Radioactivity from Fukushima Nuclear Power Plant [1]

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A Brief Review of Preliminary Studies into the Oceanic Impact of Radionuclides from the Fukushima Dai-ichi Nuclear Power Plant

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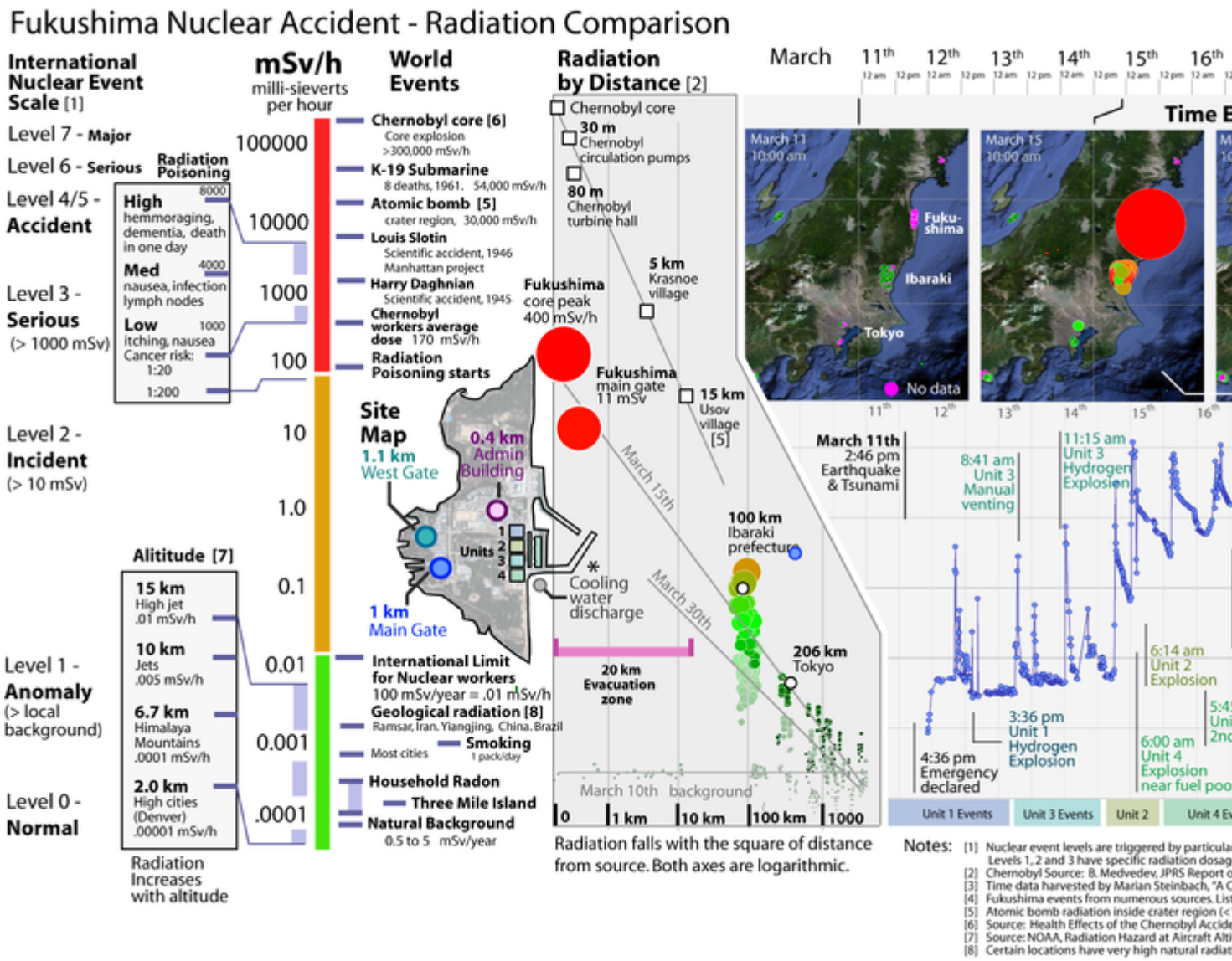
Several inquiries have been made to Ocean Networks Canada with regard to the fate and severity of oceanic contamination from the leakage of radioactive material into the Pacific Ocean as a result of the March 2011 damage to the Fukushima Dai-ichi Nuclear Power Plant (FNPP). There are on-going studies and assessments of the impacts on the ocean, primarily by the World Health Organization (1) and the Japan Agency for Marine-Earth Science and Technology (Jamstec). New or alternative results will be integrated into this living review document as they become available.

On 11 March 2011, a magnitude 9.0 undersea megathrust earthquake occurred off the coast of Japan, with an epicenter located approximately 78km west of the Oshika Peninsula (1). The resulting tsunami radiated both eastward and westward, causing significant damage and loss along the east coast of Tohoku. The Fukushima Dai-ichi Nuclear Power Plant was automatically shut down following the earthquake and backup diesel generators came online to power electronics and reactor coolant systems. These backup systems operated for approximately 50 minutes until the 13 m high tsunami arrived, and overwhelmed the plant?s 10 m high seawall. The tsunami floodwaters caused the generators to fail, leading to overheating and explosions in the nuclear reactors, and radioactive leakage (1).

There are numerous natural radionuclides in the environment, including those dissolved in the ocean. For our discussion here, we will primarily be referring to isotopes of cesium, ^{134}Cs and ^{137}Cs, with half lives of 2.07yr and 30.04yr, respectively. The unit of measure for the amount of radionuclides will be the Becquerel (Bq), which indicates the number of radioactive nuclei that decay per second. Without further units, it is a measure of the total radionuclides decaying per second, but for concentration estimates, values are reported either per unit

mass (e.g. Bq/kg) or volume (either per litre, Bq/L or per cubic metre, Bq/m^3).



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Estimates of the total amount of radioactivity material released by FNPP vary, with recent estimates in the range of 3-17 PBq (3-17 x 10^{15} Bq) (3). Amounts released into either the ocean or atmosphere, are similarly not well known, with many estimates indicating a rough 50/50 partitioning (3). Estimates of the partitioning of radionuclides that settled out of the water column in the near-field (<100km) sediments are spatially variable, but water column and sediment measurements made near the site later in 2011 indicate much lower concentrations (~10-100 Bq/kg) in the seawater than the surface sediments (100-1000 Bq/kg dry) (3). Model simulations (3) suggest that complex ocean currents strain the dissolved seawater born radionuclides into narrow tenuous ribbons stretching several hundred kilometers over the first three months (June 2011) with peak concentrations in the range of 10 Bq/L [10 Bq/kg] or 10^4 Bq/m^3 (3). Seawater concentrations in the far-field (~500km) where measured at three sites in February 2012 and were less than 0.025 Bq/L [0.025 Bq/kg] or 24 Bq/m^3 (4).

To put these values into context, let us review a few properties of seawater radionuclides. First the detection limit for dissolved cesium in seawater is about 0.1 Bq/m^3, or 10^{-4} Bq/L (4). Bomb tests in the south Pacific in the 1950s and 1960s introduced radioactive cesium ^{134}Cs

and ^{137}Cs into the atmosphere and ocean. Since ^{134}Cs only has a half-life of ~2 years, the bomb-source ^{134}Cs has now decayed below present detection levels (4). Bomb test ^{137}Cs remains in the eastern Pacific in concentrations of about 1-2 Bq/m^3, about an order of magnitude below, and therefore discernible from the FNPP cesium. The International Atomic Energy Agency publishes a Basic Safety Standard guide (5) which lists the safe concentrations of all known human source radionuclides, where the risks are sufficiently low as to not warrant regulatory control. For ^{137}Cs that level is 10^4 Bg/kg, the peak oceanic concentration measured near Fukushima (4). Finally, cesium is not the only radionuclide in seawater (6). Naturally occurring radio isotopes in the Pacific include Uranium (33 Bq/m^3), Potassium 40 (10^4 Bq/m^3), Tritium (0.5 Bq/m^3), Carbon 14 (5 Bq/m^3), and Rubidium 87 (10^3 Bq/m^3). Except for Tritium and Carbon, these naturally occurring radionuclides produce radiation several orders of magnitude higher across the entire Pacific than does the local concentrated FNPP cesium (4).

Ocean currents are typically slow and complex (6). The north Pacific has two main gyres, with branches converging near Japan, the Oyashio from the north and the Kuroshio from the south. The converged extension meanders into the central Pacific, where it further slows, spreads and diverges once it reaches the eastern Pacific into the Alaska Gyre (heading northward) and the California Current (heading southward). Computer simulations suggest contaminated seawater will take decades to reach both central and western Pacific waters, by which time the concentrations will be near the detection limit (6). The volume of water in these ocean gyres is measured in the hundreds of quadrillion (10^{17}) cubic metres. Even the near-field (<50km) oceanic region of the FNPP release is conservatively estimated at a volume of 1/millionth of the volume of the North Pacific, so in addition to the natural reduction in radioactivity associated with time, ocean dispersion works effectively to minimize any far-field concern.

Two speculative conclusions can be drawn at this time:

1. The slow spreading and dispersion of the contaminated seawater originating from the Fukushima Dai-ichi Nuclear Power Plant will soon (2014-16) result in distant (>1000km) ^{137}Cs concentrations that are similar to the pre-existing oceanic concentrations, making them difficult or impossible to detect/identify.
2. Naturally occurring oceanic radionuclides dominate the radioactive signal from seawater, not only across the entire Pacific, but even in the near-field regions along the east coast of Japan as measured in early 2012 (4).

References

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