Radiation Safety Course

(School of Science, the University of Tokyo)

Biological Effects of Radiation to Human Body

Autumn-Winter 2021

日本製鉄工場で社員2人被ばくか 年間限度量の数十倍の可能性も

2021年6月11日 18時24分

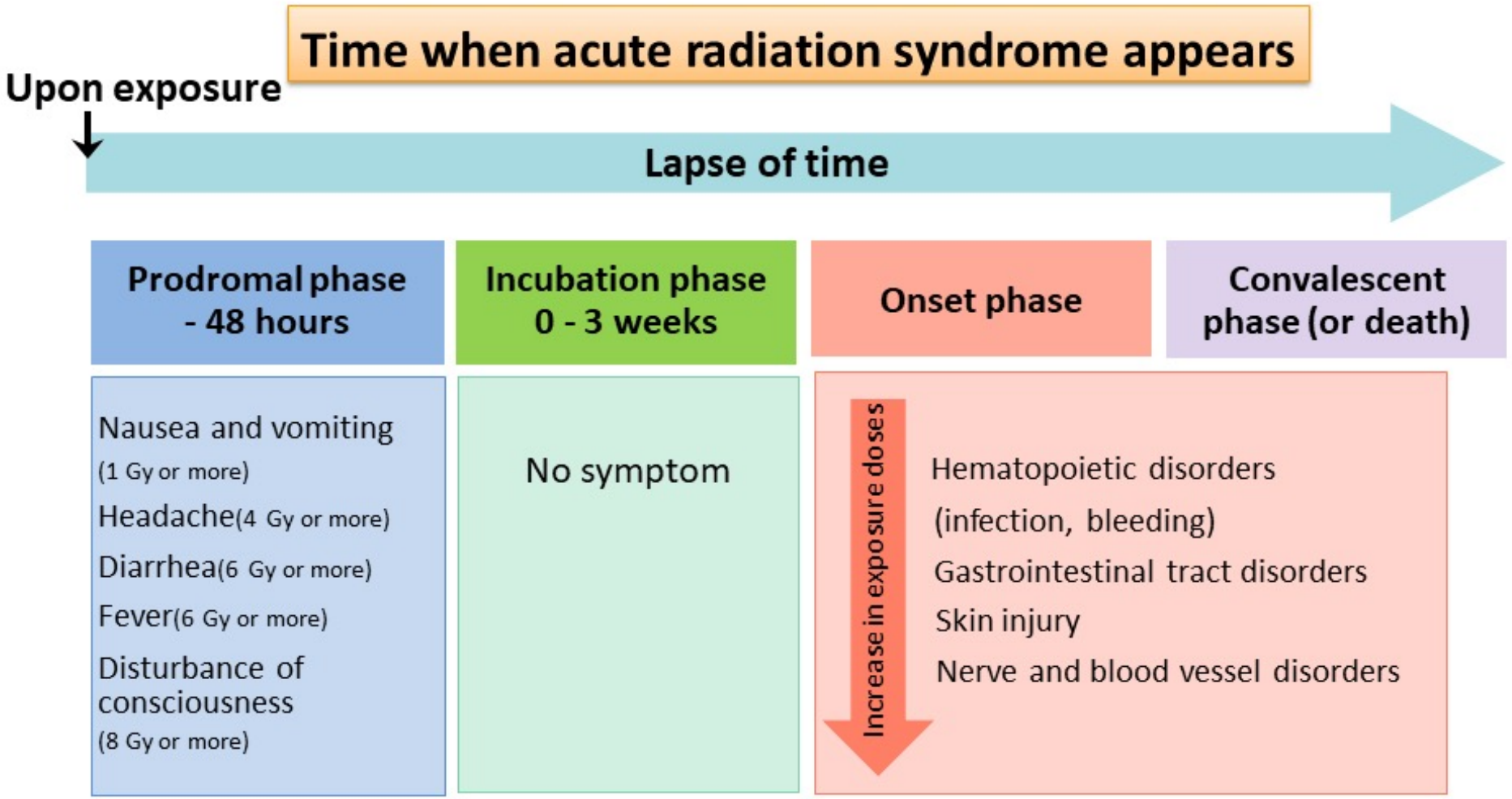
兵庫県にある日本製鉄の工場で先月、エックス線を使う測定装置の点検中に事故が起き、男性社員が年間の限度量の数倍から数十倍に及ぶ大量の被ばくをした可能性があることが関係者への取材でわかりました。事故を重く見た厚生労働省は通知を出して同様の測定装置を使っているほかの企業に被ばく防止の徹底を求めるとともに労働基準監督署などが事故の状況を調べています。

During inspection, two employees at Nippon Steel Factory may have been exposed to radiation more than dozens of times the annual limit (50 mSv/y).
The next day, they felt sick and went to see a doctor.

(Cited from NHK website)

Deterministic Effects

Acute Radiation Syndromes



* Acute radiation syndromes observed in the case of whole-body exposure to radiation exceeding 1 Gy (1,000 mGy) at one time

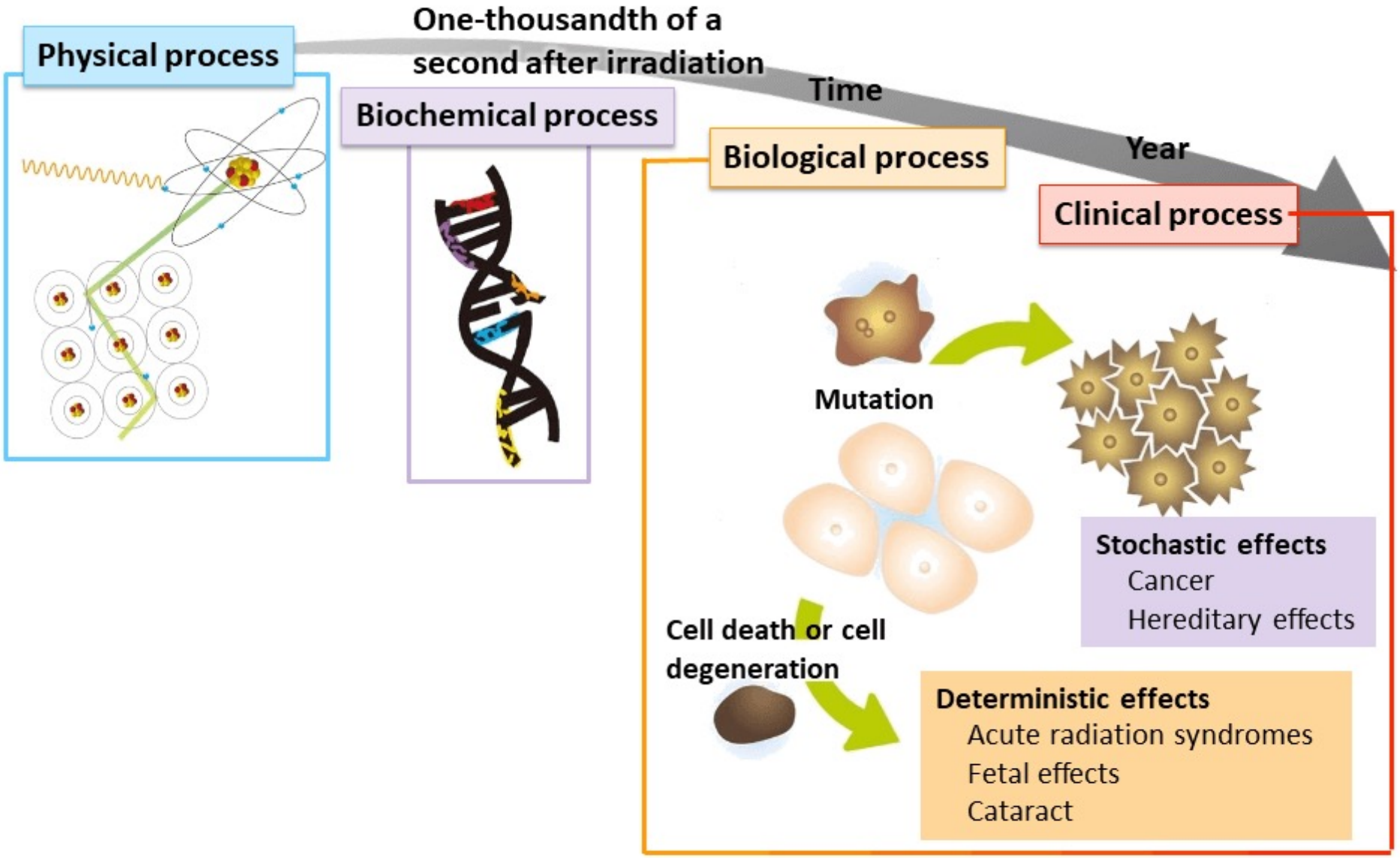
Gy: Grays

Source: "Basic Knowledge on Radiation" (a text for the Emergency Exposure Medical Treatment Training), Nuclear Safety Research Association

Source: BOOKLET to Provide Basic Information Regarding Health Effects of Radiation

Mechanism of Causing Effects on Human Body

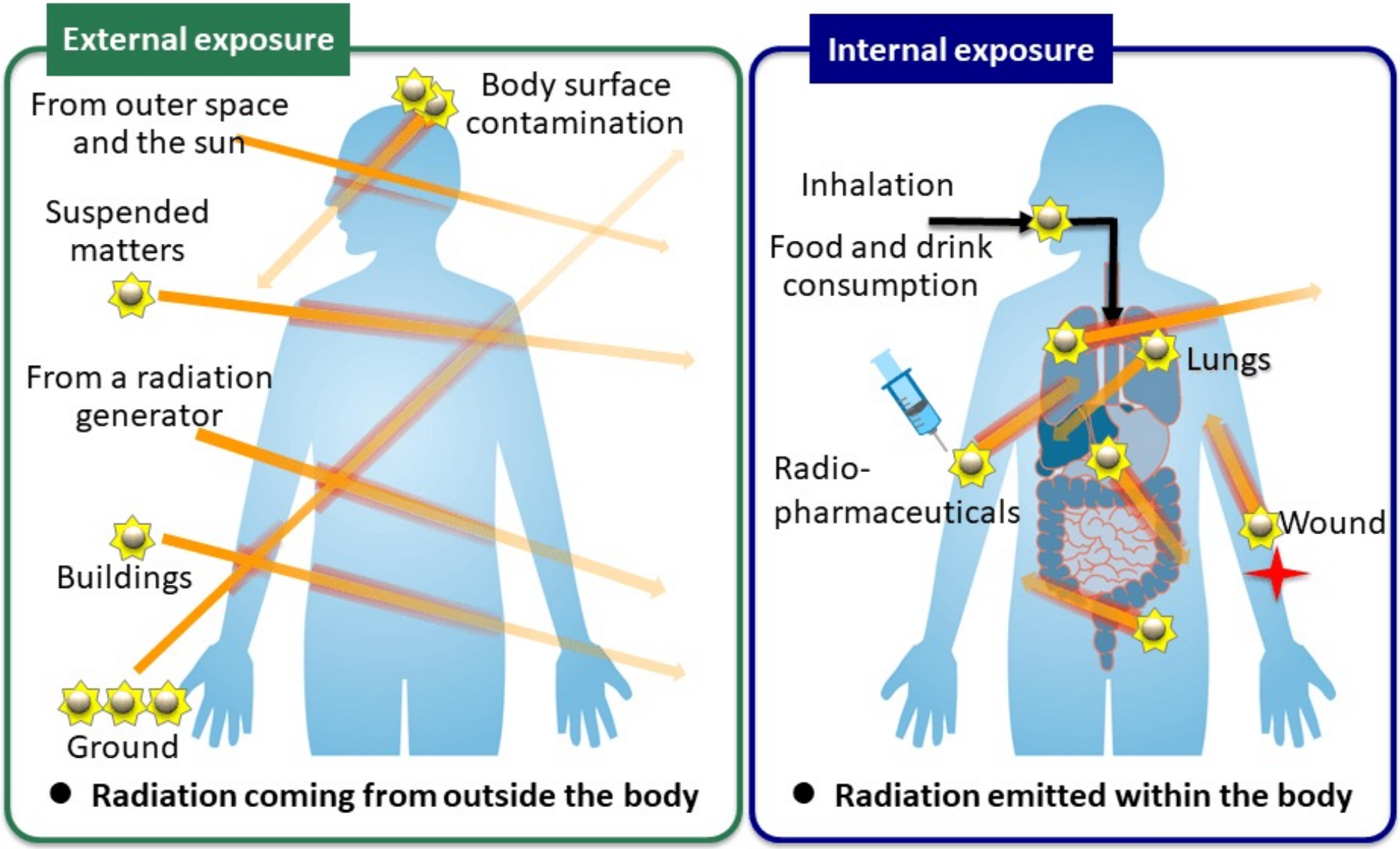
Lapse of Time after Exposure and Effects



Source: BOOKLET to Provide Basic Information Regarding Health Effects of Radiation

Exposure Routes

Internal and External Exposure



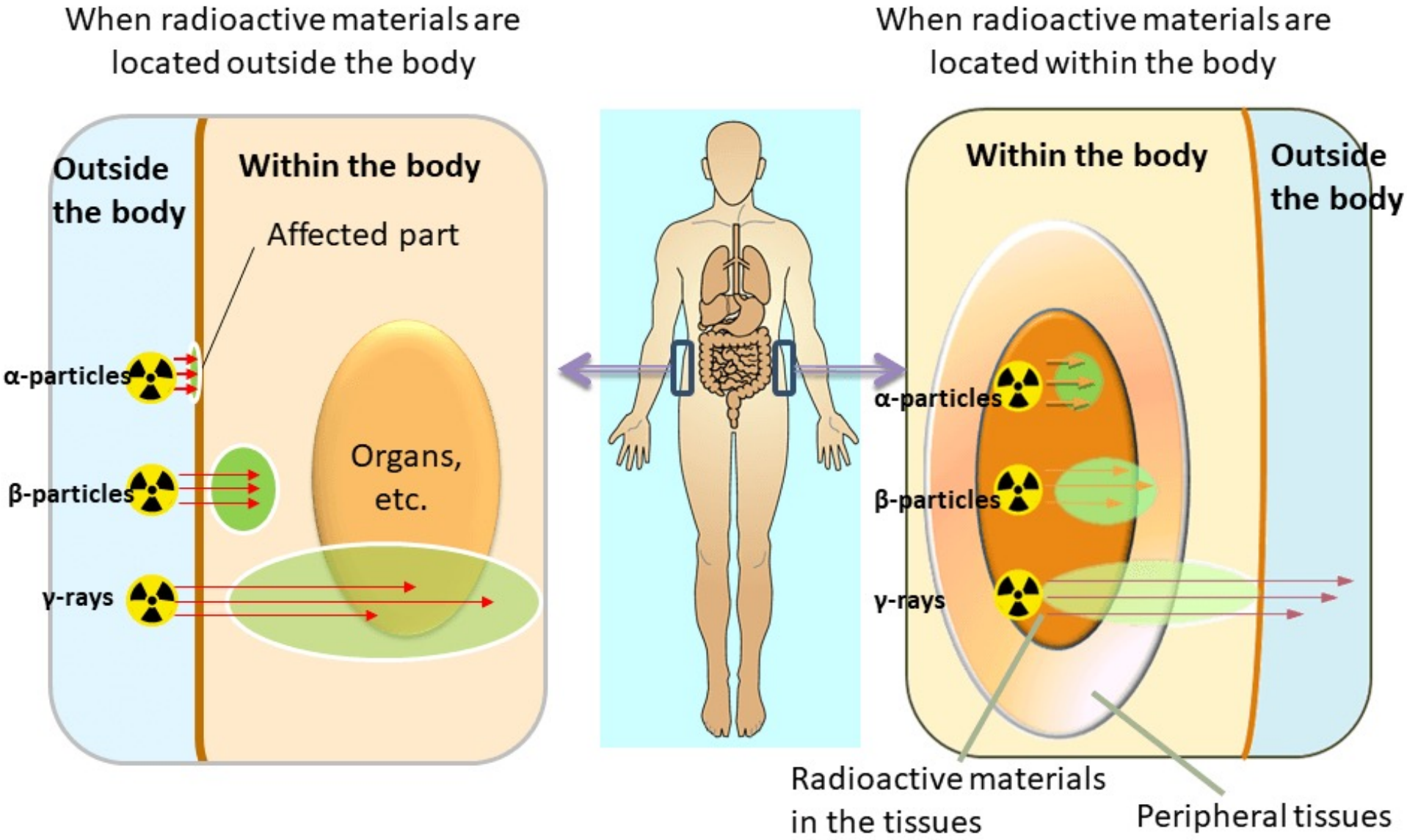
The body is equally exposed to radiation in both cases.

Radioactive materials

Source: BOOKLET to Provide Basic Information Regarding Health Effects of Radiation

Radiation

Penetrating Power and Range of Effects on the Human Body



Source: BOOKLET to Provide Basic Information Regarding Health Effects of Radiation

Exposure Routes

Internal Exposure

(i) Ingestion

From the mouth (swallowing)
Absorption through the digestive tract

(ii) Inhalation

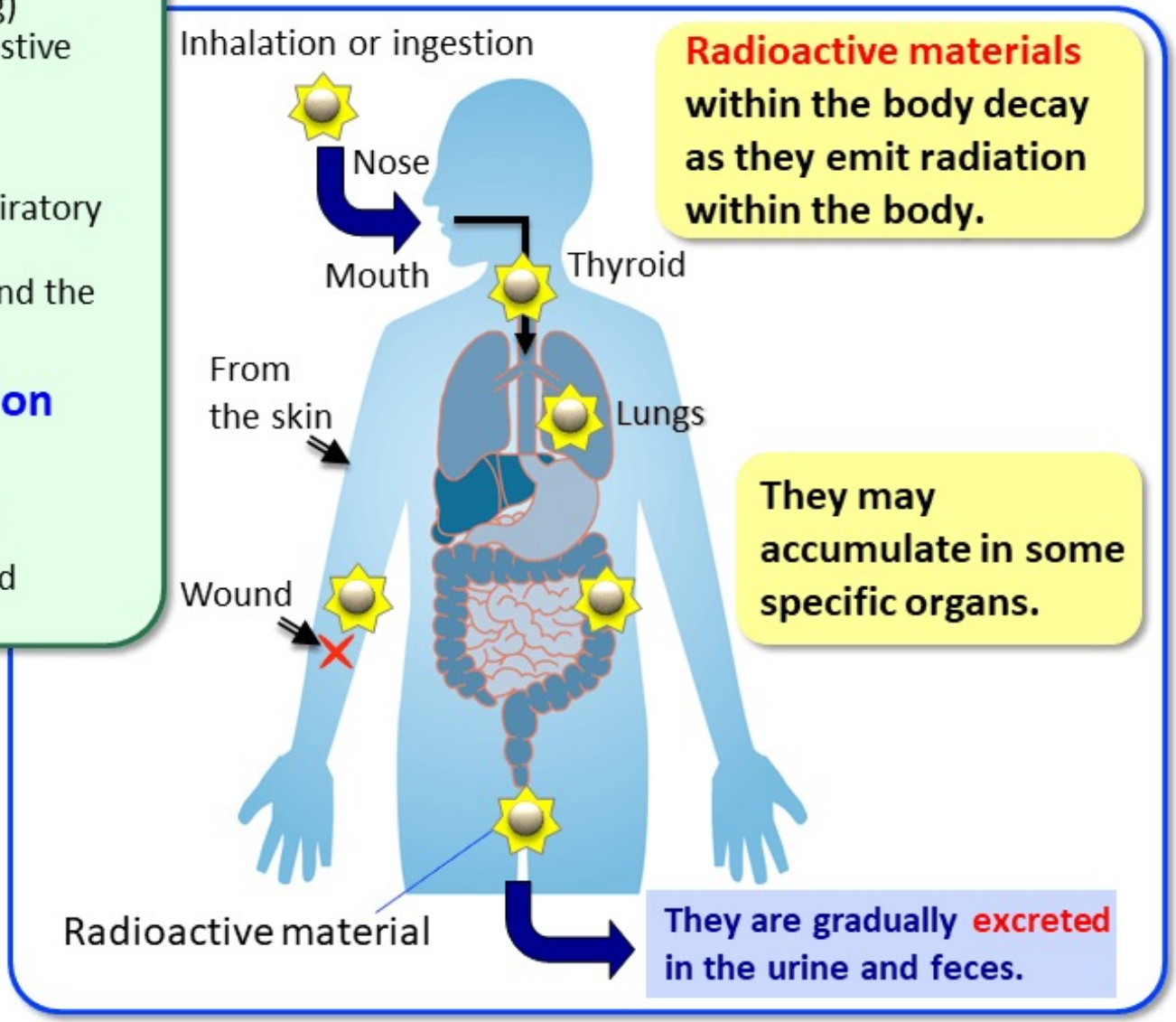
Incorporation from the respiratory airways
Absorption from the lungs and the surface of the airways

(iii) Percutaneous absorption

Absorption from the skin

(iv) Wound contamination

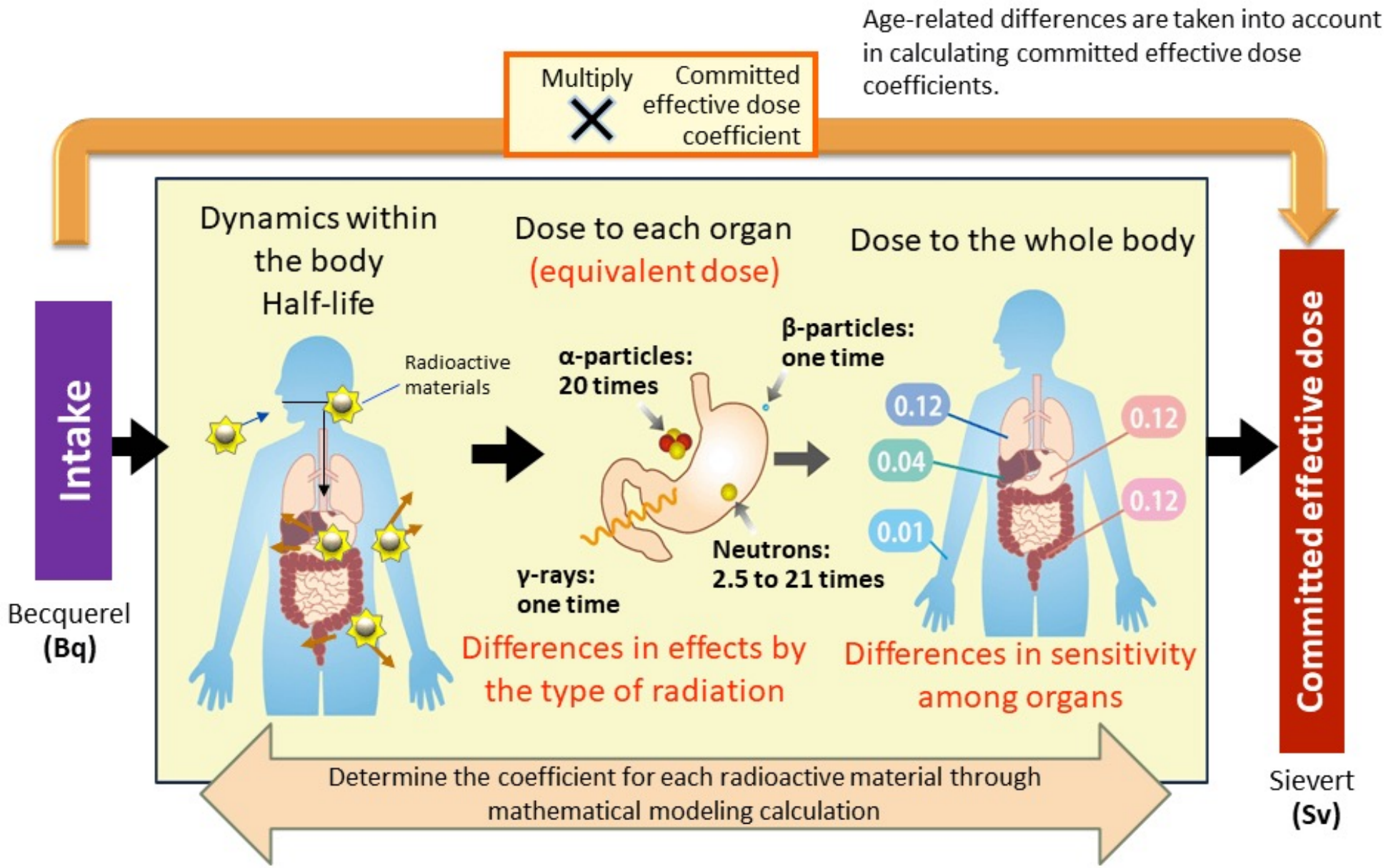
Contamination from a wound



Source: BOOKLET to Provide Basic Information Regarding Health Effects of Radiation

Dose Measurement and Calculation

Calculation of Internal Exposure Doses



Source: BOOKLET to Provide Basic Information Regarding Health Effects of Radiation

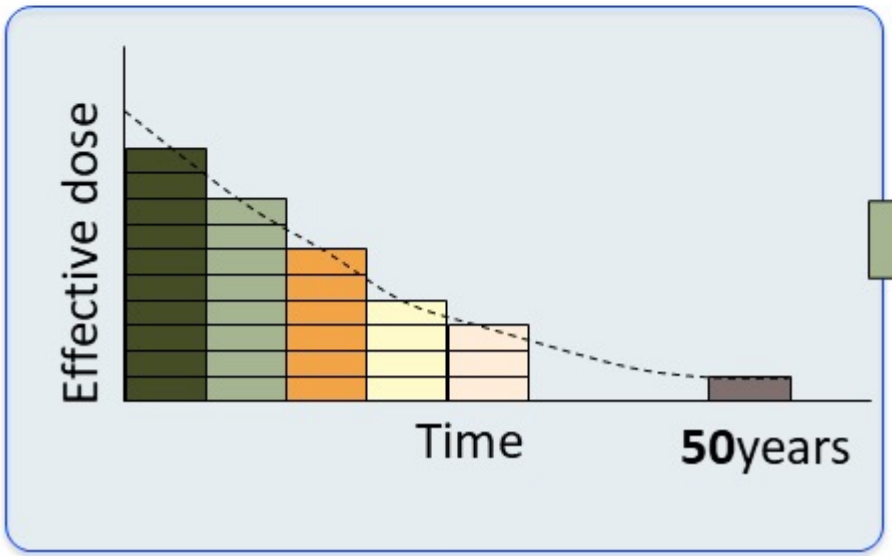
Committed Effective Doses

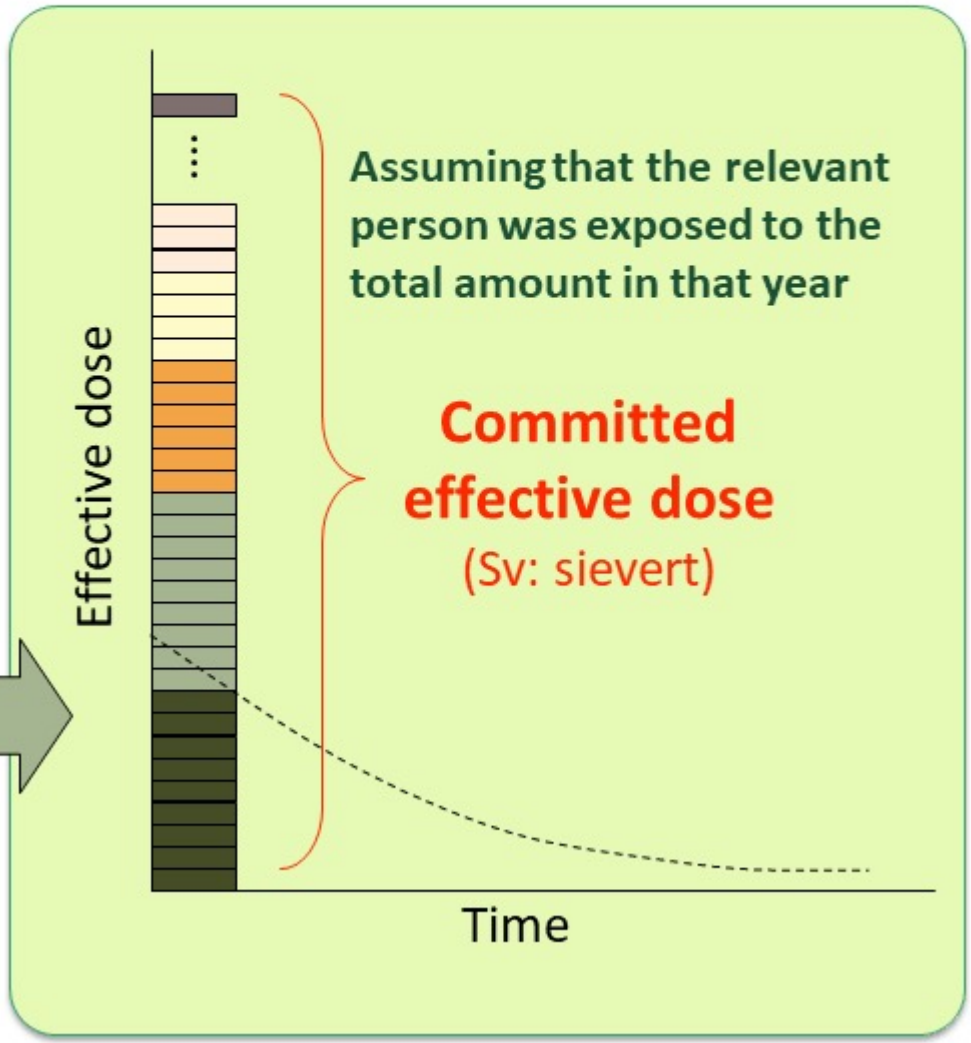
Exposure dose estimating how much radiation a person will be exposed to in lifetime from a single intake of radioactive materials

Calculation of internal exposure

Integrating future doses

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





Source: BOOKLET to Provide Basic Information Regarding Health Effects of Radiation

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

Source: BOOKLET to Provide Basic Information Regarding Health Effects of Radiation

Radiation around Us

Exposure Dose from Natural and Artificial Radiation

Natural radiation (in Japan)

From outer space
0.3mSv

From foods
0.99mSv

From radon in the air
0.48mSv

From the ground
0.33mSv

Annual dose from natural radiation (Japanese average): 2.1 mSv

Annual dose from natural radiation (global average): 2.4 mSv

Tokyo to New York Air travel (round trip) **0.11～0.16mSv**

Artificial radiation

Chest CT scan (single scan) **2.4～12.9mSv**

Chest X-ray scan (single scan) **0.06mSv**

mSv: millisieverts

Sources: Prepared based on the 2008 UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation) Report; and "Environmental Radiation in Daily Life (2011)," new edition, Nuclear Safety Research Association; ICRP (International Commission on Radiological Protection) 103, etc.

Source: BOOKLET to Provide Basic Information Regarding Health Effects of Radiation

Breakdown of Natural Exposure Doses (Japanese)

Type of exposure	Breakdown of radiation sources	Effective dose (mSv/year)
External exposure	Cosmic rays	0.3
	Ground radiation	0.33
Internal exposure (inhalation)	Radon-222 (indoors and outdoors)	0.37
	Radon-220 (thoron) (indoors and outdoors)	0.09
	Smoking (Lead-210, Polonium-210, etc.)	0.01
	Others (uranium, etc.)	0.006
Internal exposure (ingestion)	Mainly Lead-210 and Polonium-210	0.80
	Tritium	0.0000082
	Carbon-14	0.01
	Potassium-40	0.18
Total		**2.1**

Source: "Environmental Radiation in Daily Life (2011)," Nuclear Safety Research Association

Source: BOOKLET to Provide Basic Information Regarding Health Effects of Radiation

Radiation around Us

Natural Radioactive Materials in the Body and Foods

G-13

Radioactive materials in the body

When body weight is 60kg		
Potassium-40	※ 1	4,000Bq
Carbon-14	※ 2	2,500Bq
Rubidium-87	※ 1	500Bq
Tritium	※ 2	100Bq
Lead and polonium	※ 3	20Bq

※ 1 Nuclides originating from the Earth
※ 2 Nuclides derived from N-14 originating from cosmic rays
※ 3 Nuclides of the uranium series originating from the Earth

Radioactivity concentrations (Potassium-40) in foods

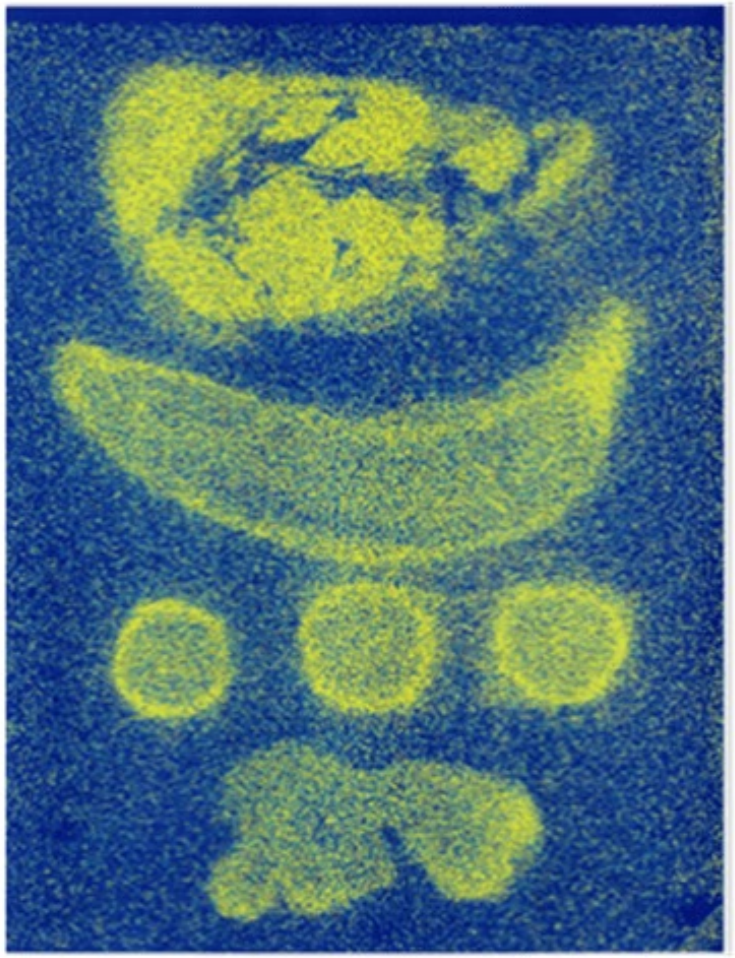
Rice: **30**; Milk: **50**; Beef: **100**; Fish: **100**; Dry milk: **200**; Spinach: **200**;
Potato chips: **400**; Green tea: **600**; Dried *shiitake*: **700**; Dried kelp: **2,000** (Bq/kg)

Bq: becquerels Bq/kg: becquerels/kilogram

Source: Prepared based on "Research on Data about Living Environment Radiation (1983)," Nuclear Safety Research Association

Source: BOOKLET to Provide Basic Information Regarding Health Effects of Radiation

Visualized Radiation



Radiographs of pork meat, banana (cut vertically and horizontally), and ginger

Radiation from foods

- Mostly β-particles from Potassium-40
- The natural abundance ratio of Potassium-40* is **0.012%**.
- Potassium-40 has a half-life of **1.26 × 10^9** years.

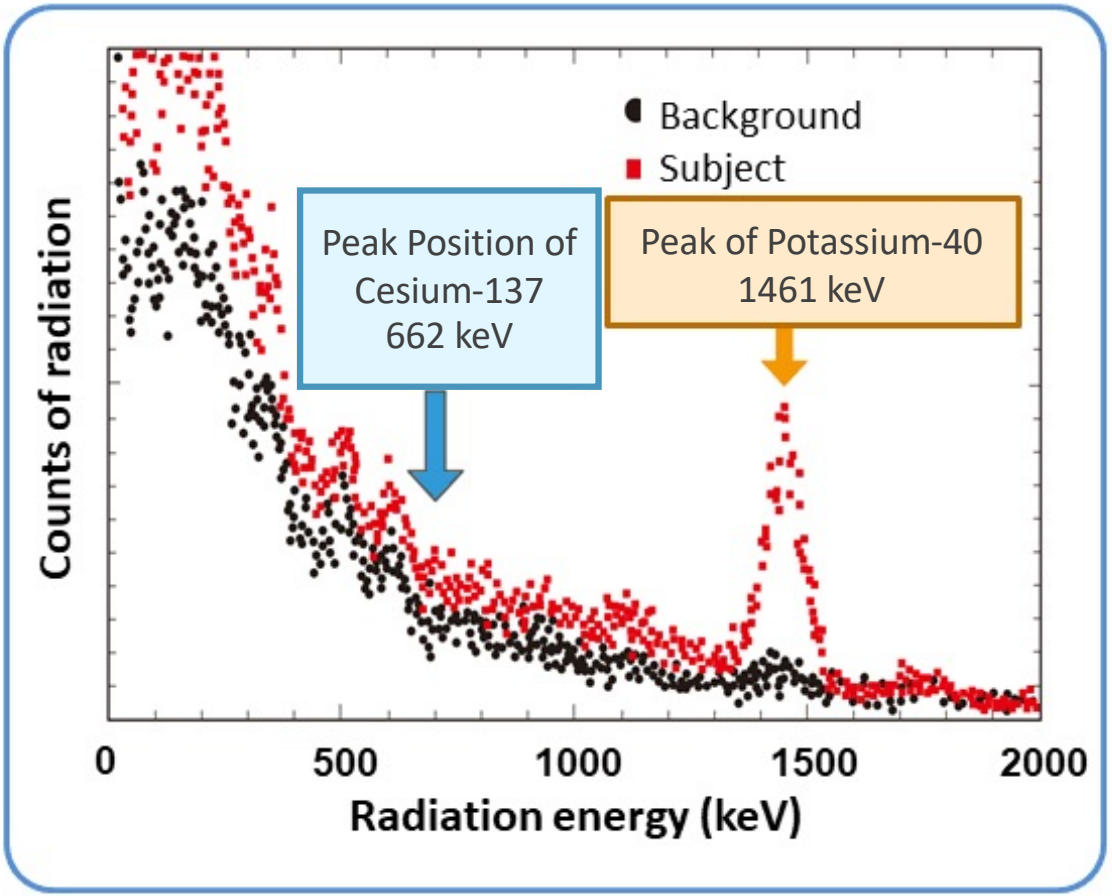
*Percentage of Potassium-40 relative to the total amount of potassium found in nature

Source: Applied Physics Vol.67, No.6, 1998

Source: BOOKLET to Provide Basic Information Regarding Health Effects of Radiation

Data on Internal Exposure Measured by Direct Counting

Whole-body counter



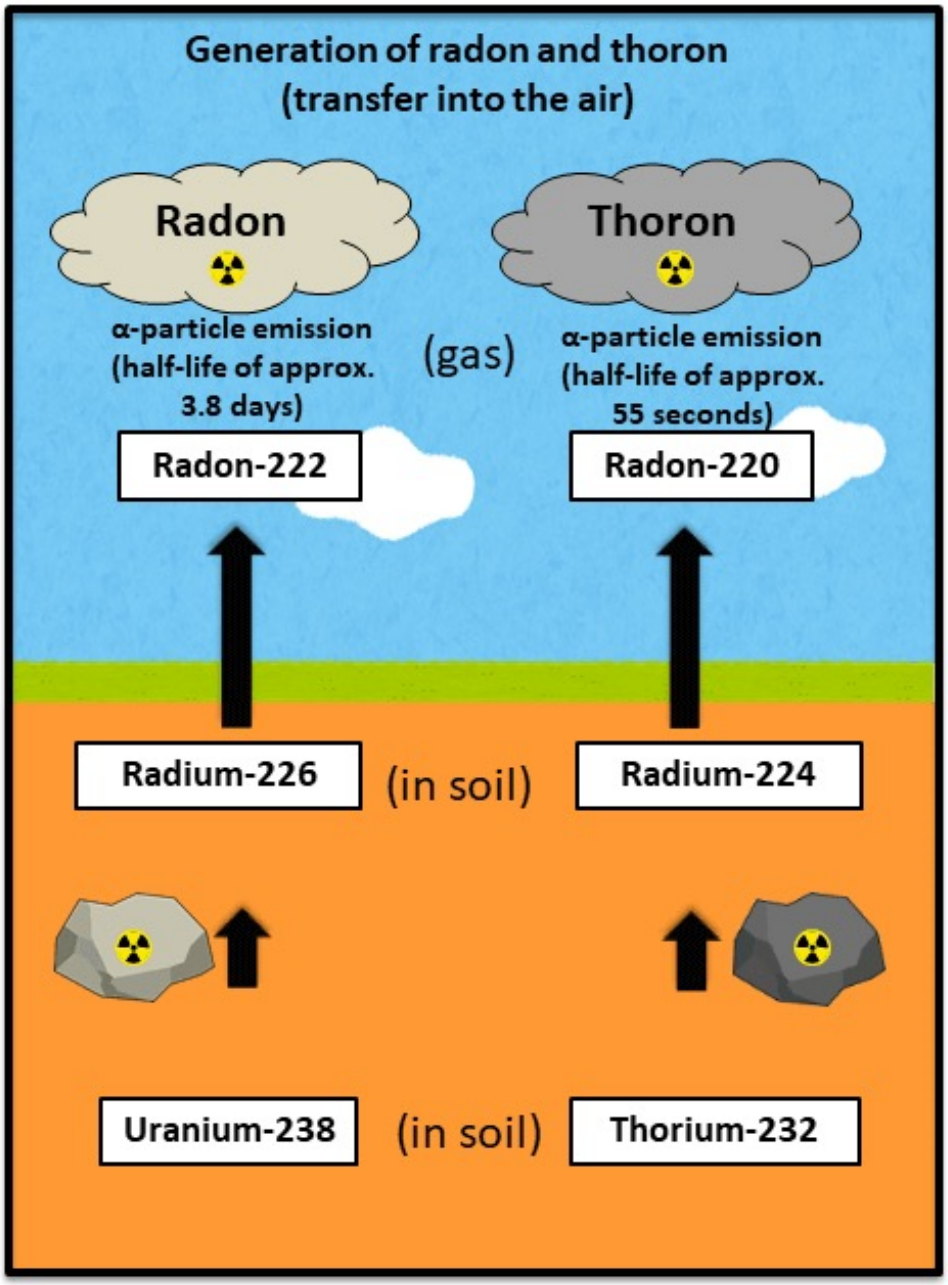
Measure radiation emitted from within the body ⇒ Measure internal radioactivity for each radioactive material

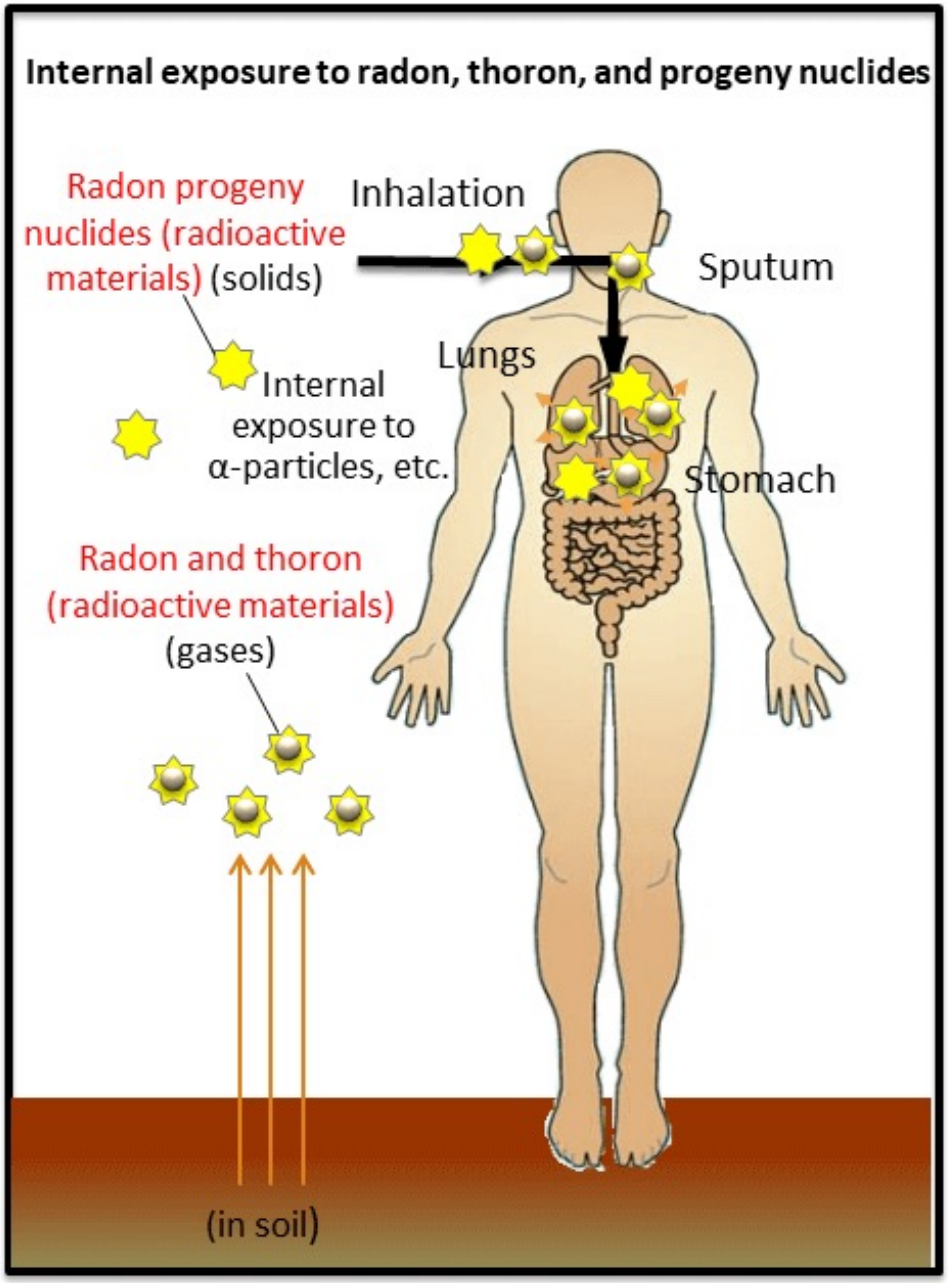
The amount of potassium in the body is around 2 g per 1 kg of body weight, and approx. 0.01% of that amount is radioactive potassium (K-40)

keV: kiloelectronvolts

Source: BOOKLET to Provide Basic Information Regarding Health Effects of Radiation (partially modified)

Internal Exposure to Radon and Thoron through Inhalation





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Question 2

An adult worker accidentally ingested 1 MBq of Strontium-90.

In this case, the committed effective dose is calculated to be…

○○ mSv