The deleterious effects of the nuclear crisis in Japan

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IN ITS classic form, when bombarded by neutrons, uranium 235 generates as fission byproducts barium 142 and krypton 91, besides releasing other three neutrons and generating energy in the form of heat. This can be represented by the following equation: ^{235}U + n à ^{142}Ba + ^{91}Kr + 3 n [1.9 x 10^7 kcal/g ^{235}U]. The three neutrons released collide with other uranium-235 atoms, which end up sustaining the so-called chain reaction. About 30 primary fission products are produced in this process, with half-lives ranging from 30 seconds (rhodium 106) to 30 years (cesium 137).

Among them, in addition to cesium, the most worrisome for their hazardous effects on living beings are iodine 131, barium 140 itself (12.8 days), and strontium 90 (28 years). Radioactive iodine produces several types of cancers in humans, of which the most common is thyroid cancer. Moreover, the literature reports low platelet count and consequent bleeding, lung inflammation and fibrosis, stomach and small intestine bleeding, a 50 percent decrease in white blood cells and alterations in the DNA structure (which is very serious since the individual who has been radiated will transmit genetic information to offspring). To mitigate its terrible impact, the ingestion of potassium iodide is usually prescribed, as the human body, saturated with stable iodine excretes radioactive iodine via sweat, urine and feces. The case of cesium is more complex since. When released into the atmosphere it settles on crops and contaminates for a long period of time the vegetables we eat. Radioactive cesium is potentially cancer forming in the nerve tissue. Similarly, emissions of radioactive strontium and barium are hazardous since, when ingested by mammals feeding in pastures, they adhere to the milk we consume. And this is extremely serious because, as alkaline earth metals, they adhere to human bones, which consist predominantly of calcium. And as the atomic radius of barium, strontium and calcium are of similar dimensions, atomic exchanges are very likely to occur, leading to the possibility of bone cancers because radioactive strontium or barium change places with calcium. Of course, it should be stressed that the greatest impacts are on children, since they are subject to higher growth multiplications (and speeds) and cell production.

It is worth mentioning that the classical method of cesium 137 decontamination involves the use, as a chelating agent, of the Prussian blue solution (iron ferrocyanide, whose structural formula is Fe7N18C18), so named because it was once used to dye Prussian military uniforms. In fact, when chelated, cesium forms a brown precipitate, thus proving the efficiency of the method.

Still, news of the recent nuclear accidents in Japan is highly concerning. If nearly 66 years ago the atomic catastrophe hit them from airspace, with the dropping of atomic bombs by U.S. bombers, this time it was the result of the tsunami formed at sea. It is relevant to mention that Hiroshima was devastated only on August 6, 1945, when 13 sq. km of land were destroyed and between 70,000 and 250,000 people instantly killed. However, the effect of residual radiation had killed another 80,000 people by 31 December of that same year. And to this date the residents of Hiroshima and Nagasaki who survived the bombings have stamped on their identity cards the word *hibakusha* (Japanese for "victim of the bombs").

We wish the evacuation plans in the affected regions in Japanese territory will be effective, so as to prevent new *hibakushas* from being created. Damage to the environment, however, is inevitable and inexorable. It is the high price of using nuclear fission technology that is not yet mature and that has proven a problem since the 1960s of the last century. After all, since then at least seven major nuclear accidents have occurred around the world, with heavy casualties. It is impossible, however, to quantify the number of deaths, since many of them occurred in secret nuclear facilities, actually a practice widely adopted by nations that use or develop nuclear research, always under the perfidious and meaningless argument of the urgent need to protect the so-called "State secret".

To further aggravate the imbroglio, at least one unit of the Daiichi-Fukushima nuclear complex uses MoX as fuel. MoX, the acronym for mixed oxide, is the fuel in which plutonium is one of the elements at a proportion between 3 percent and 10 percent. Plutonium is a heavy chemical element, nonexistent in nature, which was artificially created in 1940 as a byproduct of uranium processing by nuclear plants. The main and most dangerous isotopes are plutonium 238 (half-life of 88 years) and 239 (half-life of 24,000 years. Attention! You have not misread or misunderstood it. It is actually 240 centuries). This is one of the most radiotoxic and hazardous substances one has ever heard of. Suffice to say that the inhalation or ingestion of a millionth of a gram of plutonium-239 is simply fatal.

For all this dramatic history, we are compelled to postulate the most profound and sensible revisions of projects for the establishment of possible (and unnecessary, at least at the moment) new nuclear plants in Brazil.

After all, we have rainwater, our zero-cost fuel. Add to that the sheer abundance of renewable sources represented by solar, biomass, wind and tidal energy.

The non-disposable disposal of nuclear waste

The main problem of nuclear fission is the production of radioactive waste (also called nuclear waste), which can emit ionizing radiation for thousands of years. A crucial example is plutonium 238, whose half-life is 88 years. An even more dramatic case is that of plutonium 239, with a half-life of 240 centuries. *There is no practical solution to the problem; not even at the global level.* Because one cannot speed up the radioactive decay process of an isotope; its half-life needs to be respected. Part of the waste can be reused, such as the ^{239}Pu generated in reactors. And that was the option adopted by Japan's nuclear authorities to use MoX in one of the units in the Fukushima complex.

Traditionally, nuclear waste products are classified into three types: (1) HLW (High-Level Waste), which is the fuel radiated by the nucleus; (2) ILW (Intermediate-Level Waste), represented by the metallic material that came into contact with nuclear fuel or with the reactor; and (3) LLW (Low-Level Waste), which includes protective clothing, laboratory equipment or any other material that has been in contact with radioactive material.

ILW and LLW waste should be stored indoors and shielded until the radioactive activity level falls to a low environmental impact level. HLW waste, in turn, must be isolated for thousands of years. Some solutions have been suggested by researchers, including the possibility of sending nuclear waste into outer space where, at extremely high altitudes, radioactivity is even more intense. This solution, however, is hindered by the poor reliability of rocket launch, as seen in 1986 when the U.S. space shuttle Challenger exploded 30 seconds after liftoff from Cape Canaveral.

Other solutions, which are *always temporary*, involve burying high radioactivity waste in underground salt mines. That is what Germany does by supposing that, as ancient and stable geological structures, deactivated salt mines will remain intact for a long period of time. The United States, in turn, has chosen to bury its waste in desert regions. For decades the country has dumped nuclear waste in tunnels built in the Arizona desert. And the choice of Yucca Mountain (in the State of Nevada and 100 km from a populated area) as a nuclear waste repository is still the subject of heated discussions and great controversy.

Situation in Angra

In Angra dos Reis (RJ), which has two nuclear power plants in operation and a third one under construction, low-radioactivity waste (mostly gloves and contaminated equipment) is stored in containers housed in concrete sheds built next to the plants.

Intermediate-radioactivity waste is also stored in sheds, but they receive special treatment. Metal "claws" stack the containers holding the closed loop liquids that flow through the reactors in concrete-coated sheds. The "claws" operator works from an adjoining chamber protected by lead-reinforced glass panes, to avoid contact with radiation.

According to the government, the final destination of the worrisome and always dangerous nuclear waste in Brazil has not yet been defined. However, plants are required to temporarily store the material. The intermediate repositories of Angra I and Angra II will reach their maximum capacity in 2019. Studies are still under way (always according to government officials) for the construction of a final repository, where low- and intermediate-radioactivity waste will remain until they become less hazardous. But for now, nothing has been decided. The start-up of Angra III, scheduled for December 2015, is conditional on the construction of a final repository.

On the other hand, high-radioactivity waste, which consists of spent nuclear fuel, is stored in a "pool" next to the reactors. Although some countries are already reusing this type of waste, Brazilian officials say that currently there are no plans to recycle it. The truth is that this kind of material should remain in the plant permanently, under great care, even after the plant has been decommissioned (which in technical jargon means deactivated).

Abstract – This paper reports the severe nuclear incident occurred in Japan on March 11, 2011, due to an earthquake followed by a tsunami, where three of six existing reactors in Daiichi-Fukushima were damaged. The explosions with the release of radioactive materials into the environment are also discussed, as well as the harmful effects of human exposure to radiation. Finally, the author presents the main impediments to nuclear power generation represented by the production of non-disposable atomic waste.

Keywords: Nuclear accident, Fukushima reactors, Radiation effects, Nuclear waste.

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