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The Fukushima accident – health consequences

COMMENTARY

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The accident at the Fukushima nuclear power station in Japan in 2011 is the second biggest nuclear accident in history. Like the Chernobyl accident, it has been assigned the highest severity rating on the International Nuclear Event Scale. Fortunately, it is concluded today that the consequences were far less serious than those seen after the Chernobyl accident.

Measuring radioactive iodine in the thyroid gland of a child from the Fukushima district. Photo: Kyoda/Reuters/Scanpix

The biological effect of a dose of radiation is measured in sieverts (Sv), whereas radiation levels are often given as dose rates, i.e. doses of radiation per time unit. Background radiation in Norway is approximately 2 – 3 mSv/year, i.e. an average of 0.25 – 0.35 µSv/hour. The occupational dose limit is 20 mSv/year on average over a five year period, or 7.5 µSv/h. This is roughly equivalent to the radiation dose a person is exposed to during heart catheterisation.

Radiation can be divided into three dose rate levels on the basis of the health risk it constitutes (1, 2). 1) Lose dose rates (10 – 100 µSv/h). Doses of this magnitude have not been found to have health consequences, even after exposure for several days or weeks. 2) Medium dose-rates (100 µSv/h-100 mSv/h). A total dose of 100 mSv can cause demonstrable changes in the most sensitive cells of the body, and may lead to fetal damage in early pregnancy. A total dose of this magnitude may result from exposure at 100 mSv/h for an hour, or from exposure at lower dose rates for a longer period of time. 3) High dose rates (over 100 mSv/h) constitute a health risk after short periods of exposure, primarily because of the greater risk of cancer and heart and lung disease in later life. At total doses of more than 1 – 2 Sv, acute radiation sickness will ensue. The bone marrow is the first organ to be affected. With increasing radiation doses, affection of the gastrointestinal tract, the skin, the central nervous system and other organs will follow. Radiation doses of more than about 5 – 6 Sv are regarded as potentially fatal, even with modern intensive care treatment.

The Fukushima Dai-ichi nuclear power station

The Fukushima Dai-ichi (Fukushima number 1) nuclear power plant consists of six reactors, each of which contains a reactor tank with core fuel and a spent fuel pool. There is also a common pool for spent fuel. The reactors are cooled by water under pressure which is brought to the boil by the heat generated by the reactors. The steam is then directed into the turbines to produce electricity. An important difference from the Chernobyl power plant is that the Fukushima reactors have a steel and concrete containment to prevent the release of radioactivity if an accident should occur. The power plant lies by the sea and is protected from tsunami waves by the location of the reactors 10 – 13 metres above sea level and by a wall built in the water outside (3).

The course of the Fukushima accident

The earthquake in Japan on 11 March 2011 caused the power supply to the power station's cooling system to be cut, but the buildings were not seriously damaged and the operation of the cooling facilities was immediately restored with the aid of emergency generators. The three reactors that were active were automatically shut down. After the shut-down, the reactors continued to generate heat, however, because of the natural radioactive decay of the core fuel. About 45 minutes after the earthquake, a 14 metre high tsunami wave poured in over the facility and put the emergency generators out of operation. This led to a rapid increase in temperature in the reactors. The fuel rods gradually became exposed and began to melt, releasing radioactive decay products and hydrogen gas. The hydrogen and the oxygen in the air together formed oxyhydrogen, which caused repeated explosions in the reactor buildings.

Work was in progress throughout to cool down the facility, first externally with spray equipment and water that was released from helicopters, then with seawater that was injected into the reactors. After a while the cooling water became strongly contaminated with radioactivity and became a source for spreading radioactivity. In the days following the accident, strongly rising radioactivity was measured at the plant. The highest reading, a dose rate of 12 mSv/h, was measured on 15 March, four days after the earthquake. Because of the accident most of the power plant staff were evacuated; only 50 workers and engineers remained. A gradual reduction in the radioactivity dose rate at the plant was observed from 17 March, primarily because the cooling of the reactors with seawater began to take effect.

Health consequences for the rescue workers

The rescue work was very demanding, and often had to be interrupted because of high radioactivity levels. It was nevertheless possible to limit the radiation doses to the rescue workers through extensive use of protective suits and close monitoring of the radioactivity situation. An overview of individual radiation exposures was published on 30 April in a press release from the Tokyo Electric Power Company, the company that owns the power plant (4). It was affirmed that none of the rescue workers had been exposed to radiation levels that might cause acute radiation sickness. 45 of the 50 workers had received doses of over 100 mSv, and six of these individuals had received doses of 200 – 250 mSv (Table 1). The remaining five workers had received doses of less than 100 mSv. Two workers who had accidentally stepped in radioactive cooling water had been exposed to a local radiation dose of 3 – 4 Sv. However, these persons had not developed local radiation injuries. In the Chernobyl accident, by contrast, 134 cases of acute radiation sickness occurred , and 28 persons died of this condition in the course of the first three months. Of the in all 800 000 rescue workers who were involved in the Chernobyl accident, it is estimated that about 260 000 received a radiation dose of over 100 mSv (5). Although the radiation exposure to «The Fukushima 50» was fortunately limited by comparison, it must nevertheless be assumed that they experienced considerable mental strain.

Table 1

Overview of the number of cases of acute radiation syndrome and number of rescue workers in Chernobyl and Fukushima who were subjected to hazardous doses (≥ 100 mSv)

	Fukushima (4)	**Chernobyl (5)**
Number of persons found to have acute radiation syndrome	0	134
Number died of acute radiation syndrome	0	28
Received radiation dose – number of persons:		
Radiation doses ≥ 250 mSv	6[1]	approx. 2 200[2]
≥ 100 mSv < 250 mSv	39[1]	approx. 260 000[2]
[i]		

[i] [1] Individual dose readings

[2] Estimates

Consequences for people and environment

The emissions of radioactive contamination to the air were substantial during the first few days after the accident, but much of the radioactive material that reached the atmosphere was carried out over the Pacific Ocean by the wind, and fell down far from land. Contamination by radioactive fallout over land was therefore limited to areas in northern Japan (6). No other countries were exposed to radioactive fallout of any significance. The counter-measures employed by the Japanese authorities consisted of advice to stay indoors or to evacuate from contaminated areas, prophylactic distribution of iodine tablets for children, and food restrictions. From 12 March, the day after the earthquake, the population in a radius of 20 km around Fukushima Dai-ichi was evacuated. The evacuation zone was later increased to a radius of 30 km.

About 20 000 inhabitants in Fukushima prefecture were monitored for radioactive contamination, and radioactive contamination had to be removed from the bodies and clothes of 102 of these persons. After the decontamination, the radioactivity was reduced so much that there were no grounds for concern about health consequences for these persons (6).

At the end of March, 1 080 children aged 0 – 15 years in the most contaminated areas were examined for uptake of radioactive iodine. None of the children who were examined had received doses of over 100 mSv to the thyroid gland, which is Japan's limit for recommending use of iodine tablets (6). It should be noted that the limit in Norway is 10 mSv, so some of these children would have been recommended to take iodine tablets in Norway. Time will show whether there will be an increase in cases of thyroid cancer in children in Japan, as was the case after the Chernobyl accident (5).

A number of readings of water samples, agricultural products and seafood that were carried out in March showed high levels of radioactivity, which led to the introduction of food restrictions (7).

Substantial areas of land both inside and outside the evacuation zone have been contaminated, first and foremost by radioactive caesium, which has a half-life of about 30 years (7). This contamination will have to be eliminated before people can move back to the most contaminated areas.

As in the aftermath of the Chernobyl accident, the greatest radioactive contamination has been found in an area of some tens of kilometres around the power plant (8). Only long-term surveillance and research will show what consequences this situation will have on land and for the coastal marine eco-system in this area.

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