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Q. and A. on the Nuclear Crisis in Japan

By THE NEW YORK TIMES

Tokyo Electric Power Co., via Kyodo News, via Associated Press The Fukushima Daiichi plant on Tuesday. Reactors No. 3, left, and No. 4, center, are among those that have been damaged.

5:17 p.m. | Updated New York Times reporters answered questions from readers about the continuing nuclear crisis in Japan. Readers asked about media coverage of the crisis, health risks from radiation exposure, problems with the reactors and nuclear waste, the workers at the plant, comparisons to Chernobyl and the danger of building nuclear power plants in earthquake-prone regions.

About the Reporters

Keith Bradsher is covering the crisis from Hong Kong, where he is the bureau chief.

Henry Fountain is a science reporter covering the science and engineering of nuclear reactors.

Denise Grady, a health reporter, is covering the impact of the crisis on public health.

David E. Sanger is chief Washington correspondent and a former Tokyo bureau chief.

Matthew L. Wald reports on national energy developments from Washington and is a regular contributor to the Green blog.

Media Hysteria?

Q. Why is the media giving such hysteric coverage to an issue which at its absolute worst *might* cause some people to relocate away from the immediate vicinity of the power station and leave an expensive cleanup mess... all while there are tens of thousands dead and dying from the effects of the tsunami and a vast swath of devastation to infrastructure which poses a far more immediate and ongoing hazard to both individuals and the greater economy?

— *ddblack1, Austin, Tex.*

A. From the moment that the earthquake and tsunami hit, The Times recognized this would be a multidimensional crisis, and we began deploying our reporters to cover all aspects of it. There is the heartbreaking human story, as the bodies of thousands are uncovered, as parents go searching for their children, as the residents of the northeast

coast — an area many of us who covered Japan have often visited — try to rebuild their lives. Those stories have been told with great compassion through in articles by Martin Fackler, our Tokyo bureau chief, as well as Michael Wines and other reporters who made their way into the devastation zone. And then, of course, there are the broader issues — for Japan as it struggles its way out of two decades of economic stagnation, and for the world economic markets.

But we also quickly realized that the nuclear crisis unfolding at the Fukushima plant was unlike any we have seen in history: multiple failures, fires and radiation leaks from at least four separate reactors. While damage from the earthquake and tsunami was instantly visible, the nuclear impact, we suspected, would take days to unfold, and could affect far larger swaths of Japan and neighboring countries. Unfortunately, that is exactly what is happening. The challenge for us now is to cover both stories vigorously, with the depth, compassion, expertise and investigative zeal that Times readers expect.

— *David E. Sanger*

Health Risks

Q. I live in Oakland and can't seem to get clear information about when and if radioactive materials will arrive here from the jet stream. And if so, what dosage or for how many days we should take potassium iodide to protect our thyroids?

— *EastBay, Oakland, Calif.*

A. This is frustrating for all, because the answer depends in part on the prevailing winds, which can change. However, experts I've interviewed strongly doubt that there will be any significant risk on the West Coast, and say there is no reason to take the potassium iodide unless high levels of radioactive iodine develop. But again, scientists consider high levels unlikely in the United States. In addition, about 98 percent of a person's dose comes from drinking contaminated milk, and if fallout were to reach here (again, unlikely) most people could protect themselves by not drinking milk or eating dairy products. Children are much more vulnerable than adults.

— *Denise Grady*

Q. Is there a danger in interacting with people who have been exposed to radiation from this disaster? Particularly for young children? Would radiation be left behind in an apartment if someone from Tokyo were to come right now to stay as a guest?

— *Concerned, New York City*

A. The only risk I'm aware of would be if someone contaminated at the site came into your home wearing clothing full of radioactive fallout. Otherwise, you are O.K. If you are

worried that someone who ingested radioactive material could be harmful, that seems unlikely.

— *Denise Grady*

Q. Like many expats here in Japan I get my news from both Japanese and overseas services. But genuine nuclear experts are so inconsistent in their reactions to this crisis, and so much panic is spreading in Tokyo and throughout Japan in relation to this. With us in mind and the practicalities of our daily living, could you please give some realistic feedback as to how/whether this crisis is going to irradiate us 260 kilometers away in Tokyo, poison our food supply and create long-term serious health risks beyond that 30-kilometer radius around the plant? People here really want solid information about how radioactivity works in layman's terms, and what we need is solid information that is not laden with fear-mongering doomsday scenarios but real, practical advice.

— *Greg, Tokyo*

A. In an article in Wednesday's paper, Denise Grady reported that the Japanese government has "taken precautions that should prevent the accident from becoming another Chernobyl, even if additional radiation is released."

The Japanese government has evacuated people closest to the plant, told others to stay indoors and distributed the drug potassium iodide to protect the thyroid gland from radioactive iodine.

The great tragedy of Chernobyl was an epidemic of thyroid cancer among people exposed to the radiation as children — more than 6,000 cases so far, with more expected for many years to come. There is no reason for it to be repeated in Japan.

The epidemic in Chernobyl was preventable and would probably not have happened if people had been told to stop drinking locally produced milk, which was by far the most important source of radiation. Cows ate grass contaminated by fallout from the reactors and secreted radioactive iodine in their milk.

Read the full article, "Precautions Should Limit Health Problems From Nuclear Plant's Radiation."

— *The Editors*

Q. Folks in the vicinity of the power plant have been asked to stay indoors to protect themselves from the radiation. Is that really sufficient? How does this kind of radiation differ from an X-ray?

— *Callie, East Lansing, Mich.*

A. People near the plant have been evacuated. The ones being warned to stay inside are actually miles and miles away. Given that there is some dispersion of the cloud, levels at a

distance should diminish, so the risk diminishes, too, and staying inside, though imperfect, seems like a reasonable precaution. The Environmental Protection Agency Web site offers good information about different types of radiation and the effects of various doses.

— *Denise Grady*

Crisis at the Reactors

Q. How is water currently being pumped into the reactors? Are fire hoses the sole method being used? Reports have indicated that backup diesel generators were brought to the site but were not able to be used to drive the pumps. There have also been reports of pump failures. Have detailed descriptions of the status of each reactor (including cooling methods and equipment failures) been made public? Given the contamination of site, it would seem that finding a way to supply coolant with minimal human presence is essential.

— *Rob, Atlanta*

A. The Japanese authorities have provided few details of how they are pumping sea water into the three stricken reactors. Nuclear engineers and executives with experience at other reactors say that the Japanese are most likely using several pumper engine firetrucks in a row, with each increasing the pressure of the water and pushing it through a hose to the next truck. This technique is sometimes used in high-rise firefighting and bomb disposal, when the goal is to maximize the flow and pressure of the water actually reaching the target. At the Fukushima Daiichi nuclear power plant, maximum pressure is needed to force water into overheated reactors in which a significant proportion of the water has turned into very hot steam at very high pressure.

The pumping process has been fraught with problems — at least one engine ran out of fuel at Reactor No. 2 on Monday night for several hours, interrupting the pumping of sea water during this time, because no tanker truck was immediately available to refuel it. Temperature and pressure climbed in the reactor as a result, and may have contributed to damage to the fuel rods and to an explosion at the base of the primary containment building.

Japanese officials have looked for alternatives. One idea under consideration has been to use helicopters to drop water. But helicopter crews who participated in the response to the Chernobyl accident received heavy doses of radiation from the smoke. The United States Navy has already reported that several helicopter crews involved in post-tsunami rescue work over the past several days have shown low-level exposure to radiation; decontamination under these circumstances mainly involves a lot of soap and water to remove radioactive particles.

— Keith Bradsher

Q. Where is the sea water that is being pumped in to cool the reactors going, and is this water contaminated?

— T. Lowen, Minneapolis

A. To the best of our understanding, the sea water is turning to steam. The reactor is still so hot that the sea water they are pumping in is just intended to replace the amount that boils off. In other words, in the best of situations, they are just managing to keep the reactor covered with water.

In the reactors that have had fuel rod exposure (at least three of them, apparently), the steam would be contaminated with radioactive elements from the fuel, which has been exposed because of cracking of the zirconium cladding around it. The contaminated steam leaves the reactor vessel and enters the containment structure. To avoid a pressure buildup, the containment structure must be vented intermittently, resulting in the release of radioactivity to the environment. (In at least one of the reactors, the containment structure is reported to be damaged; if that's the case then the radiation release could be continuous.)

— Henry Fountain

Q. I keep seeing the phrase "shut down" in reference to the nuclear reactors at Fukushima, but clearly they are not shut down as they are still generating tremendous energy in the form of heat. How is a nuclear reactor "turned off"?

They can't keep using firetrucks to pump seawater through the reactor cores indefinitely. Since it is apparently not possible to turn off the reactors, what is the long term plan for preventing a meltdown?

— A.J., San Francisco

A. The reactors at the Fukushima Daiichi plant are shut down, meaning that the nuclear chain reaction (which generated heat to turn water to steam for the turbines that make electricity) has been halted. That happened automatically when the earthquake struck — in such an emergency, the reactors are designed to insert special rods into the core that absorb neutrons and stop the chain reaction.

The reactors were very hot, though (they operate at about 550 degrees Fahrenheit) and it takes a while to remove that heat. In addition — and this is the real problem — even though the chain reaction is stopped, heat is still generated in the fuel by the natural decay of the radioactive elements present. This heat is why they need to keep pumping water into the reactor core — it stays so hot that the water can boil off, exposing the fuel rods. And if the fuel rods are exposed, even for a short time (as happened at at least two of the reactors), they become damaged and radioactivity is released.

Tokyo Electric Power, the operator of the reactors, has not discussed its long-term plans, but it's probably safe to say that their goal is to restore regular electric service to the plant so that normal pumping operations can resume (although at this point, given the explosions, pump and plumbing repairs will likely have to be made, too).

— *Henry Fountain*

Related: Interactive Feature: How a Reactor Shuts Down and What Happens in a Meltdown

Q. In the case of a full core meltdown, would the entry/exit ports in the primary containment vessel used for adding cooling water and for venting steam be the first location of release of radioactive materials? Or would a full core meltdown be an explosive event that would destroy the entire containment vessel?

— *Dan Baker, San Diego*

A. Experts differ on the impact of a full meltdown of the nuclear fuel at any of the reactors. Some say that the molten fuel would be unlikely to burn through the walls of the reactor vessel, which are thick steel. (At the Three Mile Island accident in 1979, molten fuel burned only partly through the steel.) Others say that a burn-through would happen, with the molten fuel then falling to the floor of the containment structure. What would happen next is a subject of debate as well. Some experts think the fuel would not progress very far before it started to cool. Others say that it could reach the walls of the containment structure, which are made of thick concrete with a thin steel liner, and damage it, perhaps through cracking. Some experts are worried that steam explosions might completely destroy the containment structure. (A steam explosion is really an oxygen-hydrogen explosion — the fuel is so hot that if it hits water, it splits the molecules into hydrogen and oxygen, a highly combustible mix.)

Even if molten fuel remains in the reactor vessel, radiation will escape through vents into the containment structure. And even without further damage, the containment structures in at least two of the reactor buildings appear to have been damaged, allowing uncontrolled release of radioactivity.

— *Henry Fountain*

Q. The Onagawa nuclear plant is much closer to the earthquake and tsunami zone than the Fukushima plant but appears to have shut down safely while Fukushima has not. Can you explain the differences in what happened and is happening at the two nuclear locations?

— *R.J.W., Dunkirk, N.Y.*

A. We're still trying to figure it out completely, but the answer appears to lie in the backup cooling systems. At Fukushima, the plants appeared to survive the earthquake

without major damage, but the backup cooling was wiped out by the tsunami. The question of why one plant survived so well and another did not will be the focus of many of our questions as we try to reconstruct events.

— *David E. Sanger*

Q. If the reactors are still so hot, why can't they turn the turbines back on to generate electricity just for the plant and get the cooling pumps running?

— *L. Littlefield, Brooklyn*

A. The reactors are damaged to the point where there would be no way to control them enough to restore the steam supply to the turbines. And even if the operators could somehow get one of the turbines spinning, the electricity has to flow through transformers, switches and other equipment, some of which has no doubt been damaged or destroyed. It's not as simple as just hooking up a few wires from a generator to a pump.

— *Henry Fountain*

Workers at the Plant

Q. How were the 50 people remaining at the plant chosen? Did they volunteer? What are their genders? Is a medical team included? How are they being supplied with food and other necessities?

— *Alan, Hawaii*

A. In an article in Wednesday's paper, Keith Bradsher and Hiroko Tabuchi reported on the technicians who stayed behind at the Fukushima Daiichi nuclear power plant and were "perhaps Japan's last chance of preventing a broader nuclear catastrophe."

They crawl through labyrinths of equipment in utter darkness pierced only by their flashlights, listening for periodic explosions as hydrogen gas escaping from crippled reactors ignites on contact with air.

They breathe through uncomfortable respirators or carry heavy oxygen tanks on their backs. They wear white, full-body jumpsuits with snug-fitting hoods that provide scant protection from the invisible radiation sleeting through their bodies.

They are the faceless 50, the unnamed operators who stayed behind. They have volunteered, or been assigned, to pump seawater on dangerously exposed nuclear fuel, already thought to be partly melting and spewing radioactive material, to prevent full meltdowns that could throw thousands of tons of radioactive dust high into the air and imperil millions of their compatriots.

For more details, read the full article, "Last Defense at Troubled Reactors: 50 Japanese Workers."

— *The Editors*

Q. Has human error contributed to the severity of the situation? I've seen reports of a critical generator running out of fuel, a valve that was improperly left closed, and I suspect that preventive actions could have avoided the hydrogen buildup that led to at least two explosions.

— *Greg Ebert, Hillsboro, Oregon*

A. When a fire pump ran out of fuel and shut down outside Reactor No. 2 on Monday night, that was human error. But it is not clear that the rest of the difficulties are related to human error.

I have not seen confirmation that a valve was improperly left closed, and the valves have been under a lot of strain on these overheated reactors. Similarly, some Western nuclear engineers have wondered if the Japanese waited too long to begin pumping in seawater and boric acid, which temporarily cool the reactors and slow the formation of hydrogen gas. But the Japanese technicians faced a tough dilemma in figuring out how much boric acid to use and how to move the seawater after the tsunami disrupted so many of their backup systems.

— *Keith Bradsher*

Chernobyl and Three Mile Island

Q. The apparent solution to containing the "mess" in Chernobyl was to build a giant concrete sarcophagus around the reactor. Hindsight has shown that to be an error. When all is said and done here, what is the best way to deal with the toxic remnants of the reactors and nuclear waste?

— *Marklemagne, Ohio*

A. The international consensus is that eventually, reactor wastes will have to be buried. The United States plans to do that with all spent reactor fuel, and that includes the rubble from the core at Three Mile Island, which suffered a partial melt-down in 1979. It is sitting in containers at the Idaho National Laboratory, near Idaho Falls.

In the shorter term, the cores from Fukushima are also likely to go into containers, steel cylinders filled with inert gas and then sealed and placed into concrete silos. Such "dry cask storage" can keep reactor wastes isolated for decades, with minimal requirements for inspection, and no moving parts.

The Japanese “recycle” some of their fuel, chopping it up, dissolving it in acid, and then using a chemical separation process to leach out the plutonium that was created by the reactor’s operation. The plutonium is then formed into new fuel. The remaining materials can be embedded in glass. That could also happen to the reactor core rubble from Fukushima. But those wastes, too, will probably eventually be buried.

— Matthew L. Wald

(Correction: An earlier version of this answer misstated the location of the Idaho National Laboratory. It is near Idaho Falls, Idaho — not Idaho Springs, which is in Colorado.)

Q. In the event that the damaged reactors in Japan cool sufficiently to “entomb” their contents, then what? We know they will not be used again, but how can they be managed; and how long can they sustain an entombing integrity, especially considering that there may be multiple structural breaches within various components of each of these reactors? What should we expect from them in the event of future natural disasters in the same area?

— Leha, Santa Rosa, Calif.

A. At Three Mile Island, the fuel was cleaned out and shipped off site (see answer above) and the reactor vessel, empty, was left to sit until a companion plant was ready for retirement. At that point, probably both will be torn down just as other old reactors have been “decommissioned.” The Fukushima accident is not over, but unless it gets a lot worse, defueling is more likely than entombment, because eventually, someone is likely to want to reuse the site.

— Matthew L. Wald

Q. The Chernobyl plant used a graphite moderator that burned and distributed radioactive fallout over a wide area. The Japanese plant doesn’t use graphite. What, if anything, is the mechanism by which radioactive materials could be distributed over a wide area?

— Matthew, Salem, Mass.

A. There are two potential mechanisms. One is that the only form of cooling now available is to pump in cold water and wait for it to boil off, and then release the steam. The steam propels wastes into the atmosphere. The other is that the spent fuel pools are heating up. If they boil dry, there is a theory that the fuel could get hot enough so that its metal cladding, made of an alloy of zirconium, could catch fire. (The clad in the fuel in the reactors has already produced hydrogen, causing explosions.) A fire would produce enough energy to lift radioactive contaminants into the air.

At Chernobyl, the graphite burned and provided enough energy to lift the radioactive material into the jet stream at high altitude. It is not clear whether a significant portion of the wastes from Fukushima could rise that high. With a little luck, much of the material could stay in the lower atmosphere and be washed out by rainstorms over the Pacific.

— *Matthew L. Wald*

Nuclear Policy

Q. I read that Japan has 55 nuclear reactors on an island country about the size of California. How did the Japanese government justify this when the region is a hotbed for earthquakes? Were these plants pitched as being earthquake safe? How is it that with the threat of tsunamis that nuclear plants were built right on the beach?

— *K.T., Minneapolis*

A. Reactors are attractive to Japan because the country has barely any fossil fuels, neither coal nor natural gas, which together make up 70 percent of American power generation, or any significant oil supply.

Almost all of Japan's civil infrastructure is built with earthquakes and tsunamis in mind. That includes big buildings, bridges and power stations. The country is ringed with tsunami barriers. But this earthquake was the largest in recorded history, and the tsunami was higher than the planners assumed. And along with killing thousands of people, it swamped the reactors.

— *Matthew L. Wald*

Q. I understand that the Japanese government stated that all prefectures in Japan should start reporting twice a day on any signs of elevated radiation levels and that these reports should be made public. Will The New York Times be providing (translated) access to this information? Have you inquired of the U.S. government, e.g. NARAC, as to the size, direction and radiation intensity of the radioactive plume arising from the Fukushima plant? At what point should radiation monitoring reports in the U.S., particularly in counties on the Pacific Coast, be made publicly available? Have you looked into this?

— *Lyndon Comstock, Bolinas, Calif.*

A. So far the reporting on radiation levels available from Japanese authorities has been spotty, at best. We have been pursuing more comprehensive data, not only from the Japanese government, but from the United States Navy, whose ships have been offshore from the nuclear site, and more than 40 American experts from the Department of Energy who have now landed in Japan. They brought some sophisticated measuring gear with them, and we expect to soon see new measurements. My colleague Bill Broad wrote

about the plume in Monday's paper. N.O.A.A., the Air Force and others are also tracking the plume, and we will be reporting more of that information once we have vetted it.

— *David E. Sanger*

Q. It seems that too much is at stake to allow private companies to operate nuclear reactors. They can't even insure themselves, so of course they will keep operating even if they shouldn't. If we are to rely on nuclear power, why not have a federal agency analogous to NASA run them?

— *R.J.M. Hudson, Champaign, Ill.*

A. You raise an interesting policy question that came up, in different form, during last year's oil spill as well. Nuclear power plants are subject to federal regulation, of course; the question you are raising is whether safety would be better if they were state-owned. The answer to that question is far from clear. And of course, NASA no longer has a monopoly on space flight: One key element of the Obama administration's space strategy is to encourage more private firms to enter the fray.

— *David E. Sanger*