Particle size matters to bacteria ability to immobilize heavy metals

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One of the most common bacteria in the Earth, Shewanella oneidensis MR-1, uses oxygen as an energy source for respiration. But in the absence of oxygen, Shewanella uses (oxy)hydroxide minerals. These metal particles may also have adsorbed heavy metals on them. As a result, Shewanella influence the mobility and bioavailability of iron and environmental contaminants like lead, cobalt, and arsenic.

Ph.D. student Saumyaditya Bose and Professor Michael Hochella Jr., both in geosciences in the College of Science at Virginia Tech, and their research colleagues at Pacific Northwest National Laboratory (PNNL), are looking at how the size of iron oxide nano particles influences the bacteria's ability to breathe. This is the first study by any group that couples environmental microbiology and nano-mineralogy.

"This adds to our understanding of how nanoparticles might influence the environment and contaminant metal mobility in our rivers, lakes and other surface waters, as well as groundwater," said Bose.

He will present the research at the 232nd National Meeting of the American Chemical Society on September 10-14 in San Francisco.

Using iron oxide nanoparticles (less than 100 nm), which are common and the most used transition metal oxide for bacterial respiration, the researchers are looking at the interfacial reactions between the whole bacterial cell and the particles to determine the influence of mineral size on microbial reduction rates at the nanoscale. The researchers are looking at microbial reduction of nano hematite, which Bose synthesized in the lab and characterized.

"Nano particles of iron oxides are present everywhere and, due to their small size but large surface area, they provide bacteria a large amount of reactive sites," said Bose. "These particles are reduced by biological and non-biological methods. Different metals, including toxic heavy meals, are adsorbed onto these nanoparticles. When the iron oxides precipitate, they absorb the metals. When they dissolve, they release the metals. We see that larger particles are more quickly reduced and dissolved than smaller particles."

The researchers have determined that for respiration the bacteria prefer larger nanoparticles – about 100 nanometers – to smaller nanoparticles (less than 20nm) of similar shape. The reasons are still under investigation.

Nanoparticles have properties that differ from larger chunks of the same material. Physicists and chemists have been trying to describe the changes in physical and chemical properties of nanoparticles for some time but little work has been done to describe the effect of nanoparticles on natural environments where they interact with microorganisms. This effort by the Virginia Tech team is addressing one component of a wider effort by various scientists led by a PNNL team in looking at the fundamental mechanisms of metal reduction by Shewanella and its application in environmental bioremediation of contaminated DOE sites. "It will help build a whole picture of Shewanella – how it reacts with metal oxides and how the rate of this interaction is influenced by size" Bose said.

So far, the research shows that particles of similar shape but different size down to 10 nm show a 10-fold difference in bioreduction rates. Smaller nanoparticles show a lower rate of reduction than larger nanoparticles after normalized to surface area. That is, the bacteria will reduce 100 nm particles much faster than smaller particles. "This study provides the groundwork for further investigations looking into the influence of particle size in bioreduction rates of various metal oxides ," Bose said.

Source: Virginia Tech

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