“Microsieverts” and Other Nuclear-Related Units of Measure

As of April 18, 2011

Many of you may be wondering how to interpret the various information the media is diffusing about the accident at Fukushima Daiichi Nuclear Power Plants. This paper is intended to help you better understand the news brought to you by the mass media.
You may skip (*) parts which are somewhat professional.

How to Gather Information

- ○ You should not believe rumors as many of them are not accurate.
- ○ If you are not connected with Internet, we recommend that you check out the statements from the government at least once a day on TV or newspapers.
- ○ If you are connected, you can get timely information in English by accessing the web pages of the Ministry of Education, Culture, Sports, Science and Technology (MEXT, www.mext.go.jp) or the Food Safety Commission (FSC, www.fsc.go.jp). Q&As (Frequently Asked Questions and Answers) are available on the web page of the latter.
- ○ Use the direct links to the webs pages of MEXT and FSC to access them. Take note that some other web pages that refer to those official pages show irresponsible comments.

- ○ If you search for the key words “Ministry of Education, Culture, Sports, Science and Technology” and “Microsievert” on the internet, you will find a section named “Reading of environmental radioactivity level” on the web pages of MEXT. The last two pages of the document show Fig. 1 and Table 1. This Fig 1 and Table 1 will sometimes be referred to in the subsequent sections.

What is “Microsievert”?

【Keywords; radiation, sievert, millisievert, microsievert】

- ○ We see the word “microsievert” frequently on TV and newspapers. What is it?
- ○ The “sievert” is the unit representing the amount of radiation. (* To be accurate, it represents the level of influence on human bodies when they absorb energy from radiation, but you may experience no inconvenience if

you take it as amount of radiation.)

- ○ The “millisievert” is one-thousandths of a “sievert” and the “microsievert” is one-thousandths of a “millisievert.”

【Keywords: daily life and radiation, natural radiation, radiation from natural foodstuffs, regional difference】

- ○ The bigger the value is, the greater influence it exerts on human bodies. Then, which value should we use as a guideline? In this case, it may be more understandable if we compare the values with a variety of values of radiation that exists in our daily life.
- ○ Let’s look at Fig. 1 (Daily Life and Radiation). You may see in the middle part on the left a description of “Natural radiation (annual) per person,” which shows worldwide, annual average radiation exposure of 2,400 microsieverts (2.4 millisieverts). This is the amount of radiation received from the natural world when we live an ordinary life.
- ○ The breakdown of sources indicated inside the balloon (on the left side of Fig. 1 shows as follows (Note that only the values inside the balloon are in millisieverts): 0.39 millisieverts (390 microsieverts) from the space and 0.48 millisieverts (480 microsieverts) from the earth. They are radiation received from outside the human body (* it is called “external exposure”). There are also other sources: 0.29 millisieverts (290 microsieverts) from foodstuffs and 1.26 millisieverts (1,260 microsievert) from radon included in the air (* such as inhalation of radioactive gases. These are radiation received from inside human bodies (* called “internal exposure”).
- ○ It shows that radiation also comes from the foodstuffs that exist in the nature and that we live while being exposed to radiation from inside our body.
- ○ There is a regional difference between the amounts of such natural radiation. In the region of Guarapari, Brazil, it amounts to 10,000 microsieverts (10 millisieverts), four times more than the world average. (* This is the amount of external exposure.)

【Keywords: amount of radiation received from medical care, dose limit for the general public】

- ○ You can also see the amount of radiation received from medical care (* called “medical exposure”) on the right side of Fig. 1. It is said that the group examination of chest X-ray gives radiation of 50 microsieverts per examination, the group examination of stomach X-ray gives 600 microsieverts (0.6 millisieverts) and the chest X-ray computerized tomography scan (CT scan) 6,900 microsieverts (6.9 millisieverts) per examination.

○ It is better not to receive radiation if the circumstances permit. The idea is to compare the “loss” of receiving radiation with the “gain” of detecting a failure or seeking reassurance and determine that a certain level of “loss” is permissible.

○ Therefore, the amount of radiation from medical care is treated separately from other sources. In the middle of the right hand of Fig. 1, you can see a description of “Dose limit (annual) of the general public” which is 1,000 microsieverts/year. The dose means the amount of radiation received by human bodies. Therefore, this section means that the “limit of amount of radiation received by the general public in a year is set to 1,000 microsieverts (1 millisievert).” However, it is followed by a mention “except medical care,” indicating that the value of 1,000 microsieverts (1 millisievert) refers to the amount of radiation received by other means than medical care.

【Keywords: dose, dosimeter, operator】

○ On the other hand, while it is true that the “limit of amount of radiation received by the general public in a year is set to 1,000 microsieverts (1 millisievert.),” there is no way to control the dose as there is no one who carries a dosimeter (an instrument designed to measure the amount of radiation) around the clock throughout the year. It is all the more so since we receive 2,400 microsieverts (2.4 millisieverts) that exceed the 1,000 microsieverts (1 millisievert) as natural background as a global average and there is also a regional difference.

○ In fact, the criteria of “the limit of amount of radiation received by the general public in a year is set to 1,000 microsieverts (1 millisievert)” is not intended to regulate the individuals of the general public, but the corporate bodies, i.e., nuclear power stations and other facilities where radiation or radioactive substances (substances that emit radiation) are treated such as hospitals, laboratories and factories. In other words, the criteria means that “the corporate bodies shall ensure that “in addition to the natural radiation and that from medical care, the individuals of the general public will not receive radiation of more than 1,000 microsieverts (1 millisievert) even if they stay where they are supposed to be (for example, at the boundary of a hospital site and an area where the members of the general public live) throughout the year.”

【Keywords: influence of nuclear accident, μSv/h, microsieverts per hour】

○ To consider the influence from the accident of the nuclear power station, let’s look at Table 1 that indicates the results of measurements of environmental radiation taken in various parts of the country. The unit of measure “μSv/h (microsieverts per hour)” is the amount of radiation (microsieverts) per hour.

○ The rightmost field shows a range of radiation measured during normal hours in the past. You may recognize a regional difference that amounts to about two times even in Japan as well as a variation in time at the same measurement point. Roughly, it is usually in the order of 0.05 microsieverts per hour.

○ Now, there is a measurement point at which a value of 1.035 microsieverts per hour was recorded. Although it was then returning to normal, if this value of 1.035 microsieverts per hour continued for a year, which is only an assumption, not a reality, the calculated cumulative radiation received for the one year time would be 9,066.6 microsieverts as a year consists of 8,760 hours. (* This does not include the internal exposure that is radiation from inside the body.) When this value is compared with the values indicated on Fig. 1, it follows that it is an amount of radiation a little smaller than that of the annual natural radiation at Guarapari, Brazil. It is a little more than one chest X-ray CT and one stomach X-ray examination each.

【Keywords: radiation limit for special cases, radiation worker, in case of emergency work, International Commission on Radiological Protection (ICRP), International Atomic Energy Agency (IAEA), standard value acceptable to the general public in case of emergency, planned evacuation zone】

○ We have so far looked at the radiation levels experienced during our daily life. The radiation limit for special cases is indicated on the upper part of Fig. 1. The upper limit allowed to radiation workers and personnel of police and fire fighting agencies involved with disaster countermeasures is 50,000 microsieverts (50 millisieverts) annually. The upper limit allowed to emergency work was set at 100,000 microsieverts (100 millisieverts) annually, but it has been raised to 250,000 microsieverts (250 millisieverts) annually in the wake of the accident at Fukushima Daiichi.

○ Then, what about the individuals of the general public? Does the radiation limit remain to be 1,000 microsieverts (1 millisievert) annually after the accident? The limit allowed to the individuals of the general public in case of emergency is set at 20,000 - 100,000 microsieverts (20 - 100 millisieverts) annually by the international rulemaking organizations, the International Atomic Energy Agency (IAEA) and the International Commission on Radiological Protection (ICRP).

○ The “planned evacuation zone” set by the government is the area in which the amount of radiation received by the individuals of the general public in a year could reach the level of 20,000 microsieverts (20 millisieverts), the lowest value of the above-mentioned range, if the current radiation level (as of April 5 at 24:00) continued in addition to the radiation level experienced just after the accident.

○ The preceding discussions may help you determine which is within daily range and which is the limit for special cases in terms of the amount of radiation received by human beings (values in microsieverts).

Unit of "Becquerel"

【Keywords: radioactivity, radioactive substance】

○ The word "Becquerel (Bq)" has become popular. It is a unit of measure for "radioactivity."

○ The substances that emit radiation is called "radioactive substance" and "radioactivity" is a measure of how strong the capacity of such substances is to emit radiation. You are right to say as follows: "A radioactive substance of 100 Becquerels emits 100 times more radiation than one of 1 Becquerel."

○ As far as the same radioactive substance is concerned, the amount and radioactivity are proportional. So it is reasonable to say, "Radioactivity equals to the amount of the radioactive substance."

【Keywords: 40 Becquerels per square centimeter (40 Bq/cm^2), 300 Becquerels per kilogram (300 Bq/kg), contamination, decontamination】

○ The expressions such as "40 Becquerels per square centimeter (40 Bq/cm^2)" or "300 Becquerels per kilogram (300 Bq/kg)" have also become popular. The former is used when radioactive substances are attached to the surface of a human body or foodstuffs and the latter when radioactive substances have entered the whole or part of foodstuffs or water.

○ The state where radioactive substances are attached to or enter as above is expressed as "contaminated." However, foodstuffs and water inherently have radioactive substances during normal times, albeit in a very small quantity. So the word "contamination" refers to the state where the amount of radioactive substances has increased compared with the normal times.

○ When radioactive substances are attached to the surface (*called surface contamination), it is possible to eliminate contamination by wiping or water washing. This operation is called "decontamination" (*For comparison, the level of screening or level of contamination at which decontamination is required for surface contamination of the general public who visit a local health care center for checkup examination is 100,000 cpm when measured by a survey meter, i.e. 100,000 counts per minute. It corresponds to the surface contamination level of 400 Becquerels per square centimeter (400 Bq/cm^2), when a GM survey meter, most typical counter, is used.)

【Keyword: drinking water or foodstuff, interim regulation limit, Food Sanitation Law, index, radioactive iodine, cow milk, greenstuffs, fish and shellfish, tap water】

- ○ Referring to the previous item, at what Becquerel level should we be careful? It is defined as national criteria by laws and regulations.
- ○ For radioactive substances contained in drinking water and foodstuff, the “interim regulation limit” is defined by the Ministry of Health, Labour and Welfare based on the index provided by the Nuclear Safety Commission. The foodstuffs that exceed the limit are stipulated in the Food Sanitation Law to avoid ingestion as food. Drinking water is also regulated using indices for ingestion.
- ○ Such limits for radioactive iodine, for example, are 300 Bq/kg for drinking water and cow milk, 2,000 Bq/kg for greenstuffs (except edible roots and potatoes) and fish and shellfish and 300 Bq/kg for other than infants and 100 Bq/kg for infants for drinking water. (* For details, see the “Q & A” Section on the web site of the Food Safety Commission.)

【Keyword: Regulation of shipment and water intake, thyroid, International Commission on Radiological Protection (ICRP)】

- ○ Although the above values are announced, ordinary people cannot judge whether those foodstuffs and drinking water are safe or not, because they cannot measure. However they do not need to think they should measure and judge by themselves. They cannot eat and drink foodstuffs and water which exceed the regulation limits and indices, because shipment and intake of such foodstuffs and water are restricted by the laws and regulations.
- ○ How is this regulation limit defined? Let’s take radioactive iodine as an example. Assume that the condition continues for a whole year in which the same concentration of radioactive iodine as the regulation limit is contained in food and drink. Besides, suppose that you take the average amount of drinking water and foodstuffs such as cow milk and dairy products, vegetables, cereals, meat, eggs and fish and others for a year. In this case, the radiation received by the thyroid during the year will be 50 millisieverts. Conversely, the limit of 50 millisieverts will not be reached as long as you eat

and drink food and water below the regulation limit. The reason why the thyroid is focused on is because iodine is concentrated on the thyroid by nature. And the reason why the value of 50 millisieverts is set as a limit is because the radiation limit of the thyroid for iodine for a year is set at 50 millisieverts based on the recommendations of the rulemaking International Commission on Radiation Protection (ICRP).

○ For those concerned that the regulation limit may have been exceeded temporarily by eating and drinking, it is a good idea to recall that the regulation limit has been set according to the strict conditions as mentioned above.

【Keyword: pregnant or lactating woman, Japan Society of Obstetrics and Gynecology】

○ Nevertheless, pregnant or lactating women may be concerned about it. They may feel reassured by looking at the document entitled “Information for Pregnant and Lactating Women Who are Concerned About Tap Water” issued by the Japan Society of Obstetrics and Gynecology. You can easily find this document by using search words “Japan Society of Obstetrics and Gynecology pregnant lactating women” on the Internet. Here is an abstract of the document.

・ If a pregnant woman were to drink a liter of tap water contaminated with the same radioactivity level (200 Bq/kg) as that detected in Kanamachi Water Treatment Plant (slightly contaminated tap water) on March 23 everyday during the pregnancy (280 days), the amount of radioactivity received is calculated as 1.2 millisieverts. (Writer’s note: We usually receive radiation of 2.4 millisieverts annually from the natural world as a global average. There is a region with an annual, natural radiation level of 10 millisieverts.)

・ It is believed that the radiation level of 50 millisieverts or more has an impact on an embryo. (* Some are of the opinion that the limit should be 100 millisieverts as recommended by ICRP.)

・ The amount of radiation to which an embryo is exposed is smaller than that to the mother.

・ It is estimated at present that there will be no health hazard to a mother and an embryo even if a pregnant or lactating woman drink slightly contaminated tap water every day. In addition, it is estimated that no health hazard to a baby and infant will arise if nursing is continued.

・ It is recommended, however, to use drinking water other than slightly contaminated tap water if it is available as less radiation is better.

・ Pregnant women need to avoid dehydration and should not limit their water intake out of concern when water is slightly contaminated.

Countermeasures to avoid radiation as far as possible

【Keyword: recommendation for indoor evacuation】

○ The following advices are offered for the regions where indoor evacuation is recommended:

・ Remain indoors as much as possible.
・ Avoid going out unnecessarily.
・ Avoid being exposed to the rain.
・ Brush off the clothes before getting in the house.
・ Wear a mask while you are out.

【Keyword: three principles to reduce effects of radiation; shielding, distance and time; indoors and outdoors】

○ Why is it possible to avoid receiving excessive radiation if these advices are followed? First, be aware of the Three Principles of "Shielding, Distance and Time" to reduce effects of radiation.

○ The "Shielding" means "something to shield with." Radiation loses its intensity after it passes through an object. It sometimes settles inside the object. It is similar to the fact that the intensity of light is smaller when you see the light through a piece of paper than directly. It is also similar to the fact that you do not see the light anymore if the paper is too thick. You are safer indoors than outdoors since the roof and structure of a building also shield radiation.

○ The next factor is "Distance." The intensity of radiation weakens if you are far from the source of radiation, in other words, if the distance is longer. It is similar to the fact that the light of a candle looks brighter when you look at it up close, but that it loses its brightness when you are away from it. When radioactive substances are blown by the wind and fall on the roof, they are sometimes deposited on the roof or the ground surrounding the building temporarily. You can take a distance from these radioactive substances if you stay indoors.

○ It is said that, if the effects of "Shielding" and "Distance" are combined, the level of radiation received drops to a fraction or one-tenths if you stay indoors compared to outdoors.

○ The effect of "Time" is also important. The unit "μSv/h (microsieverts per hour)" that is frequently mentioned on TV or newspapers is the amount of radiation (microsieverts) per hour. For example, if you stay at a place with 1 microsievert per hour for an hour, you receive radiation of 1 microsievert. If you stay only for thirty minutes, the amount of radiation received decreases to a half, 0.5 microsieverts. That is why it is recommended to stay outdoors for as short a time as possible when the amount of radiation is larger outdoors than indoors.

【Keyword: rain, mask, measures against hay fever】

○ The next advice “Avoid being exposed to the rain and Brush off the clothes before getting in the house” are intended to prevent radioactive substances dissolved in the rain, coming on the wind or stirred up from the ground from being attached to and remaining on the surface of clothes.

○ The advice “Wear a mask while you are out” is designed to avoid sucking and ingesting radioactive substances present in the air.

○ The advices “Brush off the clothes before getting in the house” and “Wear a mask while you are out” are the same measures as against hay fever.

【Keyword: areas free from evacuation order or recommendation for indoor evacuation, National Institute of Radiological Sciences, less than 100 millisieverts, cancer, monitoring data, regional difference, difference of natural radiation among domestic measuring points, maximum difference among prefectural averages, daily level】

○ The recommendations for indoor evacuation have been described. How should we respond in the areas other than those subject to evacuation order or recommendation for indoor evacuation?

○ The web site of the National Institute of Radiological Sciences, an incorporated administrative agency engaged in specialized research into radiation medicine and effects of radiation on human bodies, states that “there is no scientific evidence that the amount of radiation exposed (Writer’s note: amount of radiation received) of about less than 100 millisieverts leads to cancer” and that “the effects of radiation do not deserve excessive concerns as they are much lower compared with the risk associated with lifestyle habits such as smoking and diet. In addition, outside the evacuation zone surrounding the nuclear power station, it would not be a cause for concern if you live in an ordinary way since the value of 100 millisieverts will not be exceeded as long as you live as usual.”

○ If you are still anxious about it, it is a good idea to determine if you should take measures as taken in the area subject to indoor evacuation by reviewing the monitoring data presented by the Ministry of Education, Culture, Sports, Science and Technology and each prefecture (amount of radiation outdoors by region: microsieverts per hour.)

○ When, for example, a calculation is made based on 8,760 hours for a year, the value of 100 millisieverts is reached if a value of 11.4 microsieverts per hour in the monitoring data persists for a whole year.

○ The monitoring data shows a value in the order of 0.05 microsieverts per hour although there is a regional difference. Let's assume a case when a tenfold value of 0.55 microsieverts per hour continues for a month before returning to the normal value. The increment observed during this period is 360 microsieverts. Now, look at the middle part on the left of Fig. 1, which shows that the "difference of natural radiation among domestic measuring points (annual)" (maximum difference among prefectural averages) is 400 microsieverts/year. While only on paper, the amount of radiation may be higher than the above-mentioned 360 microsieverts if you move from an area with low natural radiation level to one with a higher natural radiation level. Such increase and decrease in the amount of radiation may be deemed as a daily fluctuation.

【Keyword: food contamination, regulation of shipment and water intake, radioactive iodine】

○ Some may be concerned about food contamination. We cannot eat food or drink tap water if the level of radiation has exceed the regulation limit set by the government since its shipment and water intake are controlled, as previously stated.

○ For those who are still concerned, the following advice posted on the web site of the National Institute of Radiological Sciences may provide some hints.

・ Almost all radioactive substances detected on vegetables are considered to be attached to their surface. Therefore, washing, boiling (and disposing of the water), peeling of skin and trimming-off of the green tops may reduce contamination.

・ Radioactive iodine may not vanish even if the vegetables are boiled. Rather, it may be concentrated as the water evaporates.

(Writer's note: For vegetables, boiling them helps removing radioactive substances present inside or on the surface of vegetables into the water. For drinking water, however, boiling is not a solution, since the radioactive substances remain in the water while the amount of water decreases by evaporation and their concentration becomes higher.)

【Keyword: thyroid, stable iodine tablet, radioactive iodine, stable iodine, side effect, physician's order, government's order】

○ Stable iodine tablets are said to work as a means of preventing the thyroid from receiving radiation. Iodine is classified into radioactive iodine that releases radiation and stable iodine which is in a stable form that does not release radiation.
○ Iodine is concentrated on the thyroid by nature. Both radioactive and stable iodine share the same property as iodine. For this reason, the idea is that, if stable iodine tablets are taken before or just after the radioactive iodine is ingested to fill the thyroid with it, no or little radioactive iodine will enter and the amount of radiation will be less. That is the mechanism of the stable iodine tablets.
○ It is deemed important, however, to take them in accordance with the physician’s order when they are distributed in evacuation centers since they may pose a risk of side effects such as allergy.
○ In addition, if they are taken long before the ingestion of radioactive iodine is suspected, the stable iodine will be discharged from the body, resulting in poor efficacy.
○ It is recommended to take them in accordance with the instructions from the government or other competent authorities.

Information: Term “Exposure”

【Keyword: radiation exposure, exposures (‘hibaku’ in Japanese; 被曝 or 被ばく), exposed, workers, ‘bathe’ in radiation】
○ TV news and newspapers often refer to a term “radiation exposure.” The term “exposure” is sometimes used depending on the context.
○ The term was written as “被曝” before. The kanji character “曝” means “to expose,” so the term “被曝” means “to be exposed.”
○ We have used the expression “receive radiation.” This is a plain way of expressing “radiation exposure” or “exposed to radiation.” It appears, however, that the term “exposed” is used on the media to refer to such events as when workers are exposed to radiation to a reportable level in compliance with ordinances. The term “bathe in radiation” or “irradiated” is also used in this case.

【Keyword: exposure (hibaku,被曝), exposure to atomic bomb (hibaku,被爆)】
○ In the mean time, some confusion may arise if the expression “被ばく” is used instead of the former “被曝” as “被ばく” is pronounced in the same way as the so-called “被爆” of Hiroshima and Nagasaki.
○ The term “被ばく” or “被曝” refers to exposure to radiation only, while “被爆” is

used to mean the state of damages caused by heat wave and blast from the explosion in addition to radiation. The left-hand radicals "日" (sun) and "火" (fire) have totally different meanings.

【Keyword: accident of Fukushima Daiichi, termination of nuclear reaction, all electric supply blackout, cooling water, fuel rod, decay heat】

○ There has been no nuclear explosion at the Fukushima accident. It has come to a halt. Then, what is happening? The nuclear reaction has terminated, but it is considered that the all electric supply blackout has hindered the supply of cooling water, that the heat released from the radioactive substances inside the fuel rods cannot be removed, resulting in some portions of the sheaths that contain fuel (* "claddings") being damaged and some radioactive substances getting out of the fuel rods.

○ Now, let's consider in more detail why cooling is still required while the nuclear reaction has already been over. As long as the nuclear reaction exists (for example, while generating power), fission products (two or more atoms produced by fission of uranium) are accumulated in the fuel rods as a result of fission reaction. They remain after the nuclear reaction is over. Many of these fission products are unstable radioactive substances. They turn into a different substance by releasing radiation. At this time, the energy from the radiation is absorbed by the surrounding materials (such as fuel casings) when the radiation passes through. The absorbed energy is converted to heat and the state in which the surrounding materials are heated continues for a considerably long time. That is why cooling is necessary after the nuclear reaction has ceased and even after the fuel rods have been removed from the reactor.

○ The above-mentioned phenomenon of the "radioactive substances turn into a different substances by releasing radiations" is called "radioactive decay" or "radioactive disintegration" in technical terms. Also, the heat generated there is called "decay heat." These terms sometimes appear in newspapers. Though the terms "decay" or "disintegration" may give the false impression of a big object being destroyed or broken up, it actually means that "the atoms turn into different atoms" and it is used to refer to a phenomenon that occurs in the world of substances as small as atoms.

Information: Term "Half-Life"

【Keyword: radioactive substance, radioactivity, half-life】

- ○ The radioactive substances gradually lose their radioactivity by releasing radiation. The period for the radioactivity to drop to a half is called “half-life.” For example, the radioactivity of a radioactive substance with a half-life of ten days decreases to a half in ten days, a quarter in twenty days and to one-eighth in thirty days.
- ○ Although it is not precise physically, for clarity, we are going to explain the term using discharging water accumulated in a tank through a pipe. A “short half-life” corresponds to discharge through a large-diameter pipe. As the water is discharged in volume, the tank water runs out in a shorter time. To put it the other way around, the reason why the tank water runs out in a shorter time is because much water is discharged. If radioactive substances are considered instead of water, a radioactive substance with a shorter half-life releases more radioactivity accordingly in a certain time (radioactivity decreases faster accordingly, however.)
- ○ There are some articles on Internet web pages that state that “Those radioactive substances with a longer half-life are dangerous as their radioactivities are strong.” It is not true. It is a fact that radioactive substances with longer half-lives are hard to treat as their radioactivities last for many years, but it can be said that the amount of radiation they release in a certain period is smaller than those with shorter half-lives as they release radiation only little by little.

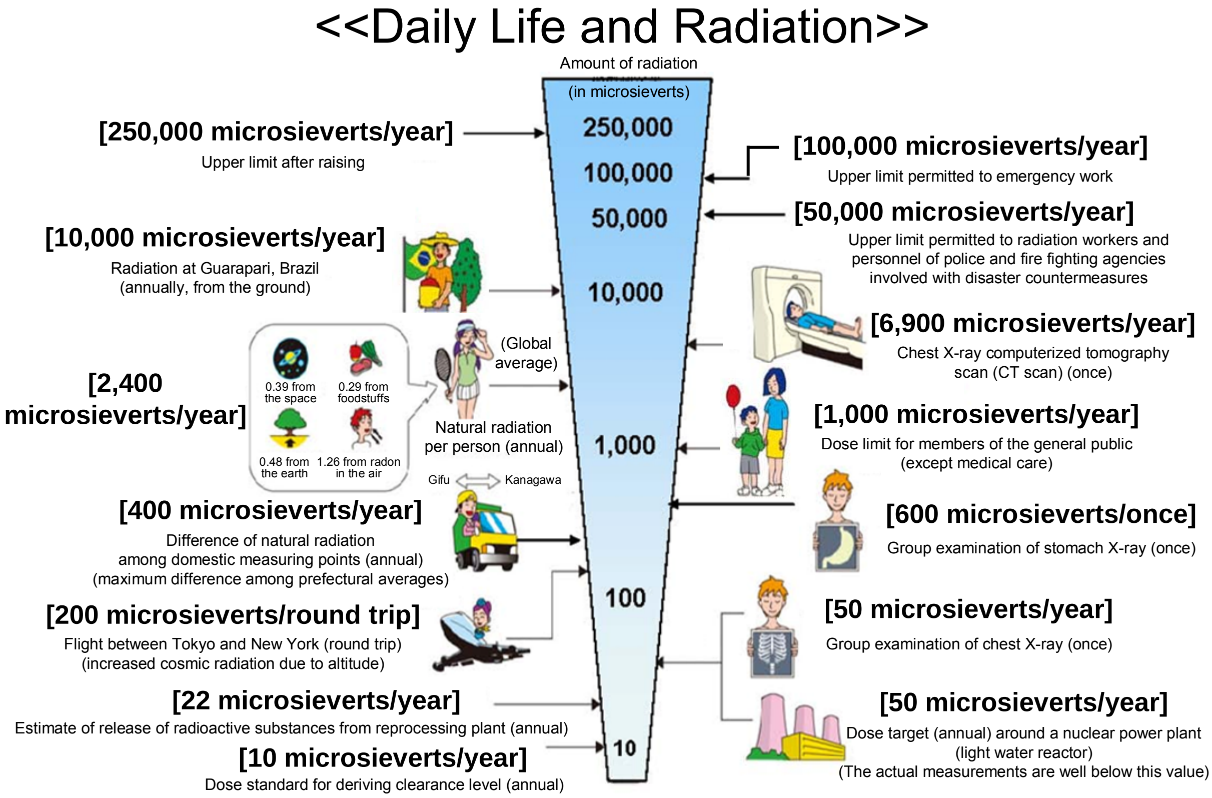
【Keyword: physical half-life, biological half-life, metabolism, Iodine-131, effective half-life, Cesium-137】

- ○ We would like to point out another mistake frequently found on Internet. “The radioactive substance, Iodine-131 has a physical half-life as short as eight days, but the radioactivity hardly decays as its biological half-life is as long as 80 days.” It is a misunderstanding.
- ○ In fact, the “half-life” is classified into a “physical half-life” (half-life commonly used) and a “biological half-life” (half-life in terms of discharge from the body through metabolism). However, this should be interpreted as follows: “The radioactivity of radioactive substances ingested into the body decays physically by releasing radiation and it also decays through discharge by biological metabolism.”
- ○ Making the analogy of discharge of water from a tank again, Iodine-131 has a large-diameter pipe that represents a physical half-life of as short as eight days and a small-diameter pipe represented by a biological half-life as long as 80 days that also works. Much water (radioactive substance) is discharged from the tank (body) mainly through the thick pipe while water is also

discharged through the thin pipe little by little. Taken together, the time for the amount of the radioactive substance inside the body to decrease to a half is 7.27 days, which is even shorter than the shorter half-life. (* This is called effective half-life.) The biological half-life of Iodine-131 of 80 days is for adults; it is 23 days for a five year-old child and even shorter for an infant, 11 days.

○ On the other hand, a radioactive substance called Cesium-137 has a physical half-life of as long as 30 years, but its biological half-life is short: 9 days for a baby of one year old or younger, 38 days for a child of nine years old or younger, 70 days for adult of up to 30 year-old and 90 days for an adult up to 50 year-old. So, the time it takes to decrease to a half inside the body is much shorter than 30 years, on the same order of the biological half-life (89.3 days for a 50 year-old person).

<Figure 1>



* Sv [Sievert] = Constant of biological effect according to type of radiation (*) x Gy [Gray]

* 1 for X-ray and γ-ray

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<Table 1>

Examination Results of Environmental Radiation Levels

March 16, 2011 20:00

(μSv/h (microsieverts per hour))

	Prefecture	March 15							March 16																	
		17-18	18-19	19-20	20-21	21-22	22-23	23-24	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	Range of past normal values
1	Hokkaido (Sapporo)	0.028	0.028	0.028	0.028	0.027	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.029	0.029	0.028	0.028	0.028	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.02～0.105
2	Aomori (Aomori)	0.021	0.022	0.023	0.024	0.024	0.025	0.025	0.026	0.026	0.027	0.029	0.026	0.023	0.021	0.021	0.02	0.021	0.021	0.022	0.021	0.024	0.022	0.022	0.025	0.017～0.102
3	Iwate (Morioka)	0.045	0.042	0.04	0.043	0.043	0.041	0.04	0.041	0.041	0.041	0.04	0.039	0.037	0.036	0.035	0.034	0.033	0.033	0.033	0.034	0.034	0.040	0.042	0.037	0.014～0.084
4	Miyagi (Sendai)	0.083	0.1127	0.1799	0.1989	0.1836	0.1719	0.1786	0.1935	0.1928	0.1896	0.1832	0.1739	0.1674	0.1649	0.1624	0.1606	0.158	0.159	0.160	0.155	0.151	0.150	0.151	0.153	0.0176～0.0513
5	Akita (Akita)	0.0355	0.0364	0.0361	0.0367	0.0368	0.0369	0.0373	0.0372	0.0364	0.0356	0.0346	0.0346	0.0346	0.0346	0.0352	0.0348	0.035	0.035	0.035	0.036	0.038	0.037	0.039	0.039	0.022～0.066
6	Yamagata (Yamagata)	0.04	0.043	0.051	0.062	0.073	0.078	0.099	0.107	0.11	0.114	0.104	0.096	0.09	0.083	0.078	0.073	0.073	0.076	0.073	0.063	0.058	0.057	0.056	0.057	0.025～0.082
7	Fukushima (Futaba)																									0.037～0.071
8	Ibaraki (Mito)	0.28	0.253	0.239	0.229	0.223	0.218	0.214	0.214	0.214	0.241	0.235	0.218	0.216	0.32	1.035	0.962	0.650	0.490	0.446	0.306	0.279	0.267	0.259	0.252	0.036～0.056
9	Tochigi (Utsunomiya)	0.388	0.375	0.321	0.305	0.293	0.272	0.286	0.281	0.299	0.322	0.309	0.312	0.31	0.306	0.335	0.337	0.254	0.229	0.224	0.223	0.220	0.218	0.216	0.215	0.030～0.067
10	Gunma (Maebashi)			0.389	0.406	0.398	0.358	0.48	0.501	0.496	0.361	0.25	0.17	0.146	0.158	0.14	0.127	0.123	0.122	0.120	0.119	0.119	0.116	0.111	0.110	0.017～0.045
11	Saitama (Saitama)	1.039	0.966	0.169	0.111	0.076	0.068	0.069	0.065	0.078	0.101	0.167	0.188	0.155	0.206	0.141	0.094	0.073	0.071	0.071	0.070	0.069	0.069	0.068	0.068	0.031～0.060
12	Chiba (Ichihara)	0.253	0.103	0.055	0.039	0.034	0.034	0.033	0.033	0.032	0.031	0.032	0.033	0.042	0.053	0.066	0.097	0.141	0.124	0.076	0.051	0.042	0.042	0.042	0.041	0.022～0.044
13	Tokyo (Shinjuku)	0.0941	0.2	0.361	0.123	0.0888	0.0657	0.0556	0.0538	0.0547	0.0672	0.101	0.141	0.143	0.142	0.104	0.0891	0.069	0.058	0.057	0.056	0.055	0.054	0.054	0.054	0.028～0.079
14	Kanagawa (Chigasaki)	0.061	0.061	0.062	0.069	0.074	0.07	0.062	0.092	0.089	0.078	0.108	0.127	0.152	0.152	0.153	0.139	0.126	0.115	0.099	0.079	0.065	0.057	0.056	0.056	0.035～0.069
15	Niigata (Niigata)	0.05	0.051	0.052	0.055	0.055	0.058	0.056	0.053	0.053	0.053	0.053	0.055	0.056	0.055	0.052	0.058	0.060	0.068	0.060	0.052	0.051	0.049	0.048	0.047	0.031～0.153
16	Toyama (Imizu)	0.063	0.063	0.062	0.067	0.065	0.062	0.059	0.052	0.052	0.051	0.049	0.05	0.051	0.049	0.049	0.054	0.058	0.059	0.053	0.050	0.050	0.049	0.048	0.048	0.029～0.147
17	Ishikawa (Kanazawa)	0.0542	0.0593	0.0662	0.0674	0.0643	0.0679	0.0645	0.0565	0.051	0.0481	0.0476	0.0533	0.0514	0.0482	0.048	0.0508	0.057	0.052	0.051	0.049	0.048	0.047	0.047	0.048	0.0291～0.1275
18	Fukui (Fukui)	0.052	0.053	0.053	0.056	0.059	0.059	0.06	0.049	0.049	0.046	0.052	0.052	0.048	0.049	0.049	0.047	0.048	0.051	0.053	0.054	0.058	0.053	0.048	0.046	0.032～0.097
19	Yamanashi (Kofu)	0.053	0.051	0.05	0.05	0.05	0.049	0.05	0.049	0.047	0.046	0.046	0.046	0.046	0.046	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.046	0.040～0.064
20	Nagano (Nagano)	0.04	0.0414	0.0431	0.0606	0.0939	0.107	0.102	0.0989	0.0964	0.0946	0.0943	0.0951	0.0959	0.0964	0.0984	0.0983	0.097	0.100	0.100	0.097	0.091	0.088	0.089	0.087	0.0299～0.0974
21	Gifu (Kakamigahara)	0.061	0.061	0.061	0.062	0.061	0.061	0.063	0.062	0.061	0.061	0.061	0.061	0.061	0.061	0.063	0.065	0.069	0.071	0.067	0.065	0.064	0.066	0.063	0.061	0.057～0.110
22	Shizuoka (Shizuoka)	0.0536	0.0525	0.0513	0.0498	0.0476	0.0469	0.0454	0.0453	0.0449	0.0444	0.0439	0.0425	0.041	0.0402	0.0403	0.0409	0.045	0.046	0.046	0.045	0.045	0.045	0.045	0.045	0.0281～0.0765
23	Aichi (Nagoya)	0.04	0.039	0.039	0.04	0.04	0.04	0.04	0.04	0.04	0.039	0.04	0.04	0.041	0.04	0.04	0.04	0.040	0.040	0.040	0.042	0.044	0.041	0.040	0.040	0.035～0.074
24	Mie (Yokkaichi)	0.046	0.0459	0.0463	0.0465	0.0477	0.0491	0.0498	0.0595	0.0659	0.0542	0.0486	0.0486	0.0521	0.0495	0.0481	0.0469	0.048	0.052	0.054	0.055	0.056	0.053	0.053	0.056	0.0416～0.0789
25	Shiga (Otsu)	0.033	0.033	0.033	0.038	0.046	0.047	0.047	0.041	0.035	0.034	0.033	0.033	0.034	0.034	0.033	0.033	0.033	0.034	0.034	0.034	0.034	0.035	0.035	0.036	0.031～0.061
26	Kyoto (Kyoto)	0.0378	0.0379	0.0379	0.0391	0.0442	0.0472	0.0443	0.0413	0.0391	0.0386	0.0385	0.0386	0.0382	0.0383	0.0381	0.0385	0.039	0.039	0.038	0.038	0.039	0.040	0.041	0.041	0.033～0.087
27	Osaka (Osaka)	0.042	0.043	0.043	0.043	0.044	0.047	0.045	0.044	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.045	0.049	0.050	0.051	0.047	0.045	0.042～0.061
28	Hyogo (Kobe)	0.037	0.037	0.038	0.04	0.044	0.042	0.039	0.038	0.038	0.038	0.038	0.038	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.038	0.040	0.038	0.038	0.038	0.035～0.076
29	Nara (Nara)	0.047	0.048	0.048	0.048	0.049	0.053	0.053	0.052	0.049	0.048	0.048	0.048	0.048	0.048	0.047	0.048	0.048	0.048	0.049	0.048	0.048	0.048	0.048	0.047	0.046～0.08
30	Wakayama (Wakayama)	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.031	0.032	0.032	0.032	0.032	0.032	0.032	0.031～0.056
31	Tottori (Tohaku)	0.074	0.067	0.065	0.064	0.064	0.068	0.066	0.068	0.066	0.07	0.071	0.068	0.066	0.067	0.067	0.072	0.071	0.078	0.087	0.077	0.069	0.066	0.064	0.067	0.036～0.11
32	Shimane (Matsue)	0.044	0.043	0.039	0.038	0.038	0.038	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.043	0.046	0.044	0.043	0.040	0.038	0.037	0.037	0.038	0.039	0.033～0.079
33	Okayama (Okayama)	0.049	0.052	0.055	0.051	0.049	0.049	0.049	0.049	0.049	0.049	0.048	0.048	0.048	0.049	0.049	0.049	0.048	0.049	0.049	0.050	0.051	0.052	0.051	0.050	0.043～0.104
34	Hiroshima (Hiroshima)	0.047	0.047	0.046	0.047	0.047	0.047	0.048	0.047	0.048	0.048	0.047	0.047	0.047	0.048	0.047	0.048	0.048	0.048	0.047	0.047	0.046	0.046	0.046	0.046	0.035～0.069
35	Yamaguchi (Yamaguchi)	0.092	0.092	0.092	0.092	0.092	0.093	0.093	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.091	0.091	0.092	0.091	0.091	0.091	0.092	0.064～0.128
36	Tokushima (Tokushima)	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.038	0.039	0.039	0.040	0.037～0.067
37	Kagawa (Takamatsu)	0.052	0.052	0.052	0.054	0.059	0.055	0.054	0.053	0.053	0.052	0.052	0.051	0.052	0.052	0.052	0.052	0.052	0.053	0.052	0.053	0.053	0.054	0.054	0.053	0.051～0.077
38	Ehime (Matsuyama)	0.0473	0.0478	0.0479	0.048	0.0478	0.048	0.0484	0.0485	0.0482	0.0483	0.048	0.0477	0.0475	0.0476	0.0474	0.0475	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.045～0.074
39	Kochi (Kochi)	0.0246	0.0245	0.0246	0.0246	0.0248	0.0249	0.0248	0.0247	0.0247	0.0251	0.0247	0.0249	0.0251	0.0247	0.0243	0.0244	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.023～0.076
40	Fukuoka (Dazaifu)	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.034～0.079
41	Saga (Saga)	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.039	0.039	0.039	0.039	0.039	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.037～0.066
42	Nagasaki (Omura)	0.029	0.029	0.029	0.029	0.029	0.029	0.03	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.028	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.027～0.069
43	Kumamoto (Udo)	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.026	0.026	0.026	0.026	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.021～0.067
44	Oita (Oita)	0.05	0.05	0.049	0.049	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.048～0.065
45	Miyazaki (Miyazaki)	0.0263	0.0265	0.0266	0.0265	0.0263	0.0262	0.0263	0.0265	0.0265	0.0265	0.0262	0.0263	0.0263	0.0263	0.0262	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.0243～0.0664
46	Kagoshima (Kagoshima)	0.0345	0.0346	0.0344	0.0344	0.0346	0.0347	0.035	0.0349	0.0347	0.0343	0.0343	0.0344	0.0342	0.034	0.0338	0.0337	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.0306～0.0943
47	Okinawa (Uruma)	0.021326	0.02125	0.021328	0.021079	0.020833	0.021382	0.021233	0.021142	0.021165	0.021519	0.021389	0.021062	0.021453	0.021145	0.021512	0.021271	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.0133～0.0575

* Spaces: Missing measurements due to maintenance.
* The data is calculated based on a conversion of 1 μGy/h (microgray per hour) to 1 μSv/h (microsievert per hour).
* Prepared based on reports from prefectures by the Ministry of Education, Culture, Sports, Science and Technology