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Captain thorium to the rescue

How one NWU nuclear engineer is rethinking thorium and South Africa's role in the atomic energy future.

By Tiana Cline

Most people have never heard of thorium. Even fewer realise that this little-known element could play a major role in shaping the future of nuclear energy. It's not uranium, it doesn't work alone and it's not always a part of the nuclear weapons conversation...and that's what makes it so interesting.

Dr Marina du Toit's path into nuclear engineering wasn't linear. Her entry into the field was a mix of curiosity and coincidence: a chemical engineering degree at North-West University (NWU), a bursary from Eskom and a final-year project on hydrogen, steered her towards high-temperature reactors. This introduced her to nuclear science and, a few more research twists later, she was doing her Master's in nuclear engineering. Her interest, from the start, was less about reactors and more about the fuel that powers them. Today, Du Toit is an associate professor at NWU researching thorium as an alternative nuclear fuel. She's now working on building simulations of how these nuclear fuels behave inside reactors, looking for ways to make them safer and more efficient.

Fissionable, not fissile

Thorium, element 90 on the periodic table, is found in abundance in South Africa. But unlike uranium-235, which occurs naturally, thorium-232, its most common form, cannot sustain a nuclear chain

> If electricity was introduced by means of the electric chair, nobody would have voted for using it.
> Dr Marina du Toit, North-West University

The Steenkampskraal Monazite Mine in the Western Cape is set to restart operations in 2026.

reaction on its own. Or, in other words, it's not fissile. But when thorium-232 absorbs a neutron, it becomes uranium-233, which is a fissile material. This makes thorium fissionable, not fissile, which is a subtle but important difference. Du Toit explains that thorium has to be used with another fissile material to start the reaction, but, once it's in the reactor, it can absorb neutrons and turn into something that is fissile. "The advantage of thorium is that you don't stockpile material with which you can make bombs," Du Toit says. "You can actually burn the current stockpile of plutonium by mixing it with thorium." This means thorium reactors lower the risk of nuclear weapons proliferation because they can be used to reduce existing plutonium stockpiles.

But because nuclear fuel experiments are costly, Du Toit and her team use simulations to model what happens inside a reactor. These multi-physics simulations combine neutronics (how neutrons behave), thermal hydraulics (how heat moves) and fuel performance (how materials degrade or swell). In the past, she says, researchers were looking at these factors in isolation, but now the research looks at the connection between the models. "All three have to talk to one another," she says. "If you don't know what the temperature distribution is, it affects the answers in your neutronics, and to know how your fuel swells, you also need to know the temperature."

Confusion, coal and clarity

South Africa's mineral wealth makes it a thorium hotspot. It's commonly found in monazite, a mineral present in rare earth deposits. It's also found in coal ash, a byproduct of burning South Africa's mineral-rich coal. "We're literally throwing away thorium in our ash," says Du Toit. "It's there in large quantities." But separating thorium from ash or ore is complex, and it can also decay into more radioactive materials, requiring shielding and careful handling. This is one of the reasons why Steenkampskraal's Monazite Mine operations were paused. But the raw potential is there.

FROM ROCK TO REMEDY

Thorium isn't just a power source; it's a part of a new wave of cancer treatments. Thor Medical, a Norwegian company, is pioneering therapies that use thorium's radioactive decay to destroy cancer cells, and it's sourcing it from South Africa. Under a memorandum of understanding, Thor Medical will receive thorium feedstock from Steenkampskraal Monazite Mine to manufacture targeted alpha therapy drugs. These drugs attach radioactive isotopes to antibodies that target tumours, allowing thorium's high-energy alpha particles to damage cancer cells while sparing healthy tissue. Because alpha particles have a short range, they're ideal for treating micro-metastases with minimal side-effects. The result is a potential revolution in nuclear medicine: precision radiotherapy powered by minerals once seen as waste. South Africa, by supplying thorium to this pipeline, is part of a global innovation story that stretches from deep underground to cutting-edge cancer clinics.

Public opinion is still one of nuclear's biggest challenge, and accidents such as Fukushima and Chernobyl have not been forgotten even though modern reactor designs are much safer. Some, like the pebble bed or molten salt reactors, are passively safe because they shut themselves down without human intervention. Du Toit says that there have been about four serious nuclear accidents, and each one was serious enough that the whole world noticed. She points out that with other energy sources, like pumped water schemes, accidents happen far more frequently...just without the global spotlight.

"Unfortunately, the way nuclear was introduced in the market was through bombs. If it was about making electricity, there would be a completely different opinion," she says. "Somebody once said that if electricity was introduced by means of the electric chair, nobody would have voted for using it."

HOW NUCLEAR ENERGY ACTUALLY WORKS

There's a big gap between the idea of nuclear and how it actually works. At its core, nuclear power is just a high-tech way to boil water. Inside a reactor, uranium or thorium fuel undergoes fission, a process that splits atoms and releases heat. That heat is used to convert water into steam, which then spins turbines to generate electricity. The difference lies in how that heat is generated and managed. Traditional pressurised water reactors, like South Africa's Koeberg, rely on enriched uranium. "The reactor that we have at Koeberg is similar to a coal power station," says NWU's Dr Marina du Toit. "The only difference is your fuel source. You burn coal to heat up water, but in Koeberg, you have the nuclear reaction that heats up the water to spin the turbines." These reactors are efficient but also produce radioactive waste that requires complex cooling systems. High-temperature reactors use helium gas instead of water, which makes them passively safe. So even if there's a failure, the system shuts down without melting. Then there are molten salt reactors, where the fuel is mixed into a liquid salt and can be drained away in an emergency. Each design has its own strengths, and thorium, because it burns longer and produces less long-lived waste, fits naturally into many of them.

NWU is the only university in Africa offering a full nuclear engineering programme. Du Toit supervises students from across the continent and is South Africa's principal investigator for the International Atomic Energy Agency (IAEA) projects that are rethinking fuel modelling with a focus on safety and accuracy. "Sometimes these predictions are so conservative that if you run the models, you actually get bad results," she says. "But every time something happens, we just come back stronger. We cannot predict what can go wrong, but we learn and improve."