NEWS IN FOCUS

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Fears over the spread of radiation from the Fukushima nuclear reactors have sparked protests in Tokyo.

NUCLEAR POWER

Radioactivity spreads in Japan

Fallout is localized, but could persist for years in some regions.

BY DECLAN BUTLER

In a week that has seen little good news about the stricken Fukushima Daiichi nuclear reactors, the latest data on radioisotope fallout from the plant is so far offering a glimmer of hope.

Monitoring efforts are showing that although the reactors have released significant amounts of radiation into the atmosphere, dangerous contamination is mostly localized in a narrow zone northwest of the plant. Emissions are also lower than immediately after the initial explosions, but radioisotope release continues and trends are unpredictable.

Working through the details is going to take time, and experts are struggling to assess the situation. "We don't have enough data yet, and what we have are still patchy," says Jim Smith, an environmental physicist at the University of Portsmouth, UK. In the meantime, the Japanese authorities are taking many of the right precautions, such as quickly implementing an evacuation zone, and banning farming and fishing in the areas worst affected, he says.

It is already clear that Japan's geography has been crucial to reducing the accident's impact. Initial estimates suggest that Fukushima's reactors have emitted one-tenth of all the radioactive material released during the Chernobyl disaster in 1986, and prevailing winds have swept most of the radioactivity over the Pacific Ocean. Austria's Central Institute for Meteorology and Geodynamics in Vienna estimated last week that although Fukushima's radioactive plume has now dispersed across the Northern Hemisphere, negligible levels of volatile radioisotopes such as iodine-131 and caesium-137 (the major components of the plume) have hit countries outside Japan. By contrast, radiation from land-locked Chernobyl spread across much of Europe (see page 562).

Fukushima's plume is still being fed by continued emissions from its damaged reactors, but when these are halted and the plume dissipates, the long-term impact on Japan will depend on which radioisotopes have been deposited on the ground, and in what quantities. Concentrations of caesium-137, which has a half-life of 30 years, are particularly important in determining which areas will be off-limits for settlement or farming, and for how many years.

On Sunday, the International Atomic Energy Agency (IAEA) reported that 16 of Japan's 47 prefectures showed daily deposition rates on the ground of less than 860 becquerels per square metre ($Bq\,m^{-2}$) for iodine-131, and 100 $Bq\,m^{-2}$ for caesium-137. The IAEA also reported that contamination has not increased in 28 of Japan's prefectures over the period 18–25 March. But higher contamination was recorded in Yamagata prefecture, immediately northwest of Fukushima prefecture: 7,500 $Bq\,m^{-2}$ of iodine-131 and 1,200 $Bq\,m^{-2}$ of caesium-137, which exceeds recommended contamination levels for growing green leafy vegetables. No data were available for Fukushima prefecture itself, where high contamination rates are expected.

Those data are consistent with the results of aerial monitoring of ground radiation carried out by the US Department of Energy. A survey of the region on 22 March showed no increase in deposition of radioactivity compared with a previous survey on 17–19 March, despite the wind blowing inland from the plant for some of that time, suggesting that there had not been a significant additional dump of radioisotopes.

The survey showed that the highest radioactivity doses on the ground (greater than ▶

0.125 millisieverts per hour; $mSv\,h^{-1}$) were restricted to a narrow band within 40 km of the plant, stretching to the northwest (see 'Fukushima's fallout'). No values anywhere exceeded 0.3 $mSv\,h^{-1}$, a dose likely to cause adverse health effects in anyone continually exposed for a few months. Still, doses at some sites over the course of a year would top 1,000 mSv, enough to cause symptoms of radiation sickness, including nausea, hair loss and reduced white-blood-cell counts.

Much of the 20-km evacuation zone around the plant had far lower dose levels, below 0.012 $mSv\,h^{-1}$. Nevertheless, that corresponds to a potential annual dose of more than 100 mSv, more than five times the annual limit permitted for UK nuclear-industry workers. The patchy distribution of fallout reflects the role of wind patterns and rainfall in washing out radioisotopes to the ground. Overall, Smith says he was "relieved" by the data, as they suggest that contamination around Fukushima will be much lower than that seen around Chernobyl.

But some areas of high contamination seem to lie outside the exclusion zone. Soil samples taken on 20 March from a location 40 km northwest of the plant showed caesium-137 levels of 163,000 becquerels per kilogram ($Bq\,kg^{-1}$) and iodine-131 levels of 1,170,000 $Bq\,kg^{-1}$, according to Japan's science ministry. Acceptable contamination levels for areas used to grow crops are much lower, typically in the range of a few hundred $Bq\,kg^{-1}$. "If there are significant areas of caesium-137 soil concentration of the order of 100,000 $Bq\,kg^{-1}$, evacuation of these areas could be effectively permanent," says Smith.

Detailed maps of caesium-137 distribution would help to identify hotspots where people need to be evacuated urgently, he adds. An estimated 200,000 people have already been evacuated from Fukushima's 20-km zone, and on 25 March, the government encouraged people living in the 10-km radius beyond that to leave voluntarily.

The dispersal of much of the radioactivity over the ocean clearly helped to prevent a worse situation inland, but it is bringing its own problems. Data released last week by Japan's science ministry showed high surface seawater concentrations of 24.9–76.8 becquerels per litre ($Bq\,l^{-1}$) of iodine-131, and 11.2–24.1 $Bq\,l^{-1}$ of caesium-137 some 30 km offshore, although these levels seem to be decreasing. By contrast, the IAEA reported this week that radioactivity levels near the plant's discharge pipes were increasing, with 74,000 $Bq\,l^{-1}$ of iodine-131 and 12,000 $Bq\,l^{-1}$ of caesium-134 and caesium-137 combined. Recommended maximum coastal discharges from nuclear power plants are typically lower than 4,000 $Bq\,l^{-1}$.

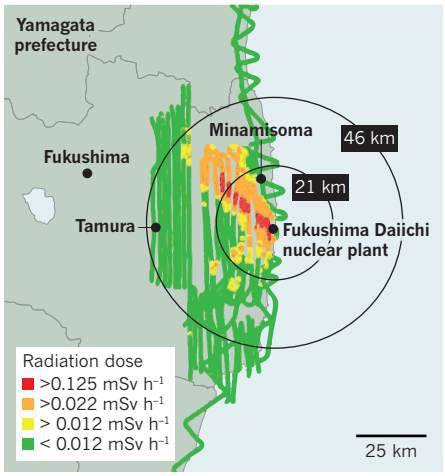
As a result of the nuclear accident, Japan has banned all fishing within 20 km of the Fukushima plant. Seaweeds and other marine organisms can concentrate radioisotopes from the water, and it will be necessary to monitor their transport through the food chain, says Timothy Mousseau, a radioecologist at the University of South Carolina in Columbia. Smith adds: "There has obviously been significant contamination of the marine system, although I would expect that the enormous dilution of the ocean would significantly limit potential doses and impacts."

On 27 March, a new threat arose from highly radioactive water flooding the basements of Fukushima's reactors, in some areas delivering a potentially lethal dose of 1,000 $mSv\,h^{-1}$. The water is seeping into piping trenches less than 70 metres from the sea shore, raising the spectre of serious contamination of the sea and groundwater in the area. Yukio Edano, Japan's chief cabinet secretary, has promised a massive effort to prevent that from happening.

As long as the reactors continue to release radioisotopes, the human and environmental toll from the Fukushima power plant can only grow. Once emissions are halted, atmospheric radiation levels will fall quickly, as will ground levels of short-lived isotopes. Iodine-131 is responsible for a large share of the total released radioactivity, for example, and has a half-life of just 8 days. But it may be many weeks, or months, before the power plant is tamed — and years before parts of northern Japan tainted by long-lived radioisotopes are habitable again. ■

FUKUSHIMA'S FALLOUT

Data from air and ground monitoring show that highly radioactive fallout is largely localized within a narrow band northwest of the stricken plant.



SOURCE: US DEPT OF ENERGY

DISASTER PREPAREDNESS

Japan faces up to failure of its earthquake preparations

Systems for forecasting, early warning and tsunami protection all fell short on 11 March.

BY DAVID CYRANOSKI IN TOKYO

Japan has the world's densest seismometer network, the biggest tsunami barriers and the most extensive earthquake early-warning system. Its population is drilled more rigorously than any other on what to do in case of earthquakes and tsunamis.

Yet this month's magnitude-9 earthquake surprised the country's forecasters. The grossly underestimated tsunami destroyed the world's deepest tsunami barrier and caught people by surprise. And the early-warning system for earthquakes largely failed. What went wrong?

The first problem was the earthquake forecast. Japan's seismic hazard map, the latest version of which was released in March 2009, breaks the offshore area of northeastern Japan into five seismic zones and envisages seven different earthquake scenarios. Each is assigned a probability based on the historical record of earthquakes. The southern Sanriku offshore region, which included the origin of this month's earthquake, was given a 30–40% chance of rupturing in the next 10 years and a 60–70% chance in the next 20 years.

As earthquake forecasting goes, these are very high numbers. "That basically means it could happen any day," says Yoshinori Suzuki of the Earthquake Disaster Reduction Research Division within the science ministry, which coordinates the map-making. But the fault was expected to unleash an earthquake of around magnitude 7.7 — about as large as any in the historical record for the area (see *Nature* **471,** 274; 2011).