Thorium: Proliferation warnings on nuclear 'wonder-fuel'

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Thorium is being touted as an ideal fuel for a new generation of nuclear power plants, but in a piece in this week's *Nature*, researchers suggest it may not be as benign as portrayed.

The element thorium, which many regard as a potential nuclear "wonder-fuel", could be a greater proliferation threat than previously thought, scientists have warned.

Writing in a Comment piece in the new issue of the journal, *Nature*, nuclear energy specialists from four British universities suggest that, although thorium has been promoted as a superior fuel for future nuclear energy generation, it should not be regarded as inherently proliferation resistant. The piece highlights ways in which small quantities of uranium -233, a material useable in nuclear weapons, could be produced covertly from thorium, by chemically separating another isotope, protactinium-233, during its formation.

The chemical processes that are needed for protactinium separation could possibly be undertaken using standard lab equipment, potentially allowing it to happen in secret, and beyond the oversight of organisations such as the International Atomic Energy Agency (IAEA), the paper says.

The authors note that, from previous experiments to separate protactinium-233, it is feasible that just 1.6 tonnes of thorium metal would be enough to produce 8kg of uranium-233 which is the minimum amount required for a nuclear weapon. Using the process identified in their paper, they add that this could be done "in less than a year."

"Thorium certainly has benefits, but we think that the public debate regarding its proliferation-resistance so far has been too one-sided," Dr Steve Ashley, from the Department of Engineering at the University of Cambridge and the paper's lead author, said.

"Small-scale chemical reprocessing of irradiated thorium can create an isotope of uranium – uranium-233 – that could be used in nuclear weapons. If nothing else, this raises a serious proliferation concern."

Thorium is widely seen as an alternative nuclear fuel source to uranium. It is thought to be three to four times more naturally abundant, with substantial deposits spread around the world. Some countries, including the United States and the United Kingdom, are exploring its potential use as fuel in civil nuclear energy programmes.

Alongside its abundance, one of thorium's most attractive features is its apparent resistance to nuclear proliferation, compared with uranium. This is because thorium-232, the most commonly found type of thorium, cannot sustain nuclear fission itself. Instead, it has to be broken down through several stages of radioactive decay. This is achieved by bombarding it with neutrons, so that it eventually decays into uranium-233, which can undergo fission.

As a by-product, the process also produces the highly radiotoxic isotope uranium-232. Because of this, producing uranium-233 from thorium requires very careful handling, remote techniques and heavily-shielded containment chambers. That implies the use of facilities large enough to be monitored.

The paper suggests that this obstacle to developing uranium-233 from thorium could, in theory, be circumvented. The researchers point out that thorium's decay is a four-stage process: isotopically pure thorium-232 breaks down into thorium-233. After 22 minutes, this decays into protactinium-233. And after 27 days, it is this substance which decays into uranium-233, capable of undergoing nuclear fission.

Ashley and colleagues note from previously existing literature that protactinium-233 can be chemically separated from irradiated thorium. Once this has happened, the protactinium will decay into pure uranium-233 on its own, with little radiotoxic by-product.

"The problem is that the neutron irradiation of thorium-232 could take place in a small facility," Ashley said. "It could happen in a research reactor, of which there are about 500 worldwide, which may make it difficult to monitor."

The researchers note that from an early small-scale experiment to separate protactinium-233, approximately 200g of thorium metal could produce 1g of protactinium-233 (and therefore the same amount of uranium-233) if exposed to neutrons at the levels typically found in power reactors for a month. This means that 1.6 tonnes of thorium metal would be needed to produce 8kg of uranium-233. They also point out that protactinium separation already happens, as part of other chemical processes.

Given the need for access to a research or power reactor to irradiate thorium, the paper argues that the most likely security threat is from potential wilful proliferator states. As a result, the authors strongly recommend that appropriate monitoring of thorium-related nuclear technologies should be performed by organisations like the IAEA. The report also calls for steps to be taken to control the short-term irradiation of thorium-based materials with neutrons, and for in-plant reprocessing of thorium-based fuels to be avoided.

"The most important thing is to recognise that thorium is not a route to a nuclear future free from proliferation risks, as some people seem to believe," Ashley added. "The emergence of thorium technologies will bring problems as well as benefits. We need more debate on the associated risks, if we want a safer nuclear future."

The researchers are: Dr Stephen F. Ashley and Dr. Geoffrey T. Parks from the University of Cambridge; Professor William J. Nuttall from The Open University; Professor Colin Boxall from Lancaster University; Professor Robin W. Grimes from Imperial College London.

Copies of the comment piece in this week's Nature are available on request. Interviews with Dr Steve Ashley can also be arranged by contacting Tom Kirk.

More information: Nuclear energy: Thorium fuel has risks, DOI: 10.1038/492031a

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