Nuclear Sickness

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Fukushima's deadly health legacy

Japan continues to struggle with the Fukushima Daiichi nuclear plant five months after the second worst nuclear accident in history. Three reactors have experienced full core melts, and spent fuel fires have also added to the fallout burden. The plant is yet to be brought under control and continues to discharge radioactivity into the environment, albeit at a lessening rate. The International Atomic Energy Agency (IAEA) continues to rate the situation as 'very serious'.

Utilising CTBT monitoring data, the Austrian Central Institute for Meteorology and Geodynamics calculated that in the first three days after the meltdown, the levels of iodine-131 (I-131) emitted was 20 per cent and caesium-137 (Cs-137) 20–60 per cent of the entire Chernobyl emissions of these isotopes. Although Chernobyl emitted significantly more fallout than Fukushima has to date, it was the I-131 and Cs-137 that accounted for most of the terrestrial human and environmental hazard, and these are Fukushima's main fallout components. Indeed, as of June 2011, 770,000 terabecquerels (TBq) of atmospheric fallout had occurred, roughly 20 per cent of the total Chernobyl fallout.

There has also been extensive contamination to the nearby coastline, with approximately 170,000 TBq of radioactive elements discharged into the sea and groundwater. A further 800,000 TBq of contaminated seawater (120,000 tonnes), used for cooling at the height of the emergency, is still contained within the reactor buildings. Concentrations of radioactive iodine off the coast have been measured at over 4300 times the legal limit, making this the worst maritime radioactive accident in history. Seawater contamination has compromised the fish stocks along the local coast and destroyed any remnants of the fishing industry that were not wiped out by the tsunami. The longer term consequences on sea creatures and vegetation are unknown.

France's Institute for Radiological Protection and Nuclear Safety (IRSN) estimated in the first week after the disaster that within 20 km of the plant the levels of contamination would exceed that of Chernobyl, and there would be 'a strongly contaminated zone', extending to 60 km in which there would be 'measurable impacts but not dramatic impacts' less than the comparable area around Chernobyl. Beyond this zone contamination would be measurable as far as 250 km but with health impacts not able to be determined. This situation has indeed eventuated.

Shortly after the explosions, a 20 km exclusion zone was established and residents between 20 and 30 km were advised to remain indoors. The IAEA and US Nuclear Regulatory Commission (US NRC) suggested this was inadequate and advised an 80 km exclusion zone, which the Japanese government ignored. As of June, airborne radiation mapping confirmed that a broad plume of contamination extending 80 km northwest exceeded the levels of the Chernobyl exclusion zone, with a larger area at its periphery exceeding the Chernobyl agricultural restriction zone. In certain 'hot spots' 40 km from the plant, the IAEA found levels over fifty times their 'operational criteria for evacuation'. The consequences would have been worse if the prevailing winds in the first week of the disaster were not offshore.

Radioactive fallout from a nuclear reactor mainly consists of the radioactive isotopes of iodine, caesium and tellurium. These elements form fine suspended particles in the air (aerosols), which due to their weight will fall to the ground gradually, with their distribution consequent on meteorological conditions. Although we speak of radial zones from the plant, the shape of the fallout represents a directional plume or plumes. Such particles contaminate all vegetation, clothing and any other surfaces including water sources within their path. Those that pose the greatest health threat are Cs-137 (with a half-life of thirty years) and I-131 (eight days). Iodine is absorbed into the bloodstream through inhalation and ingestion, concentrated by the thyroid gland, whereas caesium is deposited throughout the body. Caesium takes between ten and 100 days for half of it to be excreted from the body, so it poses a significant hazard once absorbed. Unlike iodine, which loses most of its potential for harm in a few months, caesium remains hazardous for several hundred years.

Although there is effectively an 'air curtain' at the equator that prevents contamination from reaching the southern hemisphere, minimal amounts have been detected in northern Australian monitoring stations.

There are two types of recognised ionising radiation (IR) health effects: deterministic and stochastic. The severity of deterministic effects is directly proportional to the absorbed radiation dose. These include skin damage and blood disorders due to bone marrow effects. The higher the dose the worse, for example, the skin radiation burn. These have a threshold below which they do not occur (although this may vary between individuals), which around 100 millisieverts (mSv), at which point blood cell production begins to be impaired.

Deterministic effects exceeding 1000 mSv induce acute radiation sickness—with vomiting, diarrhoea and shedding of mucosal linings of the gastrointestinal and respiratory tracts—bone marrow suppression and sterility. Once the dose exceeds more than 3000–5000 mSv, death is likely in a matter of days to weeks.

Stochastic effects are 'probabilistic' in nature; in other words, the higher the dose the greater the chance of them occurring, although their eventual severity is the same, irrespective of the original dose. The main stochastic effect is cancer; however, because it is indistinguishable from other unrelated cancers, attribution is very difficult. The current risk coefficients for the development of cancer are approximately 8 per cent per 1000 mSv (a one in twelve chance) and 5 per cent for cancer fatality (one in twenty). The US National Academy of Sciences reviewed the effects of low-level IR (defined as less than 100 mSv) in their seminal 2006 report, concluding: 'there is a linear dose-response relationship between exposure to ionizing radiation and the development of solid cancers in humans. It is unlikely that there is a threshold below which cancers are not induced'.

Ionising radiation imparts its deleterious carcinogenic health effects via damage to the cell's genetic blueprint (DNA), leading to genetic mutations. This then predisposes the initiation of cancer when the regulatory mechanisms of the cell fail. Most solid cancers do not appear for at least ten to twenty years, although some may take many decades, and leukaemia can arise in as little as five years. IR is classified as a Class 1 carcinogen by the International Agency for Research in Cancer (IARC) of the World Health Organization (WHO), the highest classification consistent with certainty of its carcinogenicity.

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We can consider two broad groups at risk. Firstly, emergency workers at the plant, unlike the general population, are at risk of developing deterministic effects as their upper allowable occupational doses have been increased to 250 mSv from the original international maximum of 100 mSv in an emergency, and up from the 100 mSv total occupational dose limits for nuclear workers over five years, and the 1 mSv per annum dose allowable to the public. One incident induced radiation burns to two emergency workers' legs after they stepped in highly radioactive water in reactor two, with each worker receiving a calculated total dose of 600 mSv. By mid April over thirty workers had received doses in excess of 100 mSv, although the average dose was only 7 mSv per worker. In order to limit occupational doses, workers have been recruited on a rotating basis from a large pool. A temporary base of 2000 workers, composed largely of itinerant contractors from around Japan, has been established at the nearby resort town of Iwaki-Yumoto. They are referred to as nuclear gypsies, the name writer Kunio Horie gave to workers who have traditionally performed the dirtiest, most dangerous jobs for Japan's power utilities.

The industry has relied on temporary workers for maintenance and repair work since the nuclear plant construction boom in the 1970s. Now, as then, those from the lowest rungs of Japanese society work for meagre wages, with little training or experience of hazardous environments. It is questionable whether proper monitoring of so many workers can be thorough enough. TEPCO, the plant owner, has already confessed to inadequate internal dose monitoring of workers in the first few months. Even if the doses they receive are below reference limits, it is highly likely that some of these workers will die of cancer. No cases of acute radiation sickness have been reported to date.

The general public is also exposed to radiation from the deposition of fallout, predominantly I-131 in the first few weeks and then Cs-137 and Cs-134 subsequently. The eventual contamination plume has extended beyond the initial 20 km exclusion zone, thus putting at risk many who were not evacuated or subject to adequate counter-measures. Potential annual doses for these residents, according to the French ISRN, may eventually reach up to 200 mSv.

It is not clear to what extent counter-measures were adopted for the populace beyond the immediate evacuation zone. It is of note that the US NRC and the Australian government had shortly after

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the commencement of the disaster advised their citizens within an 80 km radius to evacuate. There are of course other considerations before an evacuation is contemplated as a mass evacuation in such a heavily populated region would not be without risks of its own. Nevertheless, the Japanese government failed to even advocate a simple counter-measure such as advising the public to stay indoors beyond 30 km which would have minimised the risk to these people. More cynically perhaps is the observation that increasing the exclusion zone also massively increases the compensation bill which will be ultimately paid by the government.

The Japanese authorities have shown questionable regard for the safety of children, including pre-schoolers, infants and the unborn, by raising the 'acceptable' public dose to children in the Fukushima prefecture from 1 mSv per annum to 20 mSv, which corresponds to the occupational limit of adult nuclear workers. We know that children are at up to five times more risk of developing radiogenic cancer than adults. As a consequence, Professor Toshiso Kosaku, a senior prime-ministerial nuclear adviser, submitted his resignation on April 29, saying could not stay and allow the government to set what he called improper radiation limits for primary schools near the plant. Concurrently, a worldwide medical campaign was instituted to reverse this decision, and it appears that this is in the process of being redressed. Targeted evacuations of the most highly contaminated areas are proposed, and personal dosimeters are to be given to 34,000 children in Fukushima city 65 km from the plant to monitor their cumulative doses.

Caesium contamination has been identified at levels exceeding acceptable limits in spinach, mushrooms, bamboo, tea leaves, dairy and fish from the regions surrounding the plant. Contaminated hay has been found as far as 120 km away, raising concerns about the true extent of fallout. In July, beef from over 1000 herds of cattle with from contaminated feedstock was found to have been sold throughout much of Japan, with caesium levels up to six times higher than the regulated maximum. Although eating such meat on a few occasions is not likely to be hazardous, it underscores the difficulties inherent in the food-testing regimes designed to protect the public over the longer term. This minimal public health service should be functional several months after the worst nuclear accident since Chernobyl, and yet it appears the Japanese simply don't have the time, money or capacity to accomplish it in the midst of such a large disaster.

In the longer term, excess cancer cases will be much harder to define given the relatively high background incidence of cancer and the long latency period of its appearance. It took at least twenty-five years for the excess cancers to become statistically evident in the Hiroshima and Nagasaki atom bomb survivors. The prompt evacuation of people from the immediate surrounding environment of Fukushima, notwithstanding the insufficient exclusion zone, and other counter-measures will also have significantly mitigated the development of cancer. Even though risk models of cancer induction can be used to predict the likely cancers over the next six decades, it is possible that we will never know the true number of actual excess cancers in the general population due to inherent statistical limitations and large uncertainties, even several decades after the event, unless appropriate large-scale population studies are implemented and adequately resourced. Excess thyroid cancers are a rare malignancy and hence more easily statistically detected. The Japanese government has just announced lifelong thyroid monitoring of some 360,000 Fukushima prefectural residents aged eighteen years and under to detect thyroid cancer.

There are broader social and psychological implications of nuclear catastrophes that are difficult to accurately assess, much less predict. The zones most severely affected by contamination will remain no-man's lands for one to two hundred years. Assurances that these large areas can be adequately rehabilitated to any significant scale seem wildly overoptimistic. The fact that people from these highly populated areas will never return home again is traumatic enough; the social dislocation and fragmentation of once tightly knit communities will only serve to exacerbate psychological alienation, leading to the increased levels of depression, substance abuse and other psychiatric disorders.

Nuclear disasters are unique in their potential for devastating social, economic and health outcomes, the reach of which can be international and the consequences profound. As UN Secretary-General Ban Ki-moon stated in April, on the twnty-fifth anniversary of the Chernobyl disaster:

To many, nuclear energy looks to be a relatively clean and logical choice in an era of increasing resource scarcity. Yet the record requires us to ask painful questions. Have we correctly calculated its risks and costs? Are we doing all we can to keep the world's people safe?

The unfortunate truth is that we are likely to see more such disasters. ⓐ