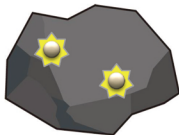


Becquerel (Bq)

Unit indicating the amount of radioactivity

One nucleus decays per second =
1 becquerel (Bq)

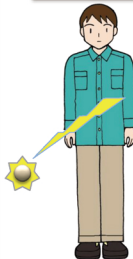
Radioactive
materials



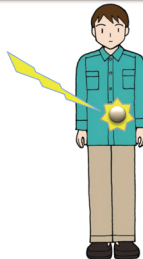
Sievert (Sv)

Unit of radiation exposure dose that a
person receives

Associated with radiation effects



1 mSv from outside
the body



1 mSv from within
the body

Nearly equal effects on
the human body

Sievert is expressed by the symbol "Sv."

- 1 millisievert (mSv)
= one thousandth of 1 Sv
- 1 microsievert (μ Sv)
= one thousandth of 1 mSv



Rolf Sievert (1896-1966)

Founder of the physics laboratory at Sweden's Radiumhemmet

Participated in the foundation of the International Commission on Radiological Protection

Source of radiation

Radiation
intensity^{*1}

Becquerel (Bq)



**Radioactive
materials**

*1: Number of nuclei that
decay per second



Receiving side

Absorbed dose^{*2}

Gray (Gy)



Amount of energy absorbed by a substance of
unit mass that received radiation

$$\text{Gy} = \frac{\text{Absorbed energy (J)}}{\text{Mass of the part receiving radiation (kg)}}$$

*2: Energy absorbed per 1 kg of substances (Joule: J;
1J $\doteq$ 0.24 calories); SI unit is J/kg.

Differences in effects depending on types of radiation

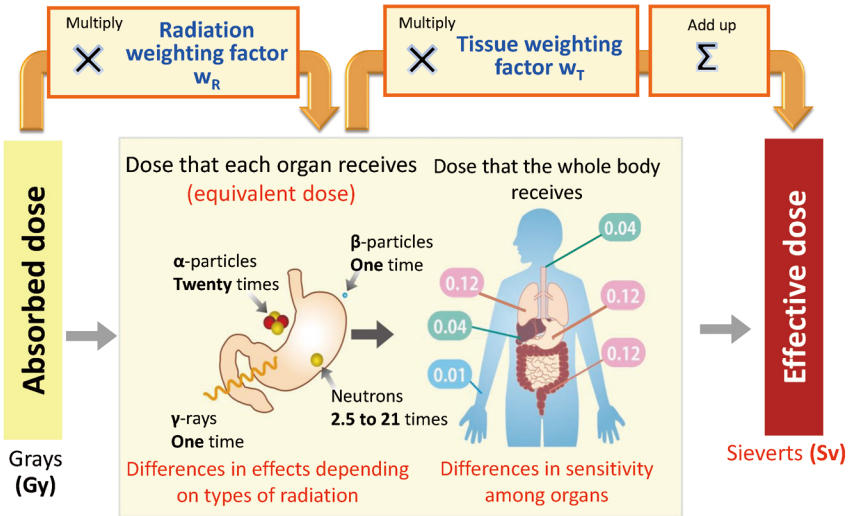
Equivalent dose (Sv)

Differences in sensitivity among organs

Effective dose
Sievert (Sv)

Unit for expressing radiation doses in terms
of effects on the human body

Conversion from Gray to Sievert



Various Factors

Equivalent dose (**Sv**) = Radiation weighting factor w_R × Absorbed dose (**Gy**)

Type of radiation	Tissue weighting factor w_R
γ-rays, X-rays, β-particles	1
Proton beams	2
α-particles, heavy ions	20
Neutron beams	2.5~21

Effective dose (**Sv**) = Σ (Tissue weighting factor w_T × Equivalent dose)

Tissue	Tissue weighting factor w_T
Red bone marrow, colon, lungs, stomach, breasts	0.12
Gonad	0.08
Bladder, esophagus, liver, thyroid	0.04
Bone surface, brain, salivary gland, skin	0.01
Total of the remaining tissues	0.12

Calculation of Equivalent Dose and Effective Dose

$$\text{Effective dose (sievert (Sv))} = \Sigma (\text{Tissue weighting factor} \times \text{Equivalent dose})$$

When the whole body is evenly exposed to **1 mGy** of γ -ray irradiation

Effective dose =

$$\begin{aligned}
 &+ 0.12 \times 1 \text{ (mSv): bone marrow} \\
 &+ 0.12 \times 1 \text{ (mSv): colon} \\
 &+ 0.12 \times 1 \text{ (mSv): lungs} \\
 &+ 0.12 \times 1 \text{ (mSv): stomach} \\
 &\quad : \\
 &+ 0.01 \times 1 \text{ (mSv): skin} \\
 &= 1.00 \times 1 \text{ (mSv)} \\
 &= \mathbf{1 \text{ millisievert (mSv)}}
 \end{aligned}$$



When only the head is exposed to **1 mGy** of γ -ray irradiation

Effective dose =

$$\begin{aligned}
 &+ 0.04 \times 1 \text{ (mSv): thyroid} \\
 &+ 0.01 \times 1 \text{ (mSv): brain} \\
 &+ 0.01 \times 1 \text{ (mSv): salivary gland} \\
 &+ 0.12 \times 1 \text{ (mSv)} \times 0.1: \text{bone marrow (10\%)} \\
 &+ 0.01 \times 1 \text{ (mSv)} \times 0.15: \text{skin (15\%)} \\
 &\quad : \\
 &= \mathbf{0.07 \text{ millisieverts (mSv)}}
 \end{aligned}$$



Physical quantities: directly measurable

Radiation intensity (Bq: becquerels)

Number of nuclei that decay per second

Radiation fluence ($\text{s}^{-1}\text{m}^{-2}$: fluence)

Number of particles incident on a unit area

Absorbed dose (Gy: grays)

Energy absorbed per 1 kg of substances

Irradiation dose (for X-rays and γ -rays) (C/kg)

Energy imparted to 1 kg of air

Doses indicating the effects of exposure on humans: not directly measurable

Defined based
on physical
quantity

Protection quantities

Equivalent dose (Sv: sievert)

indicates effects on individual human organs and tissues

Effective dose (Sv: sievert)

indicates effects on the whole body by combining effects on individual organs and tissues



Operational quantities

Ambient dose equivalent (Sv: sievert)

Directional dose equivalent (Sv: sievert)

Approximate value for protection quantity used in environmental monitoring

Personal dose equivalent (Sv: sievert)

Approximate value for protection quantity used in personal monitoring

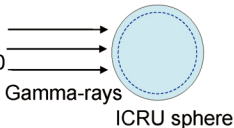
Dose Equivalents: Measurable Operational Quantities for Deriving Effective Doses

Dose equivalent = Absorbed dose at a reference point that meets certain requirements $\times$ Quality factor

To substitute for "effective doses" that cannot be actually measured, "operational quantities" that can be measured as conservative values or as nearly the same values as effective doses, such as an ambient dose equivalent and personal dose equivalent, are defined under certain conditions.

Ambient dose equivalent (1cm dose equivalent)

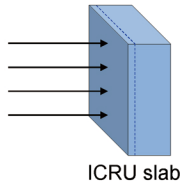
Dose equivalent is a dose that would be produced at a depth of 1 cm from the surface of an ICRU sphere, which is 30 cm in diameter and simulates human tissue, placed in a field where radiation is coming from one direction; Ambient dose equivalent is used in measurements of ambient doses using survey meters, etc.



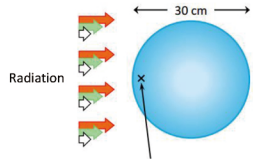
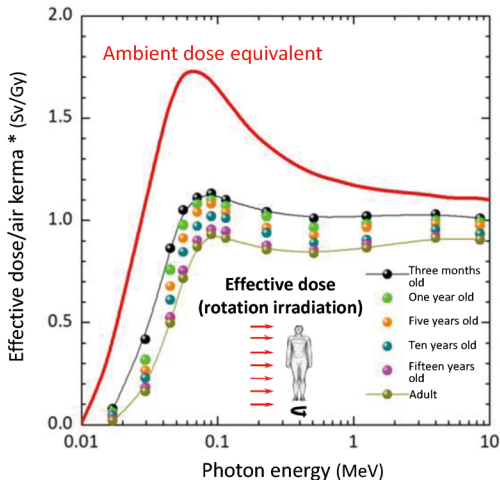
Personal dose equivalent (1 cm dose equivalent)

Dose equivalent at a depth of 1 cm at a designated point on the human body; Since measurement is conducted using an instrument worn on the body, exposure from all directions is evaluated while a self-shielding effect is always at work.

$\Rightarrow$ Personal dose equivalents are always smaller than survey meter readings!



Difference between Values of Effective Dose and Dose Equivalent



The ambient dose equivalent measured with a survey meter is defined as the dose equivalent at a depth of 1 cm from the surface of an ICRU sphere that is 30 cm in diameter. The ambient dose equivalent is also called 1 cm dose equivalent.

Source: Partially revised material 1 for the 9th meeting of the Atomic Energy Commission of Japan in 2012 (a report by Akira Endo of JAEA)

* Air kerma is a unit of physical quantity.

Doses in Units of Sieverts

