

# Radioactive 'stick-in-the-muds'

Microbes could help clean up our legacy of nuclear contamination, say Kath Morris and Jon Lloyd.

The UK produces about 20 per cent of its electricity by nuclear power. Although this will decline to only 4 per cent by 2025 (as our nuclear reactors reach the end of their working lives), uncertainties over future energy supply mean that nuclear power may be back on the energy agenda. We also reprocess spent nuclear fuel, using chemical separation techniques to isolate plutonium, highly radioactive fission products and uranium. Whatever we do in the future, our nuclear reactors and reprocessing plants have already left us a legacy of radioactive wastes and contaminated industrial sites that need to be dealt with.

One of the most significant contaminants from that legacy is the radionuclide technetium-99, which is an abundant fission product and, in certain conditions, can move quickly through the environment.

Technetium-99 emits radioactivity in the form of beta particles, and spent nuclear fuel can contain substantial quantities of technetium, which, with a half-life of 213,000 years, will essentially be around 'forever'. Authorised discharges from the Sellafield nuclear power station have released technetium-99 into the Irish Sea, causing intense public concern. Technetium is also found where radioactive materials have been processed and stored, for example, in groundwaters at Sellafield in the UK, and at a number of sites in the United States.

When there's plenty of oxygen about, technetium-99 forms technetium (VII), which is very soluble and is one of the most mobile of radionuclides in the environment. The liquid effluent from Sellafield is released into the Irish Sea, in the presence of plenty of oxygen, so you might expect technetium (VII) to disperse quickly. But studies in nearby sediments suggest that some of the technetium sticks

to the mud, and that it has been stuck, in some cases, for decades. Where the technetium is, and how it is sticking to muds, is key to understanding its environmental impact. The fact that it sticks to sediments in the Irish Sea was a surprise. Clearly, we need to understand what is happening, and whether it will

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adversely affect people's lives. And if we understand why technetium is 'sticky', perhaps we can use this information to stop radioactive contamination at nuclear sites moving below ground.

So we decided to use mud from the Humber estuary to find out why

technetium-99 sometimes gets stuck in the mud. We thought it might have something to do with how technetium-99 responds as low-oxygen (anoxic) conditions develop in marine and near-shore sediments, because where oxygen is absent or limited, technetium (IV) usually forms, which isn't very soluble.

We took some surface mud from the estuary into our laboratory, covered it with water containing technetium (VII), and put a cap on the experiment to stop air getting in. Micro-organisms in the mud quickly used up all the oxygen, making way for microbes that can 'breathe' without oxygen (by using chemical oxidants or 'electron acceptors'). Some of these use iron, reducing it from its rusty orange iron III form to the greeny/black iron II form, which accumulated in the mud—something we could measure. While these anoxic conditions developed, technetium (VII) was being moved from the water to the sediments, and stayed there. It seemed that bacteria were mediating in what happened to the technetium.

To check this, we killed the microbes

*Sellafield nuclear power station.*



### Want to know more?

The work described here has been published in *Environmental Science and Technology*, vol. 39, pp4109–4116 and further details of our work can be found at: [www.see.leeds.ac.uk](http://www.see.leeds.ac.uk) and [www.seaes.manchester.ac.uk](http://www.seaes.manchester.ac.uk). You can find out more about the legacy of radioactively contaminated industrial sites in Britain from the Nuclear Decommissioning Authority's website, [www.nda.gov.uk](http://www.nda.gov.uk).

The Committee on Radioactive Waste Management (CoRWMM) is an independent committee appointed by the UK Government to review ways to manage UK radioactive wastes. Read more at [www.corwm.org](http://www.corwm.org).

The government recently consulted the public about energy policy. You can find out more about that at [www.dti.gov.uk/energy/review](http://www.dti.gov.uk/energy/review).

Sampling in the Humber estuary.



R. J. G. Mortimer

by heating them. The technetium removal stopped. And when we sterilised the mud, then added pure cultures of micro-organisms that convert iron III to iron II, technetium was again removed from the water.

When we investigated which bacteria were growing in the mud, we found extremely diverse communities that remained unchanged over several months, even when the sediment geochemistry had altered significantly. It seems the Humber mud, rich in organic material, is a haven for particularly complex microbial communities.

But what happens to the technetium (VII)? To find out, we went with our radioactive samples to the Daresbury Synchrotron Radiation Source laboratory to do X-ray absorption spectroscopy experiments. We'd used relatively low concentrations of technetium in our laboratory, but the new experiments needed much more, so we had to design special equipment to hold the samples safely. The experiments showed that the technetium gets converted to technetium (IV) dioxide, which isn't soluble in water,

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and so gets locked up in the mud.

We've now looked at a range of different sediments from normal and contaminated environments. Each time, we've seen that technetium (VII) becomes technetium (IV) dioxide and is precipitated out of solution as oxygen gets used up and iron-reducing conditions develop.

Where locking contamination into a particular place helps clean-up operations, for example, getting technetium (VII) contamination out of groundwater by holding it in a treatment zone in the ground, getting microbes to do the job might be very useful—and cost effective. We are already looking at the potential for this approach. We're assessing the best conditions for removing technetium (VII)

and uranium (VI) from contaminated groundwater by adding organic carbon to stimulate key metal-reducing bacteria in sediment/water mixes.

Our work with technetium emphasises that to understand the fate of radionuclides in sediments we need to draw on scientific disciplines that range from classic microbiology, through radionuclide geochemistry, to powerful spectroscopic techniques. Whatever you think of nuclear power in the future, we've already inherited a radioactive legacy and we need such research to help us deal with it. Our team is now, with the help of NERC funding, beginning to study the biogeochemical behaviour of extremely hazardous radionuclides, such as plutonium and neptunium.

Kath Morris is an environmental chemist at the University of Leeds and Jon Lloyd is a geomicrobiologist at the University of Manchester. [k.morris@see.leeds.ac.uk](mailto:k.morris@see.leeds.ac.uk); [j.r.lloyd@man.ac.uk](mailto:j.r.lloyd@man.ac.uk). The work described here was funded by NERC, the Council for the Central Laboratory of the Research Councils, and the United States Department of Energy.