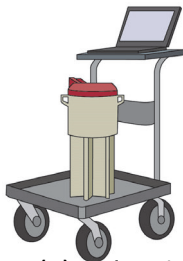
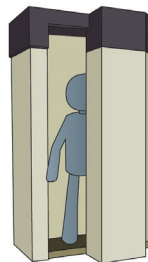


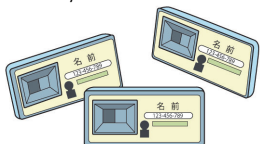
**Ge Semiconductor Detector**  
Used to measure radioactivity in foods or soil; Effective in measuring low levels of radioactivity concentrations



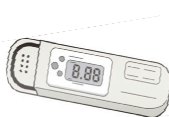
**Nal (TI) Food Monitor**  
Suitable for efficient radioactivity measurement of foods, etc.



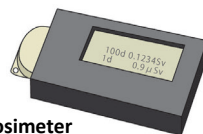
**Whole-body Counter**  
Assess accumulation of  $\gamma$ -ray nuclides in the body using numerous scintillation counters or the like



**Integrating Personal Dosimeter**  
Worn on the trunk of the body for 1-3 months to measure cumulative exposure doses during that period



**Electronic Personal Dosimeter**  
Equipped with a device to display dose rates or cumulative doses during a certain period of time and thus convenient for measuring and managing exposure doses of temporary visitors to radiation handling facilities



While radiation is not visible to the human eye, it is known to cause ionization and excitation (p.44 of Vol. 1, "Principles of Radiation Measurement"), and a variety of measuring instruments using these effects have been invented for different purposes and applications. The measuring instruments shown above all utilize the excitation effect.

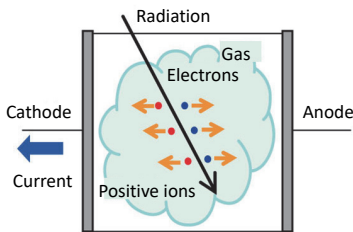
To measure radioactivity concentrations in foods and soil, measuring instruments wherein a germanium detector (Ge detector) or a Nal (TI) detector that can measure  $\gamma$ -ray spectra is installed in a lead shield are used. Ge detectors are excellent in  $\gamma$ -ray energy resolution and suitable for determining traces of radioactive materials. Nal (TI) detectors are not as excellent as Ge detectors in terms of energy resolution but are easy to handle and have relatively high detection efficiency, so they are widely used in food inspection.

Also commercially available are whole-body counters that use numerous scintillation counters or Ge detectors worn on the body to assess accumulation of  $\gamma$ -ray nuclides in the body, as well as integrating personal dosimeters and electronic personal dosimeters for managing personal exposure. In particular, after the accident at Tokyo Electric Power Company (TEPCO)'s Fukushima Daiichi NPS, a variety of electronic personal dosimeters have been invented to allow easy monitoring of information on exposure at certain time intervals.

Included in this reference material on March 31, 2013  
Updated on March 31, 2017

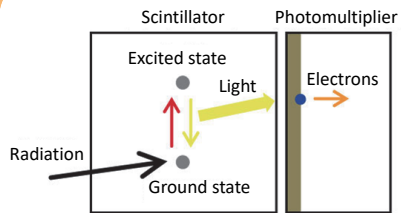
Measurements are carried out utilizing the interaction between radiation and substances.

### Ionization (with gas atoms)



- Detectors are filled with gases such as inert gases or air.
  - When radiation passes through gas, molecules are ionized, creating positive ions and electrons.
  - Positive ions and electrons are drawn toward the electrodes and are converted into electric signals for measurement.
- GM counter survey meters, ionization chambers, etc.

### Excitation



- When radiation passes through a scintillator, molecules are excited, but they return to their original state (ground state).
- Light emitted in the process is amplified and converted into a current for measurement.

NaI (TI) scintillation survey meter, etc.


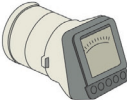
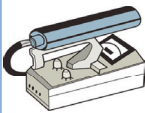

Radiation is known to interact with substances when passing through them. The amount of radiation can be measured utilizing the interaction between radiation and substances.

Geiger Muller (GM) counter survey meters and ionization chambers utilize the ionization between radiation and gas atoms. Ionization effect refers to the process in which radiation ejects electrons from nuclei in a substance. Detectors of GM counter survey meters and ionization chambers are filled with gases. When radiation passes inside a detector, it causes ionization of gas atoms, separating atoms into positive ions and electrons. Separated electrons and positive ions are attracted to the electrodes, causing a current to flow. This is converted into electric signals, which are then measured as the amount of radiation.

NaI (TI) scintillation survey meters utilize excitation with substances. Radiation gives energy to electrons of nuclei, and when an electron jumps to an outer orbit, this phenomenon is called excitation. An atom in that state is unstable (excited), and when it returns to a stable state (ground state), it gives off energy in the form of light. This is called the excitation effect. A scintillator is a substance that emits light in response to incident radiation. Weak light emitted from a scintillator is amplified using a photomultiplier and is converted into an electric signal to measure radiation. Aside from NaI (TI) scintillation survey meters, germanium semiconductor detectors also utilize the excitation effect for radiation measurement.

(Related to p.18 of Vol.1, "Ionization of Radiation - Property of Ionizing Radiation")

Included in this reference material on March 31, 2017

Type		Purpose	
<b>GM counter survey meter</b> (ionization)		Contamination detection	Has a thin entrance window and can detect $\beta$ -particles efficiently; Suitable for detecting surface contamination
<b>Ionization chamber survey meter</b> (ionization)		$\gamma$ -ray ambient dose rate	Most accurate but unable to measure low dose rates like a scintillation type can
<b>NaI (TI) scintillation survey meter</b> (excitation)		$\gamma$ -ray ambient dose rate	Accurate and very sensitive; Suitable for measuring $\gamma$ -ray ambient dose rates from the environment level up to around $10\mu\text{Sv/h}$
<b>Personal dosimeter</b> (light-stimulated luminescence dosimeter, luminescent glass dosimeter, electronic dosimeter, etc.) (excitation)		Personal dose Cumulative dose	Worn on the trunk of the body to measure personal dose equivalent of the relevant person's exposure while it is worn; A direct-reading type and types with alarm functions are also available.

Survey meters are either for inspecting body surface contamination or for measuring ambient dose rates. Geiger Muller (GM) tube-type survey meters are highly sensitive to  $\beta$ -particles and are thus suitable for inspecting body surface contamination. They are affordable and useful in locating contamination and confirming the effects of decontamination.

Ionization chambers are most suited for measuring high-level ambient dose rates but cannot measure very low dose rates. Therefore, a scintillation type is most suited for measuring ambient dose rates in the general environment.

NaI (TI) scintillation survey meters can also measure the radioactivity intensity (becquerels), but measurement results vary depending on the level of radiation at the measuring location and the way of measurement. Since calibration at a facility with a radioactive source that serves as a reference is required before converting the measurement results into becquerels, expert assistance is required to implement the measurements.

Personal dosimeters provide cumulative exposure dose readings. An electronic direct-reading type allows a person to confirm the degree of exposure at certain time intervals or after every operation.

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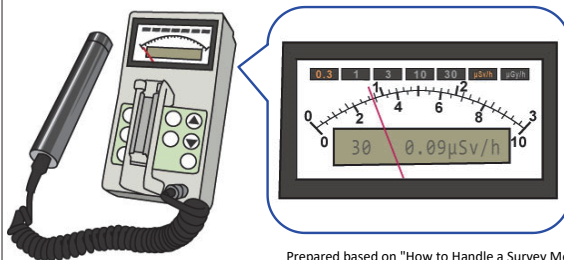
Updated on March 31, 2017

**Example: Nal (TI) scintillation survey meter (TCS-171)****(i) Background measurement****(ii) Field measurement**

- Range (the reading is indicated near the center of the scale)
- Adjustment of time constant (the value is to be read when a period of time three times the time constant elapses)

**(iii) Dose calculation**

- Reading  $\times$  Calibration constant = Dose ( $\mu\text{Sv/h}$ )

**How to interpret the readings**

0.3, 3, 30  $\mu\text{Sv/h}$  in the upper row  
1, 10  $\mu\text{Sv/h}$  in the lower row

- The photo shows a range of 0.3  $\mu\text{Sv/h}$ .
- Read the value in the upper row
- The needle pointing at 0.92

The reading at 0.092  $\mu\text{Sv/h}$

For example, when the calibration constant is 0.95  
Dose =  $0.092 \times 0.95 = 0.087 \mu\text{Sv/h}$

Prepared based on "How to Handle a Survey Meter" on the website of the Prime Minister's Office

A method of measuring  $\gamma$ -ray ambient dose rate using a Nal scintillation survey meter is shown as an example of a method of measuring doses.

Before measurement, the device is checked for soundness (appearance, power supply, high voltage) and then background is measured (set a range at  $0.3\mu\text{Sv/h}$  and a time constant at 30 sec). Normally, the background value is around  $0.1\mu\text{Sv/h}$ .

Field measurements are, in principle, carried out at a height of about 1 m above the ground. The counting range is adjusted so that the meter readings come near the center of the scale. The time constant is adjusted according to the purpose of measurement. For measurements in a rough, wide range or of high doses, the time constant is lowered. To make accurate measurements or to measure low doses, the time constant is increased. After a period of time about three times the time constant has elapsed since the start of a field measurement, the average of the readings is read (for example, the value is read after the lapse of 90 seconds when the time constant is 30 sec.).

The dose equivalent rate ( $\mu\text{Sv/h}$ ) can be obtained by multiplying the reading by the calibration constant that is preset for each measurement condition.

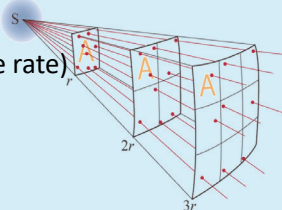
When using measuring instruments, precautions should be taken such as checking whether they operate properly before use, handling them carefully because they are precision instruments, covering measuring instruments with polyethylene sheets during rain or when making measurements in highly contaminated areas, etc.

Included in this reference material on March 31, 2017

- 1) **Distance:** Dose rates are inversely proportional to the distance squared.

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

$I$  : Radiation intensity (dose rate)  
 $r$  : Distance  
 $k$  : Constant



- 2) **Time:** Doses are proportional to the time of exposure provided the dose rates are the same.

$$\text{(Total) dose (microsieverts)} = \text{Dose rate (microsieverts/h)} \times \text{Time}$$

The intensity of radiation (dose rate) is strong (large) when the source of radiation is close, and it gets weaker (smaller) as the distance increases, even if the amount of radioactive materials remains the same. When the radioactive materials are located only in one place, the dose rate becomes smaller in inverse proportion to the distance squared. Dose rates also decrease due to atmospheric influence, etc.

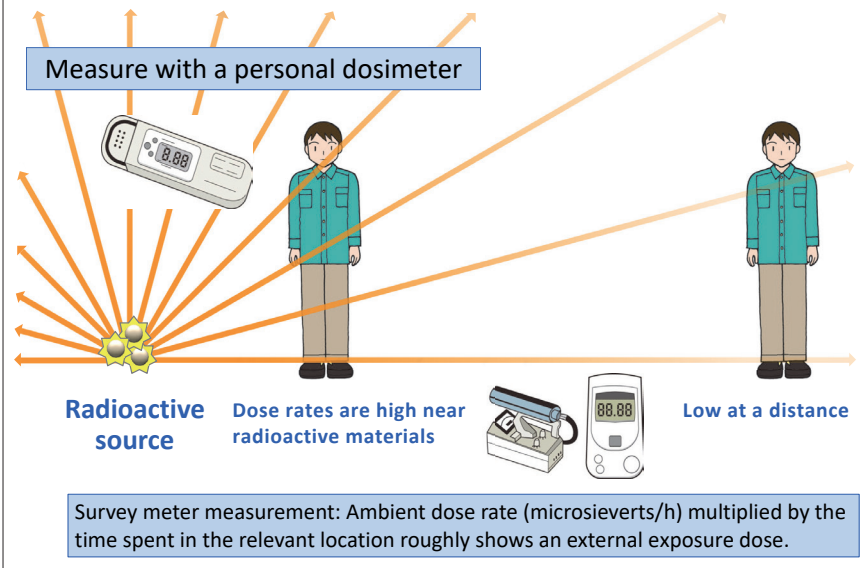
When radioactive materials are evenly distributed on a broad plain surface, the formula to express the relationship between the distance and the dose rate is rather complicated, but as in the case of a point source, the higher it is from the ground surface, the lower the dose rate is. However, radioactive materials are not evenly distributed in reality and a plain surface is not necessarily smooth, and also owing to attenuation of radiation in the air or other reasons, the dose rate does not always match the value obtained from the relational expression.

Calculation of external exposure doses is based not on the radioactivity intensity (becquerels) but on the amount of radiation (grays or sieverts) the human body is exposed to.

If the dose rate is constant, the total exposure dose can be calculated by multiplying the dose rate by the time of exposure to radiation.

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Wearing a personal dosimeter on the body is one of the means to measure doses due to external exposure. Personal dosimeters can measure cumulative amounts of radiation exposure for an extended period of time, and provide hourly readings.

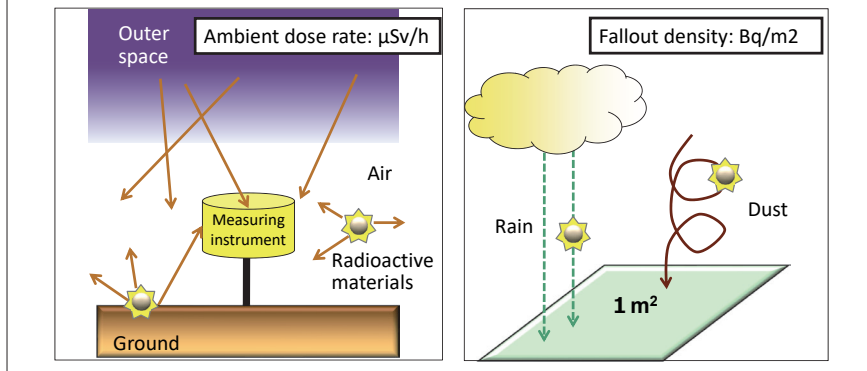
Another means is to measure radiation dose rates in a workplace with a survey meter to estimate the level of exposure supposing that a person stays in that place. Since  $\alpha$ -particles and  $\beta$ -particles from outside the body do not reach into the body (p.22 of Vol. 1, "Penetrating Power and Range of Effects on the Human Body"),  $\gamma$ -rays are measured to obtain doses due to external exposure. Many recent instruments provide readings in microsieverts per hour, so such readings are multiplied by the time a person spent in a certain location to roughly calculate his/her external exposure dose. However, these measurements must be made with an instrument, such as a NaI (Tl) scintillation survey meter, that has proper performance and is well calibrated.

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## Measurement of Environmental Radiation and Radioactivity

- **Ambient dose rate** shows measured amount of  $\gamma$ -rays in the air. Indicated in microsieverts per hour ( $\mu\text{Sv/h}$ )
- **Fallout density** is the amount of radioactive materials that have deposited (or descended) per unit area in a certain period of time. e.g., becquerels per squared meter ( $\text{Bq/m}^2$ )



The ambient dose rate is obtained by measuring  $\gamma$ -ray doses in the air, and is indicated in microsieverts per hour.  $\gamma$ -rays from radioactive materials suspended in the air and  $\gamma$ -rays from radioactive materials fallen on the ground are both detected. The measured value is not limited to the amount of radiation derived from accidents. Major natural radiation is that from the ground.

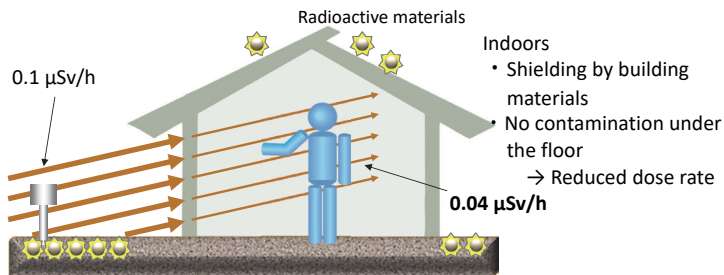
Normally, a measuring instrument is placed at a height of about 1 m from the ground, because most important internal organs are located at this height in the case of an adult.

The amount of radioactivity in fallout is expressed as the amount of radioactive materials fallen per unit area.

Generally, such amount is expressed as a numerical value per day or month for each kind of radioactive material.

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Location	Reduction coefficient*
Wooden house (one or two stories)	<b>0.4</b>
Block or brick house (one or two stories)	<b>0.2</b>
The first and second floors of a building (three or four stories) with each floor 450-900m <sup>2</sup> wide	<b>0.05</b>
Upper floors of a building with each floor 900m <sup>2</sup> or wider	<b>0.01</b>

\* The ratio of doses in a building when assuming that a dose outdoors at a sufficient distance from the building is 1

Source: "Disaster Prevention Countermeasures for Nuclear Facilities, etc." (June 1980 (partly revised in August 2010)), Nuclear Safety Commission

In the absence of an appropriate survey meter for measuring ambient dose rates (p.45 of Vol. 1, "Instruments for Measuring External Exposure"), calculations can be made based on the ambient dose rates that the government or local municipalities issued. For the amount of exposure outdoors, measurement results obtained near the relevant building are used. To calculate doses indoors, the indoor ambient dose rate is estimated by multiplying the value of nearby outdoor dose rate by a reduction coefficient.

Reduction coefficients, which take into consideration the effect of shielding by the building and the fact that there is no contamination under the floor, vary depending on the types of buildings and whether radioactive materials are suspended or deposited. When radioactive materials are deposited on soil or a building, in the case of a wooden house, for example, radiation from outside is blocked and the total amount of radiation indoors is reduced to around 40% of the initial amount outdoors. Houses made of blocks, bricks or reinforced concrete have higher shielding effects and radiation levels inside are lower than in wooden houses. When radioactive materials are mainly on the soil surface, the amount of radiation becomes smaller on higher floors because of increasing distance from the soil.

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## Additional Exposure Doses after an Accident (Example of Calculation)

It is important to subtract values in normal times.

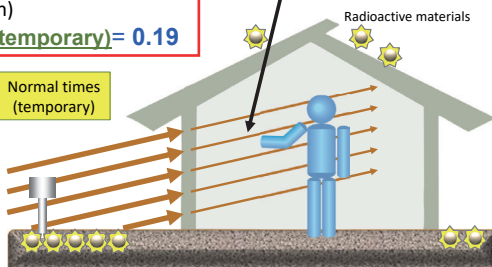
Dose rate (increase due to an accident:  $\mu\text{Sv/h}$ )  
 $0.23 - 0.04(\text{temporary}) = 0.19$

Reduction coefficient: **0.4**

When the time staying outdoors/indoors is **8 hours/16 hours**

Actual measurement (example)

Normal times (temporary)



Derived from an accident

$$\begin{aligned} &0.19 \times 8 \text{ hours (outdoors)} \\ &+ \\ &0.19 \times 0.4 \times 16 \text{ hours (indoors)} \\ \hline &(\mu\text{Sv/day}) \end{aligned}$$

$$\begin{aligned} &\times 365 \text{ days} \doteq 1,000 \mu\text{Sv/year} \\ &\doteq \underline{1.0 \text{ mSv/year}} \end{aligned}$$

The ambient dose rate measured with a survey meter includes  $\gamma$ -rays from nature. To calculate the amount of radiation released due to the accident at Tokyo Electric Power Company (TEPCO)'s Fukushima Daiichi NPS alone, the values measured before the accident (background values) must be subtracted from the currently measured ambient dose rates to ascertain the increase caused by the accident. The values before the accident are available on the website, "Environmental Radioactivity and Radiation in Japan" (<http://www.kankyo-hoshano.go.jp>, in Japanese).

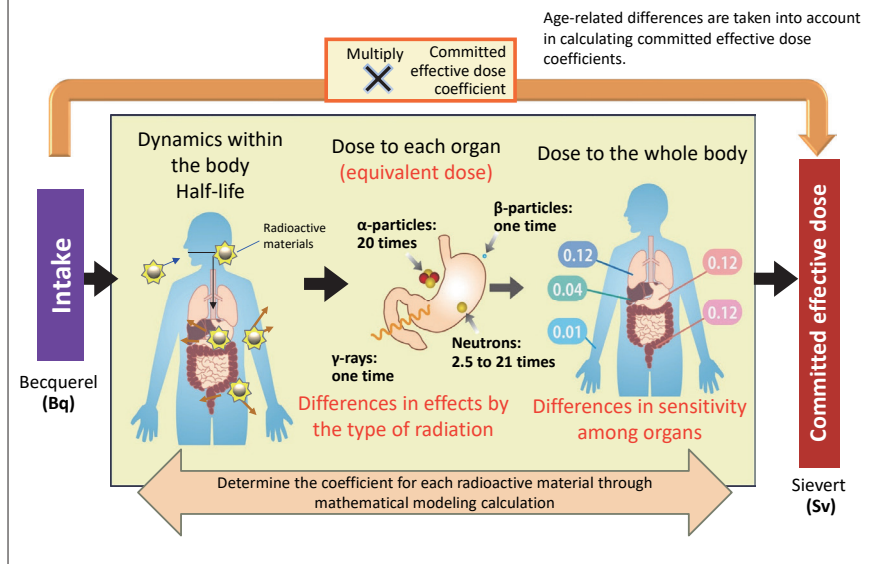
The value obtained by multiplying the increased indoor and outdoor ambient dose rates thus found by the time spent indoors and outdoors is an approximate increase in exposure dose compared with normal times (additional exposure dose).

The calculation example above for obtaining additional exposure doses after the accident is under the assumption that a person stays outdoors for eight hours and stays in a traditional Japanese house with a reduction coefficient of 0.4 for 16 hours. A daily additional exposure dose is calculated in this manner and an annual additional exposure dose is further estimated by multiplying it by 365, the number of days in a year.

An ambient dose rate of  $0.23 \mu\text{Sv/h}$ , which is the threshold for carrying out decontamination, is derived from an annual additional exposure dose of  $1 \text{ mSv}$  (hourly exposure dose of  $0.19 \mu\text{Sv}$ , which will become  $1 \text{ mSv}$  in annualized terms under the same assumption on the safe side as applied in the calculation example above, plus  $0.04 \mu\text{Sv}$  (exposure dose due to natural radiation)).

This calculation example is for external exposure and is rather conservative without considering physical attenuation of radioactive materials and weathering effects due to transfer of radioactive materials by wind and rain, etc.

Included in this reference material on March 31, 2013  
 Updated on February 28, 2018



Methods of obtaining effective doses due to internal exposure are essentially the same as for external exposure. However, how to calculate absorbed doses for respective organs and tissues is different.

The part of the body where radioactive materials accumulate varies by their types. Even the same type of radioactive material differs in the behavior within the body, such as metabolism and accumulation, depending on whether they enter the body via the respiratory organs through inhalation or via the digestive tract together with foods and drinks. Moreover, how long radioactive materials will remain in the body varies depending on whether the person is an adult, a child, or an infant.

Mathematical model calculation is performed for each of these different conditions to determine the relationship between the intake of radioactive materials and the absorbed dose of each organ and tissue. Then, differences in sensitivity by types of radiation and among different organs are taken into account in the same manner as for calculation of external exposure doses. An internal exposure dose calculated in this way is called a committed effective dose (in sieverts) (p.53 of Vol. 1, "Committed Effective Doses").

Specifically, internal exposure doses can be obtained by multiplying intake (in becquerels) by a committed effective dose coefficient. Committed effective dose coefficients are defined in detail for each type of radionuclide and age group (p.54 of Vol. 1, "Conversion Factors to Effective Doses").

Included in this reference material on March 31, 2013

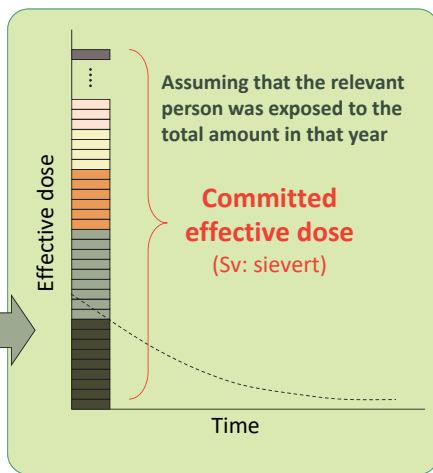
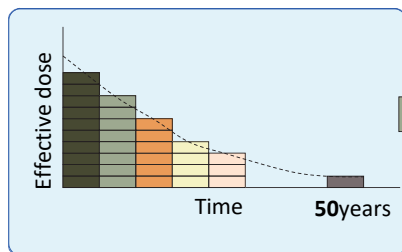
Updated on March 31, 2015

Exposure dose estimating how much radiation a person will be exposed to in lifetime from a single intake of radioactive materials

#### Calculation of internal exposure

#### Integrating future doses

- Public (adult): 50 years after intake
- Children: up to age 70 after intake



Radioactive materials remain in the body for a certain period of time after being taken into the body. In the meantime, the body will be continuously exposed to radiation. Thus, the total amount of radiation that a person will be exposed to into the future is calculated as dose due to internal exposure based on a single intake of radioactive materials. This is called a committed dose (in sieverts).

Any radioactive materials taken into the body will decrease over time. One contributing factor is the decay of the radioactive materials. Another is excretion as urine and feces. The rate of excretion from the body varies according to the types of elements, their chemical forms, and the age of the person. With these differences taken into account, the cumulative amount of radiation that the human body will receive in a lifetime from radioactive materials is assumed as the amount received in the year of the intake, and a committed dose is calculated.

In particular, the lifetime cumulative dose based on effective dose is called "committed effective dose." The lifetime here is 50 years for adults, and for children it is the number of years up to reaching age 70. In the case of radioactive cesium, which is discharged out of the body at a fast rate (Cesium-134 and Cesium-137 have effective half-lives of 64 days and 70 days, respectively) (p.31 of Vol. 1, "Radioactive Materials Derived from Nuclear Accidents"), most of the committed dose is considered to be received within 2 to 3 years after its intake.

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Committed effective dose coefficients ( $\mu\text{Sv/Bq}$ ) (ingestion)

	Strontium-90	Iodine-131	Cesium-134	Cesium-137	Plutonium-239	Tritium*
Three months old	0.23	0.18	0.026	0.021	4.2	0.000064
One year old	0.073	0.18	0.016	0.012	0.42	0.000048
Five years old	0.047	0.10	0.013	0.0096	0.33	0.000031
Ten years old	0.06	0.052	0.014	0.01	0.27	0.000023
Fifteen years old	0.08	0.034	0.019	0.013	0.24	0.000018
Adult	0.028	0.022	0.019	0.013	0.25	0.000018

 $\mu\text{Sv/Bq}$ : microsieverts/becquerel

\*Tissue free water tritium

Source: ICRP Publication 119, Compendium of Dose Coefficients based on ICRP  
Publication 60, 2012, International Commission on Radiological Protection (ICRP)

For dose assessment for internal exposure, doses are calculated by estimating an intake for each nuclide and chemical form and multiplying estimated intakes by dose coefficients. Dose coefficients are committed equivalent doses or committed effective doses for an intake of 1 Bq and a specific value has been given for each nuclide, chemical form, intake route (ingestion or inhalation), and for each age group by the ICRP.

The commitment period, i.e., the period during which doses are accumulated, is 50 years for adults and the number of years up to reaching age 70 after intake for children.

Included in this reference material on March 31, 2013

Updated on February 28, 2018

## Exposure Doses from Foods (Example of Calculation)

(e.g.) An adult consumed 0.5 kg of foods containing **100 Bq/kg of Cesium-137**

$$\begin{array}{r}
 100 \times 0.5 \times 0.013 = 0.65 \mu\text{Sv} \\
 \text{(Bq/kg)} \quad \text{(kg)} \quad \text{(\mu Sv/Bq)} \\
 = 0.00065 \text{ mSv}
 \end{array}$$


Committed effective dose coefficients (μSv/Bq)

	Iodine-131	Cesium-137
Three months old	0.18	0.021
One year old	0.18	0.012
Five years old	0.10	0.0096
Adult	0.022	0.013

Bq: becquerels; μSv: microsieverts; mSv: millisieverts

Source: ICRP Publication 119, Compendium of Dose Coefficients based on ICRP Publication 60, 2012, International Commission on Radiological Protection (ICRP)

For example, the dose that an adult who consumed foods containing Cesium-137 will receive is calculated here.

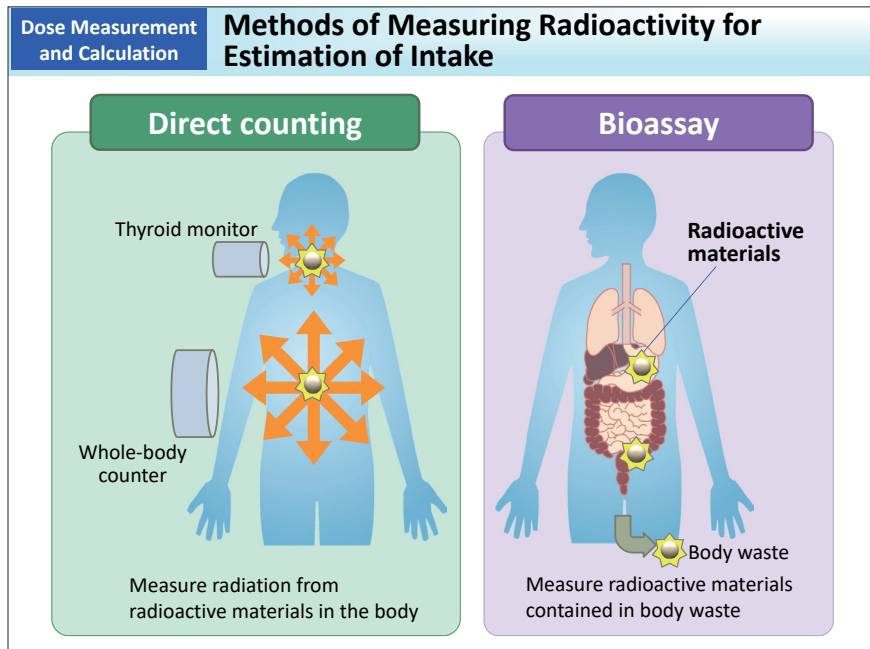
Suppose the person has consumed 0.5 kg of foods containing 100 Bq of Cesium-137 per 1 kg.

The amount of Cesium-137 actually consumed is 50 Bq. This value is multiplied by an effective dose coefficient to calculate committed effective dose (p.53 of Vol.1, "Committed Effective Doses").

Committed effective dose coefficients are defined in detail for each type of radioactive material, each intake route (inhalation or ingestion), and each age group (p.54 of Vol. 1, "Conversion Factors to Effective Doses").

Included in this reference material on March 31, 2013

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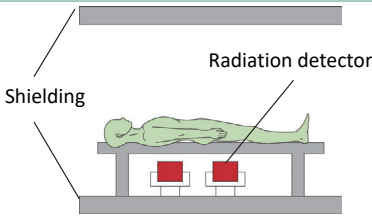
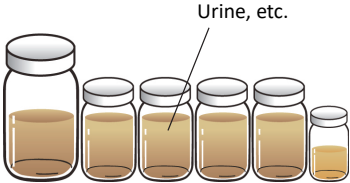
Direct counting methods that directly measure  $\gamma$ -rays coming from within the body or bioassay methods that measure the amount of radioactive materials in urine or feces are used to estimate the intake, which is required for calculating internal exposure doses.

Based on the results obtained using these methods, the time of intake of radionuclides, chemical forms, and intake routes (inhalation or ingestion) are taken into consideration and mathematical models (p.52 of Vol. 1, "Calculation of Internal Exposure Doses") are used to calculate the percentages of radioactive materials remaining in the body or found in body waste to determine the intake of respective radionuclides.

Included in this reference material on March 31, 2013

Updated on March 31, 2015

## Comparison of Methods of Assessing Internal Radioactivity

Direct counting	Bioassay
Directly measure the human body	Indirect measurement
Need to spare time to receive direct measurements	Submit samples (urine, feces, etc.)
Mainly target materials that emit $\gamma$ -rays	Able to measure all radioactive materials
Short measuring time using the apparatus	Chemical analysis takes time.
Accurate dose assessment	Large margin of error in results of dose assessment
	

In direct counting, the longer the measuring time, the more accurate values can be obtained. However, external measuring instruments also measure radiation from the environment while measuring radiation from the human body, so if measurements are carried out in locations with high ambient dose rates, sufficient shielding against environmental radiation is required. These instruments cannot measure radioactive materials that do not emit  $\gamma$ -rays.

Bioassays can measure all kinds of radioactive materials but cannot provide accurate numerical values after a single sampling and it is necessary to prepare samples for several days (urine, feces, etc.). Given that the amount of radioactive materials discharged varies depending on individuals and on their health conditions and amounts of food consumption, the margin of error is considered to be larger than for direct counting.

For both methods, if the time when a detected radioactive material was taken in cannot be clearly determined, calculation results will have a larger margin of error.

Included in this reference material on March 31, 2013

Updated on March 31, 2015



Stand-up  
whole-body  
counter



Scanning bed  
whole-body  
counter

Chair whole-body  
counter



Thyroid  
monitor



An instrument for measuring  $\gamma$ -rays emitted from the whole body, called a whole-body counter, is used to directly measure internal radioactivity. Whole-body counters have several types, including a stand-up type, bed type, and chair type.

Since radioactive cesium is distributed throughout the body, a whole-body counter is used to measure its amount within the body. If internal exposure by radioactive iodine is suspected, a thyroid monitor is used, as iodine accumulates in the thyroid. A radiation detector is applied to the part of the neck where the thyroid gland is situated to measure  $\gamma$ -rays emitted from there.

The time required for measurement is 1 to 5 minutes for simplified whole-body counters, 10 to 30 minutes for precision whole-body counters, and 2 to 5 minutes for thyroid monitors.

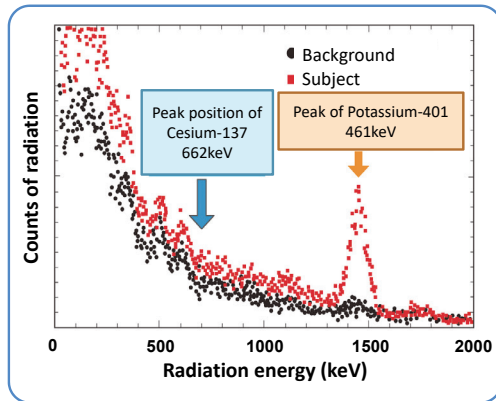
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Updated on February 28, 2018





Whole-body counter



Measure radiation emitted from within the body  $\Rightarrow$  Measure internal radioactivity for each radioactive material

The amount of potassium in the body is around 2 g per 1 kg of body weight, and approx. 0.01% of that amount is radioactive potassium (Potassium-40)

keV: kilo electron volts

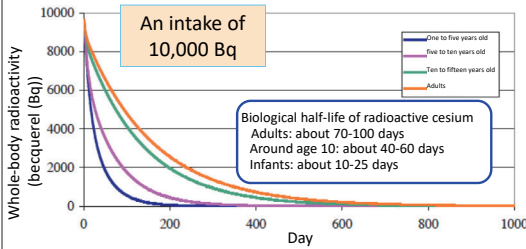
Radioactivity of each nuclide can be quantitatively assessed by measuring radiation emitted from within the body using a whole-body counter.

The black round dots in the graph represent values measured while no one is on the bed (background state). When the subject is on the bed, radiation peaks appear, as indicated by the red square dots. The energy of  $\gamma$ -rays is unique for each radioisotope. For example, radioactive potassium, K-40, emits  $\gamma$ -rays with energy of 1,461 keV. Therefore, if such amount of energy is detected, this reveals the existence of K-40 within the body. The gamma-ray energy of Cesium-137 is 662 keV.

While potassium is an element essential to life, approx. 0.01% of all potassium is radioactive. Radioactive potassium is mainly contained in water in cells and is present in muscles but is seldom present in fat cells that contain little water (p.8 of Vol. 1, "Naturally Occurring or Artificial").

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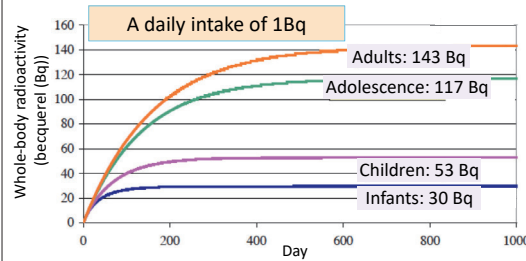
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The younger a person is, the faster the metabolism.



- Estimation of initial exposure
- will be effective for no longer than around a year even for adults.
  - will be effective for up to around half a year for children.



The younger a person is, the smaller the amount of radioactive materials remaining in the body.



- In estimating additional exposure through ingestion,
- finite values are unlikely to be obtained for children.
  - it is more reasonable to examine adults in order to detect trace intake.

Source: Modified from a material released for the Japan Society of Radiation Safety Management Symposium in Miyazaki (June 29, 2012)

Whole-body counters can measure the amount of internal radioactivity on the day of measurement but have a detection limit depending on machines' performance or measuring time, as do other measuring instruments.

Radioactive cesium has a biological half-life of 70-100 days for adults (p.11 of Vol.1, "Half-lives and Radioactive Decay"), so estimation of initial exposure would be effective for no longer than around a year after a nuclear accident. As shown in the upper figure, the radioactivity of cesium taken into the body approaches 0 Bq in a year or so because of its effective half-life, so the internal radioactivity returns to its previous value. Subsequent whole-body counting is performed for the purpose of estimating chronic exposure, mainly from foods (p.59 of Vol. 1, "Data on Internal Exposure Measured by Direct Counting").

In contrast, children have high metabolism, so estimation of their initial exposure from an intake of a trace amount of radioactive materials would be only effective for around half a year after an accident, and estimation of their chronic internal exposure would often provide values below detection limits because not much of the radioactive materials remain in children's bodies. In such cases, it would be reasonable to examine adults for estimation of exposure, given that committed effective dose coefficients are similar for both children and adults even though their rates of metabolism are different.

To estimate committed effective doses from the measurement results of internal radioactivity, it is necessary to make an appropriate assumption and choose an appropriate model while taking into account whether exposure is acute or chronic, whether radioactive materials were taken in through inhalation or ingestion, the time of intake, and other factors.

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