Japan Supplement

Due to the increased interest in all things radioactive since March 11, this is a separate report that concentrates on the Japan Fukushima Daiichi plant accident and release.

What Happened?

There was an earthquake and a tsunami caused by the earthquake. The reactors in Japan were designed to withstand an earthquake of magnitude 8.0 on the Richter scale. The earthquake that hit Japan was a magnitude 9.0 on that scale. The Richter scale is based on something called a logarithmic scale. That means that a magnitude 9 earthquake is 10 times stronger than a magnitude 8 earthquake. Some of the aftershocks have been magnitude 7 which is a very strong earthquake by itself, but after a magnitude 9 earthquake 100 times stronger, everything that can be broken is probably already broken. The earthquake was the fourth strongest in recorded history and the strongest to ever hit Japan.

After the earthquake, the reactors at Fukushima Daiichi shut down the way they were designed to do. The stronger earthquake did not cause the current problem. The control rods went into the reactor, the emergency cooling systems started, the emergency diesels started and were running the generators to power the pumps to run the cooling system.

An earthquake can move the earth several ways. One way shakes the earth along the surface of the ground. This shaking can be sideways back and forth, or as a push-pull movement. One way is an up and down shaking and pieces of the earth will push up or fall down and finally stay there. This movement happened in the ocean and is what caused the tsunami. The earth moved enough that the ocean sloshed. The wave caused by this slosh took about 50 minutes to travel from the place of the earthquake to the Fukushima Daiichi reactors. A tsunami wave in the ocean is not very tall. But as it moves and gets into shallow water, it slows down. As it slows down it starts to bunch up. Imagine a piece of paper on a desk and push the ends toward each other. The paper in the middle starts to bunch up. That paper is only 11 inches long, but a tsunami wave in the ocean can be tens of miles or more long from front to back. This is what causes tsunami waves to get so high. The front of the wave in shallow water slows down faster than the back of the wave that is still in deeper water.

The Daiichi plant was designed to tolerate a tsunami that was 5.7 meters high. The estimates of the wave that actually hit the plant was 14 meters (about 46 feet) high. At that time the wave is estimated to have been traveling about 50 miles an hour.

The wave destroyed the diesel fuel tanks that were located above ground to supply the diesel generators, so there was no more fuel to run them. The water then got sucked in by the air intakes and wrecked the diesels themselves. Lastly the water made its

way into the plant basements and spaces less than 46 feet above sea level and shorted out all the electrical equipment. This water damage is what caused the damage to the plants which has made the news.

Reference: http://en.wikipedia.org/wiki/Earthquake
http://en.wikipedia.org/wiki/Tsunami

Reactor Cooling

So if the reactors were shut down, what caused the overheating? A nuclear reactor works by fission of the uranium in the reactor. This is the main source of heat in the reactor, but there are others. The fission process produces heat directly from the energy released in the uranium nucleus splitting into two daughter nuclei. There is a smaller amount of heat produced because the splitting daughters are radioactive themselves. They don't have exactly the right amount of protons and neutrons to be stable and so they will undergo radioactive decay. This decay will go on until the daughter gets to a stable isotope that is not radioactive. This is called a decay chain.

Most fission daughters will decay by releasing a beta particle and a gamma ray. This process releases energy which becomes heat. Many of the daughters will decay almost immediately. Others will take longer to decay. This process generates what is called decay heat and can be up to ten percent of the heat generated in a running reactor. After the reactor shuts down, the fission stops, but the decay heat continues. It is not enough to generate power, but it is enough to boil water if it is not cooled. This decay is what makes spent fuel so radioactive and what is causing so much trouble for the operators at Fukushima Daiichi who are trying to get the reactors cooled down.

With no power to pump water to cool the reactors, the hot fuel slowly boiled the water off the fuel rods in the reactors of units 1, 2, and 3 and the unit 4 spent fuel pool. Unit 4 had just been defueled for maintenance and the fuel rods were still hot from decay heat. When the water is boiled off the outside temperature of the fuel rods can get very hot. When water is added back in the cladding metal of the fuel rods can react with the water and form a corrosion product and hydrogen gas. This is where the hydrogen probably came from that caused the explosions in these reactor buildings.

In U.S. nuclear power plants, the NRC required hydrogen recombiners to be installed in reactor containments to prevent this type of explosion because of what happened at Three Mile Island. There was no retrofit requirement for Japanese power plants. U.S. plants also have what is called a hard vent that pipes hydrogen gas directly to the exterior of the plant instead of the inside of the reactor building. It is not certain if these hard vents are installed on the Daiichi units. In any case, hydrogen built up inside the plants to cause the large explosions that destroyed the outside of the reactor buildings and probably caused the explosions in the lower area of Unit 2.

Heat transfer from the used fuel to the water is potentially compromised now by salt and corrosion buildup on the outside of the fuel from the use of cooling salt water from the ocean. At the time, having water on the fuel rods was more important than using pure water, but this has created problems that will have to be solved now and in the future around the continuing clean up efforts.

Reference: http://en.wikipedia.org/wiki/Nuclear_fission_product
http://www.technologyreview.com/blog/arxiv/26571/
http://www.euronuclear.org/info/encyclopedia/f/fissionproducts.htm
http://www.world-nuclear-news.org/newsarticle.aspx?id=29636&terms=march%2015

Half Life

It is important to understand the idea of half-life. All radioactive materials have a half-life. This means that for any given amount of a single radioactive material, there is length of time where half of the material will have a radioactive decay and after that time half of the material will have become something else. Sometimes that decay product is also radioactive, sometimes it is not.

The half life is what determines how radioactive something is. A half life can be less than a millisecond or billions of years. Something with a short half life will be very radioactive. Something with a very long half life is not as radioactive. Some isotopes have a half life long enough that most of the material that was present when the earth formed is still there.

So for example, a radioactive material that is in the news from the Fukushima Daiichi accident is iodine 131 (131I). It has a half-life of 8.04 days. About 8 days and 1 hour. I will call it 8 days for this example. A Curie (Ci) is a unit measure of radioactivity.

If you started with 1,024 Cis of 131I, in 8 days there would be 512 Cis left. I will tell you what all the 131I turns into at the end here.
In another 8 days there will be 256 Cis left, 2 half-lives or 16 days.
In another 8 days there will be 128 Cis left, 3 half-lives or 24 days.
In another 8 days there will be 64 Cis left, 4 half-lives or 32 days.
In another 8 days there will be 32 Cis left, 5 half-lives or 40 days.
In another 8 days there will be 16 Cis left, 6 half-lives or 48 days.
In another 8 days there will be 8 Cis left, 7 half-lives or 56 days.
In another 8 days there will be 4 Cis left, 8 half-lives or 64 days.
In another 8 days there will be 2 Cis left, 9 half-lives or 72 days.
In another 8 days there will be 1 Ci left, 10 half-lives or 80 days (and 10 hours if you are keeping track). That is less than 1/1000 or 0.1% of what you started with.

What happened to the other 1,023 Cis of iodine? The rest of it would have had a radioactive decay and turned into something called xenon 131. Xenon 131 is a noble gas and disperses in the atmosphere. It does not decay into anything else.

You can visualize this by mentally filling a room (for example your bedroom) with radioactive material and then dividing that in half 10 times. You will see how much goes away. You will be left with something the size of a stack of sheets and pillowcases to make your bed with.

Reference: http://en.wikipedia.org/wiki/Half-life
http://en.wikipedia.org/wiki/Curie
http://en.wikipedia.org/wiki/Iodine

Affect in Ohio

I used the iodine 131 in the above example because it is an isotope from the accident that is showing up in U.S. EPA samples of rainwater here in Ohio. The U.S. EPA has air sampling stations across the United States and there are six stations in Ohio. The rainwater sampling station is located near Painesville.

On March 15, the sample showed no detectable 131I in the rainwater collected. In the rain event of March 25, there was 46.8 picoCi/liter of rainwater. A picoCi is 1/1,000,000,000,000 or one one-trillionth of a curie. The U.S. EPA has set a limit of 3 picoCi/liter as the safe amount for a person to drink over a 70 year period, assuming that they would be drinking that level of contamination for the full 70 years. The Ohio page for the Japan accident on the U.S. EPA Radnet site says, “To-date, levels recorded at this monitor have been thousands of times below any conservative level of concern.”

There are people in Ohio who drink water from catchment areas and stored in a cistern as their main water supply. These private water supplies are regulated by the Department of Health. If you have any questions about your private water supply that is collected rainwater or other surface water, you should contact the Ohio Department of Health at 614-722-7221.

Reference: http://www.epa.gov/narel/radnet/
http://www.epa.gov/japan2011/rert/radnet-data-map.html

Other news sources and references:
http://www.world-nuclear-news.org/default.aspx
http://nuclearstreet.com/
http://www.nrc.gov/japan/japan-info.html
http://www.nei.org/newsandevents/information-on-the-japanese-earthquake-and-reactors-in-that-region/