Avoiding the Wrong Response to Radiation Risk

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The vagueness of the expression “it isn't something that has an immediate effect on one’s health” incites suspicion and fear. "If it is ingested once or twice, it won’t have any effect, but if you ingest it for a year, won't it have an effect? And even if you ingest it for a year, rather than having an immediate effect, won't the effects show up years in the future?” There is no clear information that dispels these doubts. If this was the case, efforts to decrease exposure as much as possible, and to refrain from buying agricultural products sourced from a broad area, would not be due to harmful rumors, but would be rational evasive behavior. On the other hand, some news channels have broadcast an expert opinion saying that exposure up to 100 millisieverts (mSv) has no clear health effects, and that there is sufficient leeway (for instance, 50 times that of iodine) between the standards and the exposure doses that would have negative impacts, all in an attempt to put people at ease. However, the opposite doubt can also arise, where people think “if that is the case, why would they stop shipments of perfectly safe agricultural products?” In addition, the shipment restrictions themselves cause the same upheaval that harmful rumors and misinformation can cause.

The factor that will effectively overcome this confusion and restore calm behavior is risk theory. What should we do?

First, we need to face the fact that it is possible for radiation to have health impacts, even in minute quantities. The outcome of low exposure dose is usually cancer and genetic effects. Whether health impacts are possible regardless of how minute the quantity, or, whether there is a threshold level below which exposure is harmless, are issues that in reality have no scientific conclusion. The International Commission on Radiological Protection (ICRP) has clearly stated that there will never be a conclusion to this problem in the field of epidemiology, and states that cancer and genetic effects can occur regardless of the exposure dose, including low exposure doses of <100mSv. With this assumption, they have expressed these possibilities as probabilities; furthermore, they have hypothesized that those probabilities are proportional to exposure dose. Based on these assumptions, they have been advising countries to apply radiation protection policies[1]. Japan, which fundamentally complies with this piece of advice as a measure to protect the general public against radiation, should give explanations to the general public that conform to that line of thinking. If there is a probability of cancer corresponding to any minute exposure, the approach towards achieving protection must be based not on seeking a level that poses no risk, but on the question “what risk level can we tolerate?” This is the shift towards a line of thinking based on risk theory. The decision as to what degree of risk we can tolerate can only be based on comparisons with other risks, and on comparisons of benefits and costs. A common unit of measurement is required in order for us to make comparisons. In this paper, I have focused on presenting materials that facilitate comparisons with other risks. I will leave comparison of benefits and costs to another time.

ICRP (2007) estimates that if a group of 10,000 individuals were each subjected to 1 Sievert (Sv) (=1000 mSv) of whole body radiation, 565 additional cases of death by cancer (non-lethal cancer was given a fixed weight and converted to a death) would occur within that group. If we take 565 cases/10,000 people/Sievert, rounded to the tens place and expressed using two digits as a ratio, it becomes

$$570/10000 = 5.7 \times 10^{-2}$$

/Sv. This is called the risk coefficient. The ICRP works on the assumption that low-level exposure of 100 mSv per person will lead to deaths from cancer in accordance with this coefficient. This means that the risk coefficient for 100 mSv is 5.7×10^{-3}, 10 mSv is 5.7×10^{-4}, and 1 mSv is 5.7×10^{-5}, or in other words, 5.7 in every 100,000 people.

For example, the current guidelines for an accumulated exposure of above 10 mSv is to take indoor refuge. The incremental increase in deaths equivalent by cancer~~s~~ that arise due to exposure of 10 mSv is estimated to be about 5.7 people per 10,000.

To judge the severity of this risk, we would be wise to compare it with other risks and their present circumstances. In 2009, 3013.6 in every 10,000 deaths were caused by cancer in Japan. Assuming hypothetically that the population is stable, this figure can be interpreted as the risk of death by cancer. Subsequently, at an exposure of 10 mSv, the number of cancer deaths would rise by 5.7, thus changing the reported figure to 3019.2 people.

As the number of deaths due to cancer rises, the average remaining lifespan accordingly decreases. We have calculated that if the number of cases of lethal cancer caused by carcinogens increases by 1 per 100,000 people, the average life expectancy decreases by 66 minutes. We used this result to evaluate the policies to cut back on various chemical substances[2]. This represents approximately a 13 year reduction in life expectancy per case of lethal cancer. This is “life expectancy,” meaning the average decrease in the lifespan of newborn.

The reduction in average expected lifespan for adults is lesser than the abovementioned value for infants, but for someone aged around 20, it would not be significantly less. Hence, if we use the figure of 13 years (=4600 days = 110,000 hours = 6.6 million minutes) per case of lethal cancer, the loss in remaining lifespan resulting from an exposure of 10 mSv is as follows:

$$5.7 \times 10^{-4} \times 4600 \text{ [days]} = 2.6 \text{ [days]}$$

The average lifespan in 2009 in Japan was 79.59 years for men, and 86.44 years for women, which was higher than that reported in 2005 by 1.03 years and 0.92 years, respectively. In other words, the average lifespan increased by about 90 days per year. This means that if all Japanese people were exposed to 10 mSv, this increase would contract by 2.6 days. It is thought that the major factor related to daily life that causes a decrease in lifespan is smoking. It is estimated that the loss of remaining life due to deaths from smoking is between a few years and a few decades[3]. This figure is estimated at 370 days just for lung cancer and 120 days for passive smoking alone[4].

At present, restrictions are being enforced on the shipping of agricultural products contaminated by radioactivity, as well as on the use of tap water. The reference values in becquerels (Bq) used for making these judgements for radioactive iodine and radioactive caesium are as follows: water and milk, 300 Bq/kg; vegetables (mainly leafy), 2000 Bq/kg; and water and milk, 200 Bq/kg; vegetables, grains, meat, eggs, and fish, 500 Bq/kg, respectively. There are a number of issues with the way these reference values are determined, including assumptions on the mechanism of decay of radioactive materials in water and agricultural products, particularly strict ways of dealing with thyroid exposure, etc., but we will not address these here. The risks associated with ingesting food or water containing borderline radioactivity relative to the reference values are calculated below.

First, the radiation dose absorbed by the body when radioactive material containing radioactivity expressed in Bq is ingested via food and drink can also be calculated using the ICRP coefficients. For example, ingesting 1 Bq of iodine-131 results in exposure of 1.8×10^{-4} mSv for an infant (3 months), 1.0×10^{-4} mSv for a child (5 years), or 2.2×10^{-5} mSv for an adult (20 years) (figure corresponding to whole body exposure). So for example, if an infant ingests water, milk, and leafy vegetables in quantities of 0.71 kg, 0.6 kg, and 0.07 kg (these are the pre-determined amounts for determining the reference values), respectively, contaminated to a level close to the reference values, the infant would have ingested

$$300 \times 0.71 + 300 \times 0.6 + 2000 \times 0.07 = 533 \text{ Bq}$$

of iodine-131. If this continued for 1 week, it would result in 3731 Bq being ingested.

Therefore, the total exposure would be

$$3731 \times 1.8 \times 10^{-4} = 0.67 \text{ [mSv]}$$

The resulting risk of cancer would be

$$0.67 \times 5.7 \times 10^{-5} = 3.8 \times 10^{-5}$$

The resulting loss of remaining life would be

$$3.8 \times 10^{-5} \times 110{,}000 = 4.2 \text{ [hours]}$$

If this is continued for a week, 17 hours would be lost, and if it continues for 1 year, 220 hours (9.1 days) would be lost. As a precautionary measure, the Ministry of Health, Labor, and Welfare gave instructions not to feed infants tap water contaminated with over 100 Bq/kg, but the gain in life expectancy resulting from lowering the concentration of radioactive iodine in water drunk by an infant from 300 to 100 Bq/kg would be, for example, over a three day period:

$$(300 - 100) \times 0.71 \times 3 \times 1.8 \times 10^{-4} \times 5.7 \times 10^{-5} \times 6{,}600{,}000 = 29 \text{ [minutes]}$$

The vegetable that was detected with the highest concentration of radioactive iodine between March 16 and April 5 was spinach produced in Ibaraki Prefecture on March 18, containing 54,100 Bq/kg. If an adult aged 20 ate 400 gm of this every day for a week, the risk would be

$$54{,}100 \times 0.4 \times 7 \times 2.2 \times 10^{-5} \times 5.7 \times 10^{-5} = 1.9 \times 10^{-4}$$

In other words, this means a lethal cancer risk of 1.9 people per 10,000, or a loss of remaining life of 21 hours. If it was 80 gm a day, rather than 400, the risk would be one fifth of this amount, or 4.2 hours of loss of remaining life.

The highest concentration of radioactive caesium was found in Fukushima Prefecture's kukitachina (standing stem vegetables) on March 21, which contained 41,000 Bq/kg of caesium-134 and 41,000 Bq/kg of caesium-137. The coefficients for converting the radioactivity of radioactive caesium to exposure dose are shown in Table 1.

Table 1: Exposure dose coefficients for ingestion of radioactive caesium (mSv/Bq)

	Infants (3 months)	1-year-old children	5-year-old children	Adults (20 years old)
Caesium 134	2.6×10^{-5}	1.6×10^{-5}	1.3×10^{-5}	1.9×10^{-5}
Caesium 137	2.1×10^{-5}	1.2×10^{-5}	9.6×10^{-6}	1.3×10^{-5}

ICRP (1996), Publication 72, *Annals of ICRP*, 26(1), p.27

If an adult ate 400 gm of this every day for a week, the risk would be

$$41{,}000 \times 0.4 \times 7 \times (1.9 + 1.3) \times 10^{-5} \times 5.7 \times 10^{-5} = 2.1 \times 10^{-4}$$

In other words, it means a lethal cancer risk of 2.1 people per 10,000, or a loss of remaining life of 23 hours. If this was continued for a year, it would result in a loss of remaining life of 50 days, but continuing to eat this type of high-concentration vegetable every day is highly unlikely, even if the restrictions were removed. In reality, shipment is restricted and the average concentration is probably far lower.

From the above, when we consider how we normally deal with the multitude of risk factors related to our daily life, and which determine our life expectancy, changing our behavior because of worries about the risks of radioactive material present in the food and water that we ingest daily would seem to indicate a lack of consistency in our behavior. Not worrying about it in the slightest would probably be the best course of action for individuals. There are other factors that need to be considered when deciding the pros and cons of policies such as shipping restrictions. This will be dealt with at another time.

References

1. ICRP (2007), Publication 103, *Annals of ICRP*, 37(2-4).
2. Gamo, Oka and Nakanishi (1996) Expression using the Loss of Remaining Life from Cancer Risk due to Exposure to Carcinogens—Conversions Using the Life Table—Journal of Environmental Science Volume 9 Pages 1-8. Toshihiro Oka(1999)Environmental Policy Statement, Iwanami Shoten
3. Junko Nakanishi (2004) Environmental Risk Studies, Nippon-Hyoron, p80
4. As above