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Fukushima's uncertainty problem

Science holds few definitive answers for those worried about radiation exposure, says Geoff Brumfiel.

18 July 2012

It's been well over a year since multiple meltdowns at the Fukushima Daiichi plant in Japan sparked the worst nuclear crisis in 25 years — and it is remarkable how little we still know about its impact.

I was reminded of this fact by a paper published yesterday[1] that tries to put numbers on the health effects from the accident. The paper, by engineers John Ten Hoeve and Mark Jacobson of Stanford University in California, seems at first glance to be a thorough analysis, but the uncertainties surrounding the crisis mean that the work is unable to provide even an order-of-magnitude guess for the number of cancer deaths that will result from Fukushima. Anywhere from 15 to 1,100 people may die as a result of exposure to radioactivity released by the plant, it finds. Another 24 to 1,800 people may experience the debilitating effects of cancer, although they will not perish from the disease.

To most people, there's a big difference between 39 cancers and 2,900. Why can't science do better? The problem is that these types of estimate depend on models and assumptions. In other words, it's guesswork — of a very educated kind, but guesswork nevertheless.

Best guesses

First, there's the question of how much radioactivity the plant released. Ten Hoeve and Jacobson estimate that something like 6.5×10^{16} becquerels of iodine-131 were released from the plant, along with another 1.7×10^{16} becquerels of caesium-137. Never mind what a becquerel is, these are just guesses. The fact is that the tsunami that caused the meltdowns also knocked out most of the radiation monitoring equipment around the plant. A global monitoring network has allowed scientists to make a rough guess, but estimates vary by a factor of two.

Second, there's the question of who was exposed and when. Atmospheric transport models (based on real weather data) give a sense of where the radioactivity might have gone, and where it would have fallen out of the atmosphere. But in the chaos following the earthquake and tsunami, no one can say where the residents of Fukushima prefecture actually were. The authors' model makes assumptions about the habits of evacuees (for example, that they sheltered inside for just 12 hours a day) and about their locations, assuming that they were spread perfectly uniformly around the plant. The assumptions of a separate report[2] by the World Health Organization (WHO) are slightly different, but no one knows for sure who was where when the crisis began.

Finally, at the most fundamental level, there's the question of what effect low-level radiation exposure has on the human body. Researchers know that there is a small but detectable increase in cancer risks when subjects are exposed to more than 100 millisieverts (mSv) of radiation, but they don't have any evidence for what happens below that level. The best estimates of the WHO suggest that almost no civilians in Fukushima received a dose above 50 mSv, so there's no real way to derive their risk empirically. The best guess of science is something called the linear no-threshold model of human exposure, which extrapolates the known risks in order to estimate low radiation doses. Not everyone believes the model: some say that low-dose radiation might be worse for you than predicted; others say that it might actually make you healthier. There's no way to know with the data we have.

Known unknowns

Add it all together, and you end up with a huge range of possible cancers from the accident. Moreover, there will be no way to tell which of these studies is right. Cancer rates run high in developed countries such as Japan, and even if thousands were to become sick, the cancer rate is unlikely to rise detectably above the background rate (roughly 40% of the population will get cancer at some point). Even if it did, no one will be able to say for sure whether their cancer, or the cancer of a loved one, was caused by the nuclear accident last March.

It is a frustrating state of affairs, and a situation that is unlikely to change. At the moment, it seems that the data sets needed to substantially reduce the errors in the models simply don't exist. Even if they did, the uncertainties surrounding the linear no-threshold model means that the numbers would be far from certain. (Although there are some intriguing efforts to improve on this model, it is

unlikely to be revised radically anytime soon.) At best, it seems, the various estimates by the WHO, independent researchers and the Japanese government can be said to overlap.

Despite wishing that there was more to be said, I don't believe that this situation is a failure of science. Although uncertainties about the numerous independent estimates remain large, taken together the estimates are actually leading to a fairly strong consensus view about the health risks from Fukushima: the risk from radioactivity is relatively low, and the cancers it causes will probably never be picked out from the background. It's probably not the most reassuring message, but it is an honest one.

Nature | doi:10.1038/nature.2012.11031

References

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2. World Health Organization. *Preliminary Dose Estimation from the Nuclear Accident after the 2011 Great East Japan Earthquake and Tsunami* (WHO, 2012); available at http://go.nature.com/yip2np