Effects of Radiation Exposure on Human Health

Kiminori Itoh

Yokohama National University

Global COE Program, “Global Eco-Risk Management from Asian Viewpoints

Context

Currently, due to the reactor accident at the Tokyo Electric Power Company's Fukushima Dai-ichi Nuclear Power Plant, radioactive material has been released into the atmosphere and the ocean. It is important for us to understand what sort of effects radiation has on overall human health, or in other words, the health risks related to radiation exposure. In reality, however, it is extremely difficult for the general public to understand the radiation intensity figures being reported, and what degree of risk they represent. For this reason, we have attempted here to explain the same in a manner that is simple and easy for the general public to understand. The difficulty in understanding the hazards of radiation exposure lies in the fact that the general public may not understand the health impacts without prior knowledge, even if the strength in units of radiation is explained to them. Moreover, if someone mentions the risk of cancer, it won't mean a thing. However, when we use the phrase “the change to healthy life expectancy,” we can relate it with not only radiation, but with the impacts of a variety of other health hazards. In addition, by projecting the issue in this manner, we can grasp the impacts of radiation in layman's terms (Kan Sanju). You may go over the table now if you prefer, but it would be easier to understand if you read the explanation first. However, this is by no means the only approach. Please understand that these are rough estimates.

Method

Healthy life expectancy: Healthy life expectancy is the number of years one can expect to live independently without nursing care, or in other words, the number of years one can live in a healthy condition.

When this figure increases because of any reason, it means that one's healthy life span will be longer; conversely, when it decreases, the healthy life span will be shorter. These two phenomena are called gain and loss in healthy life expectancy, respectively.

The probability of death by cancer caused by radiation: Table 1 demonstrates the total whole body exposure (cumulative whole body exposure level) in Sieverts (Sv). Ingestion through air, food, and water is called internal exposure, but here we will only address external exposure.

The calculation was performed as follows. We uniquely consider cases in which cancer occurs some years after exposure to radiation, followed by death.

According to the International Commission on Radiological Protection (ICRP), among cases exposed to an annual radiation level of 0.3 mSv continuously through their life, one to two people per one hundred thousand die of cancer each year (Reference 1). Here, the probability of dying because of cancer is $3–6x10^{-2}$/Sv. However, life expectancy varies with each individual, so statistical alterations have been applied. Prof. Oka of Fukui Prefectural University has based his calculation on the ICRP2007 annual publication (ICRP Publication 103) to arrive at the probability of $5.7 x10^{-2}$/Sv for whole body exposure. Larger figures have also been reported, but are not routinely used according to Prof. Oka.

Conversion to loss in healthy life expectancy: To express this in terms of healthy life expectancy, we use the method of Gamo et al., who calculated that for Japanese people, healthy life expectancy contracts by 13 years due to death because of cancer[2]. (You may refer to the detailed explanation given by Prof. Oka that is posted on the website.)

In other words, 1 Sv shortens healthy life expectancy as follows: $(3–6 \times 10^{-2}$/Sv) x 1 Sv x 13 years = 0.4–0.8 years. This is the calculation for loss in life expectancy of an infant under 12 months of age, so the decrease would be greater for an adult. Therefore, you should think of it as being under 0.8 years/Sv. In Table 1, we have used the figure of 0.74 years, used in Prof. Oka's thesis.

Finally, we calculated the loss in healthy life expectancy using the following equation: (loss in healthy life expectancy) = (total amount of exposure expressed in Sieverts) x 0.74 years

The loss in healthy life expectancy calculated by this method is shown in Table 1. In summary, it is roughly 1 year for each Sv of radiation.

Table 1: The impact of exposure levels on total healthy life expectancy of an individual

Exposure level (Sv)	The impact on healthy life expectancy	
10 Sv	−7.4 years	
3 Sv	−2.4 years	
1 Sv	−270 days	
300 mSv	−81 days	
100 mSv	−27 days	
30 mSv	−8.1 days	
10 mSv	−2.7 days	
3 mSv	−19.5 h	
1 mSv	−6.5 h	Annual allowable exposure limit for the general public
0.3 mSv (300 μSv)	−2 h	
0.1 mSv (100 μSv)	−39 min	
0.03 mSv (30 μSv)	−12 min	
0.01mSv (10 μSv)	−3.9 min	
0.003 mSv (3 μSv)	−1.2 min	
0.001 mSv (1 μSv)	−23.4 sec	

In Table 1, from 0.001 mSv (i.e., 1 μSv) to 1000 mSv (i.e., 1 Sv), each value increases by a factor of three. Because it is a proportional relation, the same calculations can be used for other exposure levels as well. Furthermore, if one is exposed to large amounts of radiation in a short timeframe (above 250 mSv), acute sickness develops within a few weeks, and the lethal dose is established as 7 Sv.

Becquerels (Bq) are often used in place of Sieverts, but conversion between the two varies depending on a number of factors, such as the amount of food ingested, etc. Therefore, we shall only address Sv in this paper for consistency. Furthermore, from the calculations in Reference 1, we assume that 1 Bq is equivalent to 3.7×10^{-6} Sv (or 270,000 Bq are equivalent to 1 Sv).

The maximum allowable exposure: The maximum allowable annual exposure for the general public is approximately 1 mSv (Reference 3). If exposure of 0.3 mSv per year results in 1–2 individuals dying of cancer per every 100,000, then an annual exposure of 1 mSv would mean approximately 3–6 individuals per 100,000. Furthermore, for a lifespan of approximately 80 years, the total maximum allowable exposure level would be 80 mSv. The Table shows that 100 mSv results in an impact of −27 days, so 80 mSv would be equivalent to about −22 days. In order interpret this, please refer to the comparisons with other types of risks that appear later.

As research has progressed, the maximum allowable dose has demonstrated a downward trend (Reference 4). The figure for medical professionals is an annual maximum of 50 mSv (Reference 5). The data from these documents is attached as addendums at the end.

Exposure levels: The exposure level in Sv is often reported per hour, but the figures in Table 1 are total amounts. For this reason, the hourly radiation level must be used to calculate the total radiation level. The level of exposure per hour is often written as the radiation intensity. Table 2 shows the relationship between the radiation intensity (Sv/h) and the total exposure level (Sv). Therefore, the total exposure level can be easily derived from the reported radiation intensity. However, the radiation intensity is assumed to be constant over a given period of time, whereas radiation levels frequently move in the form of a sharp spike. When that happens, an estimate of exposure level can be derived from halving the product of the height of the peak and the duration (area of a triangle).

Table2: The relationship between Sieverts per hour and the total exposure level (Extraordinarily large fields were omitted)

Period / Radiation intensity	1 hour	1 day	1 week	1 month	1 years	10 year
100 mSv/h	100 mSv	2.4 Sv	16.8 Sv			
10 mSv/h	10 mSv	240 mSv	1.68 Sv	7.2 Sv		
1 mSv/h	1 mSv	24 mSv	168 mSv	720 mSv	8.64 Sv	
100 μSv/h	100 μSv	2.4 mSv	16.8 mSv	72 mSv	864 mSv	8.64 Sv
10 μSv/h	10 μSv	240 μSv	1.68 mSv	7.2 mSv	86.4 mSv	864 mSv
1 μSv/h	1 μSv	24 μSv	168 μSv	720 μSv	8.64 mSv	86.4 mSv
0.1 μSv/h	0.1 nSv	2.4 μSv	16.8 μSv	72 μSv	864 μSv	8.64 mSv
0.01 μSv/h	0.01 nSv	240 nSv	1.68 μSv	7.2 μSv	86.4 μSv	864 μSv

As a guide, combinations of the period and exposure levels above 80 mSv are shown in red, and combinations below 80 mSv are shown in blue.

For example, if an individual is continuously exposed to radiation of 1 μSv/h for 1 month, the cumulative figure would be 720 μSv. Table 1 shows an impact of −2 h at 300 μSv; therefore, 720 μSv would result in an impact of approximately −5 h.

Comparisons with other Risks: What should we make of the calculated loss in healthy life expectancy shown above? Here, a comparison is made with a variety of other health risks that are presented in Junko Nakanishi's "Environmental Risk Studies." Figure 1 shows a variety of health risks, such as smoking, diesel particles, arsenic, benzene, etc., in terms of loss of remaining life (similar to loss in healthy life expectancy).

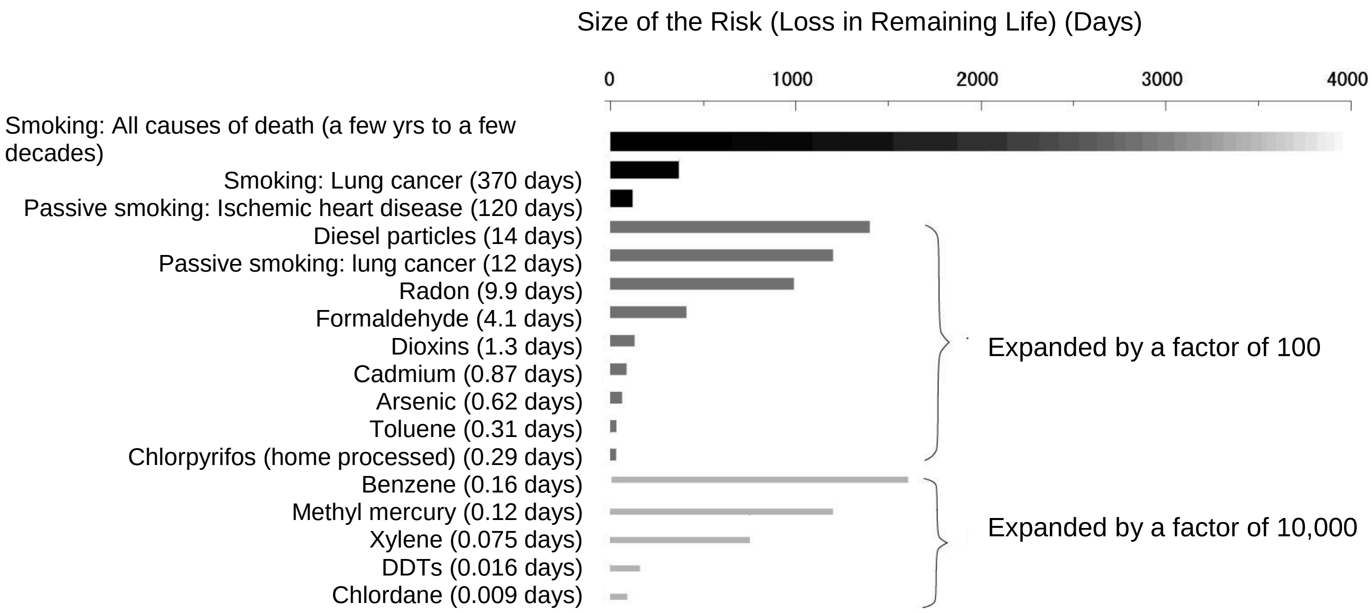


Figure 1. Comparison of a variety of health risks (*Environmental Risk Studies*, Junko Nakanishi, p.104) "Loss of remaining life" is a concept that is almost the same as loss in healthy life expectancy.

The impact of of smoking is the highest, ranging from a few years to decades. Among radioactive materials, naturally occurring radon has a figure of 9.9 days. The figure for the well-known dioxins is 1.3 days. Furthermore, the risks shown below “diesel particles” have been multiplied by 100 or 10,000.

By using this method, a variety of health risks can be compared with the risks associated with radiation exposure. The abovementioned example of the risk of 1 μSv over 1 month (a loss of 5 h in healthy life expectancy) is equivalent to the risks shown below the centre of the list in Figure 1.

<u>Gains in healthy life expectancy:</u> Healthy life expectancy decreases when health risks exist, but it increase when something good for your health occurs. For example, people who eat an average of around 10 gm of fish/day gain 0.5 years of healthy life expectancy compared to those who do not eat fish at all. In other words, this adds extra 0.5 years to the healthy

life expectancy. Other types of lifestyle improvements are also assumed to lead to a gain in healthy life expectancy.

Conclusion: We live in the midst of a variety of health risks. Comparing each individual risk, and taking measures to move towards lower risk, is to some degree a natural instinct in humans. This has enabled biological organisms including human beings to survive. However, there are cases where our instincts fail to help us. For risks like radiation that cannot be detected by our sensory organs, we have no choice but to rely on our wisdom as our sensor.

We believe that the calculation of loss and gain in healthy life expectancy is suitable for comparing these risks. We are considering providing related reference information at the GCOE as required. We hope this can be of use.

References

1) http://blog.goo.ne.jp/harumi-s_2005/e/79a28f5179a1c8d81979ce33b1d2e4e9
2) Gamo,,M., Oka,,T., Nakanishi,J.; Journal of Environmental Science (1996) 9:1-8
3) http://testpage.jp/m/tool/bq_sv.php
4) http://www.rri.kyoto-u.ac.jp/NSRG/kid/radiation/permisib.htm (See Appendix Table 1)
5) http://shimonagaya.com/radiation.htm (See Appendix Table 2)

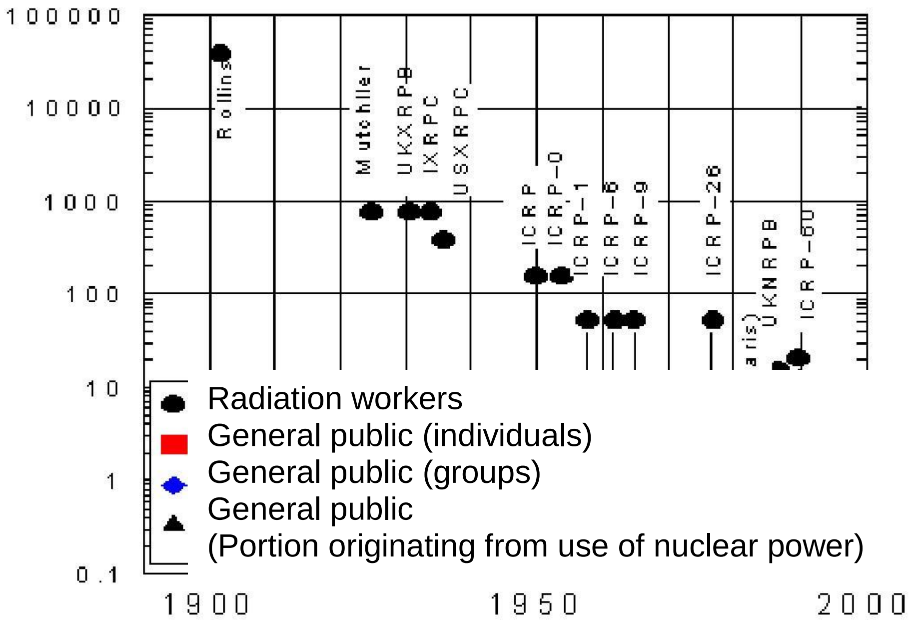
Appendix 1: The Change in the Permissible Dose of Radiation

Sourced from:

http://www.rri.kyoto-u.ac.jp/NSRG/kid/radiation/permisib.htm

Changes to the so-called 'permissible dose' of radiation

(Millisieverts / year)



Year

Immediately after the discovery of radiation and radioactivity, there was little understanding of exposure, and the limits were extraordinarily high. Since then, scientific knowledge on the degree of accumulated radiation-related risk and the limits for exposure moved in only one direction: downward. The reason why the regulation for groups in the general public exists is because the gene groups of a whole population were taken into consideration.

Rollins and Mutchller are the names of researchers.

UKXRPB: UK X-Ray and Radium Protection Board

IXRPC: International X-Ray and Radium Protection Committee

UKNRPB: UK National Radiological Protection Board

USXRPC: US X-Ray and Radium Protection Committee

ICRP: International Commission on Radiological Protection (The numbers following are the recommendation numbers)

USNRC: US Nuclear Regulation Commission

USEPA: US Environmental Protection Authority

Appendix 2: Permissible Exposure Dose

Sourced from:

http://shimonagaya.com/radiation.htm

Article 30-27 of the Enforcement Regulations of the Medical Service Law (Permissible Dose)

For 3 months:

Radiation workers (whole body) maximum permissible dose	30 mSv (30000μSv)
Exposure only of the skin	80 mSv (80000μSv)
Hands, feet, joints	200 mSv (200000μSv)
Stomach area of women of childbearing age	13 mSv (13000μSv)
Stomach area of pregnant women from the day pregnancy was diagnosed until birth	10 mSv (10000μSv)
Annual (whole body) maximum permissible exposure dose	50 mSv (50000μSv)

Exposure dose considered to pose no risk on health both now and in the future, as per the International Commission on Radiological Protection (ICRP) = 1Sv (1000 mSv = 1000000μSv)