'Nuclear-powered' missile accident in Russia: What really happened?

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Credit: AI-generated image (disclaimer)

A missile engine exploded at a naval test range, west of the city of Severodvinsk on Russia's northern coast at 9am on August 8. At least five people were killed and several others injured. As it is associated with Russia's defense program, the incident is shrouded in mystery. But shortly after the explosion the state weather monitoring agency, Roshydromet, reported a spike in radiation 40 km away.

At first, the Russian authorities denied the radiation leak, then later confirmed it. There were conflicting reports of the source of the explosion and a planned, then later canceled evacuation of a nearby village. Unsurprisingly, tabloid media speculation followed that the Russian authorities may be hiding a Chernobyl-like accident.

Missile tests don't usually involve radioactive materials, unless the missile in question is carrying a nuclear warhead (which is prohibited under the UN's Treaty on the Non-Proliferation of Nuclear Weapons). So what is going on? No one outside of the Russian government and military can yet be entirely certain but, as an academic researcher in nuclear materials, I can do my best to piece together the available evidence.

Russian authorities have confirmed that the explosion involved "an isotope power source in a liquid propulsion system". There's nothing particularly new about the propulsion system—early ballistic missiles used a pressurized stream of liquid fuel and oxygen which, when ignited, expanded and rushed out of the bottom of the missile, propelling it in the opposite direction.

The "isotope power source" part is new though. Radioactive isotopes are unstable atoms that release excess energy by emitting radiation. So if the missile is powered by isotopes this indicates the Russians have developed a mini-nuclear reactor—able to fit inside a missile—that is capable of using radiation to heat the liquid fuel for propulsion. This has never been achieved before.

Severodvinsk (red dot) is on the coast of the White Sea, just below the Arctic Circle. Credit: CIA/wiki

This admission prompted American and UK experts to conclude the source of the radiation leak must be a type of long-range missile that Russia has previously claimed would be nuclear powered. It is known by the Russians as 9M730 Burevestnik, and by NATO as the SCC-X-9 Skyfall.

The exact details of the mini-nuclear reactor that may have been developed to power a Russian missile are not known, but there are a few potential types that may be used. The key difference between a nuclear reactor used to generate energy and one that might be used to power a missile is the quantity of material required. The RBMK reactor that blew up at Chernobyl contained 200 tonnes of uranium dioxide fuel. A significantly smaller amount of fuel would be required—perhaps a few kilos at most—to lift a missile.

One possibility is what's known as a radioisotope thermoelectric generator (RTG). This converts heat from radioactive decay into electricity. Potential candidates for the fuel are plutonium-238, 4.8kg of which powered the Curiosity Rover on Mars, americium-241—widely used to power smoke detectors—and polonium-210, infamously used in the poisoning of Russian spy Alexander Litvinenko. Strontium-90, which emits both beta and gamma radiation in its radioactive decay, has been used in both American and Russian applications of RTGs in the past, including inside Russian lighthouses. Given the measured increase in gamma activity at nearby Severodvinsk, the latter is certainly plausible.

The second possibility is that the missile was powered by a nuclear thermal reactor. This is perhaps more likely given the authorities' description of the accident. These reactors could use the heat generated from radioactive decay to heat liquid hydrogen fuel. Such a system could theoretically use a solid uranium core, a liquid radioisotope core, or even gaseous uranium to power a missile in flight for long distances. However, none of these technologies have been proven, at least with regard to missiles, and it is not possible to guess the fuel type with any certainty, making the radiation in Severodvinsk difficult to explain.

Whatever the source of radiation, the release seems to be relatively small. To the layperson, 16 times above background rate may sound like a lot, but that background rate is tiny and relatively harmless—for instance the English county of Cornwall has three times the background rate thanks to naturally-occuring uranium-bearing rocks in the earth there. Compare this with the Chernobyl accident, which released radioactivity 7,000 times above background.

Norwegian and Finnish authorities are monitoring the air but have not yet reported anything abnormal. Western scientists are even asking residents of Severodvinsk to donate their car air filters, so that, at some point, we may understand more about what was released and how harmful it might be. That should give some indication as to the threat posed by the testing of such weapons.

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