The threat of radioactive substances in its civilizational context

Radioactivity Around Us

Assoc. Prof. Jerzy W. Mietelski is chief of the Environmental Radioactivity Laboratory at the PAN Institute of Nuclear Physics

JERZY W. MIETELSKI
Henryk Niewodniczański Institute of Nuclear Physics
Polish Academy of Sciences
jerzy.mietelski@ifj.edu.pl

The fear of radioactive contamination is one of the anxieties that are part and parcel of modern civilization. Mankind's biologically-coded way of reacting to such fears is twofold: "fight or flee." The natural reaction is to take immediate action

The biological purpose of fear, like pain, is to ensure survival. Without fear, an animal would stand little chance of surviving and producing offspring. But despite the benefits of sensing fear, psychology considers fear to be a negative emotion, especially if remains present for an extended duration.

Nevertheless, fear is an inseparable part of human civilization. I once came across an assertion by a well-known sociologist, maintaining that a significant portion of well-developed countries' GDPs is generated by the collective fears of modern civilization. They motivate us to spend money to fund military weaponry, a considerable portion of scientific research, the insurance sector, security companies, a large part of the pharmaceutical industry, the justice system, the police, and even journalists.

One of the widespread fears of modern civilization is the fear of radioactive substances, or more broadly, of penetrating radiation undetectable to the senses. And we have good reason to sense such fear. We are unable to "fight" radiation, and do not know where to "flee" since our senses cannot tell us where the danger is greater or worse. Once we feel sick it might already be too late (illustrated recently by the tragic case of an intelligence agent poisoned with polonium). In the general societal impression, penetrating radiation is on par with a devious murderer who can only be dealt with by completely eliminating him from society.

Sławomir Mielnik, Agencja Gazeta

When drinking a glass of milk, we take the entirely natural radioactive potassium isotope ^{40}K into our own bodies. It has a half-life of more than a billion years, and is present everywhere on the globe in a constant proportion to stable potassium. The atoms of the isotope we absorb from drinking a glass of milk will decay at a pace of 10 per second


GAMMA/BE&W

Artificial radioactive substances have been introduced in the global environment chiefly as a consequence of atmospheric testing of nuclear weapons carried out by the nuclear powers

Yet unlike some other threats, radiation cannot be entirely eliminated from our surroundings. Everything around us, including our bodies themselves, contain trace amounts of radioactive substances. When drinking a glass of milk, we take the entirely natural ("natural" does not mean "neutral"!) radioactive potassium isotope ^{40}K into our own bodies. We constantly absorb and give off carbon ^{14}C, generated in the atmosphere by secondary cosmic radiation. These two isotopes are the main source of radioactivity in the human body, although it also contains such isotopes as ^{226}Ra, ^{228}Ra, ^{238}U and ^{234}U in concentrations more than 100 times smaller. We receive significantly more radiation from the radon (plus the products of its decay) contained in the air.

Contamination by mankind

The normal operation of a nuclear power plant introduces trace amounts of radioactive substances into the environment. But paradoxically, coal-fired electric plants actually release more radioactivity into the atmosphere, since coal contains traces of ^{40}K and uranium, thorium, and their decay products. Mines likewise release radioactivity into the environment. The Vistula River in Kraków contains 40 mBq of ^{226}Ra per liter of water. Concentrations 500 times greater are caused in certain rivers and streams in Upper Silesia by mine dumpings.

The harmfulness of radiation depends on the so-called effective dose, expressed in sieverts (Sv), gauging the risk of exposure to radiation. The average resident of Poland, throughout their life, receives an effective dose of 150–180 mSv. Over the course of a year, we receive 2.7 mSv. A one-off dose that is several hundred times greater, such as 1 Sv, causes acute radiation sickness, while a dose of 10 Sv precludes any chance of survival.

At this point the world has more than 450 nuclear reactors used to generate nuclear power. More than a dozen of them are located within 300 km of our borders. The problems related to nuclear energy, therefore, are likewise not something we can "flee."

Current measurement methods are capable of detecting extraordinarily small traces of radioactive substances. For example, after the Transit satellite, carrying a SNAP-9A isotope power supply containing slightly more than a kilogram of the plutonium isotope ^{238}Pu, burnt up in the atmosphere 50 km above the Indian Ocean in April 1964, this plutonium spent the next several years falling out of the stratosphere all around the globe. Traces of it can now be detected everywhere, from Antarctica to Poland's Tatra Mountains, even in the soil in our own backyards. Our being able to detect the traces of a kilogram of material that was dispersed worldwide nearly 50 years ago represents a sensitivity not possible for any other type of non-radioactive substance, even the most toxic.

Artificial radioactive substances in the global environment have chiefly come from the atmospheric tests of nuclear weapons carried out by the nuclear powers. A total of 400 such charges have been detonated, with a total force of some 20,000 times the bomb dropped on Hiroshima. As a result of the consequent radioactive fallout, 5600 Bq of ^{137}Cs, 4000 Bq of ^{90}Sr and some 60 Bq of plutonium isotopes are estimated to have fallen upon every square meter in Poland.

The Chernobyl catastrophe

We remember the Chernobyl catastrophe for being considerably more serious than any previous event of its sort. And it is true

The threat of radioactive substances in its civilizational context

GAMMA/BE&W

The radioactive substances released during the Chernobyl catastrophe, essentially from a single location, caused local contamination levels (within an area of tens of km²) significantly in excess of those seen at any nuclear testing site. But nowadays, more than 20 years on, we do know that vast and unprecedented efforts managed to minimize the negative health impact of the catastrophe

that the radioactive substances released at this one location caused local contamination levels (within an area of tens of km²) significantly in excess of those seen at any nuclear testing site. But nowadays, more than 20 years on, we do know that vast efforts managed to minimize the negative health impact of the catastrophe. The number of immediate casualties did not exceed 50, and the evacuation and resettlement of nearly 200,000 individuals saved some 50,000 of them from early cancer.

The Chernobyl catastrophe caused public support for nuclear energy to plummet. The special circumstances involved, meaning that this was not a typical accident that could occur at any nuclear power plant, have completely escaped public attention.

The Chernobyl plant was operating a reactor of the RBMK-1000 type, of a special design allowing plutonium to be recovered with an optimal isotope proportion for military purposes. All told, some 13 such reactors were built, and most of them continue to operate without any accident. Reconciling the two objectives with one another required a design compromise, which took its toll on safety. This type of reactor does not include a safety shield, and thus becomes unstable when operating at low power. Commissioning the RBMK-1000 reactors for use even necessitated a change in the Soviet atomic regulations, which had previously prohibited reactors that could experience such instability.

The immediate cause of the Chernobyl catastrophe was a special test carried out at the power plant, paradoxically meant to improve safety. The experiment required the reactor to operate at low power, and all five automatic safeguard systems had to be turned off. The test was meant to be carried out on the afternoon of 25 April, and the staff for that shift was trained for it. But after the daytime experiment was started the local grid controller demanded that the full power supply be reinstated and that the planned shutdown be postponed until nighttime. The abortion of the test initiated problems with the reactor's stability. In the meantime, another shift came on duty. The operator's inept attempts to stabilize the reactor, operating at low power, led to a situation that was unacceptable under the reactor's safety regulations, reducing the number of control rods to three times less than required. The reactor demonstrated its inherent design flaw, instability at low power, when power suddenly increased more than 100-fold. The resulting heat changed all the water in the cooling system into steam, rupturing it. Once reaching the graphite moderator, heated to a temperature of more than 1500°C, the steam broke down into hydrogen and oxygen, which immediately began to react with one another and boosted the strength of the explosion.

That explosion started a fire that lasted 10 days. It is estimated that 100% of gasses, some 30% of volatile substances, and 3% of non-volatile substances, such as plutonium, were released from the reactor during that time.

The radioactive cloud passed over Poland for nearly three days, although it originated only from the first 24 hours of emissions. Radioactive fallout contaminated Polish territory very unevenly. The greatest contamination with the main long-life isotope, ^{137}Cs, actually occurred in the Opole region in Poland's southwest, as a consequence of rainfall during the time when the cloud was passing through the area. This is called the "Opole anomaly," where the maximum contamination exceeded by 20 times the average deposition of the isotope following nuclear weapons tests. Generally, however, northeastern Poland is more contaminated than western or southeastern Poland. A somewhat different isotope composition was also observed in northeastern Poland. Here there was additional fallout from the explosion of somewhat larger dust particles comprised of non-volatile substances, called "hot particles." At the Institute of Nuclear Physics, Polish Academy of Sciences, we have estimated that the plutonium and ^{90}Sr contamination within this small area (the region of the Augustów Forest plus areas to the north) is about half of the contamination levels observed in Poland and throughout Europe following nuclear weapons tests.

GAMMA/BE&W

The catastrophe started by the explosion in the fourth reactor of the Chernobyl power plant on 26 April 1986 has made a lasting mark on society's memory, and caused support for the development of nuclear energy to plummet

According to CLOR estimates, residents of Poland received an average dose of 0.32 mSv in 1986. Over their lifetimes, the dose they receive as a consequence of the Chernobyl disaster is in the worst case less than 10% of the dose that they receive from natural substances present in our environment, and on average it is not quite 1% of that dose. Contrary to popular opinions, specialists agree that the Chernobyl catastrophe did not create a radiological danger in Poland.

Energy for the future?

Mankind has not yet discovered any means of economic growth that does not require increased energy production. Limited resources and CO_2 omissions make fossil fuels unsuitable to become our salvation from this energy conundrum. Alternative fuels, such as renewable or ecological ones, do offer interesting options but it is almost always debatable just how ecological they truly are. Moreover, there are political aspects to consider: by exploiting fossil fuels, we pour funding into countries that begin to desire to shape the world as they see fit. There are many signs, therefore, that we should rationally rethink our attitude towards nuclear energy. Nuclear technology is now a well-developed, routine industry which does not entail greater threats than the chemicals industry. Opting out of nuclear energy means opting out of economic growth and consenting to a lower standard of living.

However, one difficulty lies in the fact that at the same time we do have to maintain society's fear of radiation on a certain level, so as to prevent world leaders from recklessly using nuclear weapons. ■

Further reading:

Mietelski J.W. (2001). Plutonium in the environment of Poland (a review). *Plutonium in the Environment*. Ed. A. Kudo - Elsevier, 401.

Mietelski J.W., Szwałko P., Tomankiewicz E., Gaca P., Grabowska S. (2003). Geotrupine beetles (Coleoptera: Scarabaeoidea) as bio-monitors of man-made radioactivity. *Journal of Environmental Monitoring, 5*, 296–301.

Mietelski J.W., Kitowski I., Gaca P., Grabowska S., Tomankiewicz E., Szwałko P. (2006). Gamma Emitters, ^{90}Sr, $^{238,\,239+240}$Pu and ^{241}Am in Bones and Liver of Eagles from Poland. *Journal of Radioanalytical and Nuclear Chemistry, 270*, 131–135.