Physical Sciences | Paolo Finocchiaro

Providing better radiation monitoring for nuclear waste

Despite the immense potential benefits of nuclear power, many people are understandably concerned about the dangerous radioactive waste (or radwaste) it generates. To provide reassurance that nuclear waste is being safely stored, Dr Paolo Finocchiaro and colleagues at Italy’s National Institute of Nuclear Physics (INFN) have developed an advanced new system for monitoring the material’s radioactivity in real-time. Using distributed networks of robust sensors, their radiation monitoring system accurately detects the presence of various radioactive substances in simulations and tests, a capability the team hope to expand to real-world scenarios in future research.

Within cores of enriched radioactive material, unstable atomic nuclei spontaneously decay, transforming into different nuclei and emitting radiation in the form of helium nuclei (α, or alpha particles), electrons, and high-energy gamma rays. A particular type of decay is nuclear fission, where a heavy nucleus splits apart into a pair of smaller nuclei and emits gamma rays and two to three neutrons.

If carefully controlled, this radiation can be used in a wide range of applications, from targeted cancer therapy to detailed imaging of microscopic systems. Alternatively, initiating fission inside a nuclear reactor by means of neutrons can provide an abundant source of carbon-free energy. Yet despite the clear advantages they bring, technologies based on nuclear fission are well known for the dangers they present if stringent safety precautions aren’t taken.

Among the most pressing concerns is the generation of nuclear waste. Nuclear waste is usually a by-product of nuclear fission reactors, but it can also be generated through industrial processes and medical applications. The problem here is that the nuclei resulting from fission are typically radioactive themselves, and will only decay into less harmful substances over a certain period of time—which can vary significantly depending on the material’s composition.

“Unfortunately, the timescales we are talking about can range from a few hours to years for medical and industrial radioactive waste; and up to tens of thousands of years for high-level waste from nuclear fission reactors,” describes Dr Paolo Finocchiaro from Italy’s National Institute of Nuclear Physics (INFN).

This material would be incredibly harmful if exposed to human populations or natural ecosystems due to its radioactivity. As a result, it can only be managed and transported by the most qualified experts, with strict radiation monitoring protocols, and must be sealed away in some of the most secure locations on Earth—completely sealed off from the outside world.

“As mishandled radioactive waste could contaminate the environment or, far worse, be used for the production of weapons, there are now regulations and technologies to make sure the waste is handled safely,” Finocchiaro continues.

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Finocchiaro’s team, within the MICADO project, has set up a system demonstrator that will shortly be installed in real storage scenarios to monitor radwaste.

As Finocchiaro explains, both SiLiF and SciFi would need to satisfy a stringent set of requirements. ‘In order to be suitable for mass deployment, these detectors have to be compact, reasonably inexpensive, robust, easy-to-use, and reliable,’ he says. ‘The sensors we describe possess all of these features.’ Having probed SiLiF’s responses using artificial sources and neutron beams, the team estimated that a distributed network of the sensors would be sensitive to small amounts of highly radioactive plutonium inside a drum of nuclear waste. In parallel experiments, an array of SciFi detectors were able to locate radioactive isotopes emitting gamma rays.

PROVIDING REASSURANCE

Building on the successes of these initial tests, Finocchiaro’s team are now going to apply both sensors to monitoring waste in real storage scenarios. By surrounding drums of nuclear waste with arrays of SiLiF and SciFi sensors, they aim to gather accurate information about any change occurring inside that would indicate possible anomalies.

This kind of monitoring is currently performed manually at long time intervals, whereas the proposed automatic real-time monitoring system will improve the data quality while minimising the risk to the operators. Moreover, in the event of an unlikely accident, a real-time alarm would prevent severe consequences by alerting operators to early signs of anomaly.

Alongside MICADO, the potential for this technology is also being explored by two additional EU-powered projects: named Pre-disposal Management of Radioactive Waste (PREDIW), and Cyber Physical Equipment for Unmanned Nuclear Decommissioning Measurements (CLEANDEM).

With such a high level of support, the researchers hope that the real-world application of their approach may not be too far away. If achieved, this could enable the operators of nuclear waste sites to glean continual streams of accurate and detailed data in safer operating conditions, rather than relying entirely on periodic inspections.

These more robust techniques could provide the public with extra reassurance that nuclear waste is being safely monitored – potentially providing more governments with the confidence they need to expand their rollout of nuclear power. In turn, the technology may provide a small but important step towards the more widespread adoption of nuclear power, expanding what has so far remained one of the most under-used tools for reducing our greenhouse gas emissions.

References


Personal Response

How might your sensor systems detect that something has gone wrong during waste storage and transport?

Three or four detectors of each kind, suitably arranged around a drum, count the number of outcoming neutrons and gamma rays per unit time. Any change occurring in counting rate, ie, asymmetry between the detectors’ behaviour, hint at a change occurred in or to the drum: corrosion, cracks, internal displacement of the content, or tampering.