Basic Information on Radiation Risk

THE CABINET OFFICE, THE CONSUMER AFFAIRS AGENCY, THE RECONSTRUCTION AGENCY, THE MINISTRY OF FOREIGN AFFAIRS, THE MINISTRY OF EDUCATION, CULTURE, SPORTS, SCIENCE AND TECHNOLOGY, THE MINISTRY OF HEALTH, LABOUR AND WELFARE, THE MINISTRY OF AGRICULTURE, FORESTRY AND FISHERIES, THE MINISTRY OF ECONOMY, TRADE AND INDUSTRY, THE MINISTRY OF THE ENVIRONMENT, THE SECRETARIAT OF THE NUCLEAR REGULATION AUTHORITY

About this document

This document is the concise collection of basic information such as radiological status due to radioactive contamination in Fukushima, information and scientific knowledge necessary for the assessment of radiation health risk, and international and academic views on the reduction of radiation exposure.

So far, relevant ministries and agencies released information on radiation in the fields they are respectively responsible for. This document intends to systematically summarize basic contents common to such information released so far, and to help readers systematically overview the fields concerned.

To perform an actual risk communication activity, data and materials must be prepared which will satisfy the specific needs of personnel and address specific concerns. This document is expected to serve as a basic material which precisely explains the uses of technical terms and other basic information in plain language as much as possible when such an activity is conducted.

In order to write this document in plain language and further improve the correctness of the information involved in it, the responsible ministries and agencies studied advice kindly provided by specialists and experts to create this document.

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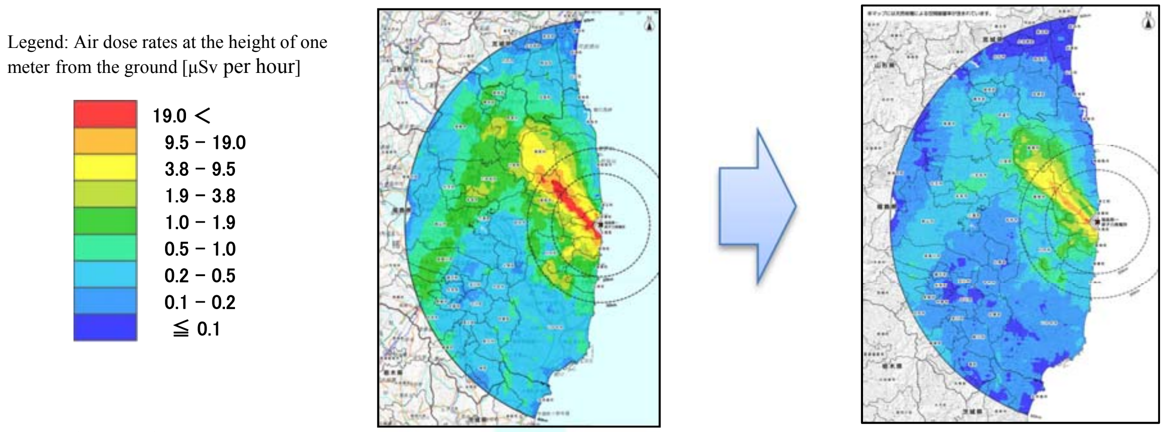
1. Secular Changes of Air Dose Rates

- Aircraft monitoring has been conducted to estimate the air dose rates* of surface areas at the height of one meter from the ground since the accident at TEPCO's Fukushima Daiichi Nuclear Power Station (*:please refer to the Glossary).
- The monitoring result of November 2011 and that of September 2015 were compared, and it was confirmed that the air dose rates of the area within a 80 kilometer radius had reduced by 65% on average although the rates varied depending on where they were measured.
- Since the decrease of the air dose rate during the above period deduced from radioactive cesium's physical half life* is about 55%, it is concluded that the remaining decrease of about 10% is due to decontamination and weathering effect.

Air Dose Rate Map

(Air dose rates at the height of one meter from the ground within a 80 kilometer radius of TEPCO's Fukushima Daiichi Nuclear Power Station)



(As of November 2011)

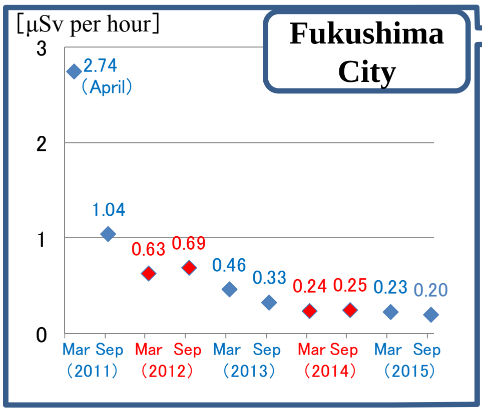
(As of September 2015)

(Source)

- The Ministry of Education, Culture, Sports, Science and Technology, "Measurement Results from the 4th Airborne Monitoring," December 16, 2011 (the ministry was in charge of the airborne monitoring then)
- The Secretariat of the Nuclear Regulation Authority, "Air Dose Rates Monitored by Aircraft at TEPCO's Fukushima Daiichi Nuclear Power Station," February 2, 2016

Changes of Air Dose Rates

[Unit: µSv per hour]



	Fukushima City North area Public Health and Welfare Office	**Aizuwakamatsu City** Government Office Complex	**Iwaki City** Government Complex
Normal Value before the Great Earthquake	0.04	0.04～0.05	0.05～0.06
April 1, 2011	2.74	0.24	0.66
September 1, 2011	1.04	0.13	0.18
March 1, 2012	0.63	0.1	0.17
September 1, 2012	0.69	0.1	0.1
March 1, 2013	0.46	0.07	0.09
September 1, 2013	0.33	0.07	0.09
March 1, 2014	0.24	0.07	0.08
September 1, 2014	**0.25**	**0.07**	**0.08**
March 1, 2015	0.24	0.06	0.07
September 1, 2015	0.20	0.06	0.07

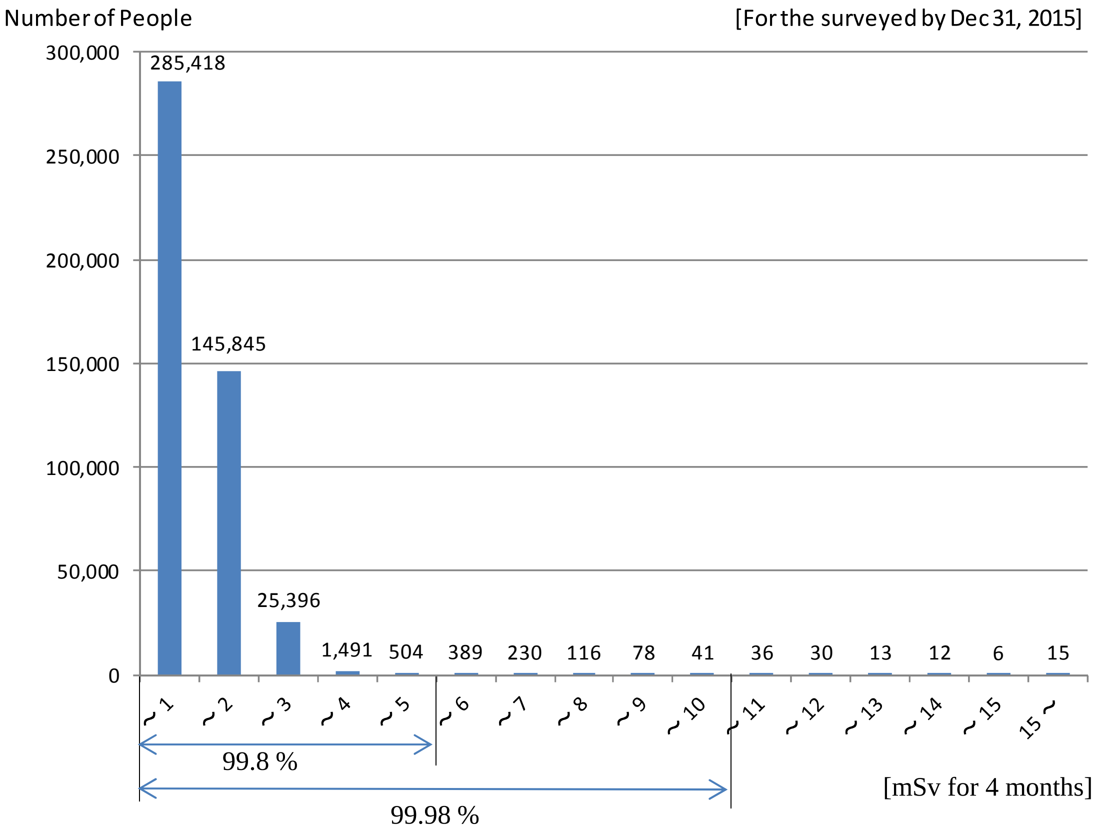
(Note) Figures were measured at midnights of respective dates.

(Source) Fukushima Prefecture, "Measurement Results of Environmental Radioactivity in the Prefecture's Seven Areas"

2. Status of External Exposures after the Accident

- Fukushima Prefecture has been conducted the “Fukushima Health Measurement Survey” to obtain the behavioral records of evacuation, such as the “time,” “place” and “duration” of their staying as well as the “route” of their passage from March 11 to July 11 in 2011, to estimate the effective doses* due to external exposure* they might have incurred immediately after the accident occurred.
- The effective doses due to external exposure the people might have incurred for four months after the accident were already estimated with regard to 460,000 people by December 31, 2015 excluding radiation workers. The result is that the estimated effective doses are less than 2 millisieverts (mSv) for 93.8% of them, less than 5 mSv for 99.8%, and less than 10 mSv for 99.98% (the estimated maximum effective dose is 25 mSv). Based on this result, the Health Management Survey Exploratory Committee” has made an assessment, saying “it is hard to believe that the radioactivity has affected the residents’ health.”

〈 The Distribution of the Effective Doses due to External Exposure Estimated from the behavioral Records of evacuation in the “Fukushima Health Management Survey” (excluding radiation workers) 〉



(Source) Health Management Survey Exploratory Committee (the 22nd meeting)

3. Status of External Exposures Measured with Personal Dosimeters

- In Fukushima Prefecture, a certain municipal governments have been using personal dosimeters after the accident occurred to monitor the radiation doses of their residents, mainly children and pregnant women.
- The published radiation doses measured by the personal dosimeters are as shown below, and (average) annual individual doses in municipalities after FY2013 were less than 1mSv per year.

Measurement Results of External Exposure Dose with Personal Dosimeters

Municipalities	Measurement Period	Persons Monitoerd	Number of people (A)	Number of people over 1mSv/year (B)	Percentage (B) ÷ (A) [%]	Average Annual Individual Dose [mSv/year]
Iwaki City	November 2011 to January 2012	Junior high school students or younger	31,235	477	1.53%	0.44
Koriyama City	June to September 2015	Infants and pregnant women	7,142	13	0.18%	0.319
	May to July 2012	Infants and pregnant women	7,847	3,556	45.32%	1.00
	June to September 2015	Elementary school and junior high school students	4,816	7	0.15%	0.31
	October to Nobember 2011	Elementary school and junior high school students	25,551	17,188	67.3%	1.33
Fukushima City	September to November 2014	Applicants not older than 15years	8,616		0%	0.32
	September to November 2013	Applicants not older than 15years	10,100	659	6.52%	0.44
	September to November 2012	Applicants not older than 15years	16,223	1,830	11.3%	0.56
	September to November 2011	Applicants not older than 15years	36,767			1.04
	September to November 2014	All citizens	46,436	2,056	4.43%	0.44
Aizuwakamatsu City	July to September 2012	Junior high school students or younger	4,781	1	0.02%	0.18
	November 2011 to Febrary 2012	Junior high school students or younger	8,679	12	0.14%	0.30
Sukagawa City	September to November 2014	Applicants not older than 18years	5,950	32	0.54%	0.36
	September to Nobember 2011	Applicants not older than 18years	11,461	2,991	26.10%	0.84
Minamisoma City	April to June 2015	All citizens	5,582	297	5.32%	0.4
	June to August 2013	All citizens	9,619	2,263	23.53%	0.8
Date City	July 2014 to June 2015	All citizens	12,912	2,022	15.7%	0.59
	July 2014 to June 2015	Applicants not older than 15years	5,309	183	3.45%	0.38
	Jury 2012 to June 2013	All citizens	52,783	17,811	33.7%	0.89
Shirakawa City	July to September 2014	Junior high school students or younger	7,016	25	0.36%	0.28
	July to October 2012	Junior high school students or younger	8,818	219	2.48%	0.44
	August to October 2011	Infants to junior highschool students and pregnant women	9,737	1,509	15.5%	0.72
Nihonmatsu City	May to July 2014	Infants to highschool students and women	5,526			0.67
	September to November 2011	Infants to highschool students and women	8,725			1.53
Kitakata City	June 2013 to March 2014	All citizens	2,560	0	0.0%	0.028
	June 2012 to March 2012	All citizens	3,340	0	0.0%	0.054
Soma City	September to Nobember 2015	Infants to junior highschool students and pregnant women	1,949	0	0.00%	
	October to Decrmber 2011	Infants to junior highschool students and pregnant women	4,010	556	13.87%	
Motomiya City	June to August 2015	Infants to junior highschool students and pregnant women	3,125			0.32
	September to November 2011	Infants to junior highschool students and pregnant women	4,745	2,603	54.86%	1.09
Nishigo Village	September to November 2014	Junior high school students or younger	2365	4	0.17%	
	September to November 2013	Junior high school students or younger	2375	19	0.80%	
	September to November 2012	Junior high school students or younger	2,493	104	4.17%	
	September to November 2011	Junior high school students or younger	2,879	648	22.51%	
Yabuki Town	October to December 2011	Elementary school and junior high school students	1,484	2	0.13%	0.31
Koori Town	August 2013 to January 2014	Junior high school students or younger	633	16	2.53%	0.4
	August 2012 to January 2013	Junior high school students or younger	1,050	150	14.29%	0.6
Ono Town	September to November 2015	High school students or younger	377	0	0	0.22
	September 2012	High school students or younger	730	0	0	0.25
Kunimi Town	August to October 2013	Junior high school students or younger	501	6	1.2%	
Hirata Village	October to November 2011	Applicants not older than 15years	884	5	0.57%	
Samegawa Village	October 2011 to Febrary 2012	Infants to highschool students and pregnant women	511	1	0.2%	0.336

※ Compiled from data published values for the measurement results within the municipalities. In the case there is no publication value, columns are blank.

※ "Number of people over 1mSv/year (B)" based on annual conversion of the individual dose period.

※ When making data comparisons between municipalities and points in time, it is necessary to be aware that the methods were conducted via means specific to each of the municipalities, and that measurement dates/periods, the distribution targets for the dosimeters, and the measuring equipment are not necessarily unified.

※ There is a tendency for the measurement values to be higher when they include those who spend many hours outdoors in instances where they do not restrict age and measure all inhabitants.

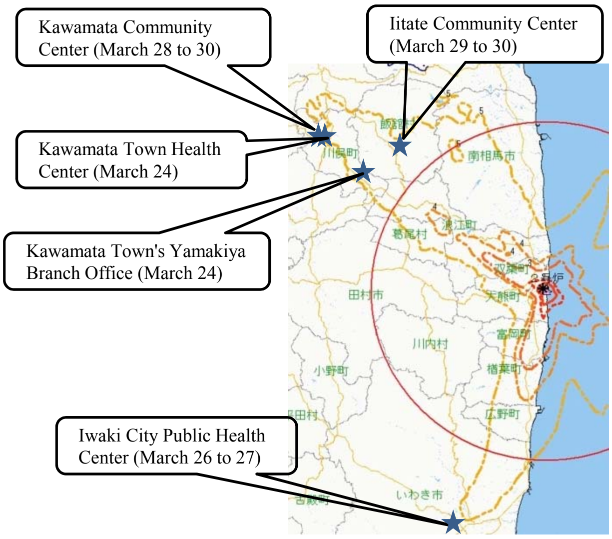
4. Internal Exposures Dose in Early Phase

(Screening Survey of Children’s Thyroid Glands Conducted Immediately after the Accident)

- The Local Nuclear Emergency Response Headquarters, having studied the iodine-131 inhalation estimate which the System for Prediction of Environmental Emergency Dose Information (SPEEDI) network system calculated on March 23, 2011, conducted the screening survey of childhood thyroid glands exposure to understand health effects on children, following the request from the Emergency Advice Organization of the Nuclear Safety Commission.
- Simple measurements[*1] of children’s thyroid glands were conducted in Iwaki City, Kawamata Town and Iitate Village on March 24 to 30, 2011. The measured dose rates of 1,080 children[*2] surveyed were less than 0.2 μSv per hour[*3], which the Nuclear Safety Commission had set as a screening level.

⇒The Nuclear Safety Commission, “Evaluation on the Survey Results of the Radiation Exposure of Children’s Thyroid Gland,” September 9, 2011

- Furthermore, since the physical half life[*] of iodine-131, which might accumulate in thyroid glands, is eight days, it has already decayed in the early stage, and, no one is likely to be exposed to it presently.(*:please refer to the Glossary)



Equivalent Doses for Internally Exposed Organs
Accumulation Period: 6:00 March 12, 2011 to 00:00 March 24, 2011
Coverage: 92 kilometers by 92 kilometers
Isotope: Total Iodine
Target Age: One-year -old Infants
Organ’s Name: Thyroid Glands

(Legend)
Radiation iso-dose lines [mSv]
1＝10000 ━━━━━
2＝ 5000 ┅┅┅┅┅
3＝ 1000 ─·─·─·─
4＝ 500 ─··─··─
5＝ 100 ─···─···─

(Source) Estimation Result Using SPEEDI

[*1] The ambient dose rates of radiation emitted from thyroid glands were measured.

[*2] Excluded from the 1,149 persons surveyed were the 66 persons who could not be appropriately evaluated because the background ambient dose rates[*] at measurement sites were too high for simple measurements and the three persons whose ages were not clear, resulting in the 1,080 persons mentioned above .

[*3] The screening mentioned here relates to internal exposure[*] due to inhalation, and the cut-off value, which is used to judge whether measures against internal exposure due to radioactive iodine are necessary, is called a screening level (the Nuclear Safety Commission, “Recommendation for Screening,” February 24, 2012) . The ambient dose rate of 0.2 μSv per hour corresponds to the equivalent dose[*] of 100 mSv (which is the operational intervention level to take shelter and to conduct the oral administration of stable iodine prophylaxis) for the thyroid gland of a one-year-old infant .

5. Thyroid Ultrasound Examinations

- In the Chernobyl Nuclear Accident, increase of childhood thyroid cancer was confirmed as a health effect caused by the radioactivity among residents.

⇒The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR 2008 Report)

- In order to monitor long-term health conditions of young generations, “Fukushima Health Management Survey” has been conducted using high-precision thyroid ultrasound examinations for all the prefectural residents who were aged 18 years and younger at the time of TEPCO’s Fukushima Daiichi Nuclear Power Station accident.
- The survey started “Initial Screening” to gain the baseline status (from October 2011) and is currently conducting “Full-scale Screening” to check the trend (All the subjects are checked from April 2014 to March 2016, and after that once every two years to those aged 20 years or younger and once approximately every five years to those aged 20 years and older.).
- The preliminary results from the “Initial Screening”, reported until the end of June 2015, indicated that 113 people were diagnosed as “malignant or suspected” as a result of Initial Screening and 99 persons had surgery, 95 persons were papillary carcinoma, 3 persons were poorly differentiated carcinoma and one person was begin nodules.

<Results of Thyroid Ultrasound Examinations : Initial Screening> (Reported until June 30, 2015)

		Criteria	**Number of persons**	**Percentage (%)**	
Persons whose grade were fixed			300,476	100.0	
grade A	**A1**	No nodules or cysts were found.	154,606	51.5	99.2
	A2	Nodules not larger than 5.0 mm or cysts not larger than 20.0 mm were found.	143,576	47.8	
grade B		Nodules not smaller than 5.1 mm or cysts not smaller than 20.1 mm were found.	2,293	0.8	
grade C		Subsequent examinations were required based on the conditions of thyroid glands.	1	0.0	
113 persons had malignancy or suspected					

<Results of Thyroid Ultrasound Examinations : Full-scale Screening> (Reported until December 31, 2015)

		Criteria	**Number of persons**	**Percentage (%)**	
Persons whose grade were fixed			220,088	100.0	
grade A	**A1**	No nodules or cysts were found.	89,565	40.7	99.2
	A2	Nodules not larger than 5.0 mm or cysts not larger than 20.0 mm were found.	128,704	58.5	
grade B		Nodules not smaller than 5.1 mm or cysts not smaller than 20.1 mm were found.	1,819	0.8	
grade C		Subsequent examinations were required based on the conditions of thyroid glands.	0	0.0	
39 persons had malignancy or suspected					

(Explanations for the persons diagnosed in each grade)

- Follow-ups for those with grade A1 and A2 until next examinations
- Subsequent examinations for those with grade B and C (The dates and places of the subsequent examinations will be notified to those who will take the subsequent examinations).

(Remarks)

＊ Grade B was applied to those of grade A2 for whom diagnoses were made that they should take subsequent examinations considering the conditions of their thyroid glands.

(Source) Health Management Survey Exploratory Committee (the 22nd meeting)

5. Thyroid Ultrasound Examinations
(continued)

- The preliminary results from the “Full-scale Screening”, reported until the end of December 2015, indicated that 51 people were diagnosed as “malignant or suspected” as a result of Full-scale Screening and 16 persons had surgery with diagnosis of papillary thyroid carcinoma for 16 persons.

- The frequencies of finding nodules or cysts among childhood and the variations of the results in the examinations are not clearly known because a large scale survey with such precision have never been conducted before. Therefore, the Ministry of the Environment led an effort to conduct thyroid ultrasound examinations in three prefectures other than Fukushima Prefecture similary to the Fukushima Health Management Survey, and the results were almost similar to the result in Fukushima Prefecture.

- The Ministry of the Environment also convened an Expert Meeting Regarding the Status of Health Management of Residents Following the Accident at the Tokyo Electric Power Company’s Fukushima Daiichi Nuclear Power Station, which concluded as follows;

  “We have not found any evidence of biological effects due to the radiation exposure up to this time, and have concluded that there was little possibility that the risk of some diseases would increase by radiation exposure going forward. However, as we have uncertainty in the estimation of radiation exposure dose, and as we recognize that this issue must be dealt with on a mid to long-term basis, we need to monitor trends of thyroid cancer, towards which residents feel a great anxiety, carefully.”

➡ Expert Meeting Regarding the Status of Health Management of Residents Following the Accident at the Tokyo Electric Power Company's Fukushima Daiichi Nuclear Power Station Interim report, December - 2014

Results of Survey of Prevalence of Nodular Thyroid Diseases and others
in three prefectures outside Fukushima Prefecture

		Aomori Prefecture (Hirosaki City)				Yamanashi Prefecture (Kofu City)				Nagasaki Prefecture (Nagasaki City)			
Grade		Number of persons		Percentage (%)		Number of persons		Percentage (%)		Number of persons		Percentage (%)	
A	A1	670	1,609	41.1	98.7	404	1,351	29.6	98.9	779	1,361	56.9	99.4
	A2	939		57.6		947		69.3		582		42.5	
B		21		1.3		15		1.1		8		0.6	
C		0		0.0		0		0.0		0		0.0	
(Total)		1,630		100.0		1,366		100.0		1,369		100.0	

		Fukushima Prefecture /references							
		Initial Screening				Full-scale inspection			
Grade		Number of persons		Percentage (%)		Number of persons		Percentage (%)	
A	A1	154,606	298,182	51.5	99.2	89,565	218,269	40.7	99.2
	A2	143,576		47.8		128,704		58.5	
B		2,293		0.8		1,819		0.8	
C		1		0.0		0		0.0	
(Total)		300,476		100.0		220,088		100.0	

(Conducted from November 2012 to March 2013)

Survey of Prevalence of Nodular Thyroid Diseases and others was conducted in 2012 fiscal year in these prefectures outside Fukushima Prefecture, we showed the result in Initial Screening of Thyroid Ultrasound Survey in Fukushima Health Management Survey as reported until June 30, 2015; and that in Full-scale Screening as reported until December 31, 2015.

6. Current Status of Internal Exposures
(Whole Body Counter Measurements)

- Through the whole body counter (WBC) measurements conducted by Fukushima Prefecture, the status of internal exposure* caused by cesium-134 and cesium-137 introduced through food intakes*1 are currently evaluated.
- About 280,000 persons examined by the end of November 2015, and the effective doses* of the 99.99% of them are estimated to be less than one mSv. Fukushima Prefecture explains that the internal exposure dose levels of those who were examined "are not high enough to affect their health conditions".

WBC Measurement Results in Fukushima Prefecture

(1)Municipalities governments which conducted the measurements

All 59 municipalities in Fukushima Prefecture

(2) To conduct internal exposure inspection by whole body counter intended for the person who has been evacuated to outside the prefecture.

[The inspection in permanent organization]

Hirosaki University School of Medicine & Hospital, Morinomiyako Occupational Health Association, Atom World, Niigata Prefecture, National Hospital Organization Kanazawa Medical Center, Japanese Red Cross Otsu Hospital, Ehime University Hospital, Hiroshima University Hospital, and Nagasaki University Hospital (As of January 27, 2016)

[Whole body counter vehicle]

Fukushima Prefecture circulates a whole body counter vehicle so that those who have evacuated from the prefecture can take examinations.

(3) Results (Committed effective doses) (for those conducted until December 2015: Published in January 2016

	June 27, 2011 to January 31, 2012	February 1, 2012 to January 27, 2016	Total
～ 1mSv	15,384 persons	265,438 persons	280,822 persons （99.99%）
1mSv	13 persons	1 persons	14 persons （0.00%）
2mSv	10 persons	0 persons	10 persons （0.00%）
3mSv	2 persons	0 persons	2 persons （0.00%）
Total	15,409 persons	265,439 persons	280,848 persons （100%）

* Committed effective doses: They assumed one time ingestion on March 12, 2011 before January 31, 2012, and continued daily ingestion of certain uniform amounts after February 1, 2012 up to the day before the examination. Internal exposure doses inside human bodies were accumulated for 50 years in case of adults and for the period up to the time when ages become 70 years old in case of children.

(Source Data) Fukushima Prefecture, "Implementation Status of Internal Exposure Examinations by the Whole Body Counter"

1: Examinations started in June 2011, and iodine-131 whose physical half life is short has not been detected.

7. Radioactive Materials in Foods
(Monitoring of Radioactive Materials in Foods)

- The limits for radioactive materials in foods[1] were established to ensure that the total additional radiation dose from foods does not exceed "1mSv" per year, based on the risk assessment by Food Safety Commission of Japan and the guidelines set by the Codex Alimentarius Commission[2], which sets international standards for food.
- The monitoring of radioactive materials in foods is conducted by the prefectural governments on the basis of the "Inspection planning for the local governments" in guideline[3] drawn up by the Government's Nuclear Emergency Response Headquarters. Food products that are found to exceed the respective limits are recalled or disposed of. If an excess level signals regional spread, distribution restriction[4] will be ordered. These approaches are combined to prevent foods with radiation levels exceeding the respective limits from being distributed on the market.
- The percentage of food products exceeding the limit has been decreasing year by year. As for wheat and barley, no samples have exceeded the limit since 2012. As for vegetables, fruits, tea and livestock products, no samples have exceeded the limit since 2013.

Monitoring results of radioactive cesium in foods

Food item	From the accident to the end of FY2011			FY2012			FY2013			FY2014		
	No. of samples exceeding the limit	Percentage of samples exceeding the limit	Total number of samples	No. of samples exceeding the limit	Percentage of samples exceeding the limit	Total number of samples	No. of samples exceeding the limit	Percentage of samples exceeding the limit	Total number of samples	No. of samples exceeding the limit	Percentage of samples exceeding the limit	Total number of samples
Rice	592	2.2%	26,464	84	0.0008%	10.38 millions	28	0.0003%	11.04 millions	2	0.00002%	11.01 millions
Wheat	27	4.8%	557	0	0%	1,818	0	0%	592	0	0%	383
Pulse	16	2.3%	689	63	1.1%	5,962	21	0.4%	5,167	4	0.12%	3,459
Vegitables	385	3.0%	12,671	5	0.03%	18,570	0	0%	19,657	0	0%	16,712
Fruits	210	7.7%	2,732	13	0.3%	4,478	0	0%	4,243	0	0%	3,302
Tea	192	8.6%	2,233	13	1.5%	867	0	0%	447	0	0%	206
Other cultivated plants	16	3.2%	498	14	0.5%	3,094	0	0%	1,618	0	0%	1,049
Raw Milk	8	0.4%	1,919	0	0%	2,421	0	0%	2,040	0	0%	1,846
Meat and eggs (excluding wild meat)	1058	1.3%	79,181	4	0.003%	154,866	0	0%	194,945	0	0%	188,304
Mushrooms and wild plants	779	20.2%	3,856	605	9.2%	6,588	194	2.6%	7,581	103	1.2%	8,557
Fish products	1,476	17.2%	8,576	1,093	5.6%	19,565	302	1.5%	20,695	100	0.5%	20,922

- Compiled from data provided by MHLW and prefectural governments. Data are those of the 17 prefectures designated by "Concepts of Inspection Planning and the Establishment and Cancellation of Items and Areas to which Restriction of Distribution and/or Consumption of Foods concerned Applies" (Nuclear Emergency Response Headquarters). Data for fishery products are those from the whole of Japan. As for grains (rice and pulse), samples are recorded according to their production years whenever they are tested.
- When counting the number of samples exceeding the limits before the end of FY2011, the revised limits which were enforced in April 2012 were applied rather than the provisional regulation values established right after the nuclear accident in March 2011. Refer to Page 20 for the detailed information of the limits of radioactive cesium in foods.
- As for the category of "tea", only green tea, to which the standards of drinking water (10 Bq/kg) is applied, has been recorded since 2012. In 2011, the standard limit of tea was 500 Bq/kg, inspected in the form of tea leaves.
- All rice bags produced in Fukushima have been subject to screening since 2012.

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*1 Specifications and Standards for Foods, Food Additives, etc.(MHW Notification No.370 of 1959 1. A-12) and Radioactive Substances Designated by the Minister of Health, Labour and Welfare (MHLW Notification No.129 of 2012)

*2: A joint intergovernmental body of Food and Agriculture Organization of the United Nations (FAO) and World Health Organization (WHO)

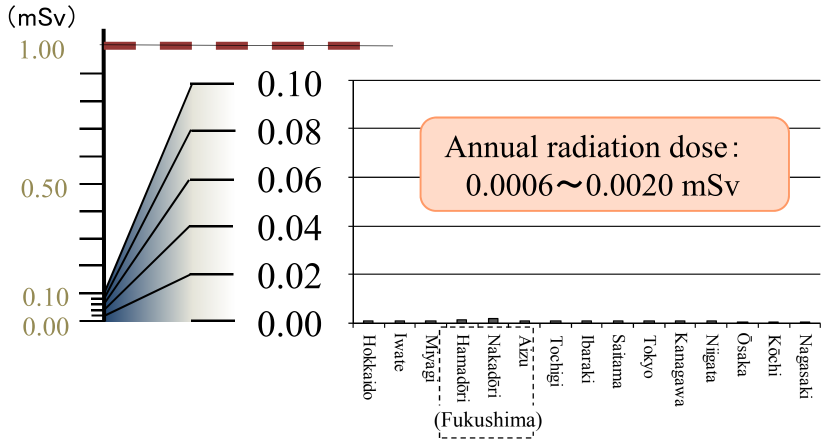
*3: "Concepts of Inspection Planning and the Establishment and Cancellation of Items and Areas to which Restriction of Distribution and/or Consumption of Foods concerned Applies"（The Nuclear Emergency Response Headquarters, compiled on April 4, 2011, revised on March 20, 2015）

*4: The Instruction to the Prefecture on March 20, 2015 based on the Article 20.2 of the Act on Special Measures Concerning Nuclear Emergency Preparedness (Act No. 156, 1999)

7. Radioactive Materials in Foods (Survey of Dietary Intake of Radionuclides)

- The Ministry of Health, Labour and Welfare (MHLW) surveyed the dietary intake of radionuclides in 15 areas across Japan in the February–March 2015 period and estimated the annual radiation dose (committed effective dose) from radionuclides derived from standard meals. The survey[*1] was conducted by commissioning the National Institute of Health Sciences.
- The estimated annual radiation doses from radioactive cesium in foods collected in these areas in this period were in the range of 0.0006–0.0020 mSv. They were below 1% of 1 mSv as the basis of setting of the current limits.

Annual Radiation Dose from Radionuclides in Foods



(Source) "Survey of Dietary Intake of Radionuclides" commissioned by MHLW

(Survey protocol)

Estimation was based on the market basket method (MB method)[*2].

Target areas (15): Fukushima Prefecture (Hamadōri, Nakadōri, Aizu), Hokkaido, Iwate Prefecture, Miyagi prefecture, Tochigi prefecture, Ibaraki Prefecture, Saitama Prefecture, Tokyo, Kanagawa Prefecture, Niigata Prefecture, Ōsaka Prefecture, Kōchi Prefecture, Nagasaki Prefecture

Measurement and estimation method:

- Products that were distributed in the target areas between February and March 2015. Locally-grown products were chosen wherever possible, or the products produced in neighboring prefectures were purchased.
- Collected products were roughly divided into 14 food groups based on average portions that were expected to be consumed for each product according to target areas and they were served as MB samples as they were or after cooked.
- Radioactive cesium in the MB samples were measured consecutively for 22 hours using a germanium semiconductor detector. The radiation dose, mSv/year, from radionuclides was estimated using the measured values(the sum of Cs-134 and Cs-137) and the committed effective dose coefficient[*3] based on the assumption that standard meals were eaten for a year.

Market basket samples are divided into 210 samples(15 areas × 14 food groups)

Food products groups(14)

(1)Rice, (2) Other cereal grains, potatoes, (3)Sugars and confectioneries, (4)Fats and oils, (5)Pulses, (6)Fruits, (7)Colored vegetables, (8)Other vegetables, pickles, mushrooms, algae, (9)Beverages, (10)Fishes and shellfishes, (11)Meats and eggs, (12)Milks, (13)Seasonings, (14)Drinking water

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[*1] The survey was conducted by commissioning the National Institute of Health Sciences as "Survey of Dietary Intake of Radionuclides"

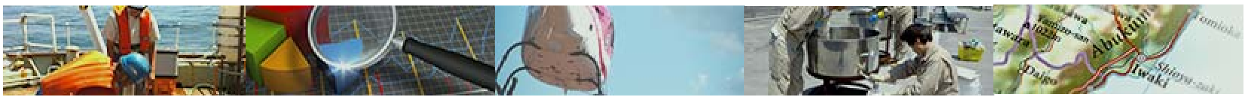
[*2] The Market Basket Method is designed to estimate the intake of various chemicals.

[*3] Committed effective dose coefficients of adult members of the public in ICRP publication 72.

8. Implementation Status of Various Environmental Monitoring

- The accident at TEPCO's Fukushima Daiichi Nuclear Power Station released radioactive substances to wide areas, and responsible Ministries and local governments have been monitoring radiation doses, densities of radioactive substances and other various environmental parameters, with regard to land and sea areas, food, etc. Data obtained from such monitoring activities are collected and shown at a portal site for the purpose of information dissemination.

(Portal site：http://radioactivity.nsr.go.jp/en/)



- Efforts will be made to continue the long term collection and storage of such data, which will serve as basic data for the health management of local residents, and to provide such information in plain language.

Major Monitoring Activities

Overall Environment of Fukushima Prefecture's Whole Areas

･Measurements of air dose rates and cumulative doses through monitoring cars and monitoring posts
･Monitoring of atmospheric suspended dust ･Environmental soil survey ･Airborne monitoring
･Detailed monitoring of areas under evacuation orders, etc.

Overall Environment of the Whole Country

･Monitoring of all prefectures in the country through monitoring posts and other means
･Wide area airborne monitoring (neighborhood of Fukushima Prefecture)

Sea Areas

･Monitoring of sea water, marine soil and marine organisms

Schools, Nursery Centers, etc.

･Measurements of air dose rates of schoolyards, etc.
･Measurements of the densities of radioactive substances in the water of outdoor swimming pools
･ Measurements of the densities of radioactive substances contained in school lunch

Harbors, Airports, Parks, Sewerage, etc.

･Monitoring of harbors' atmosphere and sea water
･Measurements of city parks, etc. ･Measurements of tourist sites

Water Environment, Natural Parks, Wastes, etc.

･Monitoring of rivers, lakes and headwaters, etc..
･Monitoring of groundwater
･Monitoring of natural parks ･ Monitoring of wild fauna and flora ･Monitoring of wastes

Agricultural Soil, Forest Land, etc.

･ Monitoring of agricultural soil ･ Monitoring of forest land and grassland

Food

･Monitoring of food conducted by respective prefectures
･Estimation of actual radiation doses due to food intakes

Monitoring of Tap Water

･Measurements of the densities of radioactive substances in purified water at water purification plants and in raw water at water intake areas

9. Assessment by the WHO and the UNSCEAR

- World Health Organization (WHO) issued a report “Health risk assessment from the nuclear accident after the 2011 Great East Japan Earthquake and Tsunami, based on a preliminary dose estimation” in February 2013. Health risk assessment in the report was carried out with the limited information obtained by the end of 2011. Based on overestimated radiation doses of general public, the report states about health effects as follows:*1.

  “Outside the most contaminated parts even in locations inside Fukushima Prefecture, no observable increases in cancer are expected”.

(Source) World Health Organization, “Health risk assessment from the nuclear accident after the 2011 Great East Japan earthquake and tsunami”, on April 2, 2014 based on a preliminary dose estimation,” February 2013

- The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) carried out a more realistic dose assessment while considering recent information, and published a report titled “Levels and effects of radiation exposure due to the nuclear accident after the 2011 great east-Japan earthquake and tsunami”

  The following conclusions were drawn in the UNSCEAR’s report,:

  - The occurrence of a large number of radiation-induced thyroid cancers in Fukushima Prefecture – such as observed after the Chernobyl accident – can be discounted because absorbed doses to the thyroid after the FDNPS accident were substantially lower than those after the Chernobyl accident. The ongoing ultrasonography survey in Fukushima Prefecture is expected to detect relatively large numbers of thyroid abnormalities, including a number of cancer cases, which would not normally have been detected without such intensive screening.
  - The prenatal exposure resulting from the accident at FDNPS is not expected to increase the incidence of in spontaneous abortion, miscarriages, perinatal mortality, congenital effects or cognitive impairment prenatal exposure . In addition, the Committee does not expect any discernible increase in heritable disease among the descendants of those exposed from the accident at FDNPS. The Committee does not expect that any radiation-induced increase in breast cancer incidence will be discernible.
  - The most important and manifest health effects of the nuclear accident in the short term would appear to be on mental and social well-being. Furthermore, the evacuation following the accident caused immediate aggravation of the condition of already vulnerable groups.

(Source) UNSCEAR, Levels and effects of radiation exposure due to the nuclear accident after the 2011 great east-Japan earthquake and tsunami, UNSCEAR 2013 Report, Vol. Ⅰ, 2014.

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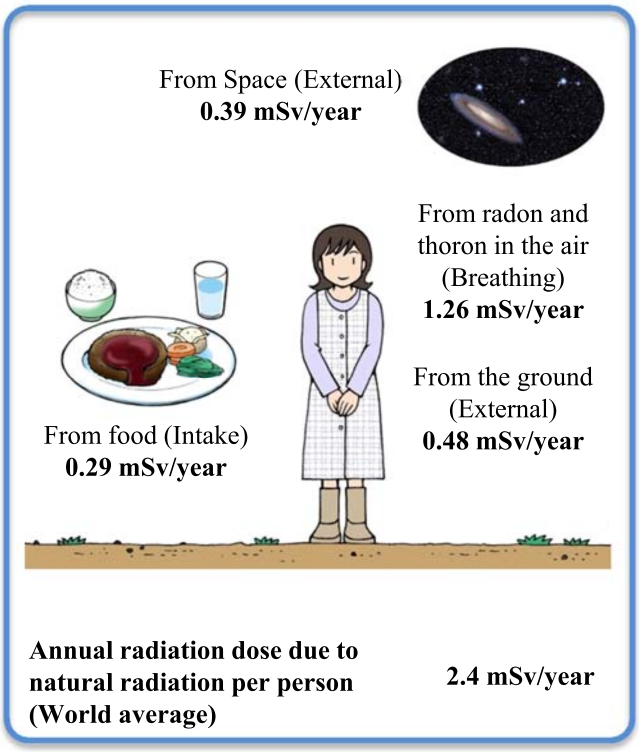
*1: WHO’s report estimated rather higher risk based on the precondition of overestimating rather than underestimating health risk so as to prevent people’s health risk from being underestimating and under an assumption of continually taking food originating from disaster-afflicted areas. Though based on such an assumption, WHO assessed “lifetime risk for some cancers may be somewhat elevated above baseline rates in certain age and sex groups that were in the most affected areas.” The purpose of this report’s is said to identify the target population who should be subjects of health management and the range of diseases, rather than to predict future health risk. It expresses its views that continuing the Fukushima Health Management Survey Fukushima Prefecture has currently conducted will contribute to the health management of residents.

10. Radiation around Us

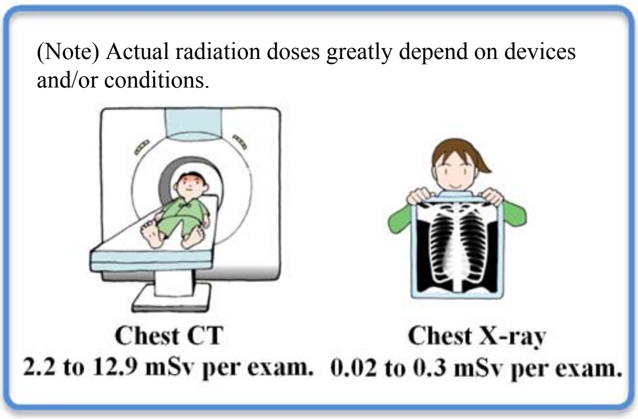
- There have existed many types of radiation in our universe since its birth, and many are still falling to the Earth from space. In addition, radioactive substances have been existing in the Earth's ground and atmosphere since its birth, and radioactive substances also exist inside plants and animals which have absorbed them into their organs.
- In our daily life, we receive natural radiation such as radiation from space, radiation emitted from radon in the atmosphere and from the ground, and radiation emanating from radioactive potassium contained in food we take.
- In addition, we may receive radiation during Computed tomography (CT) or X-ray examinations.

Radiation around Us

(Natural radiation we receive in our daily life)



(Radiation we receive voluntarily for specific purposes)



(Other)

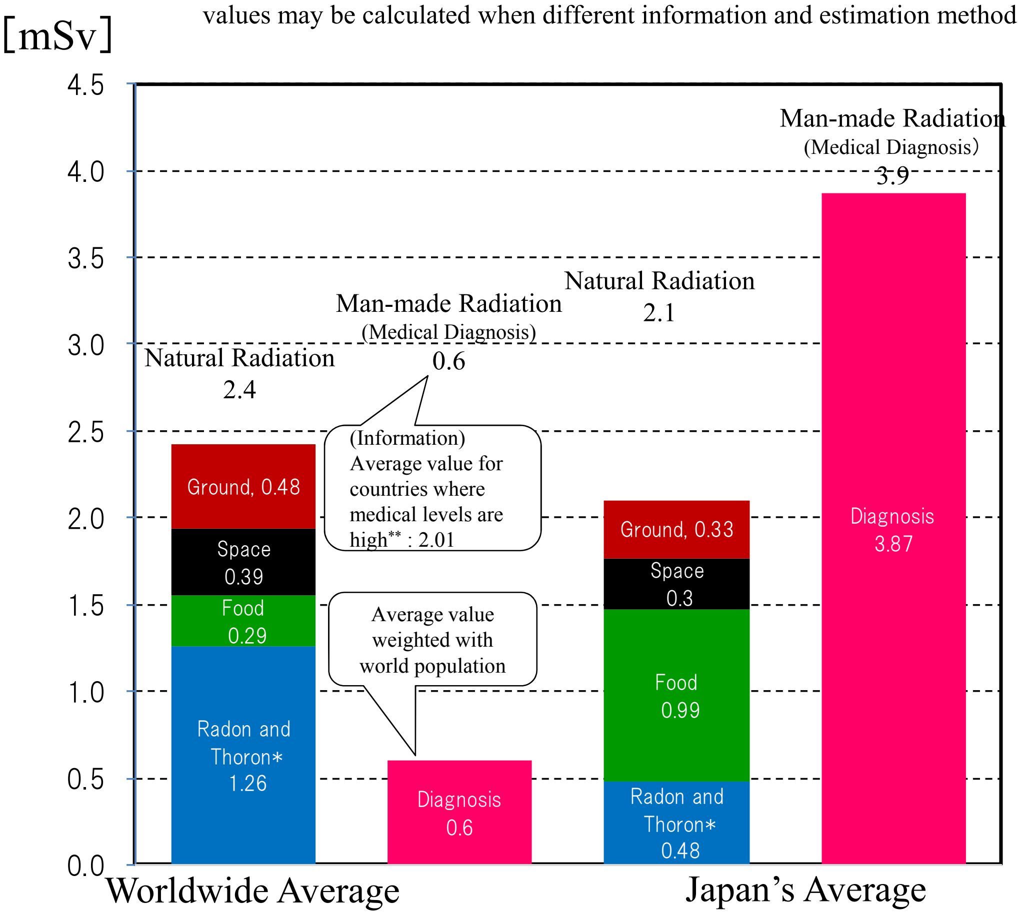
(Note) Numerical figures are from the UNSCEAR 2008 report.

11. Radiation Exposure in Our Daily Life

- The worldwide average of the effective doses due to exposure to natural radiation is 2.4 mSv per year, and Japan's average is 2.1 mSv per year[*1].
- If we compare the dose from each origin of Japan's natural radiation with that of the world's, we can notice the characteristic tendency that exposure due to radon, etc. in the air is lower, and exposure due to food is higher in Japan.
- Effective doses, which individuals may receive for the purpose of medical diagnoses, may depend on the types and frequencies of such diagnoses, and vary from individual to individual. However, it has been known that average radiation dose for a Japanese is higher[*2].

Annual Effective Dose due to Exposure in Our Daily Life

(Note) Because these average values were estimated with limited information, different average values may be calculated when different information and estimation methods are used



*: Radon (^{222}Rn) and thoron (^{220}Rn) are radioactive noble gases which exist naturally. Uranium and thorium contained in rocks and soil decay, and dissipate into the atmosphere.

**: The countries which the UNSCEAR assigns as those at the level of having at least one doctor for the population of 1,000 persons.

***: Those of dental examinations, nuclear medical diagnoses, etc., are also included in Japan's data.

(Source) The UNSCEAR 2008 report for the worldwide average, and "Living Environment Radiation," (the Nuclear Safety Research Association, 2011) for Japan's average.

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*1: The figure does not take into account the effects due to TEPCO's Nuclear Power Station after the Great East Japan Earthquake.

*2: It is said that radiation doses are increasing because the medical technology is advancing and proliferating all over the world.

12. Status of Natural Radiation in the World and Health Effects

- Natural radiation levels may vary depending on countries and regions, and they may also vary depending on areas inside countries and regions. Furthermore, there are regions in the world whose natural radiation levels are several times higher than Japan's, such as India and China, and there are countries in Europe where the concentration of indoor radon are high.
- An epidemiological survey (an example of long-term exposures) conducted in the region of Kerala, which is one of the areas where natural radiation dose levels are high, reported that increased cancer risk was not observed even for a group with the total doses of more than 500 mSv (Nair *et al.*, Health Phys 96, 55, 2009).
- Furthermore, health risks due to longer-term radiation exposures are estimated lower than for shorter-term radiation exposures with the same radiation doses, and such effects are called dose and dose rate effects[*1].

Population Distributions vs. Natural Radiation Levels in Various Countries

(External and internal exposures are included)

(Unit: 10,000 persons)

Region/Country	Effective Dose [mSv/yr]	Less than 1.5	1.5 to 3.0	3.0 to 5.0	5.0 to 7.0	7.0 to 10.0	10 or more
East Asia	Japan	6,021	6,455				
	China (Hong Kong)		550	93	6	1	
	Malaysia	1,249	424				
Northern Europe	Denmark		360	130	25	8	2
	Finland	22	341	100	24	15	12
	Lithuania.	168	162	36	4	2	1
Western Europe	Belgium	28	780	184	22	5	3
	The Netherland	1,402	148	8			
Eastern Europe	Bulgaria		704	184			
	Hungary	56	543	269	102	35	15
	Romania		1,337	826	107		
	Russia	8,094	5,203	971	271	147	124
Europe	Albania	5	270	60	15		
	Italy	15	4,093	1,200	320	80	20
	Portugal	365	407	156	15		
Percentage		39%	48%	9%	2%	1%	1%

Typical Regions with High Natural Radiation Levels

Region/City	Average Indoor Air Dose Rate (mSv/yr)	Region's Characteristics
India/Kerala, Chennai (former Madras)	**9.2 (5.2 to 32.3)**	Coastal area with monazite sand
China/Yangjiang in Guangdong Province	**2.3**	Coastal area with monazite sand
Iran/Ramsar	**4.7 (0.49～613)**	Pond

＊ The value of 0.7 Sv/Gy is used for the air dose rate conversion.

＊ Dose rates for the regions above are adopted by the UNSCEAR from various documents, and they cannot be used for precise comparison among regions because they are from different periods.

Typical Regions with High Indoor Radon Densities

Country	Indoor Radon Concentration (Bq/m^3)	Annual Effective Dose (mSV/yr)
Montenegro	**184**	**4.6**
Finland	**120**	**3.0**
Czech	**118**	**3.0**
Luxembourg	**110**	**2.7**
Sweden	**108**	**2.7**

＊ The indoor radon densities listed above are average values for respective countries. They do not include thoron.

＊ The equilibrium factor of 0.4, occupancy factor of 0.8 and dose conversion coefficient of 9 $nSv/Bqhm^{-3}$ which the UNSCEAR adopts are used to calculate the annual effective doses listed above.

[*1] When compared with shorter term exposures like those due to atomic bomb explosions, lower health risks are estimated for exposures in the environment of lower dose rates for a longer term even if the integrated values of the doses are the same. Such effects have been observed in animal experiments. (Reference: the International Commission on Radiological Protection (ICRP), "The 2007 Recommendations of the International Commission on Radiological Protection, ICPR Publication 103")

13. Radiation Effects on Health

- According to an epidemiological survey on about 120,000 survivors from the Hiroshima and Nagasaki atomic bombings, it was found that after the exposure doses due to the atomic bombs exceeded around the level of 100 to 200 mSv (acute, one time), the risks cancer mortality increased as the exposure doses increased. On the other hand, the statistical analyses of the data from the survey could not confirm whether radiation exposures would increase the risks below the level mentioned above.
- Furthermore, when radiation exposure doses are less than 100 mSv, the cancer risk due to radiation exposures would become so low and in turn would not be distinct from other cancer risks due to other factors in the living environment. Therefore, it is internationally recognized that to prove the apparent increase of the cancer risk due to radiation exposures may be difficult.

Cancer Risks due to Radiation and Life Style

Acute Radiation Dose (mSv)	Relative Risk of Cancer* (times)	Lifestyle Factors
1000 – 2000	1.8	
	1.6	Smoking
	1.6	Heavy drinking (no less than 3 glasses of whisky a day)
500 – 1000	1.4	
	1.4	Heavy drinking (no less than 2 glasses of whisky a day)
	1.29	Underweight (BMI<19)
	1.22	Overweight (BMI≧30)
200 – 500	1.19	
	1.15-1.19	Lack of exercise
	1.11-1.15	High salt foods
100 – 200	1.08	
	1.06	Poor intake of vegetables
	1.02-1.03	Passive smoking (Non-smoker female)
Less than 100	Not detectable	

(Source) the National Cancer Center

*: To obtain the relative risk of a factor, the incidence rate of one group having the factor is divided by the incidence rate of another group not having the factor. This table shows how high the cancer risk of one person having the factor is when compared with another person not having the factor.

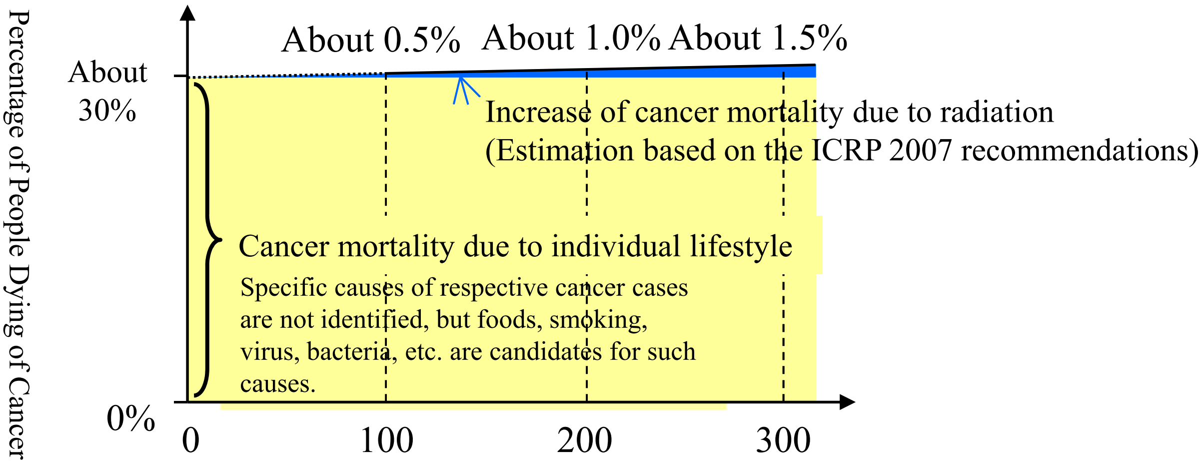
(Note) In order to produce this table, a ten-year follow-up survey was conducted after a questionnaire survey was given to adults, and cancer incidence rates were studied. For example, this table implies that the number of persons who got cancer is 1.6 times higher in one group which answered “Yes, I smoke.” than in another group which answered “No, I do not smoke.”

14. Basic Approach Recommended by the ICRP on Implementation of Radiation Protection Measures

- The International Commission on Radiological Protection (ICRP) recommended to assume "for the purpose of radiation protection, even low doses under the annual radiation dose of less than 100 mSv have risks of cancer and hereditary effects, which are those hereditary effects caused by mutated germ cells and inherited by descendants, and such risks are proportional to the increase of radiation doses above background doses" (the LNT model) when planning radiation protection[*1, *2].
- Based on the results of past research studies on atomic bomb survivors, etc., the ICRP used the LNT model, and, assuming the dose and dose-rate effectiveness factor of 2[*3], estimated that the lifetime fatal risk[*4]when exposed in a low dose environment for a long time would increase by about 5% per one Sievert (about 0.5% per 100 mSv).

(Reference)

According to the 2009 mortality data, about 30% of Japanese died of cancer. If the dose and dose-rate effectiveness factor of 2 is applied to the atomic bomb survivor survey result "the risk of dying of cancer increases by about 10% when exposed to the radiation of one Sievert," the lifelong risk of dying of cancer is estimated to increase by about 0.5% when exposed to the cumulative radiation of 100 mSv for a long term. On the other hand, the maximum difference among the cancer mortality rates in Japan's prefectures is more than 10%.



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*1:The objective of the recommendations is "to prevent deterministic effects (harmful tissue reactions), and to reduce the risks of stochastic effects (cancer or hereditary effects) to the levels reasonably achievable" in order to protect human health.

*2:The ICPR also mentioned that even the LNT model had some uncertainties.

*3:The dose and dose-rate effectiveness factor is a factor determined based on the judgment that health effects per unit dose is usually lower for the long-term radiation exposures of low doses and low dose-rates than for the short-term radiation exposures of high doses and high dose-rates. The ICRP adopts the factor of 2 based on animal experiments and other research studies, while admitting some uncertainties, and some others adopt the factor of 1.5.

*4.A risk is a scale to show the probability that some harmful event might happen, and does not mean either the antonym of the word "safety" or a hazard.

14. Basic Approach Recommended by the ICRP when Taking Radiation Protection Measures (Continued)

- The International Commission on Radiological Protection (ICRP) has classified human exposures into following three types of situations, and defined protection standards.
  - (1) Everyday situations involving the planned operation of sources (planned exposure situations)
  - (2) Situations such as accidents and nuclear terrorism, requiring urgent action (emergency exposure situations)
  - (3) Situations including prolonged exposure situation during long-term recovery and reconstruction after an accident, etc. (existing exposure situations)
- Under a planned exposure situation, as additional "dose limits," 1 mSv per year is applied to the public exposure[*1], and the annual average of 20 mSv for five years is applied to the occupational exposure. The dose limits are values to manage (total) exposure doses of individuals from various sources under control. Limiting values set for respective sources from which individuals may receive doses are called "dose constraints[*2]."

  ☞Please refer to Appendix 3 "Examples of 'Planned Exposure Situations'"
- When a radiation source becomes out of control due to an accident, etc., such a situation shall be treated as an emergency exposure situation. Under such a situation, it is determined to set an appropriate "reference level[*3]" in the range of 20 to 100 mSv for a one-year or one-time dose depending on the situation, and to use the reference level as a criterion to plan and implement radiation protection measures. With regard to such a reference level, it is not required that the exposure doses of respective local residents should become immediately lower than the reference level; but, rather it is required to take measures to make the doses to respective residents lower than the reference level, and to reduce the radiation doses step by step.
- Then, when a recovery or reconstruction phase (an existing exposure situation) comes, in order to reduce public exposures close to or equivalent to an ordinary level, it is required to select an appropriate "reference level" in the lower range of 1 to 20 mSv per year depending on the situation[*4], and to set the reference level to 1 mSv per year as a long-term goal.

(Reference) "Dose constraints" and "reference levels" are considered as criteria to take measures based on the principle of "optimization" to reduce radiation doses to levels as low as reasonably achievable while considering economic and social factors. However, "dose limits" are not applied to patients' medical exposures because the patients might not be able to receive required examinations and medical treatments, and their interests might be damaged.

[*1] The value of 1 mSv per year, additionally set as the dose limit of the public exposure (effective dose), is not meant to define the boundary between "safety" and "hazards" on health. It is rather adopted to maximally reduce public exposure doses to the extent possible for the purpose of requesting entities who introduce and operate radiation sources to exercise rigorous controls. With regard to facilities, for example, nuclear power stations where radioactive materials are used, Japan's laws and regulations also require the operators who use radioactive materials to exercise controls so that the effective doses public people might be exposed to outside such facilities shall not exceed 1 mSv per year.

[*2] Portions of a dose limit are assigned to respective radiation sources, and the value of a dose constraint is smaller than that of the dose limit.

[*3] For a rescue operation, a reference level exceeding 100 mSv may be allowed.

[*4] An intermediate reference level may be set as a benchmark when it is necessary to improve a situation step by step.

15. Japan's Efforts to Manage the Fukushima Nuclear Disaster

(Evacuation Order and Its Lifting)

- Having considered the "reference level"[*1] band (20 to 100 mSv per year) of the International Commission on Radiological Protection (ICRP) for radiation protection in an emergency exposure situation, the Government of Japan adopted the most strict value of 20 mSv per year in the band, and issued an evacuation order[*2].

20 mSv per year = Radiation doses per day times 365 days

Indoor radiation doses (3. 8 μSv times 16 hours times 0.4 (reduction factor))
plus
Outdoor radiation doses (3. 8 μSv times 8 hours)

* The reduction factor of 0.4 for wood frame houses is adopted from the report "Planning For Off-Site Response to Radiation Accidents in Nuclear Facilities (IAEA-TECDOC-225)" prepared by the IAEA.

* (1) Internal exposures, and (2) the physical attenuation of radioactive substances and weathering effects are not considered in the formula above. This is because it is assumed that dose increases due to (1) and dose decreases due to (2) cancel out each other.

- Then, after December 2011 when the Fukushima Daiichi Nuclear Power Station reached a condition equivalent to cold shutdown, if the annual radiation doses of an area were confirmed to become no more than 20 mSv, the area was considered to have entered into an existing exposure situation, and classified as an "area to which evacuation orders are ready to be lifted." With regard to such an area, although the evacuation order will continue to be maintained for a while, measures to support the area's recovery and reconstruction, such as decontamination and restoration of infrastructure, and employment measures will be implemented expeditiously so that its residents will be able to return to their homes as soon as practicable.
- The evacuation order for a specific area will be lifted after satisfactory discussions with prefectural and other local governments as well as with original residents when the area's infrastructures and living-related and personal services have almost restored their original conditions, and when decontamination operations of the area's environments including children's living environments have sufficiently progressed.
- As of January 2016, The evacuation order for Tamura City, a part of Kawauchi and Naraha Town was lifted.

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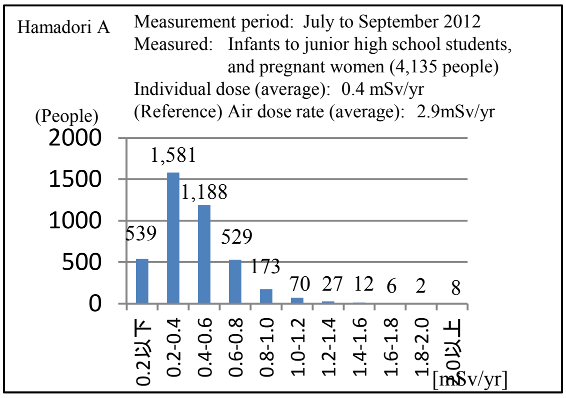
*1:A reference level is a criterion to take measures based on the principle of "optimization" to reduce radiation doses to levels as low as reasonably achievable while considering economic and social factors.

*2:Areas under the evacuation order are those areas whose radiation doses per year after the accident were estimated to reach 20 mSv per year based on the measurements of air dose rates[*] (conservative assumptions were made that people would spend 8 hours outdoor and 16 hours indoor per day, the reduction factor for wood frame houses was 0.4, and no attenuation would occur thereafter) .

15. Japan’s Efforts to Manage the Fukushima Nuclear Disaster

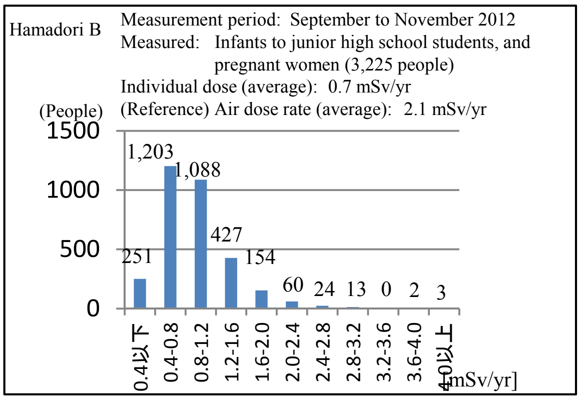
(Evaluation on External Exposures of Local Residents after Their Returning Home)

- Because it was difficult to individually measure radiation doses with personal dosimeters during the early stage of the accident, results of radiation dose estimation from air dose rates, which may be used to make evaluations on the safe side, have been used to determine areas to be placed under the evacuation order, and so on.
- It is well known that if radiation doses are estimated from air dose rates measured by fixed-point monitoring, etc., the behavior patterns of residents and the reduction factor of houses being assumed to be uniform for such estimation, they are different from measurement results of radiation doses with personal dosimeters, which can reflect actual living conditions.
- It has been found that the radiation doses measured with personal dosimeters in municipalities so far, although tending to be lower than those estimated from air dose rates, vary depending on individual residents’ lives and activities.
- The Nuclear Regulation Authority(NRA) issued a report entitled “Basic Principles on Safety and Security Measures for Evacuees Returning Back to Their Homes,”. In the report, NRA recommended that for assessment of dose to residents after they return back to homes individual radiation doses measured with personal dosimeters are preferable to estimates from air dose rate.



Hamadori A

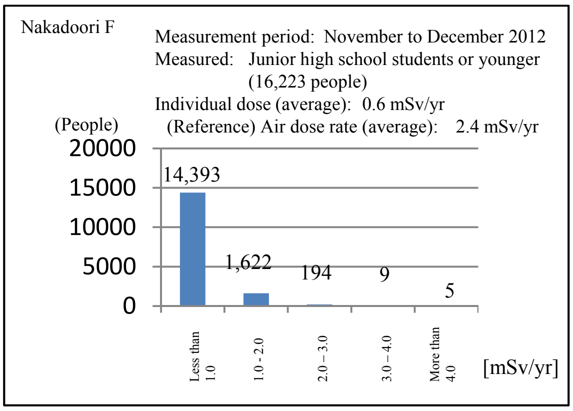
Measurement period: July to September 2012
Measured: Infants to junior high school students, and pregnant women (4,135 people)
Individual dose (average): 0.4 mSv/yr
(Reference) Air dose rate (average): 2.9mSv/yr



Hamadori B

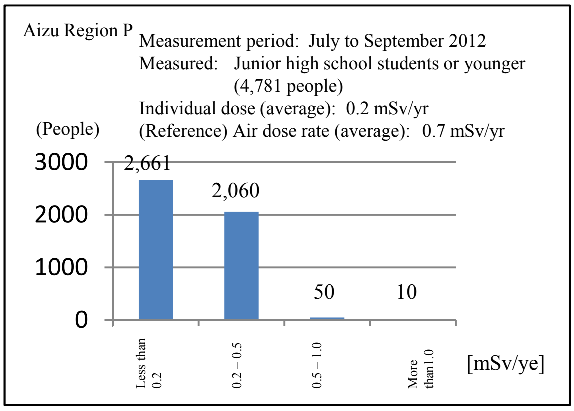
Measurement period: September to November 2012
Measured: Infants to junior high school students, and pregnant women (3,225 people)
Individual dose (average): 0.7 mSv/yr
(Reference) Air dose rate (average): 2.1 mSv/yr

(Note) A, B, F and P correspond to those municipalities listed in the table of “3. Status of External Exposures Measured with Personal Dosimeters.



Nakadoori F

Measurement period: November to December 2012
Measured: Junior high school students or younger (16,223 people)
Individual dose (average): 0.6 mSv/yr
(Reference) Air dose rate (average): 2.4 mSv/yr



Aizu Region P

Measurement period: July to September 2012
Measured: Junior high school students or younger (4,781 people)
Individual dose (average): 0.2 mSv/yr
(Reference) Air dose rate (average): 0.7 mSv/yr

＊ With regard to the “individual dose (average)” above, measured values were simply converted to those on an annual basis. Background was extracted.

＊ With regard to the “air dose rate (average)” above, average values of air dose rates of respective municipalities monitored by aircraft during the period same as that of the measurement periods were used to estimate annual radiation doses, with the assumption that people would spend 8 hours outdoor and 16 hours inside wood frame houses per day.

(Source) The ” Study Team on Safety and Security Measures for Evacuees to Return Homes” (the second meeting) of the Nuclear Regulation Authority, “Explanatory Material for Ministries and Agencies Related to the Nuclear Emergency Response Headquarters ‘About Fukushima Prefecture’s Current Status (Radiation Dose Measurement Results)’”

15. Japan’s Efforts to Manage the Fukushima Nuclear Disaster

(Regulations on Radioactive Materials in Foods)

- After the accident at TEPCO’s Fukushima Daiich Nuclear Power Station, provisional regulation values of radioactive materials in foods were established*1, and measures such as shipment restrictions were taken to prevent foods containing radioactive materials exceeding the provisional regulation values from being sold in markets.
- Since April 1, 2012, in order to further improve the safety and security not for the purpose of emergency responses but for the purpose of a long-term vision, the upper limit for additional effective doses people may incur due to food intakes has been set to 1 mSv per year, and the limits for radioactive cesium in foods has been established*2 based on the upper limits.
- Based on inspection results, when the territorial spread of items exceeding the maximum limits is uncertain, the surrounding areas are inspected to determine the need for the restriction on distribution. And the areas where distribution is to be restricted, when a significantly high level of concentration is detected in items, the restriction of consumption is immediately established, regardless of the number of samples collected for the items concerned.

Reference Values for the Densities of Radioactive Cesium in Foods [Unit: Bq/kg]

	Japan (Since April 2012)	Codex Alimentarius Commission*3	EU (Foods Circulated Regionally)	USA
Drinking Water	10	1000	1000	1200
Milk	50	1000	1000	1200
General Foods	100	1000	1250	1200
infant Foods	50	1000	400	1200

(Note) Reference values of respective entities differ from each other because assumptions made to calculate the reference values were different.

Japan: The upper limit for the additional effective doses due to food intakes was set to 1 mSv per year, and it was assumed that 50% of general foods were contaminated at the level equivalent to the limits. With regard to milk and infant foods, most of those sold in Japan were (and are) made in Japan, and the limits for them were set to be half of the limits for general foods.

The Codex Alimentarius Commission: The value of 1 mSv per year was adopted for an intervention exemption level (the level below which specific measures are not considered necessary), and the origins of about 10% of all foods were assumed to be contaminated areas.

The EU: The reference values were established so that additional radiation doses would not exceed 1 mSv per year, and the 10% of foods people would take during their lifetime were assumed to be contaminated at the levels equivalent to the regulation values.

The USA: The effective radiation dose of 5 mSv was adopted, and it was assumed that 30% of foods taken were contaminated.

(Source) The Reconstruction Agency prepared the table based on “Codex General Standard for Contaminants and Toxins in Food and Feed (CODEX STAN 193-1995), ” “ Council Regulation (EURATOM) 2007/0103 (CNS) “ and “CPG Sec. 560.750 Radionuclides in Imported Foods - Levels of Concern.”

1: The provisional regulation values were established based on the effective dose of 5 mSv per year for radioactive cesium. These values take into account the contribution of radioactive strontium.

*2: Effects due to radioactive materials other than radioactive cesium were also considered to establish the reference value, so that the additional effective dose would not exceed 1 mSv per year.

*3: The Codex Alimentarius Commission, established by the United Nations Food and Agricultural Organization (FAO) and the World Health Organization (WHO) in 1963, is an intergovernmental organization to develop international standards for foods (Codex standards). Its aims to protect the health of consumers, and to promote the fair trades of foods. Currently, more than 180 countries are its members.

(Appendix 1) Implementing Measures to Reduce Radiation Exposures
- Examples in Date City, Fukushima Prefecture -

- In Date City, Fukushima Prefecture, the air dose rate* in one area is more than 3 micro-Sieverts per hour (equivalent to the annual external exposure dose[*1] of about 15.8 mSv) while that in another area is less than 0.5 µSv per hour (equivalent to the annual external exposure dose of about 2.3 mSv), and the radiation contamination conditions there vary depending on areas. Therefore, in order to perform decontamination operations, the city was divided into three areas, and decontamination operations have been preferentially performed starting from the highest dose area[*2] while methods suitable for specific radiation dose levels have been adopted.

Area A (an area with relatively high doses, including specific spots recommended for evacuation)

・・・Wide area decontamination (residential areas, roads and forest edge areas)

(Full-scale operations started in October 2011. Operations were complete in June 2013.)

Area B (an area adjacent to Area A and with relatively high doses. An area with the annual external exposure doses of more than 5 mSv estimated from air dose rates.)

・・・Wide area decontamination in combination with spot decontamination of mini-hot spots, etc. (residential areas and roads)

(Full-scale operations started in October 2012. Operations in 16 out of 25 districts were complete as of October 8, 2013.)

Area C (an area with relatively low doses. An area with the annual external exposure doses of more than 1 mSv estimated from air dose rates.)

・・・Spot decontamination of micro-hot spots, etc. (residential areas, roads)

(Full-scale operations started in March 2013. Operations in 146 out of 230 administrative districts were complete as of October 8, 2013.)

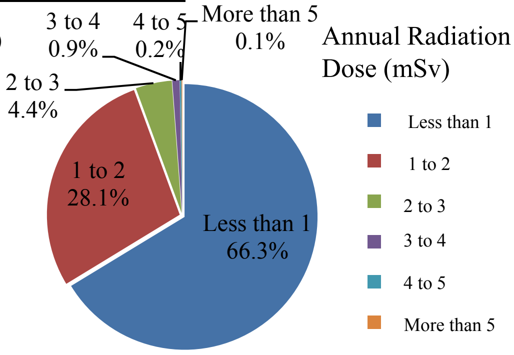
(Note) Areas A, B and C were selected based on the air dose rates measured in March 2012, and the current air dose rates there are reduced because decontamination operations have progressed.

- The city distributed personal dosimeters(glass badges) to Date citizens and the city explained the effects for their health and necessity of decontamination works, using the results of measurement of glass badge. These risk communications of radiation protection have been actively implemented to help the citizens understand current situation.

Glass Badge Measurement Result Covering Whole Citizens

- # of Citizens Measured: 52,783 people (those citizens who were measured for a whole year)
- Reference Date: October 1, 2013 (about 81.2% of the whole)
- Measurement Period: July 2012 to June 2013 (measured 4 times every 3 months)

⇒ 1) Annual Radiation Dose Averaged over Whole Citizens: 0.89 mSv
⇒ 2) Whole Citizens' Annual Radiation Doses (distribution) :
  66.3% received less than 1 mSv/yr, and the percentage is the highest.
  28.1% received 1 to 2 mSv, and the percentage is the second highest.
  4.4% received 2 to 3 mSv.
(Note) 0.521 to 0.572 mSv/yr in the district where the average air dose rate was 0.23 µSv/hr.



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*1: The value was estimated based on the assumption that people would spend 8 hours outdoor and 16 hours indoor per day, the reduction factor of wooden frame houses would be 0.4, and no attenuation would occur thereafter.

*2: Priority was given to schools irrespective of their Areas.

(Appendix 2) Comparison with the Chernobyl Nuclear Accident
- Comparing Emissions of Radioactive materials, etc. -

- With regard to the Chernobyl Nuclear Accident (1986), foods and drinks taken by affected people were mainly for their self-consumption, and internal exposures* due to intakes of contaminated foods, and especially intakes of milk contaminated with radioactive iodine increased radiation doses to their thyroid glands.(Reference 1)

  But to the accident at TEPCO’s Fukushima Daiichi Nuclear Power Station, There is small release of strontium and plutonium, and iodine disappears early. As of January 2016, Government surveying mainly influence of radioactive cesium.

  Because prompt measures were not taken, thyroid cancer was observed in more than 6,000 children and youths who had drunken milk contaminated with radioactive iodine-131, and 15 of them died by 2005. With regard to health effects on local residents caused by other radiation exposures, no plausible evidence was found. (the UNSCEAR 2008 Report)

  (Reference 2)

  Some evaluation results view that according to Hirosaki University’s examinations on thyroid glands of residents in the Fukushima Prefecture region, the average (median) of the equivalent doses* to the residents’ thyroid glands was 4.2 mSv per year for those not older than 19 years, and 3.5 mSv per year for adults; and that the average equivalent dose was one hundredth of that of the Chernobyl Nuclear Accident (according to the UNSCEAR 2008 report, the average equivalent dose of the thyroid glands of evacuees in the Chernobyl Nuclear Accident was 490 mSv per year).
- Japan has been making efforts to set the reference values which are viewed to be very strict according to the international standard and to conduct vigilant and watchful inspections so that foods exceeding the reference values will not be sold in markets. As a result, the internal exposure dose is maintained at the level of far lower than 1 mSv.
- In the Chernobyl Nuclear Accident, radioactive substances such as strontium which tends to be accumulated in bones and plutonium whose physical half life* is 24,000 years were released to wide areas. As a result, those wide areas were designated as restricted areas. In the accident at TEPCO’s Fukushima Daiichi Nuclear Station, such nuclear species were hardly released.
- The Chernobyl Forum (consisting of eight UN organizations including the IAEA and the WHO) reported that the worst disaster caused by the Chernobyl Nuclear Accident was not health hazards caused by radioactive substances, but mental stresses caused by evacuations, etc.

Comparing Amounts of Radioactive Substances Released to the Atmosphere

[Unit: 10^{16}Bq]

Radioactive Substances Emitted **[Figures in ( ) are physical half lives.]**	**Accident at TEPCO’s Fukushima Daiichi Nuclear Power Station**	**Chernobyl Nuclear Accident**	**Chernobyl Nuclear Accident/Accident at TEPCO’s Fukushima Daiichi Nuclear Power Station**
Total Emission (iodine equivalent)*1	77*2	520	6.8
Iodine-131 (8 days)	16	180	11.3
Cesium-134 (2 years)	1.8	4.4	2.4
Cesium-137 (30 years)	1.5	8.5	5.7
Strontium-90 (29 years)	0.014	0.8	57
Plutonium-239 (24,000 years)	0.0000003	0.003	10,000

*1: Only iodine-131 and cesium-137 were considered. (For example, 180 plus 8.5 times 40 (conversion factor) equals to 520 in 10^{16}Bq)

*2: The then Nuclear and Industrial Safety Agency reported the figure of 480 quadrillion becquerels in February 2012. However, events which might not happen in the real world were assumed to estimate the figure, and the above figure is listed instead in this document.

(Source) The IAEA Report (2001), ”Report of the Japanese Government to the IAEA Ministerial Conference on Nuclear Safety” (June 2011), etc.

(Appendix 3) Examples of "Planned Exposure Situations"

- Status of Dose Management for Radiation Workers, etc. -

- Radiation workers, etc. use radiation counters to periodically measure doses due to external exposures*.
- According to the result of a survey conducted by the Council on Personal Dosimetry Service[*1], about 90% of medical workers (about 340,000 people) were exposed radiation of less than 1 mSv per year, and remaining 10% was exposed to radiation of more than 1 mSv per year (about 5,000 people of them were exporsed to more than 5 mSv per year).
- Radiation workers individually measure and record radiation doses for appropriate management to reduce the radiation doses.

(Reference)

Japanese laws adopted the "1990 Recommendations of the International Commission on Radiological Protection (ICRP)" (ICRP Publication 60), and established dose limits accordingly. The ICRP has defined the dose limits not as the borderline between "safety" and "hazards" but as the level exceeding which would result in effects on individuals not generally acceptable. In Japan, the limit to the exposure dose of a radiation worker is set to 100 mSv for 5 years, not exceeding the upper limit of 50 mSv per year. In addition to the above limit, the limit of 5 mSv for 3 months is set for a female.

Occupational Exposure Doses

(Fiscal 2014) (Unit: People)

Effective Dose (mSv/year)	General Medicine	Dental Care	Veterinary Care	Total
～1mSv/year	300,817	21,916	13,984	336,717
	90.1%	99.3%	99.1%	91.0%
1～5mSv/year	27,709	148	111	27,968
	8.3%	0.7%	0.8%	7.6%
5～10mSv/year	3,768	11	7	3,786
	1.1%	0.0%	0.0%	1.0%
10mSv/year～	1,636	3	6	1,645
	0.5%	0.0%	0.0%	0.4%
Total	333,930	22,078	14,108	370,116
	100.0%	100.0%	100.0%	100.0%

(Source) the Council on Personal Dosimetry Service

[*1] People who used the individual dosage measuring services provided by the member companies of the Council on Personal Dosimetry Service were surveyed.

Glossary

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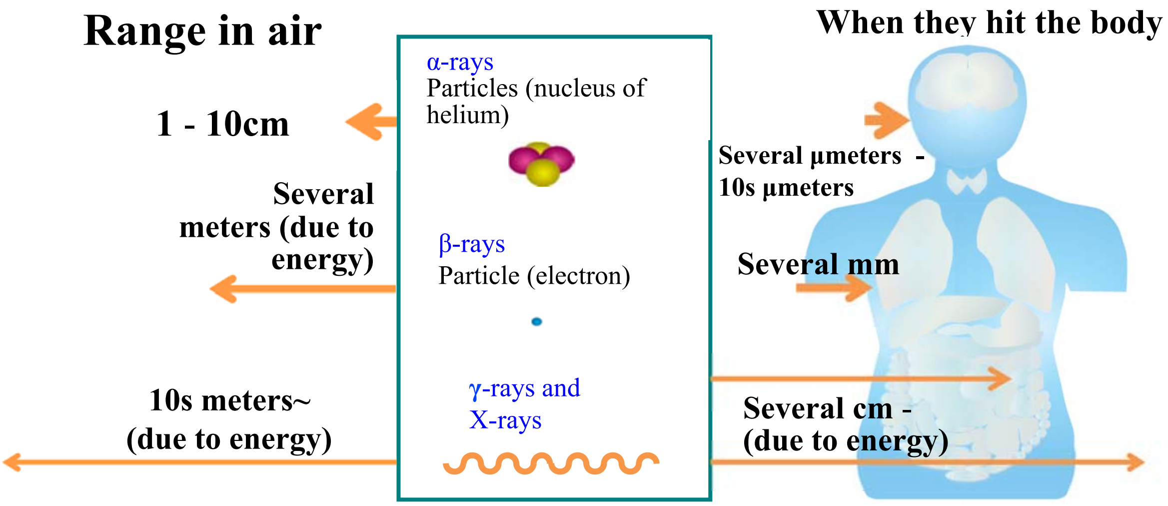
Travel Distance of Radiation (Range)

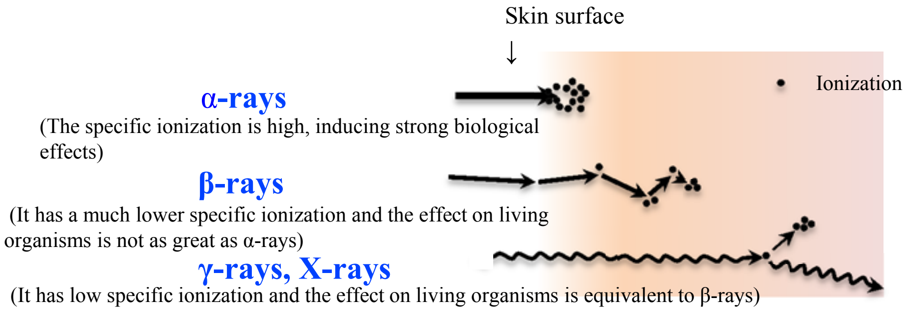
- The penetration rate through air and human body differs among the types of radiation. Therefore in external exposure and internal exposure, the type of radiant ray (α- (alpha) ray, β- (beta) ray, γ- (gamma) ray) and radioactive substances (radionuclides) that would be watched vary.

- α-Rays can travel a few centimeters in air, and can be stopped by a sheet of paper. With external exposures, they do not penetrate deeper than the outer layer of the skin (horny layer) consisting of dead cells, and therefore will not have a significant effect. However once they enter inside the human body, they transfer their energy intensively to surrounding cells.

- β-Rays can travel for a few meters in air, and hardly ever contribute to contamination when the radiation source is at a distance away from the human body. Once they reach the surface of the human body, they can transfer energy by penetrating the skin and subcutaneous tissues, or once inside the human body they can transfer energy in the range of several millimeters in circumference.

- γ-Rays and X-rays are highly penetrating, and can travel beyond dozens meters in air. They may even penetrate the human body.





α-rays
(The specific ionization is high, inducing strong biological effects)

β-rays
(It has a much lower specific ionization and the effect on living organisms is not as great as α-rays)

γ-rays, X-rays
(It has low specific ionization and the effect on living organisms is equivalent to β-rays)

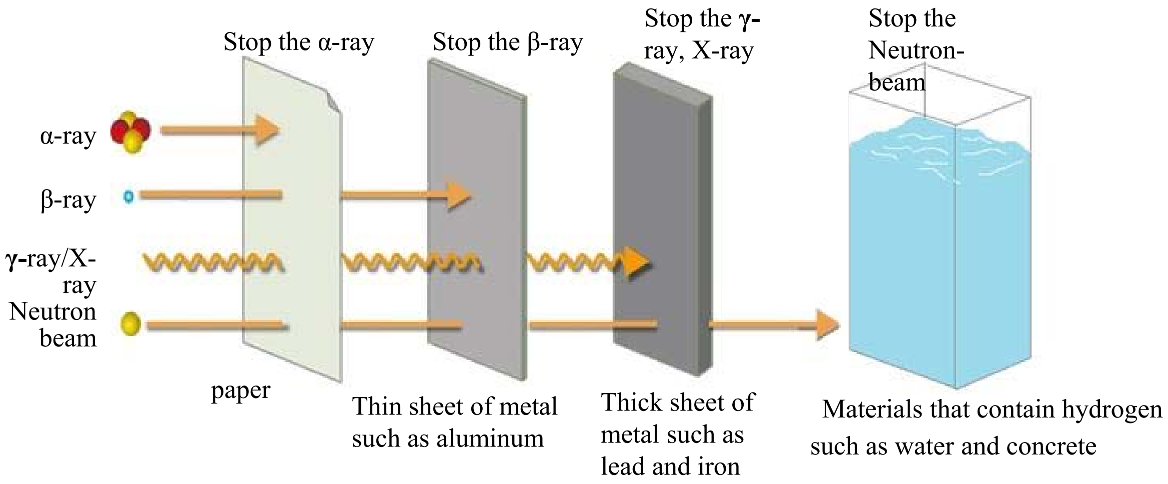
Radiation Penetration

- Particles and electromagnetic waves that hold an electric charge, interact with substances through electromagnetic forces and as a result of energy loss, suffer loss in penetration power and ultimately stop.

- α-rays where ionization density is high travel only for a few centimeters in air, and can be stopped by a sheet of paper. Although it depends on their energy, β-rays in general stops at around a couple of meters in air, 1cm with plastic, and about 2 - 3mm with aluminum boards. γ-rays and X-rays have a higher penetrating power compared to α-rays and β-rays, and again it depend on their energy, but can penetrate beyond a few tens of meters to a few hundred in air. γ-rays can be shielded by high density materials such as thick lead or iron boards, and can also be shielded by thickened concrete, soil or even deepened water.

- The shielding of X-rays, g-rays, and neutrons is qualitatively different. Neutrons do not have electric charges, and therefore when they collide directly with particles that constitute a substance they lose their kinetic energy and stop. The most effective way to deprive a neutron of its kinetic energy is to collide it with a proton (nucleus of hydrogen).

<Radiation Penetration>



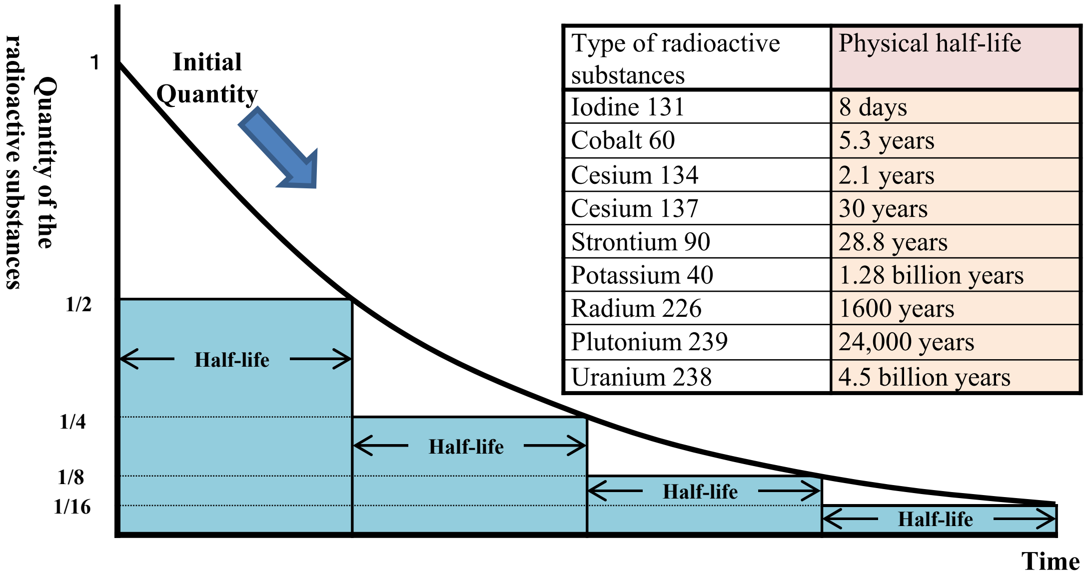
< The Effect of Radiation Shielding>
(Radiation from Cesium-137)

[Source Data] Japan Atomic Energy Agency (JAEA)
“Dose Calculation to Derive the Upper Bound of Radioactivity Concentration in Disposal of Transuranium Wastes” (2008)

Half-life of Radioactive Substances

- Physical half-life is the time in which the nucleus of a radioactive substance will lose half of its activity through radiation emission and changing into another nucleus. There is diversity in the physical half-life between different types of radioactive substances.

<Physical Half-Life>



Type of radioactive substances	Physical half-life
Iodine 131	8 days
Cobalt 60	5.3 years
Cesium 134	2.1 years
Cesium 137	30 years
Strontium 90	28.8 years
Potassium 40	1.28 billion years
Radium 226	1600 years
Plutonium 239	24,000 years
Uranium 238	4.5 billion years

- Biological half-life is the time it takes for a radioactive substance after entering the body to lose half of original value. This varies in accordance with the type of radioactive substance and the age of recipient.

<Biological Half-Life>

	Iodine 131	**Cesium137**
Biological half-life	Infant : 11 days 5 years old : 23 days Adult: 80 days	up to 1 year old : nine days up to 9 years old : 38 days up to 30 years old : 70 days up to 50 years old : 90 days

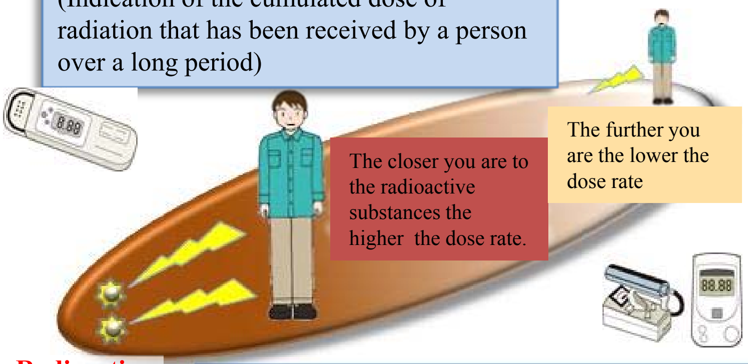
[Source data] Argonne National Laboratory (U.S.) "Human Health Fact Sheet" (August, 2005)
V. N. Korzum et al., "Chernobyl: Radioactivity and Nutrition" (1994)

Effective half-life is defined as the period of time required to reduce the radioactivity level of the radioactive substance inside the body to exactly one half its original value due to the involvement of both physical half-life and biological half-life.

External Exposure and Internal Exposure (1)

- External exposure occurs when radiation from a source external to the body, such as one on the surface of the earth, airborne or deposited on clothing or body surface, penetrate the body.
- The further a person is from a radioactive source (in case of **γ**-rays the intensity is inversely proportional to the square of its distance from the radiation source) and the shorter the length of stay at that location (proportional to the length of stay) the lower the exposed dose of the radiation. The dose will decrease even further when there is a shield that blocks the radiation.

< The Characteristics of External Exposure to γ-Ray >



Calculation based on personal dosimeter (Indication of the cumulated dose of radiation that has been received by a person over a long period)

The closer you are to the radioactive substances the higher the dose rate.

The further you are the lower the dose rate

Radioactive substances

Measure with survey meters (Indicated ambient dose (equivalent) rate [in units of microsieverts per hour (μSv/h)] is multiplied by the time length of stay.)

☞ “Various Quantities Expressed in Sievert (Ambient dose and personal dose)”

1) Distance: Dose rate is inversely proportional to the square of its distance

$$I = \frac{k}{r^2}$$

I : The intensity of the radiation (dose rate)
r : Distance
k : Constant

For example the difference of the intensity of a radiation at 1cm away and 1 m away from the source of radiation is 10,000 times. (When there are several radiation sources the calculation will not be so straight forward.)

2) Time: If the dose rate is the same, this is proportional to the length of exposure

(Total) Dose (μSv) = dose rate (μSv/h) × time

- Internal exposure occurs when radiation is emitted from radioactive substances which are present within the body. Internal exposure occurs when:
  1)Airborne radioactive substances are inhaled and enter the body
  2)Radioactive substances enters into the body while eating or drinking
  3)Radioactive substances are taken into the body through wounds

After a radioactive substance enters the body, the radioactivity will decrease with the progress of time. However the body will be exposed to radiation until it is mostly eliminated from the body by being excreted in the urine or faeces, or lost in decay (*1).

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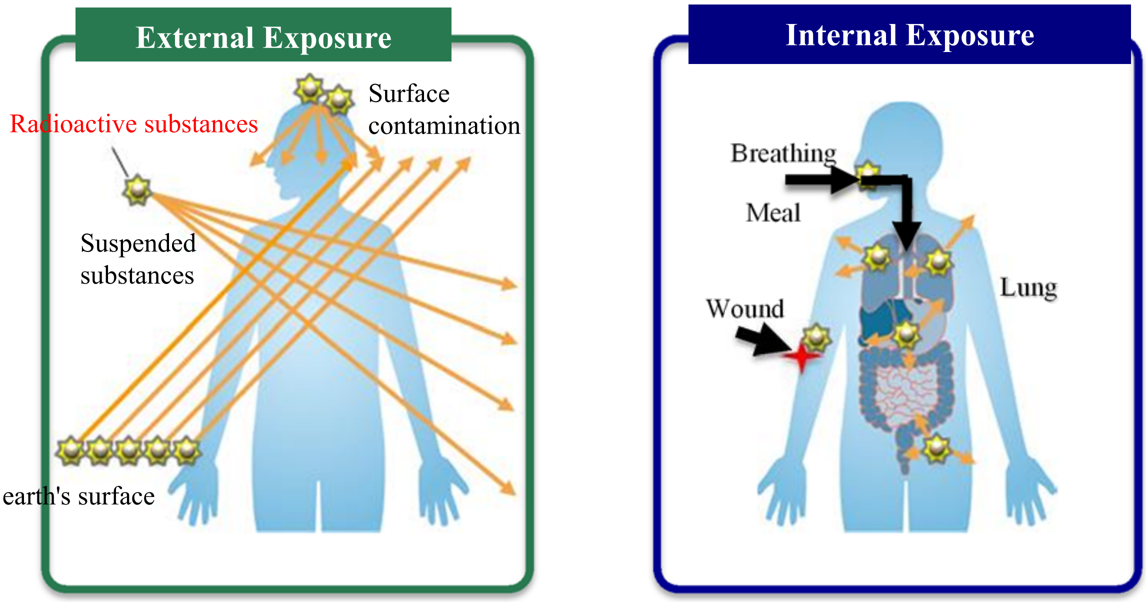
*1 Radioactive iodine accumulates mainly in the thyroid gland and strontium tends to accumulate in bone. Cesium does not have a tendency to accumulate in any particular organ.

External Exposure and Internal Exposure (2)

- The difference between external exposure and internal exposure is the location of the radioactive sources that emit radiation, and both are same in the sense that the body is exposed to radiation.

- Furthermore, if the effective doses are of equal value, the risks of (stochastic) effects are the same. However, with external exposure, the contribution of **γ**-rays and X-rays that have strong penetration power is high, and with internal exposure the contribution of α-rays and β-rays that have weak penetration power is high.


<External Exposure and Internal Exposure>

Units of Radiation
(becquerel, gray, sievert)

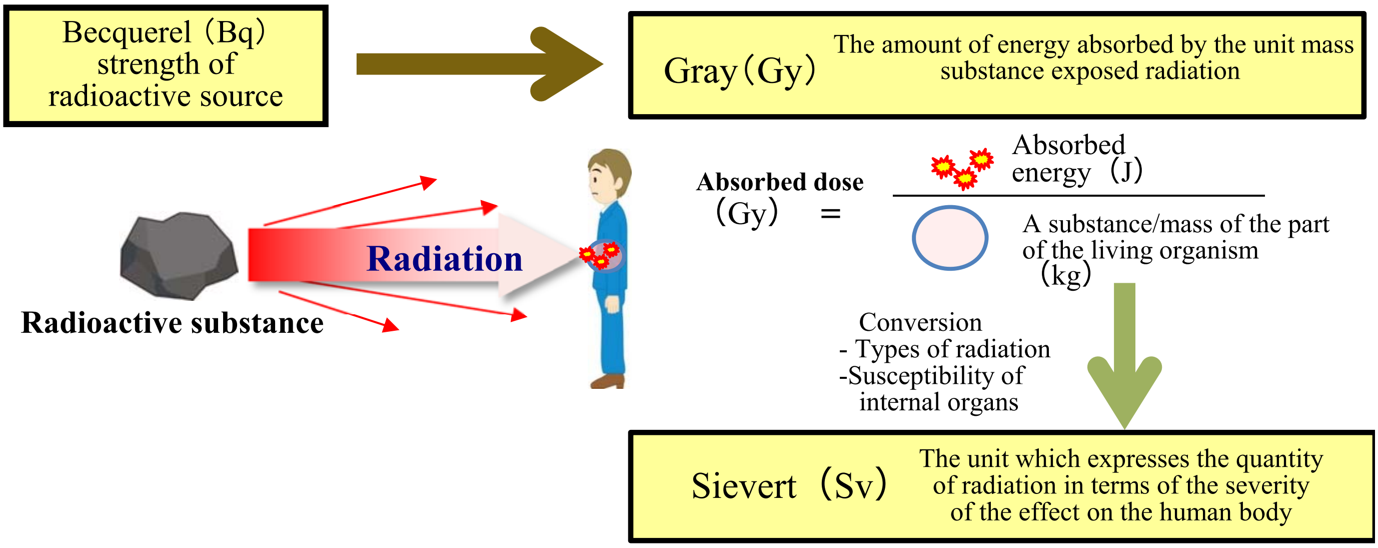
- Units of radiation can be divided roughly into the units for measuring radiation that is given off, and the units for measuring radiation that is exposed. “Becquerel (Bq)” is a unit of the intensity of radiation and measures the radiation that is given off. On the other hand, units such as “gray (Gy)” (used for absorbed dose) and “sievert (Sv)” (used for equivalent dose, effective dose and ambient dose, etc.) are for measuring the radiation that has been exposed.

- Becquerel (Bq) is used to measure the quantity of radioactive substances (strength of the source of radiation) in soil, food and drinking water. 1 Bq is equal to the quantity of the radioactive substance in which one nucleus decays per second.

- Gray (Gy) is used to measure the amount of energy (absorbed dose) that is absorbed by the substance through which the radiation passed. 1 Gy is equal to an absorbed dose of 1 Joule per 1 kilogram of the substance.

- Sievert(Sv) is used to express the radiation effects (stochastic effects) on human body exposed to radiation. (Sievert is the special name for the SI unit of equivalent dose, effective dose and operational dose quantities).

- Bq and Gy both measure physical quantities, and are measurable. On the other hand, Sv cannot be directly measured, and is obtained through model calculation and therefore have some uncertainties. However, it is useful for grasping the radiation exposure level. (Note: The Sv used in survey meters and personal dosimeters are figures that were converted from measurable quantities (such as quantities of ion, strength of light, etc.)).



Becquerel（Bq）
strength of
radioactive source

Gray（Gy） The amount of energy absorbed by the unit mass substance exposed radiation

Absorbed dose (Gy) = Absorbed energy (J) / A substance/mass of the part of the living organism (kg)

Conversion
- Types of radiation
-Susceptibility of internal organs

Sievert（Sv） The unit which expresses the quantity of radiation in terms of the severity of the effect on the human body

Various Quantities Expressed with the Sievert
(Equivalent dose and effective dose)

○ The sievert (Sv) is used as a unit for expressing the level of radiation exposure of human bodies (stochastic effects on human bodies).

○ When radiation passes through the internal organs or tissues, a part of the radiation energy is absorbed into them. The absorbed energy level (calorie) [unit: joule] per 1kg of organs, tissues or a human body is called an absorbed dose [unit: gray].

Even if the absorbed dose is the same level, stochastic effect received varies with the type of radiation. The Equivalent Dose [unit: Sv] indicates the exposure level on the organs and tissues that is weighted and converted according to the degree of the effect on them. In case of γ-rays, the conversion factor* is 1: therefore the value of an absorbed dose becomes the same as that of an equivalent dose.

○ An Effective Dose [unit: Sv] is a dose developed in a way that the difference of susceptibility of organs or tissues to cancer or a hereditable effect (genetic effects under which reproductive cells mutate and are passed on to descendants) is weighted (tissue weighting factor) and all of the values of each organ are added together.

○ If the numerical value of the effective dose is the same both in internal and external exposure to radiation, the effect on the body is the same. Effective doses can be added together, accordingly the effect on the body is assessed by adding together the effective doses both in internal and external exposure to radiation. When an effective dose is used, the degree of the radiation effect can be compared with the same yardstick even if the exposed areas are different.

（Cases where confusion might occur）

When the exposed area is only the skin and the exposure dose is 50 mSv (equivalent dose), the effective dose becomes 0.5 mSv by multiplying 50 mSv (equivalent dose) by 0.01 (tissue weighting factor), whereas when the whole body is exposed to radiation and the exposure level of the organs and tissues is respectively 50 mSv (equivalent dose), the effective dose is 50 mSv. Thus the exposure level is different depending on whether the dose is calculated as an equivalent dose or effective dose even if the same sievert is used as the unit.

● Effective dose (Sv) =Σ (tissue weighting factor x equivalent dose (Sv))

Tissues	Tissue weighting factor (A)	Number of tissues (B)	Σ tissue weighting factor (A x B)
Bone-marrow (red), colon, lung, stomach, breast, remainder tissues**	0.12	6	0.72
Gonads	0.08	1	0.08
Bladder, esophagus, liver, thyroid	0.04	4	0.16
Bone surface, brain, salivary gland, skin	0.01	4	0.04
Total			1.00

**0.12 is given for the average dose to 14 organs including adrenal, extrathoracic region, gall bladders, hearts, kidneys, lymphatic nodes, muscle, oral mucosa, pancreas, prostate (♂), small intestine, spleen, thymus, and uterus/cervix (♀).

【Source】2007 Recommendations of the International Commission Radiological Protection

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*1 is applied for γ-rays, x-rays and β-rays, 2 for proton beams, 20 for α-rays, and 2.5-21 for neutron depending on energy.

Various Quantities Expressed with the Sievert
(Air dose and individual dose)

○ The effective dose is calculated using phantoms of reference person and biokinetic models and is not measurable in practice. Therefore operational quantities are used for the conservative estimates of effective doses. The ambient dose equivalent (air dose) that can be actually measured is used for monitoring external exposure. In this case, the unit is the sievert. With a survey meter for radiation control, an ambient dose equivalent rate (air dose), which is an ambient dose equivalent per unit time (air dose) , is displayed to show the intensity of radiation of a place.

○ Although an annual external exposure of a person is estimated using an air dose rate, the estimated figures vary depending on whether the following conditions are taken into consideration: the daily length of indoor/outdoor stay, dose reduction rates owing to a protective effect of buildings, physical attenuation of radioactive substances and weathering effects.

○ A personal dosimeter displays a personal dose equivalent (unit: Sv) of an individual exposed over a certain period of time. If a person carries a personal dosimeter at any time, he/she will be able to know the integrated value of the external exposure so that the external exposure control for each person becomes possible.

(Reference 1) The unit of the sievert is used for the read scale of survey meters and personal dosimeters, and the values are used as approximate values of an equivalent dose and an effective dose (protection quantities). This is called the operational quantity. The radiation protection quantities are calculated from the dose to the internal organs or tissues of human bodies, and cannot be easily measured with a measuring device. The operational quantities are defined for measuring doses. The quantities have been designed to become slightly larger values than the protection quantities in an actual external exposure in order to ensure a safer assessment is made.

(Reference 2) The ambient dose equivalent (air dose) shows the dose at a 1cm depth from the surface of a ball of 30cm diameter (ICRU ball) in place of the human body. Most of internal organs whose effective doses are to be assessed are located deeper than 1cm from the surface of the human body, consequently the ambient dose equivalent (air dose) usually becomes higher than the effective dose in the case of γ-rays. Therefore, radiation control can be conducted on the safe side.

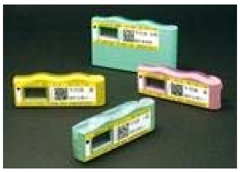
(Survey meter)

(NaI scintillation survey meter)

GM type survey meter

(Personal dosimeter)

OSL dosimeter



Glass dosimeter

Pocket dosimeter

Various Quantities Expressed with the Sievert
(Committed effective dose)

○ Once radioactive substances are taken into the body, they stay in the body for a long period of time, during which the body is incessantly exposed to radiation. The dose by the internal exposure is calculated using the quantity of radioactive substances taken in at one time, and then the total dose of radiation which a person continues to receive in the future is considered. This is called a Committed Dose (unit: Sv).

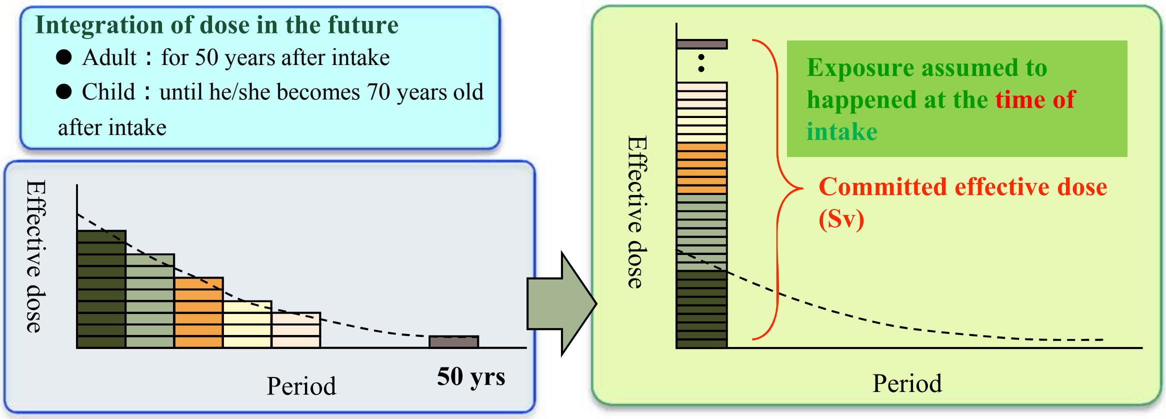
○ The absorbed radioactive substance decreases over time in the body. One of the factors is disintegration according to the physical half life of radioactive substances. The other factor is excretion by urine and feces, for example. The period until the radioactive substances are halved is called the biological half-life.

○ The excretion speed varies with the type of elements, chemical forms and the age of the victims. A committed dose is a lifetime radiation dose* to which the human body is exposed due to radioactive substances. Difference in the above factors are considered when integrating the doses. In the case of a nuclide with a comparatively short effective half-life, most of the radiation doses are received in the early stages.

○ In particular, the lifetime radiation dose integrated in an effective dose is called a Committed Effective Dose (unit: Sv).

(Reference) For instance, when an adult orally intakes 1,000 Bequerel (Bq) of Cesium-137 at one time, this results in exposure to about 90% of a committed effective dose (approx. 0.013 mSv) in the initial year.

<Calculation of internal exposure>



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*The lifetime means 50 years for adults after intake and the number of years until which a child becomes 70 in the calculations. The calculation uses average models.

Deterministic Effects and Stochastic Effects

○ The effects of radiation on the human body are classified according to the Deterministic Effect* and Stochastic Effect depending on the difference in the effect causing mechanism.

○ Deterministic effects result in symptoms such as hair loss, cataracts, skin reaction, etc. caused by death or degeneration of large amount of cells that organize internal organs and tissues. These symptoms do not manifest until the death of cells reaches a specific level as the surviving tissues substitute for the functions of organs and tissues. Once the level is surpassed, the effect appears. Accordingly, this is called a Deterministic Effect.

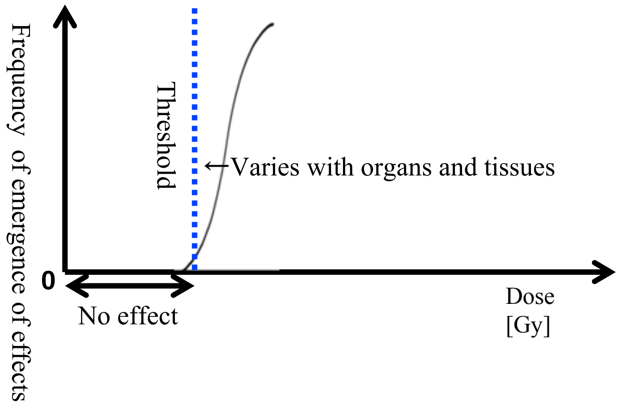
○ The characteristic of deterministic effects is the existence of a threshold: when the death of the cells is less than the threshold, there is no effect, while when it exceeds the level, there is an effect. The threshold varies with the type of organs and tissues.

○ Stochastic effects result in disorders such as cancer, hereditary effects (genetic effects under which reproductive cells mutate and are passed on to descendants), etc. Even if only one cell mutates, theoretically, the probability of the appearance of a hereditary effect increases. Therefore this is called a stochastic effect.

○ The International Commission on Radiological Protection (ICRP) focuses on the stochastic effects and recommends that radiological protection should be considered on the assumption that **no matter how low the radiation dose is, there is a risk, and the risk is proportional to the increase in the radiation dose.**

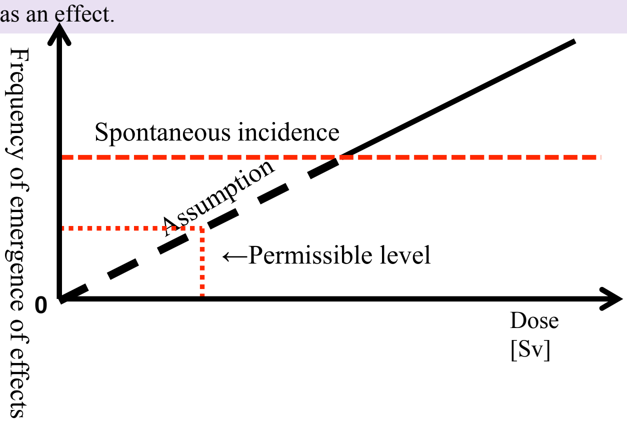
Deterministic effects

The threshold is set on a dose which develops a disorder in 1% victims with the highest radiosensitivity out of those who were exposed to radiation. (ICRP Recommendations 2007)



Stochastic effects

In case of a lower dose below a specific level, radiological effects are hidden behind the carcinogenic effects due to other factors such as smoking, drinking, etc. ICRP determines the benchmark of the radiological protection on the assumption that even such a low dose has an effect.



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*The deterministic effect is also called tissue reaction.

DNA Damage Caused by Radiation and DNA Repair (1)

○ DNA which serves as the store of hereditary information is contained in the cell nucleus. DNA consists of four types of bases; in DNA, many base molecules are linked with each other to form a strand, and the base sequence in the strand provides the specific gene information. In general, DNA has double-strand in which two strands are twisted together like a rope, called DNA-helix. When the DNA strand is exposed to radiation, DNA is partially damaged to some degree according to the radiation dose.

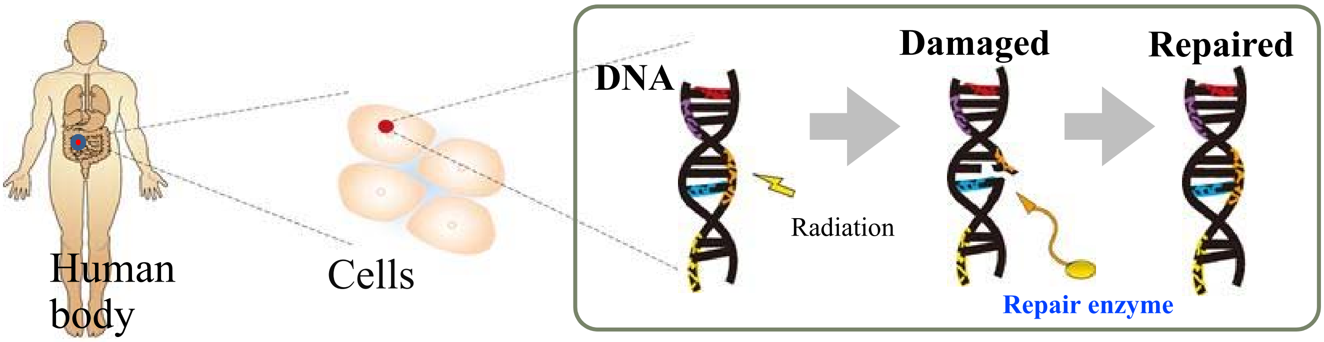
（Reference information）

When cells are exposed to 1mGy of X-rays, DNA single-strand breaks are considered to arise in one portion in average in a cell, and DNA double-strand breaks in a portion of 0.04 in a cell. In other words, if 100 cells are equally exposed to 1mGy of X-rays energy, the DNA double-strand breaks arise in one portion in each of the 4 cells.

○ Except for radiation, many responsible factors for damage to DNA (e.g., carcinogens in food, cigarettes, chemical substances in environment, active oxygen, etc,) exist in our daily life environment. Also, in the process of cell division, DNA strand is damaged. Considering all types of damages to DNA, it is estimated that 10,000 – 1,000,000 damages are added to DNA in a cell per a day.

○ For such damage to DNA, each cell has DNA damage repair functions (repair system). When DNA is damaged, many types of repair enzymes are recruited to the damaged portion to repair DNA rapidly.

＜DNA Repair System＞



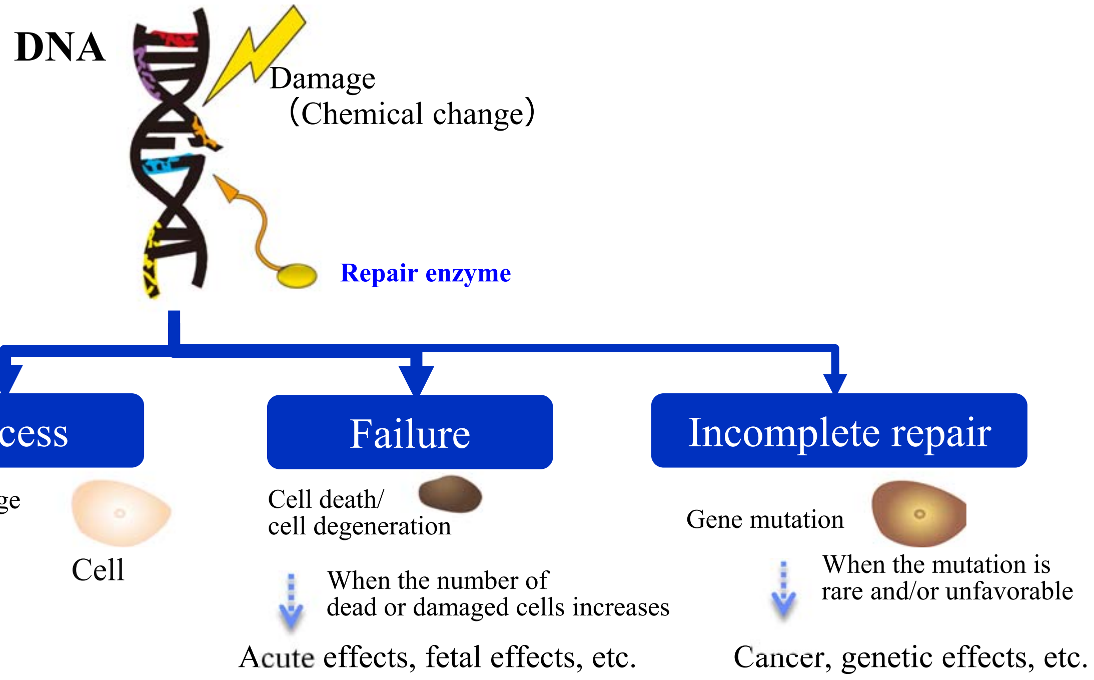
DNA Damage Caused by Radiation and DNA Repair (2)

○ Basically, when damage to DNA is slight and the DNA is repairable with the repair system, the damaged DNA may return to its original condition.

○ However, when severe or large-scale damages are given to DNA, the repair system is unable to repair the damages and the whole cell will die. Wide-ranging cell death will lead to acute effects, fetal effects, etc. in an individual body, while the death of a few cells is compensated by the nearby cells and not to cause dysfunction of the tissue or the organ.

○ On the other hand, some cells having defective genes due to errors at the time of repair could survive in some case. Such gene mutation is suspected to cause cancers and genetic effects*.

○ Cell death does not necessarily bring about acute effects, and similarly, gene mutation does not always cause a cancer. Many factors including quantity/quality of damage to DNA, the individual's physical condition, etc. are related to the acute effects and the carcinogenicity in multiple ways.



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*Genetic effects on descendants due to remaining gene mutations in reproductive cells (sperm cells and egg cells): Genetic effects on humans have not been confirmed, and also, it has been recognized that the likelihood of generation of genetic effects might be lower than those estimated in the past. Therefore, the ICRP lowered the genital gland tissue weighting factor from 0.12 (recommendation in 1990) to 0.08 (recommendation in 2007).

Overseas Organizations that Deal with Radiation Issues

○ United Nations Scientific Committee on the Effects of Atomic Radiation: UNSCEAR

UNSCEAR is one of the committees of the UN, established based on the resolutions adopted by the UN General Assembly at its 10th Session in 1955. It aims to observe radiation and radioactive substances in the atmosphere, investigate their effects on the environment and human health, and provide reports on the investigation results to member countries of UN. As of 2013, 27 countries participate in the Committee.

The UNSCEAR report has been utilized as fundamental data in UN member countries for discussion on radiological protection and radiation safety, as well as being utilized in ICRP Recommendations.

○ International Atomic Energy Agency: IAEA

The IAEA was proposed by the US President at the 8th Session of the UN General Assembly, 1953, and Statute of the IAEA was effected in 1957. As of 2012, the number of member countries was 154.

The objectives of the IAEA are described in Article 2 of the Statute of the IAEA as follows: 1) The IAEA shall seek to accelerate and expand the contribution of atomic energy to peace, health and prosperity throughout the world. 2) The IAEA shall ensure, so far as it is able, that assistance provided by it or at its request or under its supervision or control is not used in such a way as to further any military purpose. Moreover, the IAEA administers the International Nuclear Event Scale (INES) in association with Organization for Economic Co-operation and Development / Nuclear Energy Agency (OECD/NEA).

○ International Commission on Radiological Protection: ICRP

The objectives of the ICRP are to promote radiological protection as scientific technology and provide recommendations and guidelines on radiological protection for the benefit of the public. Considering scientific data on the effects of radiation, the technological level of radiological protection and safety, social criterion of value, etc., the ICRP discusses the basic idea and concept of radiological protection, and regulations for establishing standard values of dose limits and other items. The results of the discussions are disclosed as recommendations or reports from the Commission, and can be read in ICRP publications.

These recommendations and reports are made with the intention of being read by radiological protection experts and regulatory agencies in each country and are recognized as the basis for establishing radiation safety standards in the countries around the world.

○ World Health Organization: WHO

WHO was founded in accordance with the Constitution of the World Health (effected on April 7, 1948) adopted by the International Conference on Health held in 1946 in New York. Its objective is the attainment by all peoples of the highest possible level of health (Article 1 of the Constitution).

(Source) Materials of the Expert Committee on Radiation Hazards Prevention, Nuclear Safety Commission (July, 2002), HP of Ministry of Foreign Affairs of Japan, etc.

Experts and Intellectuals whom we asked for Confirmation and Advice

The documents were prepared by asking for confirmation and advice from experts and intellectuals regarding the accuracy and validity of the information and whether up-to-date information and knowledge are reflected in its contents.

Advice given by experts is reflected in the documents as far as is possible. We plan to make effective use of opinions which are not adopted here; for example, we will reconsider the opinions while updating the documents.

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（敬称略·五十音順）

February 2016