Synchrotron Tackles Earthy Issues for the Environment

X-ray vision is helping Australian researchers tackle some serious environmental challenges.

Have you heard the one about the fish that didn't get away? Major fish kills in northern NSW have concerned farmers, fishers and scientists for years. The recent revelation of an unexpected form of aluminium released from acid sulfate soils could help solve some of their frustrations.

Formed under waterlogged conditions, acid sulfate soils contain iron sulfide minerals such as pyrite. When exposed to oxygen, these minerals react to form sulfuric acid, which releases toxic concentrations of iron, aluminium and heavy metals from the soil.

Acid sulfate soils are associated with serious water quality problems, harmful algal blooms and aquaculture destruction in tropical and subtropical regions around the world. In some parts of South-East Asia, acidification due to acid sulfate soils and sediments has released toxic levels of arsenic into previously-potable groundwater, potentially affecting millions of people. Similar problems are emerging in Australia as a result of higher groundwater extraction rates in drought conditions.

In coastal NSW and Queensland, disturbed acid sulfate soils have devastated local commercial fishing, damaged aquatic ecosystems and promoted harmful algal blooms. The estimated cost is over $200 million per year.

The Tweed River in NSW received widespread public attention in 1987 when heavy rains following drought conditions created a toxic river environment that killed hundreds of thousands of fish. While fish kills still occur, their severity has been substantially reduced by improved land management and changes to sugarcane farming practices.

For the past few decades, scientists have believed that aluminium solubility in acid sulfate soils was controlled by a very rare mineral called jurbanite ($AlSO_4(OH).5H_2O$). Suspicious of this diagnosis, Richard Collins, Adele Jones and David Waite from the University of NSW used X-ray absorption spectroscopy on the soft X-ray beamline at the Australian Synchrotron to compare their natural materials with reference samples.

The synchrotron data conclusively showed that the natural materials contained not jurbanite but basaluminate ($Al_4(OH).10SO_4.5H_2O$). What looks like a subtle difference in the relative proportions of the different elements has serious consequences. For the same quantity of aluminium, basaluminate generates roughly 2.5 times as much acidity as jurbanite – and 2.5 times as much lime is needed to neutralise it.

A fishy business: environmental problems affect everyone.

Photo: University of NSW

"We use a lot of different research techniques in our field studies and fundamental laboratory studies, but synchrotron XAS is the only technique that can definitively identify the specific mineral forms we're investigating," Collins said. "Now we know which minerals to focus on."

The team's latest findings suggest that aluminium and iron transport and transformation processes in the Tweed River estuary could help explain why fish kills still occur in the estuary. They will return to the synchrotron again soon to conduct further experiments.

Another "down-to-earth" research group using the synchrotron is looking at smectites, layered clay minerals used as environmental barriers for landfill, including wastes contaminated with heavy metals or radioactive materials. Will Gates, John Cashion and Rosalie Hocking from Monash University are using soft X-ray and far-infrared spectroscopy to find out how minute changes in chemical composition affect the behaviour of smectites.

Meanwhile, Don McNaughton from Monash University has his sights on a loftier subject: the behaviour of atmospheric gases implicated in global warming or capable of interacting with the ozone layer. Don and his colleagues are using a special cryogenic gas cell to study the high-resolution spectra of these gases on the far-infrared beamline.

Further afield, synchrotron techniques helped resolve some major environmental concerns associated with transforming a former US nuclear weapons plant near Denver, Colorado, into a wildlife reserve. X-ray absorption spectroscopy confirmed the main form of plutonium present in Rocky Flats soils, and revealed erosion rather than water-soluble transport as the main process governing the movement of plutonium on the site.

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