A new look at prolonged radiation exposure

Massachusetts Institute of Technology
A new study from MIT scientists suggests that the guidelines governments use to determine when to evacuate people following a nuclear accident may be too conservative.

The study, led by Bevin Engelward and Jacquelyn Yanch and published in the journal *Environmental Health Perspectives* [1], found that when mice were exposed to radiation doses about 400 times greater than background levels for five weeks, no DNA damage could be detected.

Current U.S. regulations require that residents of any area that reaches radiation levels eight times higher than background should be evacuated. However, the financial and emotional cost of such relocation may not be worthwhile, the researchers say.

“There are no data that say that’s a dangerous level,” says Yanch, a senior lecturer in MIT’s Department of Nuclear Science and Engineering. “This paper shows that you could go 400 times higher than average background levels and you’re still not detecting genetic damage. It could potentially have a big impact on tens if not hundreds of thousands of people in the vicinity of a nuclear powerplant accident or a nuclear bomb detonation, if we figure out just when we should evacuate and when it’s OK to stay where we are.”

Until now, very few studies have measured the effects of low doses of radiation delivered over a long period of time. This study is the first to measure the genetic damage seen at a level as low as 400 times background (0.0002 centigray per minute, or 105 cGy in a year).

“Almost all radiation studies are done with one quick hit of radiation. That would cause a totally different biological outcome compared to long-term conditions,” says Engelward, an associate professor of biological engineering at MIT.

How much is too much?

Background radiation comes from cosmic radiation and natural radioactive isotopes in the environment. These sources add up to about 0.3 cGy per year per person, on average.

“Exposure to low-dose-rate radiation is natural, and some people may even say essential for life. The question is, how high does the rate need to get before we need to worry about ill effects on our health?” Yanch says.

Previous studies have shown that a radiation level of 10.5 cGy, the total dose used in this study, does produce DNA damage if given all at once. However, for this study, the researchers spread the dose out over five weeks, using radioactive iodine as a source. The radiation emitted by the radioactive iodine is similar to that emitted by the damaged Fukushima reactor in Japan.

At the end of five weeks, the researchers tested for several types of DNA damage, using the most sensitive techniques available. Those types of damage fall into two major classes: base lesions, in which the structure of the DNA base (nucleotide) is altered, and breaks in the DNA strand. They found no significant increases in either type.

DNA damage occurs spontaneously even at background radiation levels, conservatively at a rate of about 10,000 changes per cell per day. Most of that damage is fixed by DNA repair systems within each cell. The researchers estimate that the amount of radiation used in this study produces an additional dozen lesions per cell per day, all of which appear to have been repaired.

Though the study ended after five weeks, Engelward believes the results would be the same for longer exposures. “My take on this is that this amount of radiation is not creating very many lesions to begin with, and you already have good DNA repair systems. My guess is that you could probably leave the mice there indefinitely and the damage wouldn’t be significant,” she says.

Doug Boreham, a professor of medical physics and applied radiation sciences at McMaster University, says the study adds to growing evidence that low doses of radiation are not as harmful as people often fear.

“Now, it’s believed that all radiation is bad for you, and any time you get a little bit of radiation, it adds up and your risk of cancer goes up,” says Boreham, who was not involved in this study. “There’s now evidence building that that is not the case.”

Conservative estimates

Most of the radiation studies on which evacuation guidelines have been based were originally done to establish safe levels for radiation in the workplace, Yanch says — meaning they are very conservative. In workplace cases, this makes sense because the employer can pay for shielding for all of their employees at once, which lowers the cost, she says.

However, “when you’ve got a contaminated environment, then the source is no longer controlled, and every citizen has to pay for their own dose avoidance,” Yanch says. “They have to leave their home or their community, maybe even forever. They often lose their jobs, like you saw in Fukushima. And there you really want to call into question how conservative in your analysis of the radiation effect you want to be. Instead of being conservative, it makes more sense to look at a best estimate of how hazardous radiation really is.”

Those conservative estimates are based on acute radiation exposures, and then extrapolating what might happen at lower doses and lower dose-rates, Engelward says. “Basically you’re using a data set collected based on an acute high dose exposure to make predictions about what’s happening at very low doses over a long period of time, and you don't really have any direct data. It's guesswork," she says. "People argue constantly about how to predict what is happening at lower doses and lower dose-rates."

However, the researchers say that more studies are needed before evacuation guidelines can be revised.

"Clearly these studies had to be done in animals rather than people, but many studies show that mice and humans share similar responses to radiation. This work therefore provides a framework for additional research and careful evaluation of our current guidelines," Engelward says.

"It is interesting that, despite the evacuation of roughly 100,000 residents, the Japanese government was criticized for not imposing evacuations for even more people. From our studies, we would predict that the population that was left behind would not show excess DNA damage — this is something we can test using technologies recently developed in our laboratory," she adds.

The first author on these studies is former MIT postdoc Werner Olipitz, and the work was done in collaboration with Department of Biological Engineering faculty Leona Samson and Peter Dedon. These studies were supported by the DOE and by MIT's Center for Environmental Health Sciences.

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