NUCLEAR CRISIS
JAPAN & THE FUTURE OF ENERGY POLICY

1. JAPAN QUAKE: Parsing terms, fears in the Fukushima nuclear crisis

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When considering the current troubles at three nuclear reactors of Japan's Fukushima Daiichi power plant, two words must be promptly defined: radiation and meltdown.

The former carries fears of spreading, invisible poison; the latter seems one step away from an atomic blast.

Neither is quite what it seems.

Most importantly -- and this cannot be stressed enough -- no commercial nuclear reactor contains a high enough concentration of nuclear material to cause an atomic explosion. A meltdown is a crisis of an entirely different order, one of chemical energy and, at times, explosions. The worst-case scenario for reactor meltdowns is, in modern terms, radioactive "dirty bombs."

There are two past meltdowns that guide reaction to Fukushima: Chernobyl and Three Mile Island.

Chernobyl can easily be discarded. The nuclear reactions in 1986 at Chernobyl's core sped up when coolant was lost in a reactor whose design was opposite to Western standards. And, more importantly, Chernobyl lacked the massive steel-and-concrete containment structure common at Japanese and American plants. When the Chernobyl core began to burn, the plume easily stretched out into the atmosphere. Chernobyl was a dirty bomb.

Three Mile Island (TMI) has proven the better guide for Fukushima, though vitally that 1979 accident, near Middletown, Pa., on March 28, 1979, saw only one reactor in crisis, as opposed to Fukushima's three. Like Fukushima, the control rods at TMI worked properly, absorbing the subatomic particles that would cause more uranium to split and release energy. But also like Fukushima, TMI's cooling failed, allowing the radioactive elements remaining in the core to begin overheating.

Nearly half of TMI's core subsequently melted and slumped toward the bottom of its reactor vessel, allowing radioactive particles to escape from several levels of containment -- the metallic tubes holding ceramic fuel pellets, which in turn contained uranium. (The Fukushima plant is similar in design.) However, despite this meltdown, the containment structure of TMI remained intact, and practically no additional radiation spread to the surrounding area. There have been no fatalities tied to Three Mile Island's meltdown, experts say.

While TMI saw a similar hydrogen bubble to Fukushima, there was no explosion. The blasts at Fukushima erupted outside of the containment structure, which Japanese officials say has not been compromised. Thanks to a desperate backup plan using seawater to cool the reactors, there have not yet been indications that Fukushima has seen melting similar in scale to TMI. Certainly, some fuel has cracked or melted, judging from the radioactive profile of gases vented to keep the reactor's pressure down, but it is impossible to say if this rises to the level of a "partial" meltdown.

Should the Japanese fail to prevent a meltdown in the reactors, it's likely that the molten mix of radioactive elements would be contained. It is a poorly understood reality of Three Mile Island that the meltdown didn't penetrate the steel reactor vessel containing the core, let alone the surrounding containment structure. Would the Fukushima reactors show a similar resilience, following an earthquake and tsunami? That's a question engineers are likely scrambling to answer.

If containment holds, the largest public concern will be the partially radioactive gases vented from the reactors to keep their internal pressure down. Many of these gases are unbalanced cousins of common, simple elements that quickly morph back into their stable, safe counterparts, posing no health concern. But several elements detected in the gas, including radioactive iterations of iodine, cesium and strontium, can pose health risks at elevated doses.

The most tangible health problem caused by Chernobyl was a tragic rash of thyroid cancer in children surrounding the plant, located in Ukraine, caused by radioactive iodine. These elements essentially spread like nuclear fallout: The particles land on grass and forage, and are consumed and accumulated in cows and their milk. (Concerns about strontium in milk prompted the end of atmospheric testing of atomic bombs.) The slow-decaying elements then displace common atoms in the thyroid or bones, spitting out damaging radiation as they arrive.

So far, Japanese officials have not indicated that the dangerous radioactive particles released by the plants' venting are close to dangerous levels. And the radiation levels immediately surrounding the plants, they say, though slightly elevated, are not hazardous.

Traveling energy

Beyond meltdowns, radiation is a frequently invoked specter when it comes to nuclear power, and for good reason. It seems otherworldly that, for example, nuclear reactions and their subsequent radiation -- which is simply a release of energy -- cannot be doused like a raging fire. They seem fundamentally beyond control.

But despite this unfamiliarity, radiation is far more common than many realize.

The world is awash in radiation, which can be thought of as traveling energy. Much of it can be found as variations of light: the radio waves that carry our chatter or the radar that guides our planes. Called non-ionizing radiation, it disperses energy by heat, which can cause molecular agitation -- think microwave dinners -- but does not have enough oomph to destroy DNA bonds or tear electrons off atoms, a process called ionization.

When most people think of radiation -- the kind of radiation produced at Fukushima -- it is ionizing radiation they have in mind.

Ionizing radiation is used for nuclear weapons, for medical imaging and for cancer therapy. It is a fundamental part of the universe.

Of the 117 known elements, there exist some 3,100 isotopes -- variations on an atom's nucleus -- many of which have an unbalanced number of protons and neutrons, the complementary particles that constitute the nucleus. Since atoms seek equilibrium, these unstable -- or radioactive -- nuclei jettison neutrons, electrons, photons or even whole smaller atoms, like helium, in a struggle toward the mean. This can take time.

The march toward stability often requires a chain of decay. The atom first transforms into another radioactive element, and so on, until finally, rest. This is how, after 14 or more steps, uranium turns into inert lead.

Ionizing radiation comes from many sources. One of every 8,550 potassium atoms is radioactive. Bananas, rich in potassium, are radioactive, though you'd have to eat a truckload to get the radiation dose of one X-ray scan.

People are radioactive, too. As one radiation biologist says, every year, he tells his students that each time they have sex, they're irradiating their partner.

Streaming down on and through all of us is cosmic radiation, mostly in the form of protons, shot out from supernovas, neutron stars and black holes. And seeping up through the soil is radon, which accounts for some 50 percent of the average worldwide yearly dose of radiation, which is about 3 millisieverts (mSv), to use a common measure. Typically, government-regulated radiation workers receive much higher doses.

Diversity

Radiation can be confounding in its diversity. It can be electrically charged or not; relatively massive or not; spat out by dense, burning plasma or by ripping scotch tape.

Perhaps the most common form of radiation is massless, energized light photons, called X-rays or gamma rays, which can stream through most materials, like skin and organs, with ease, shedding bits of energy along the way. Along with chargeless neutrons -- the ejected nucleus components that ricochet about in a nuclear reactor, causing fission -- gammas are the critical radiation threat from nuclear power.

There is no doubt that high doses of ionizing radiation can cause cancer and, at levels like those reached at Hiroshima after the atomic bombing there in 1945, death after a matter of days or weeks. Catastrophic radiation exposure is simple and brutal. The radiation buzzsaws through the body's most vulnerable cells, located in the bone marrow, stomach lining and intestines. The body cannot survive such assaults.

At more moderate and prolonged doses, though, radiation is far more insidious. Starting at levels around 200 mSv, radiation increases risks of cancer. As the mysteries of DNA came to be understood, this cancer risk was tied to radiation's ability to cause breaks in the DNA. Some of these damaged cells would die and some would be repaired, and others would heal incorrectly: The mutated DNA would lead, at times, to cancer.

Since it is possible that even one particle of radiation could cause a DNA break that leads to cancer, for the past 40 years, the radiation protection community has operated under what is called the linear no-threshold hypothesis. Although unable to directly measure the health effects of low-dose radiation, scientists have extrapolated radiation risks down from high doses (around 200 mSv) on a linear scale, meaning that any additional radiation, no matter how low, is a health risk. Nearly all of these data stem from two tragic cases: the 113,169 survivors of the Hiroshima and Nagasaki bombings.

Many scientists have questioned whether this safety model, often confused with scientific "truth," works.

Some point out the seemingly healthy inhabitants of Ramsar, Iran, where the background radiation is 66 times higher than U.S. levels. Others say that humans evolved when background radiation levels were much higher; radiation resistance is part of our biology. Parts of the population, though, may be especially susceptible to radiation damage, other scientists argue -- perhaps more protections are needed. Given that a third of the U.S. population will develop cancer at some point in their lives, it's a nearly impossible question to sort out whether low doses of radiation can be tied to an increase in cancer risk.

When it comes to nuclear power and health, then, the best reaction to the invocation of radiation is, simply, more questions: How much radiation (in scientific units, not multiples of safety guidelines)? What kind of radiation? How does it enter the body?

Radiation is always with us, ethereal and ineffable, and treating it with respect and skepticism can go a long way toward adding more light, not heat, to the conversation.