New method of studying environmental toxins

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View of the TVA Kingston Fossil Plant fly ash spill. Work using X-ray beams is clarifying how pollutants bind or release from solid surfaces and move into groundwater. Credit: Stanford University

In 1986, Gordon Brown used SLAC's Stanford Synchrotron Radiation Lightsource (SSRL) to visualize something no one had ever seen before: the exact way that atoms bond to a solid surface. The work stemmed from a eureka moment that Brown had during the doctoral defense of graduate student Kim Hayes but has since grown into one of the seminal works in inorganic geochemistry, and even spawned a new field of study—molecular environmental science.

Knowing how charged ions interact with solid surfaces is crucial for understanding how toxic metal ions such as lead, arsenic and mercury or radioactive elements such as uranium may be released from particles in soils and sediments and into groundwater or vice versa. Using the techniques Brown's team helped pioneer, scientists today can paint exquisitely detailed pictures of how metal ions bind to different solid surfaces, including those on nanoparticles.

"You can determine what other atoms are around the pollutant ions of interest, the inter-atomic distances separating them and the number and types of chemical bonds that keep them bound to the surface," says Brown, a professor of geological sciences and of photon science. "This is crucial for understanding how easily they move from one place to another."

Synchrotron-generated X-rays like those produced at SSRL are ideal for this type of investigation for a number of reasons, says John Bargar, a senior scientist at SLAC and Brown's former PhD student. For one thing, synchrotron X-rays are highly focused, much like laser beams. "All of the photons produced are condensed into either a pencil beam or a narrow fan," Bargar says. "That means you can use nearly all of the photons that you're making with very little waste."

Another advantage of synchrotron X-rays, Brown says, is that their extremely high intensity makes it possible to detect and study pollutant ions at the very low concentration levels typically found in many polluted environmental samples.

Moreover, synchrotron X-rays are polarized, meaning their waves vibrate primarily in a single plane. By modifying the direction of polarization, scientists can create very powerful probes for studying chemical bonds in molecules.

"A metal ion sitting inside a larger molecule is surrounded by many bonds. Oftentimes, we don't want to interrogate all of those bonds at once," Bargar says. "With polarized X-rays, we can selectively interrogate the bonds in a specific orientation."

Recently, Brown and Bargar have collaborated to study how organic matter and live microbial organisms affect the binding affinities of different environmental pollutants to solid surfaces. Bargar and Brown are also investigating ways to harness bacterial aggregations called biofilms to neutralize the effects of environmental pollutants. In addition, they are also using synchrotron X-rays at SSRL to look for more efficient ways of safely extracting oil and gas from tight shales via hydraulic fracturing, a process that is transforming the energy landscape of the United States.

"The X-ray beams synchrotrons are able to generate today are about 15 orders of magnitude brighter than what was available when I was a graduate student. This has led to a revolution in all areas of science and engineering," Brown says. "I could collect the data for my entire PhD thesis in one morning at SSRL now."

Provided by Stanford University

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