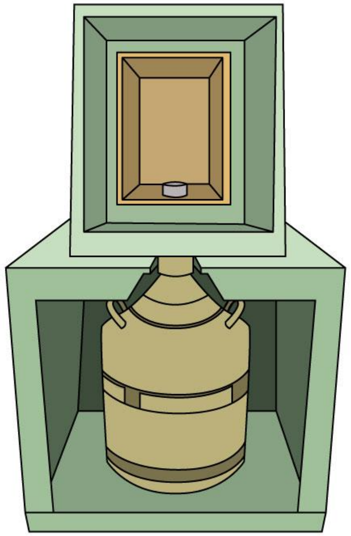
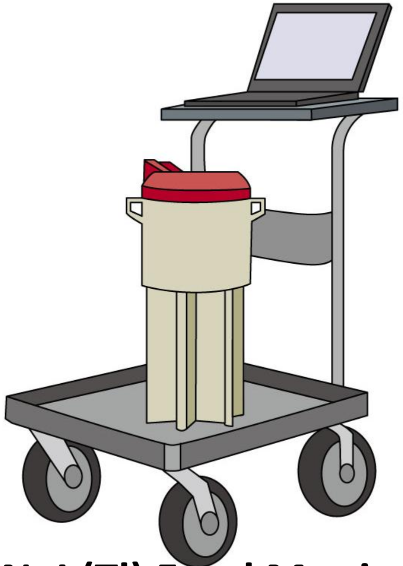
Various Measuring Instruments



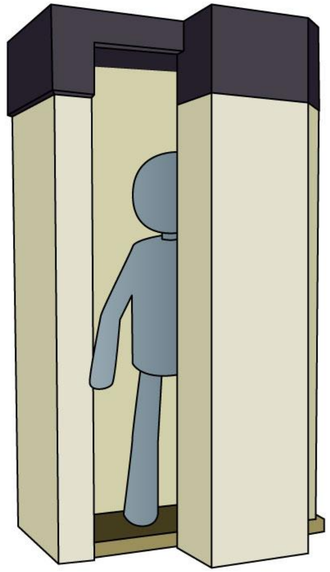
Ge Semiconductor Detector

Used to measure radioactivity in foods or soil; Effective in measuring low levels of radioactivity concentrations



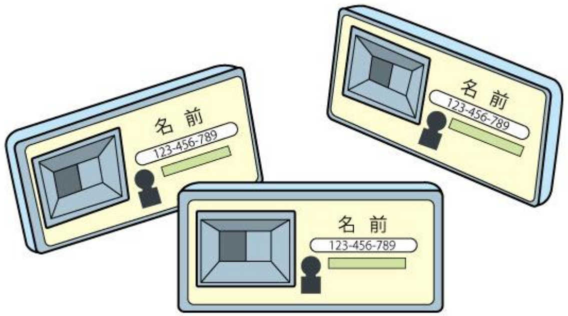
NaI (Tl) Food Monitor

Suitable for efficient radioactivity measurement of foods, etc.



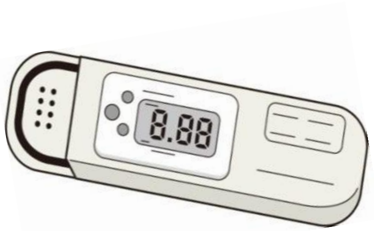
Whole-body Counter

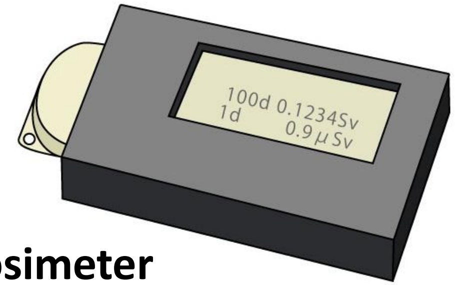
Assess accumulation of γ-ray nuclides in the body using numerous scintillation counters or the like



Integrating Personal Dosimeter

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





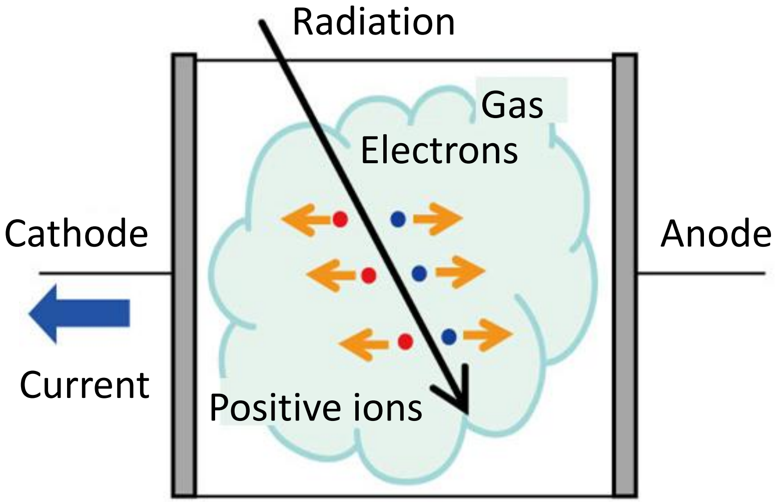
Electronic Personal Dosimeter

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

Principles of Radiation Measurement

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

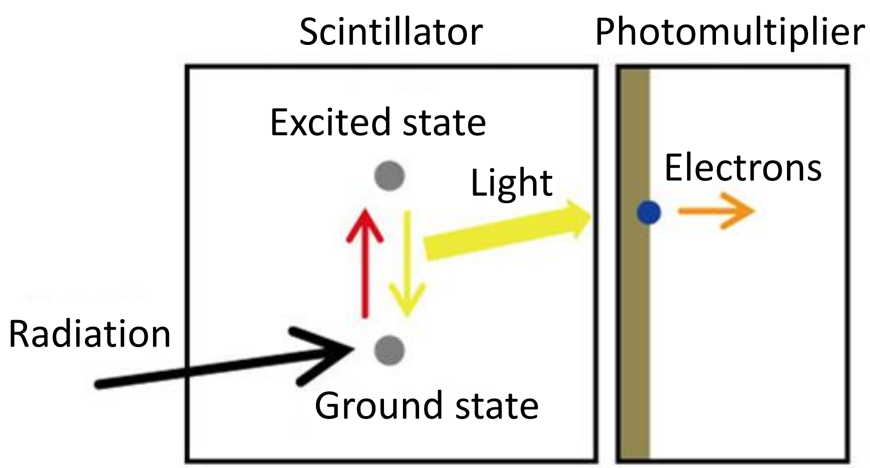
Ionization (with gas atoms)



- 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 (Tl) scintillation survey meter, etc.

Detection Limit

ND: Abbreviation of "Not Detected"

ND = The measured value was less than the detection limit.

≠ **The measured value was zero.**

The measurement result "ND" means that the measured value was less than the detection limit.

Detection limits vary depending on measurement time and the sample amount. Detection limits are set by each measurement laboratory in accordance with the purpose of the measurement.

- **The longer the measurement time is, the lower the detection limit becomes.**

The measurement time is increased by X times.
→ The detection limit becomes $\frac{1}{\sqrt{X}}$ times.

Example 1: When the measurement time is doubled, the detection limit becomes $\frac{1}{\sqrt{2}}$ times.

Example 2: In order to lower the detection limit from 60 Bq/kg to 30 Bq/kg, the measurement time needs to be increased by four times.

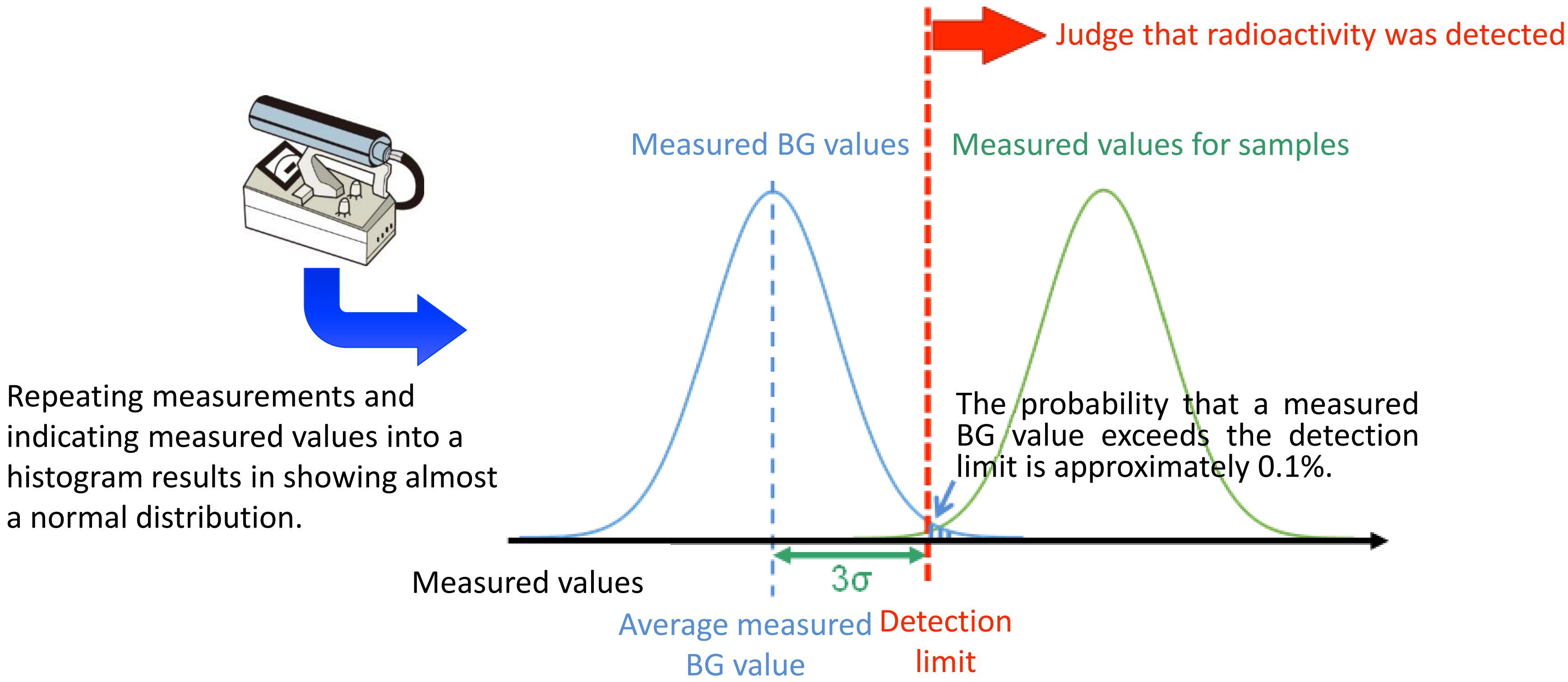
- **The larger the sample amount is, the lower the detection limit becomes.**

Example: If the detection limit is 200 Bq/kg when the sample amount is 0.2 kg, increasing the sample amount to 1 kg leads to lowering the detection limit to 40 Bq/kg.

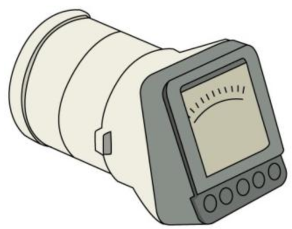
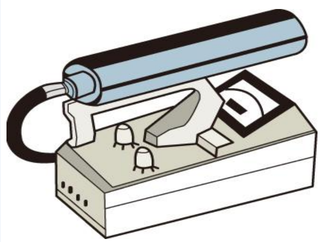
Prepared based on the "Analysis of Radioactive Materials" (December 2011) by Ministry of Agriculture, Forestry and Fisheries
https://www.maff.go.jp/j/syouan/seisaku/data_reliance/maff_torikumi/pdf/rad_kensyu.pdf (in Japanese)

Ideas on Detection Limits (3σ Method)

- Even a minor change in measurement conditions can influence measurement results and there is also background (BG) radioactivity derived not from samples themselves. Therefore, due consideration is required when setting a detection limit in order to assure statistical reliability.
- One of the representative ideas on detection limits is the 3σ method. Under the 3σ method, a detection limit is defined as a value obtained by adding three times sigma of the measured background values to their average. When a measurement result exceeds this value, it is judged that signals (radioactivity, a dose rate, etc.) from a sample are detected.



Instruments for Measuring External Exposure

Type		Purpose	
GM counter survey meter **(ionization)**		Contamination detection	Has a thin entrance window and can detect β-particles efficiently; Suitable for detecting surface contamination
Ionization chamber survey meter (ionization)		γ-ray ambient dose rate	Accurate but unable to measure low dose rates like a scintillation type can
NaI (Tl) scintillation survey meter (excitation)		γ-ray ambient dose rate	Accurate and very sensitive; Suitable for measuring γ-ray ambient dose rates from the environment level up to around 10μSv/h
Personal dosimeter **(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.

Methods of Measuring Doses

Example: NaI (Tl) scintillation survey meter (TCS-171)

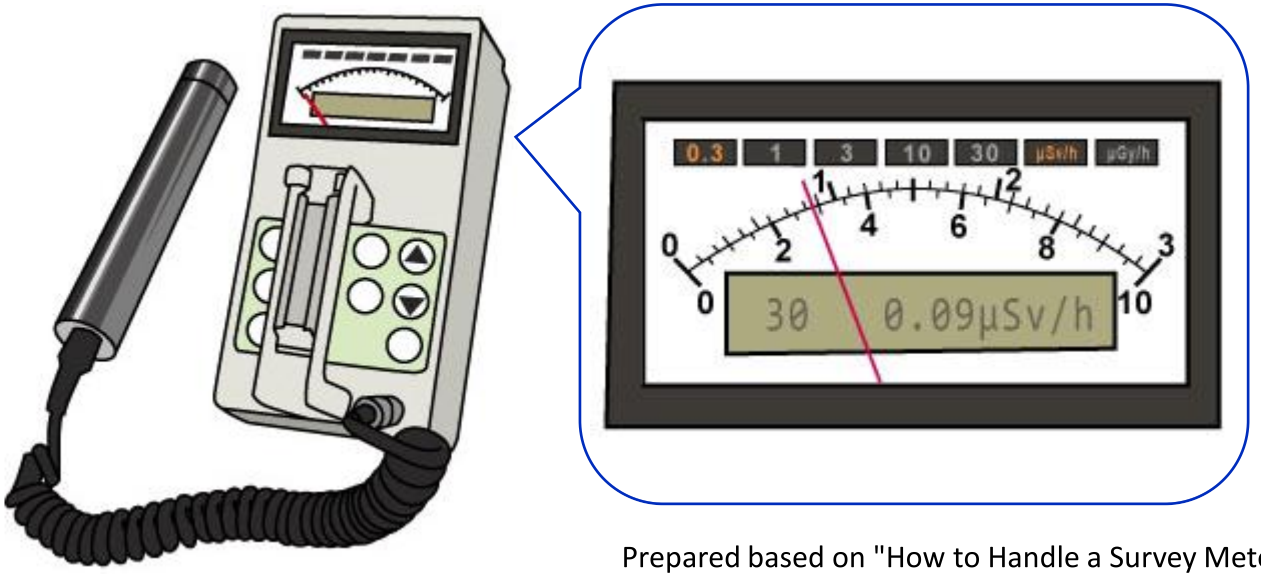
(i) Background measurement

(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 × Calibration constant = Dose (μSv/h)



How to interpret the readings

0.3, 3, 30 μSv/h in the upper row
1, 10 μSv/h in the lower row

- The photo shows a range of 0.3 μSv/h.
- Read the value in the upper row
- The needle pointing at 0.92

The reading at 0.092 μSv/h

For example, when the calibration constant is 0.95
Dose = 0.092×0.95 = 0.087 μSv/h

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

Characteristics of External Exposure Doses

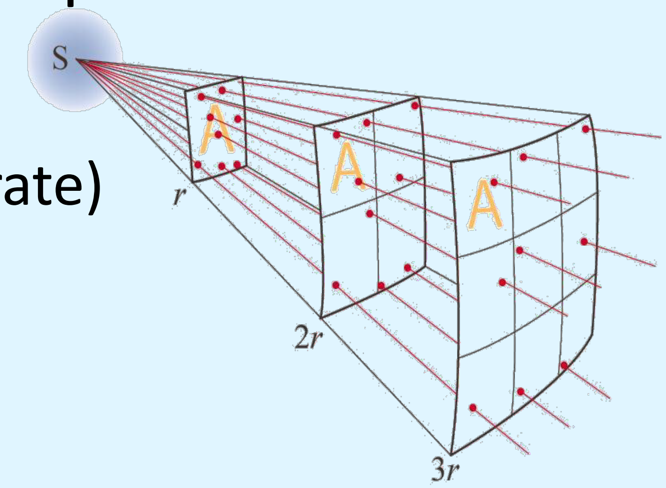
1) **Distance**: Dose rates are inversely proportional to the distance squared.

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

I : Radiation intensity (dose rate)

r : Distance

k : Constant

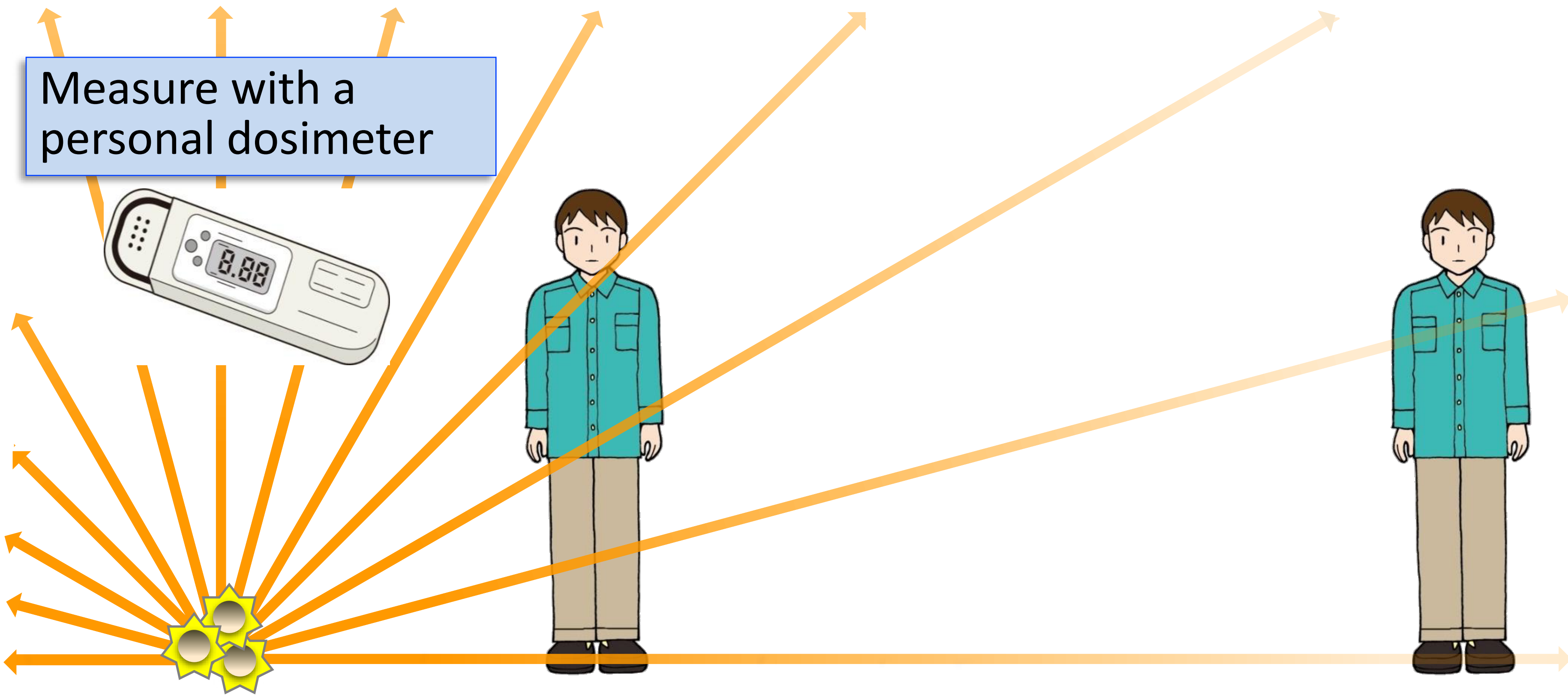


2) **Time**: Doses are proportional to the time of exposure provided the dose rates are the same.

(Total) dose (microsieverts) = Dose rate (microsieverts/h) × Time

Dose Measurement and Calculation

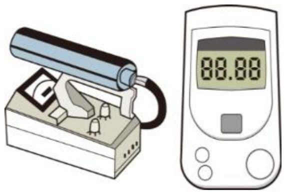
External Exposure (Measurement)



Radiation source

Dose rates are high near the radioactive materials

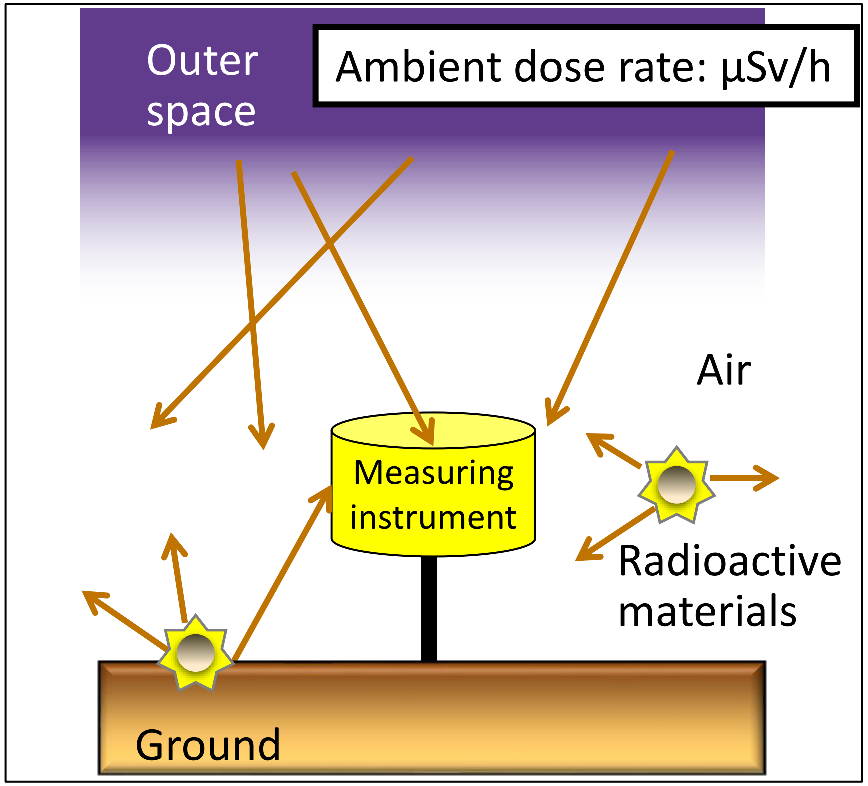
Low at a distance

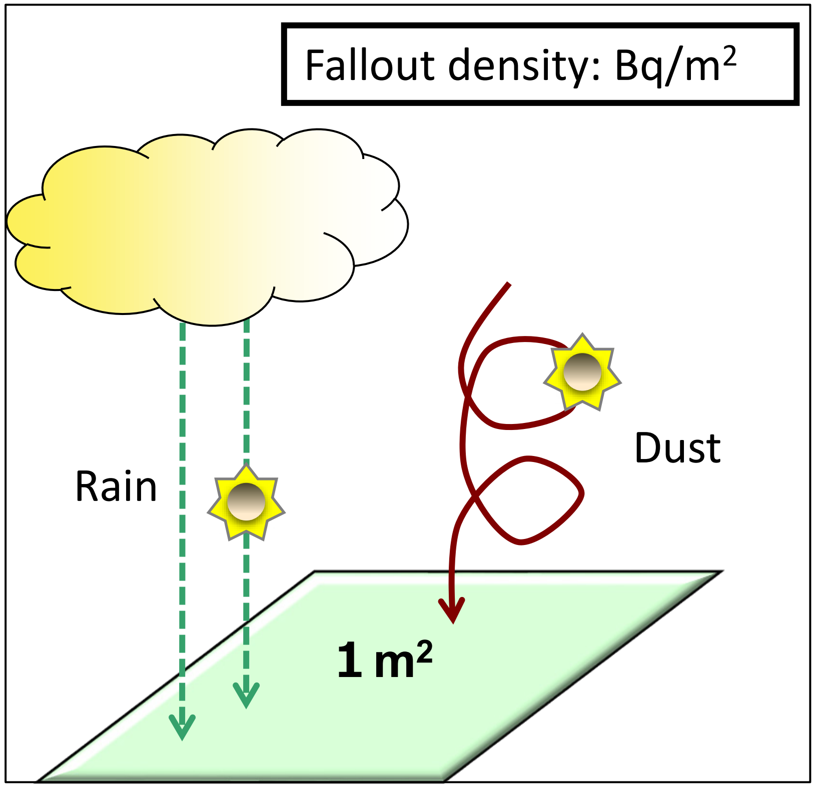


Survey meter measurement (microsieverts/h) multiplied by the time spent in the relevant location can be used as the approximate value of external exposure dose.

Measurement of Environmental Radiation and Radioactivity

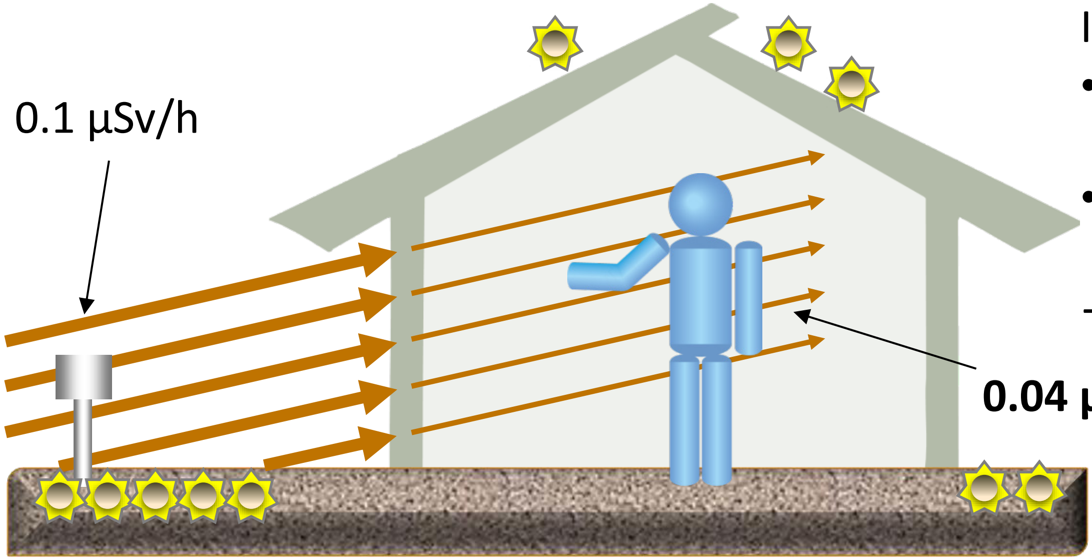
- **Ambient dose rate** shows measured amount of γ-rays in the air.
  Indicated in microsieverts per hour (μSv/h)
- **Fallout density** is the amount of radioactive materials that have deposited (or descended) per unit area in a certain period of time.
  e.g., becquerels per squared meter (Bq/m^2)





Dose Measurement and Calculation

Shielding and Reduction Coefficient



Indoors

- Shielding by building materials
- No contamination under the floor

→ Reduced dose rate

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

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

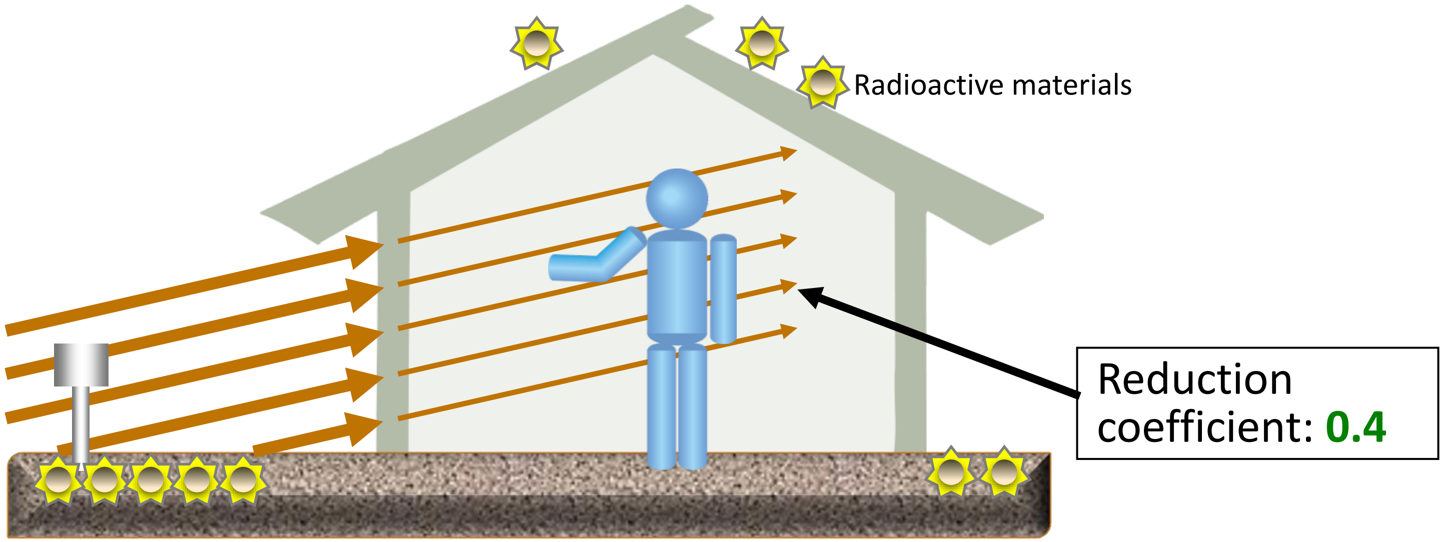
Source: Prepared based on the "Disaster Prevention Countermeasures for Nuclear Facilities, etc." (June 1980 (partly revised in August 2010)), Nuclear Safety Commission

Dose Measurement and Calculation

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: μSv/h)
Actual measurement - Value in normal times
= Exposure rate at the time of the accident

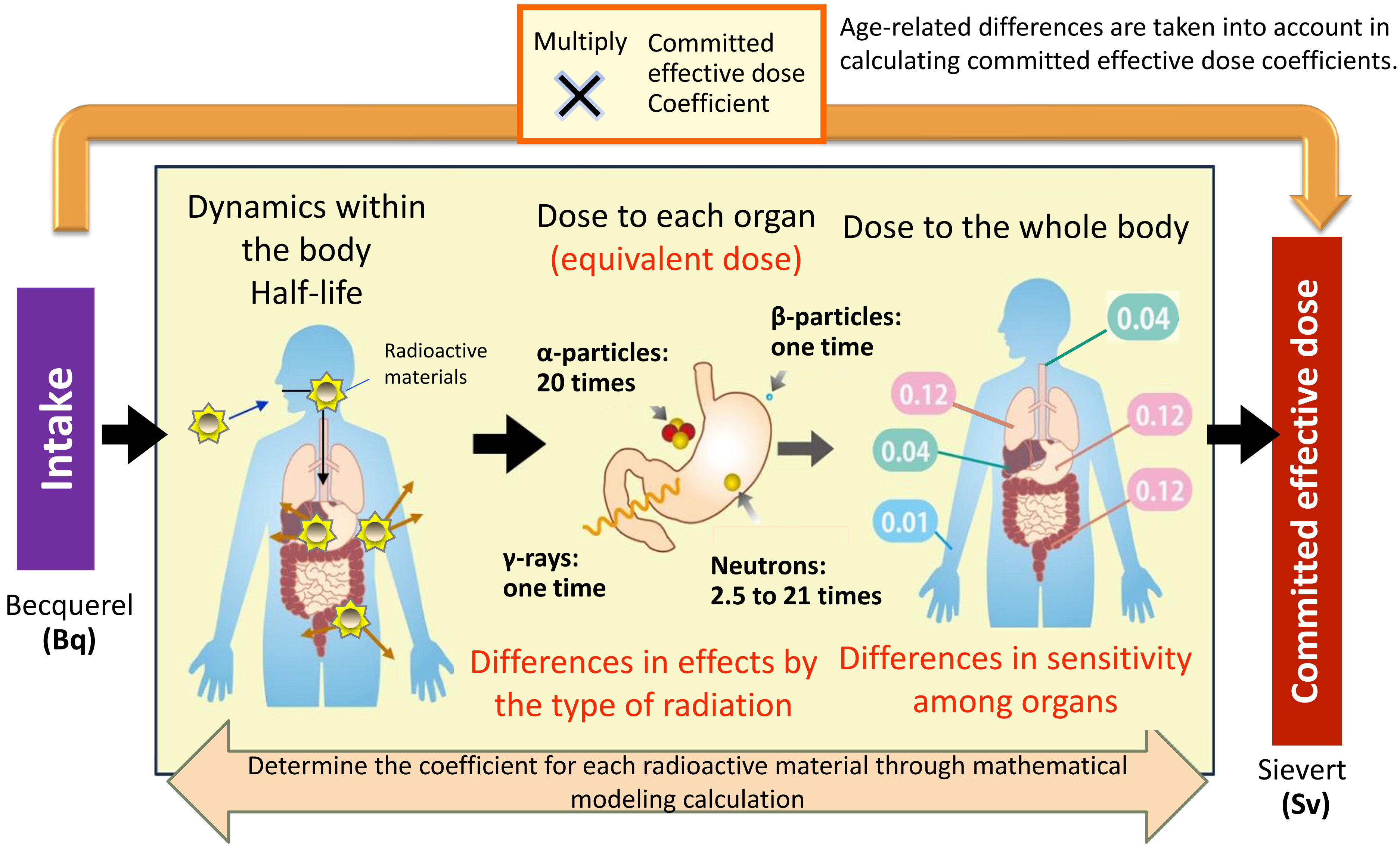


Exposure rate at the time of the accident
× Number of hours spent outdoors in a day
+
Exposure rate at the time of the accident × 0.4
× Number of hours spent indoors in a day

Daily exposure dose

× 365 days = Annual additional exposure dose

Calculation of Internal Exposure Doses



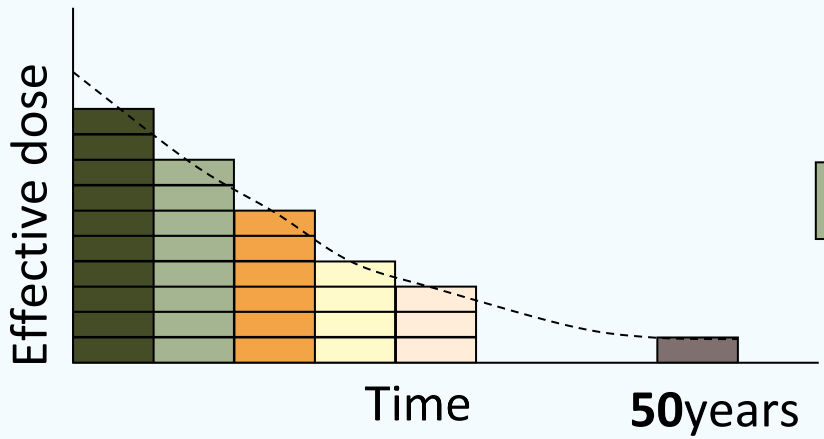
Committed Effective Doses

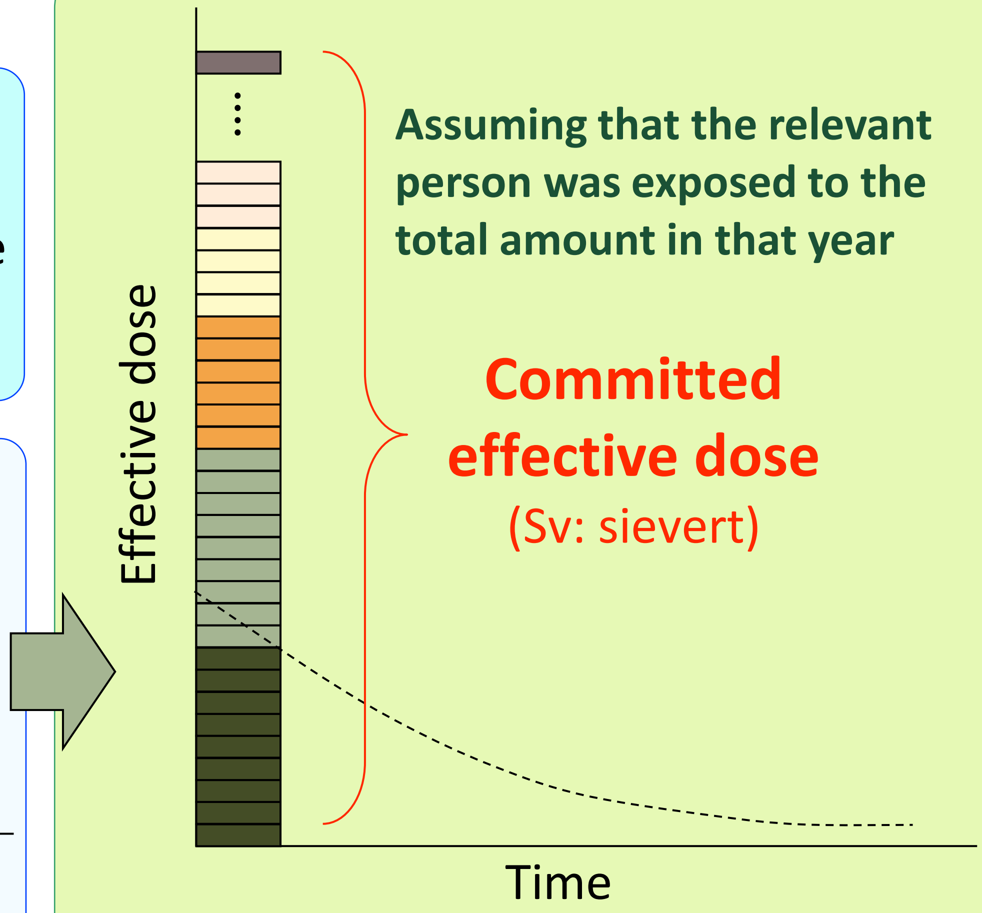
Exposure dose estimating how much radiation a person will be exposed to in lifetime from a single intake of radioactive materials

Calculation of internal exposure

Integrating future doses

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





Dose Measurement and Calculation

Conversion Factors to Effective Doses

Committed effective dose coefficients (μSv/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

μSv/Bq: microsieverts/becquerel

*Tissue free water tritium

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

Exposure Doses from Foods (Example of Calculation)

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

$$100\ (\text{Bq/kg}) \times 0.5\ (\text{kg}) \times 0.013\ (\mu\text{Sv/Bq}) = 0.65\ \mu\text{Sv}$$

$$= 0.00065\ \text{mSv}$$

Committed effective dose coefficients (µSv/Bq)

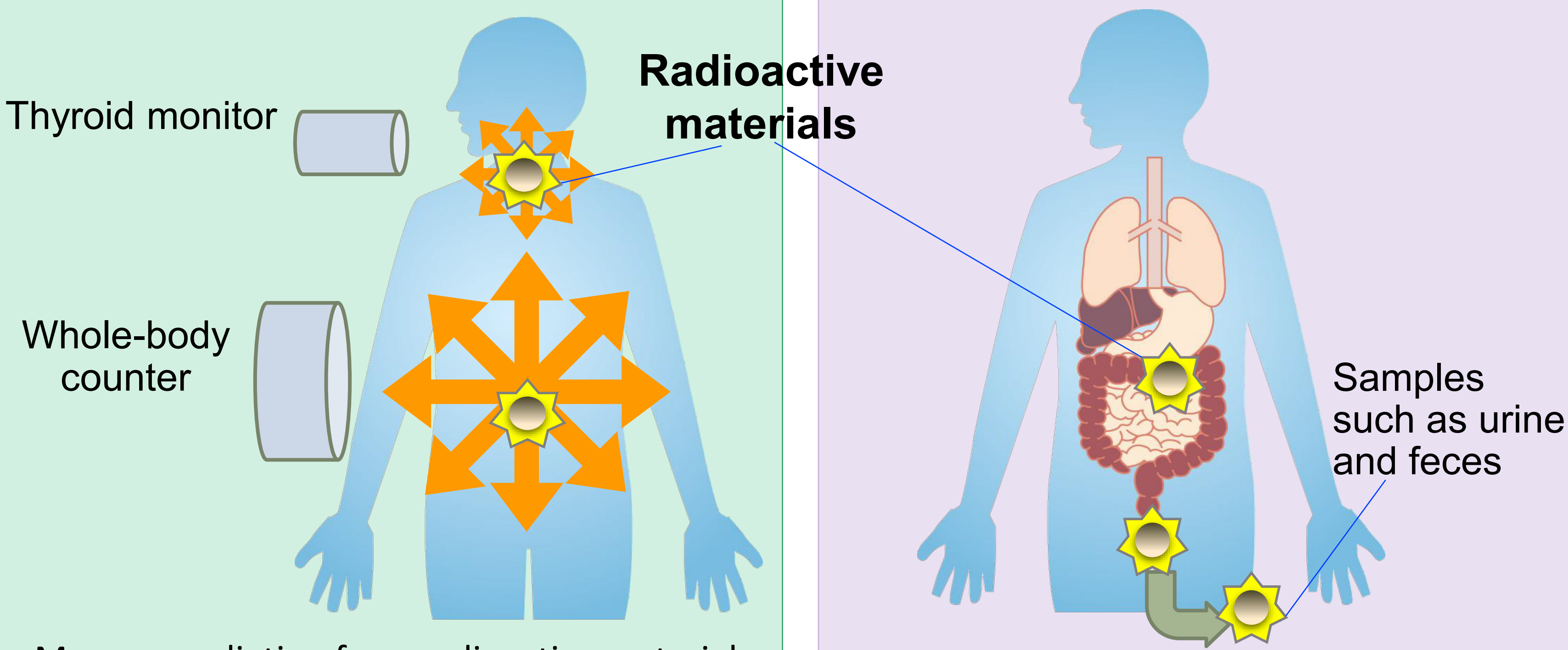
	Iodine-131	Cesium-137
Three months old	0.18	0.021
One year old	0.18	0.012
Five years old	0.10	0.0096
Adult	0.022	0.013

Bq: becquerels; µSv: microsieverts; mSv: millisieverts

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

Dose Measurement and Calculation

Measuring Methods for Estimating the Intake of Radioactivity



Direct counting

- Measure radiation from radioactive materials in the body.
- Subjects for direct counting need to set aside time for measurement.
- Materials that emit γ-rays are mainly measured.
- The measuring time is short.
- The accuracy of dose assessment is high.

Bioassay

- Measure radioactive materials contained in excretion.
- Submit samples (urine, feces, etc.).
- All radioactive materials can be measured.
- It takes time to conduct chemical analysis.
- The margin of error in dose assessment results is large.

Instruments for Measuring Internal Exposure

Stand-up whole-body counter

Scanning bed whole-body counter

Chair whole-body counter

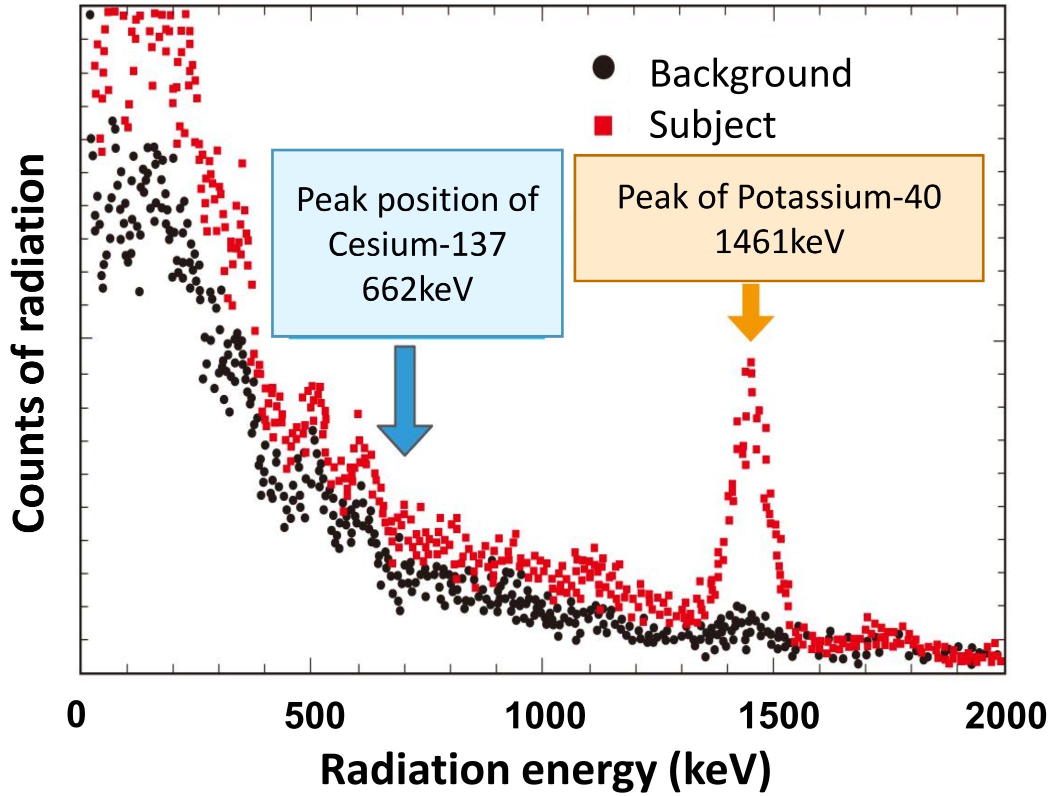
Thyroid monitor

○ Detector

Dose Measurement and Calculation

Data on Internal Exposure Measured by Direct Counting

Whole-body counter

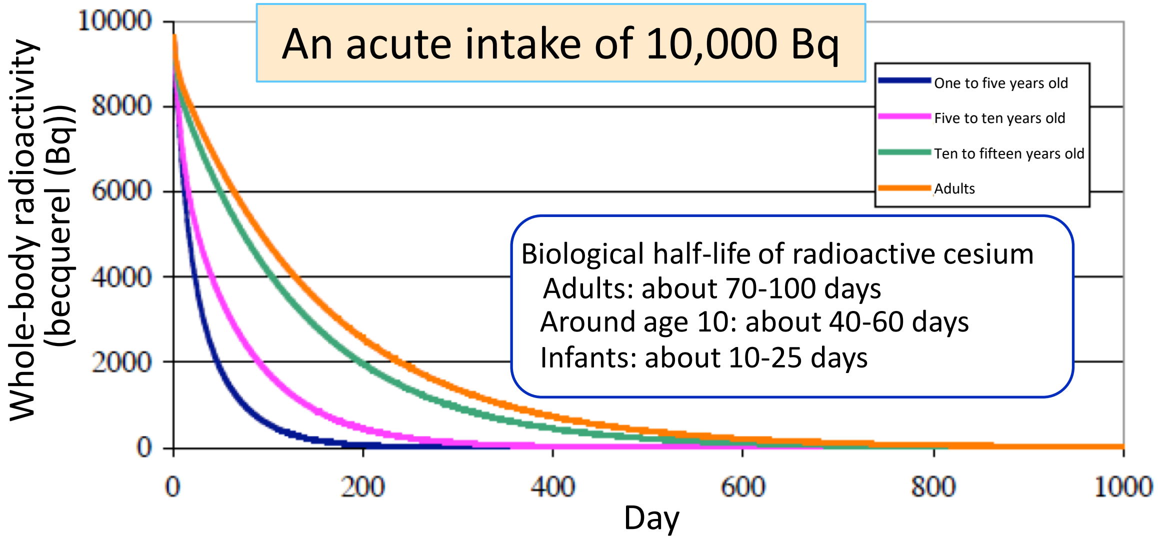


Measure radiation emitted from within the body ⇒ Measure internal radioactivity for each radioactive material

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 in the Body and Dose Assessment

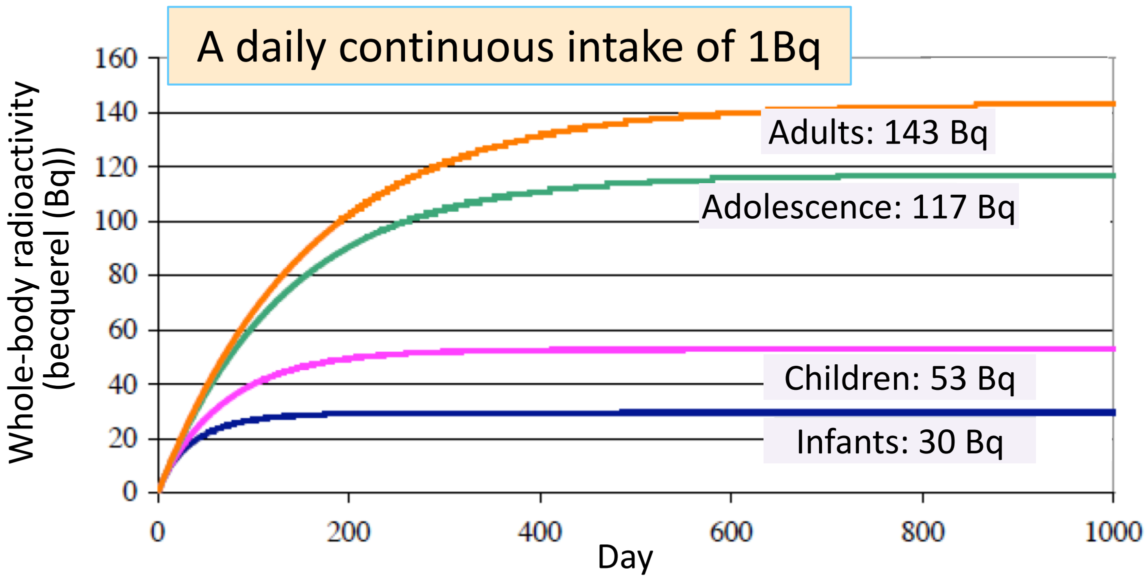


The younger a person is, the faster the metabolism.

↓

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,

- significant values are unlikely to be obtained in children.
- it is more reasonable to examine adults in order to detect trace intake.

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