Unanticipated Radioactive Repercussions

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I have been asked to provide some facts about radiation from nuclear plants.

A crippled nuclear reactor is dangerous not because it gives off invisible rays, but because it disseminates harmful radioactive pollutants. So I prefer to use the word "radioactivity" rather than "radiation".

What is radioactivity?

Radioactivity is not a thing, but a property of certain materials. While there are a handful of significant naturally-occurring radioactive elements, there are about 1000 human-made radioactive materials. Most of these were not seen in nature in measurable amounts prior to 1939. With very few exceptions, they are only created in significant quantities as byproducts of nuclear fission.

Each one of these hundreds of radioactive elements has its own particular physical and chemical properties. As a result, each one follows its own distinct ecological pathways through the environment and biochemical pathways through the body.

Every radioactive atom has an unstable nucleus that will eventually disintegrate, or explode, giving off one or two subatomic projectiles. Each such radioactive projectile comes directly from the nucleus, and is one of four kinds: an alpha particle, a beta particle, a gamma ray, or a neutron.

These projectiles are all ionizing, meaning that they are able to break molecular bonds easily, thereby killing or crippling nearby living cells. Crippled cells can sometimes reproduce, leading to a mass of rogue cells years later that we call cancer.

Alpha and beta particles are primarily internal hazards, because they are less penetrating, whereas gamma rays and neutrons are external as well as internal hazards because they are highly penetrating. A large exposure to any of these types of radioactive emissions can cause death within days or weeks, while chronic low-level exposures can cause cancers years later. Damage to eggs or sperm can lead to genetically defective offspring. Such defects can appear in the immediate offspring or several generations after the original cellular damage. Chronic exposure to radioactivity can also compromise the immune system, increase the incidence of cardiovascular diseases, cause a decrease in intelligence among young children, and accelerate the aging process. Young children and women of all ages are more vulnerable than men.

Most sources of radiation within our experience, whether ionizing or non-ionizing, can be shut off with a switch. An x-ray machine, a CAT scan, a microwave oven, a tanning bulb, all these can be turned off quickly, and once they are off they are harmless.

Not so with radioactivity. Radioactivity is a form of nuclear energy that cannot be shut off. That is why meltdowns can occur even after a nuclear reactor is completely shut down. TMI and Fukushima are examples of this. On-going radioactive disintegrations in the core provide enormous heat and drive the temperature of the fuel up to 2800 degrees C, twice the melting point of steel. At that temperature the ceramic fuel begins to melt like candle wax.

Because radioactivity cannot be shut off, the effects of radioactive contamination can be very long-lasting, leaving no-man's lands – for example around the Chernobyl site, the Fukushima site, the Marshal Islands test areas, and the site of the Kyshtym disaster over 60 years ago in the Ural Mountains of the USSR.

When it comes to radioactive waste, since radioactivity cannot be shut off or rendered harmless, waste "disposal" is actually a euphemism for waste "abandonment". Nuclear agencies say that waste disposal means that they have "no intention to retrieve" the stuff. But that is a political definition, not a scientific one. In fact there is no scientific definition of disposal. The long-term confinement of radioactive post-fission waste is an unsolved problem of mammoth proportions.

Catastrophe Potential

In 1976, British nuclear physicist Sir Brian Flowers wrote a report for the UK Government on "Nuclear Energy and the Environment". In it he pointed out that if nuclear energy had been deployed in Europe before the outbreak of WWII, large parts of Europe would be uninhabitable today because of WWII. That is because Chernobyl-like meltdowns can be brought about by acts of malice – warfare or sabotage.

It is estimated that the Chernobyl accident released about 80,000 terabecquerels of cesium-137, along with a host of other radionuclides. A becquerel is one disintegration per second, and a terabecquerel is a million million becquerels.

For 20 years after the Chernobyl accident, sheep farmers in Northern England and Wales could not freely sell their sheep meat for human consumption because of radioactive contamination by cesium-137 from Chernobyl. To this day, the meat of wild boars killed by hunters in Germany, Sweden, and Belarus is unfit for human consumption because of radioactive cesium contamination.

Cesium-137 is a beta-emitter, and it is also a powerful emitter of penetrating gamma radiation. Gamma rays are similar to x-rays, but more powerful. Accordingly, ground concentrations of cesium-137 are used to decide which areas need to be evacuated. Around Chernobyl, it is expected that land in a 30-km radius will be uninhabitable for at least 300 years. There are 2.2 million people living within 30 km of Pickering. Can you imagine all those families being permanently displaced, and that land being uninhabitable for centuries?

A single irradiated CANDU fuel bundle, freshly discharged from a Pickering reactor, can deliver a 100 % lethal dose of radiation to any unshielded human, at a distance of 1 metre, in about 20 seconds. There are over 2500 such bundles in each Pickering reactor. Moreover, there are over 400,000 irradiated bundles in the Pickering spent fuel pools, under water, containing at least 4 million terabecquerels of cesium-137. That is 50 times the amount of cesium-137 released from Chernobyl (which, as noted above, was about 80,000 terabecquerels.) These pools are not protected by thick reinforced concrete walls. If severe damage to the pools were to occur for any reason, massive amounts of radioactivity could easily escape into the environment.

To take an extreme example, if a nuclear explosion were to occur near the Pickering plant, the water in the pool would be vaporized by the fireball, the zirconium metal cladding on the fuel bundles would ignite, burning with intense heat, and lofting virtually all of the cesium-137 in the fuel bundles into the atmosphere in the form of radioactive vapours and aerosol particles. That would create a no-man's land of monumental proportions, releasing 50 times more cesium-137 than the amount released from the Chernobyl disaster.

Because there was relatively little local radioactive fallout from the Hiroshima atomic explosion, that City could be rebuilt after World War II and is now a thriving metropolis. If there had been heavy contamination of the land due to long-lived emitters of intense gamma radiation such as cesium-137, reconstruction would have been difficult or impossible. So major cesium-137 releases from Pickering's irradiated fuel pools could turn the entire Toronto area into a radioactive wasteland, remaining uninhabitable for centuries.

Long-Lasting Implications

At Fukushima, seven years after the triple meltdown in 2011, there are some 800,000 tonnes of radioactively contaminated water that the Japanese nuclear authorities would like to simply dump into the Pacific Ocean. The amount is growing every day, as TEPCO builds one new 300-tonne tank every four days, to add to the 1000 tanks it already has. The authorities have used equipment to remove about 70 different kinds of radionuclides from this heavily contaminated water, but they cannot remove the radioactive tritium. That's because radioactive tritium is chemically identical to ordinary hydrogen.

It is incredibly difficult to separate a radioactive isotope from a non-radioactive isotope of the same element, because chemically speaking they are like Siamese twins. Wherever one goes, the other one goes. Tritium is radioactive hydrogen. It forms radioactive water molecules that are identical with ordinary water molecules except for the fact that they are radioactive. No municipal water treatment plant can remove the tritium from drinking water, because you cannot filter water from water.

Because hydrogen is one of the most common elements in living things, being present in all organic molecules, including DNA molecules, radioactive tritium becomes incorporated into all living things and some fraction of it is "organically bound" into the body's molecular structures. It has been known for decades that tritium is at least 3 times more biologically harmful than gamma radiation, per unit of energy absorbed by tissue, but our nuclear regulator, the CNSC, pays no attention to that scientific fact. In addition, two independent scientific advisory bodies appointed by the Government of

Ontario have found that the permissible levels of tritium in drinking water are currently 350 times too high (compared with other cancer-causing agents that are regulated) -- but again, our nuclear regulator pays no attention to such inconvenient scientific truths.

The example of tritium points to a larger problem. Nuclear fission creates radioactive versions of many elements that are otherwise non-radioactive, such as cesium, strontium, nickel, silver, cobalt, iron, calcium, and many more. Once these radioactive varieties are disseminated into the environment, they become inseparable from the non-radioactive varieties. While most of the naturally-occurring radionuclides – like uranium, thorium, radium, and polonium – are chemically distinct from non-radioactive materials and can therefore be separated out by chemical means, such is not the case with the deluge of human-made radioactive elements created by fission.

Already it is proving very difficult to find uncontaminated metals with which to fabricate radiation monitors such as Geiger counters. Evidently, if the metal from which the monitor is made is already radioactive, it will interfere with the operation of the monitor – making it increasingly difficult to determine where the radioactive emissions are coming from.

There are many other important topics about radioactivity, but time does not permit. I'll just mention two:

(1) Half-lives can be deceptive, as some radioactive materials become more radioactive as time goes on, not less. Examples include radon gas and depleted uranium. Even irradiated nuclear fuel, which decreases in radioactivity for the first 50,000 years, eventually increases in radiotoxicity after that period of time. Plutonium has a 24,000 year half-life, but when it disintegrates it is transformed into another radioactive element with a 700 million years half life. So half-lives can be deceptive.

(2) Some radioactive materials are very difficult to detect, even in a well-equipped nuclear plant, because they give off non-penetrating alpha or beta radiation – yet they can be extraordinarily dangerous. Examples are beta-emitting carbon-14 dust, which workers at Pickering tracked into their homes in the 1980s, and alpha-emitting plutonium dust, which over 500 contract workers inhaled on a daily basis for almost three weeks at Bruce in 2009.