an industrial accident or some kind of spill, Wiesner comments.

The researchers say that they needed such high concentrations for adequate detection levels at timescales that simulated the residence time of wastewater during treatment. "We wanted to be able to reproduce the behavior of nanoparticles over that critical time period," Jarvie says. King adds that the small-angle neutron scattering detection method is sensitive enough to show that there were no interactions among the nanoparticles themselves or dissolution of their silica shells; he says this means that the nanoparticles used by the team would have behaved like commercial silica nanoparticles.

Wiesner comments that the structure of the nanoparticles used in the team's experiments may not accurately represent those that would be used in commercial products or pure silica nanoparticles. "Having said that," Wiesner continues, "the thinness of the [silica] shell is of interest [for] the possible effects it might have." Thin gold shells around quantum dots, for example, are used in particles for tumor treatments, and the surface interactions with the gold govern the behavior of the nanoparticle. If, for example, the core is suddenly exposed, the particle would behave very differently.

How these particles would fare in wastewater is a question for further exploration, Wiesner says: "It's hard to say what would happen in a full-scale waste-treatment process." Add bacterial growth, increased nanoparticle–bacteria interactions, and the generation of material by microbes during secondary treatment, and those microbes are "likely to have an enormous impact on the material," he says.

The true contribution of the new work may be advancing the use of small-angle neutron scattering methods that are capable of measuring nanomaterials in complex matrices such as sewage effluent. If the team has made quantitative measurements of their test particles in wastewater, recording exactly what they put into the complex matrix, Wiesner says, "that would be a significant accomplishment."

Jarvie and colleagues tested the behavior of silica nanoparticles during wastewater treatment.
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