# Radiation in Their Future:

## Dealing with the contaminated environment in Japan

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The situation with the damaged Fukushima nuclear power plants remains serious and it cannot be said that there will be no further environmental contamination before the problems with the reactors are fully under control. Even if contamination levels do not rise, Japanese residents will have to make some decisions regarding the extent of environmental contamination they are willing to live with. Important trade-offs will need to be made: on the one hand, to leave home and community, abandon tracts of land, destroy foodstuffs, etc., while on the other to remain and live in a contaminated environment and consume contaminated food. Bearing in mind that all food and all environments are naturally radioactive, the question really becomes: how much is too much?

In facing such important and far-reaching decisions about trade-offs, it is important to keep in mind the nature of our radiation risk estimates, their primary purpose, and how they were developed. *Radiation risk estimates were not generated to address the hazards of living in a contaminated environment.* They have been generated in order to establish radiation protection guidelines for the workplace[1]. These situations are so different, and have such drastically different requirements for citizens, they require equally different approaches to addressing the radiation hazard.

Here is how our strategy has developed for generating risk estimates for radiation exposure in the workplace. The biggest impact of moderate to high doses of radiation is the induction of cancer that will show up years or decades in the future. But because the natural cancer fatality rate is

[1] Radiation limits to the general public are routinely set a 1/10th the limits established for radiation workers. [The limits apply only to manmade radiation sources and exclude all natural radiation and all medical exposures.]

high (~ 22 %) and because the risks of small radiation doses are low, especially doses that are spread out in time, it is extremely difficult to quantify precisely how dangerous low doses really are. This is bad news since essentially all occupational doses are very small. The way we deal with this uncertainty is simply to require that all employers keep worker doses very, very low. This is done, in effect, by routinely and deliberately invoking conservative assumptions as we estimate the risks of radiation. That is, we assume that radiation is more hazardous than the most accurate evaluation of the available data would predict. Such an approach is practical and even prudent for the workplace where the source is tightly controlled by the employer and where the employer takes care of (and pays for) all dose avoidance strategies. It is also relatively easy and cost-effective to protect all employees at the same time (for example, erecting a thick shielding wall protects everyone simultaneously). Keeping doses low is a 'cost-of-doing-business' and this cost is simply passed on to the consumer. The fact that we do not know how necessary it is, from a health perspective, to minimize doses has become a minor issue, primarily because we are able, in the occupational scenario, to keep the doses very low. That is, requiring that the employer reduce radiation to very low levels in the work place effectively removes the need to really know how dangerous radiation is.

Should these risk estimates be used to project long-term health effects from contaminated environments? Caution is often specifically expressed *against* extending this approach to predicting the long term effects of small doses to a large population[2]. However, since few recommendations have been generated for precisely *how* to project the effects of small doses there has been little option but to use the occupational risk estimates.

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[2]The (i) International Commission on Radiological Protection (ICRP), the (ii) US National Academy of Sciences' BEIR V report, the (iii) US Health Physics Society, are examples of agencies or committees who have cautioned against using risk estimates generated for radiation protection in the workplace for projecting long term health effects of small doses to large populations:
(i) "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation: 1980" Committee on the Biological Effects of Ionizing Radiations, National Academy Press, Washington, DC, 1980.

(ii) "Radiation Risk in Perspective" Position Statement of the Health Physics Society, adopted January 1996, reaffirmed March 2001 and revised August 2004. http://www.hps.org

(iii) ICRP Report 103: The 2007 Recommendations of the International Commission on Radiation Protection, 2007.

But the occupational radiation protection situation is very different from a scenario involving a contaminated environment. In this case the source of the radiation is no longer controlled. Dose can be avoided, or at least minimized, but only by taking significant and often costly steps. The burden for bearing these costs (both financial and effort) has shifted from the owner of the source to *individual members of the public* as well as to society at large. For instance, it is individual members of the public who undergo the upheaval of evacuation, who may need to leave their homes and communities to live in shelters or temporary housing (sometimes for long periods of time, perhaps permanently), who face lost opportunity costs, who will face prohibitions against consuming local food and water, and who may need to abandon farmland or livestock. Local communities will need to determine what to do with radioactive waste products such as the water from decontamination procedures and surfaces deemed too contaminated to clean, and to make decisions regarding access to such things as community buildings and transportation routes.

These are very heavy costs. For how long must these costs be borne? The $^{131}$Iodine contamination with its 8-day half-life will soon be immeasurable, but the $^{137}$Caesium that is already in the environment will stay around for decades to come. Since it has a 30-year half-life, some of the costs listed above might have to be borne for a very long time.

With each member of the public now engaging in his or her own efforts for dose avoidance, paying the costs, it is very important that these efforts be clearly justified in terms of the real health benefits they will gain.

Our radiation risk estimates, as mentioned earlier, incorporate a number of explicitly stated conservative assumptions. I will briefly review two such assumptions. First, it is standard practice when dealing with radiation in the workplace to make use of a hypothetical model that states that any dose of radiation carries with it some measure of harm (this is called the linear, no-threshold risk model). It is important to realize that this is only a hypothesis. There are other hypotheses that propose different ways of estimating the effects of small doses of radiation. One theory says the body is able to effectively deal with small doses and increased cancer would only occur after a sufficiently large radiation dose has been received (the threshold model). Another suggests that low levels of radiation have a stimulatory effect causing our immune system to respond better to any negative stimulus so that overall, low level radiation might provide a benefit (the hormesis model). All of these models remain scientific hypotheses; none of them has been shown to be accurate. The conservative approach (assuming all radiation is harmful) has been adopted in the workplace, for reasons discussed earlier. However this model does not provide best estimates of the risk of living in a contaminated environment and therefore should not be applied to this situation.

A second way we've been conservative with occupational risk estimates is the handling of the dose-rate effect. Here are some facts about dose-rate and it's effect on biological outcome:

1. Everything we know about radiation effects confirms that a given dose, spread out over time, is less biologically damaging than the same dose delivered quickly[3].
2. When a large dose is spread out over a matter of minutes or hours, the biological damage is reduced[4] by a factor of ~4 relative to an acute delivery.
3. When the dose is spread out even longer, long enough to comprise a sizeable portion of the lifespan (as would be the case when living with elevated $^{137}$Caesium levels for decades), the biological damage is reduced[4] by a factor of ~10.
4. However, when we go to very low dose rates (down to hundreds of times the normal background levels) it becomes very difficult to observe *any* negative effects of the radiation[4]. In fact, these low dose rates have been reported to increase longevity, not decrease it as is seen with higher doses and dose-rates.

The US National Council on Radiological Protection (NCRP) published a report in 1980 carefully examining the dose-rate effect[4]. They interpreted the apparent life lengthening at low dose-rates as reflecting "a favorable response to low grade injury leading to some degree of systemic stimulation." They go on to state that "…there appears to be little doubt than mean life span in

[3] This is true for x-rays and for all beta particles and gamma rays we face in a contaminated environment. It is not true for very densely ionizing radiation such as alpha particles or the heavy energetic particles that astronauts face from beyond our solar system.

[4] "Influence of Dose and its Distribution in Time on Dose-Response Relationships for Low-LET Radiations" NCRP Report No. 64, April 1, 1980, National Council on Radiation Protection and Measurement, Bethesda, MD. This remains the most comprehensive examination of the impact that delivery time has on biological outcome.

some animal populations exposed to low level radiation throughout their lifetimes is longer than that of the unirradiated control population ." [page 104, NCRP 64]

Our occupational risk estimates use a dose-rate factor of 2.0 (or 1.5). That is, the risk of a given dose in the workplace is assumed to be only half as dangerous as the same dose received very rapidly. This value is acknowledged to be conservative by many regulatory bodies and while it may be appropriate for use in the workplace, a dose-rate factor of 2.0 is clearly not a best estimate of the impact low dose rates from environmental contamination will have on cancer risk.

What does this mean for the choices that have to be made? It means that if we use our occupational risk estimates to determine how hazardous a contaminated environment might be we will substantially overestimate the health risk. It means we overestimate the danger of consuming radioactive food and water. Why is this bad? It is bad because the more hazardous we think the radiation is, the more we will sacrifice to avoid it. The things that some Japanese face giving up are high cost items: living in their homes, remaining with their local communities, consuming certain foodstuffs and water. [Food interdiction limits are also derived from risk estimates that are based on a linear model of risk and use a dose-rate effect factor of only 2.0.] While conservative risk estimates have a role to play in radiation protection, what the Japanese residents need now are best estimates of risk, estimates that are the most consistent with available data.

Best estimates? The cumulative radiation doses received by the Japanese people, even for those most heavily exposed in Fukushima prefecture, are low[5]. No increase in cancer risk has been detected from doses in this range, even within the largest and most comprehensive dataset available regarding the health impact of radiation (the long-term follow-up of the A-bomb survivors). In fact, the most recent summary of the A-bomb survivor follow-up reports that a radiation risk model with a threshold of 40 milliSievert is just as consistent with the data as a

[5] I have estimated a total cumulative dose, as of 4 April, of 7.6 milliSievert to a resident at the measurement position in Iitate Village (where the highest dose-rates in Fukushia prefecture beyond the 20 km evacuation zone have been recorded). [See "Comments on the radiation levels resulting from the damaged nuclear power plants in Fukushima and the impact of these levels on human health." 4 April, J.C.Yanch.] 7.6 milliSievert is approximately the dose received from a CT examination of the chest for a person with no additional body fat, that is, for an individual who is not overweight.

linear model that passes through zero risk[6] (which predicts radiation-induced cancers at low doses where we have not actually observed them). Thus, it could be that doses below 40 milliSievert (even rapidly received) do not increase cancer risk.

So, do I have a best estimate of the risk of radiation at the low levels facing some Japanese residents? No, not a numerical value of the risk. For all the reasons described above getting this answer is very difficult (and the risk may, in fact, not exist). But I do know that our current risk estimates were never meant to be used in this way and that they very substantially overestimate the risks of living in a contaminated environment.

I think of how I would react by imagining myself and my family in the place of many Japanese at this time. The contamination levels would have to be very high before I would willingly give up my home or farm and my community since those are very high prices to pay and I am not convinced that low levels of radiation will do me and my family significant harm. Would I feed my three children contaminated food or water? That depends. If there are other foodstuffs *readily available* then the prudent response would be "why undertake any risk at all, even the chance of a risk?" But if there are no other choices for nutrition, or if the price for this nutrition involved large costs (long-term relocation, waiting for long times away from family in order to acquire uncontaminated food, funds that could be spent on other things such as housing or necessary clothing, etc.), then I would not hesitate to give my children contaminated food. We all face risks of different magnitudes every day. Nutrition associated with a small risk is better than no nutrition at all. The downside of not enough nutrition will be felt a lot sooner than the downside of small increases in radiation dose that result in small increases in the chance of getting cancer many years in the future. And the risk may be very small indeed.

Devastation from the recent earthquake and tsunami have had an impact on food availability in Japan. Farmlands have been salinated, feedmills, greenhouses and livestock operations have been damaged, and many fruit and vegetable crops have been destroyed. To add to this the voluntary

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[6] This is my interpretation of the following statement: "*Based on fitting a series of models with thresholds at the dose cutpoints in the person-year table, the best estimate of a threshold was 0.04 Gy with an upper 90% confidence bound of about 0.085 Gy. However this model did not fit significantly better than a linear model.*" from D.L. Preston et al, "Solid Cancer Evidence in Atomic Bomb Survivors: 1958-1998" *Radiation Research*, 168, 1-64, 2007.

disposal in foodstuffs and farmlands based on very conservative suppositions of long-term risks of radiation would seem to be a tragic waste of valuable resources. I have seen news reports showing farmers discarding lightly contaminated milk and have heard suggestions that rice crops may not be planted in April in some areas contaminated with $^{137}$Caesium. I understand that ionizing radiation is a topic that makes many people fearful; I also realize my own fear has been dissipated after more than a quarter century studying and teaching the topic of low dose radiation and human health. But as the Japanese people consider the various trade-offs they face going forward, it is crucial that they be guided not by fear, and not by risk estimates that were designed specifically for a different situation – a situation that bears little resemblance to one they are facing today.