



# Environmental Radiological Risk Assessments

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Risetpro Scholarship, JSPS Scholarship, ERAN research Funds, IREM, Kurita, LPDP dll  
Scientific Organization : CTBTO, UNSCEAR, AORA, PPI



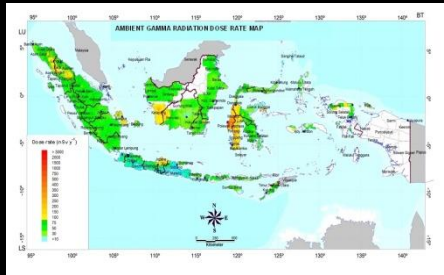
# Outline

- Introduction
- Risk vs dose Concept
- Source Identification
- Pathway
- Dose Calculation
- Modelling Tools



# Research Center for Technology of Radiation Safety, Metrology and Nuclear Quality

## Background



The radiation application in various fields requires safety for radiation workers, society, and the environment as well as providing nuclear quality assurance in terms of science and technology products. Radiation safety assurance is carried out through mastery of competence in the fields of nuclear and radiation safety, radiation protection, radioecology, radiation metrology, and nuclear quality assurance.

## Research Competencies

- Radiobiology and nuclear techniques in medicine
- Dosimetry of ionizing radiation and standardization of radionuclides
- Radiation Safety and Protection
- Radioecology
- Nuclear Quality
- Nuclear emergency preparedness

## Research Theme for 2023-2024

### Radiobiology

- Radiomic biomarkers as a response to radiation exposure in workers, patients, and the public
- Radio mitigation as the impact of radiation overexposure on workers, patients, and cases of nuclear emergencies

### Radiation safety of Ionizing radiation

- Radiation safety for patients in radiotherapy and nuclear medicine based on dose distribution within the patient's body.
- Development of a safety and radiation protection system for patients, medical personnel, and the environment in accelerator-based medical facilities.

### Radioecology

- Research on environmental protection technology from the hazardous effects of radiation:
- Study of radiotracer on mobility, transfer, and tracer in abiotic compartments and tropical biota's networks,
  - Radionuclide risk assessment on biota and ecosystems,
  - Application of radiation detection technology in the environment

### Radiation dosimetry and standardization of radionuclide

- Ionizing radiation beam dosimetry of charged and uncharged particle radiation based on passive and active dosimeters.
- Radionuclide standardization for radiation health and safety

### Nuclear Quality

Actualization and implementation of quality control in nuclear quality research through nuclear reactor research activities, radiation safety, nuclear applications in the medical and industrial fields,

### Nuclear emergency preparedness

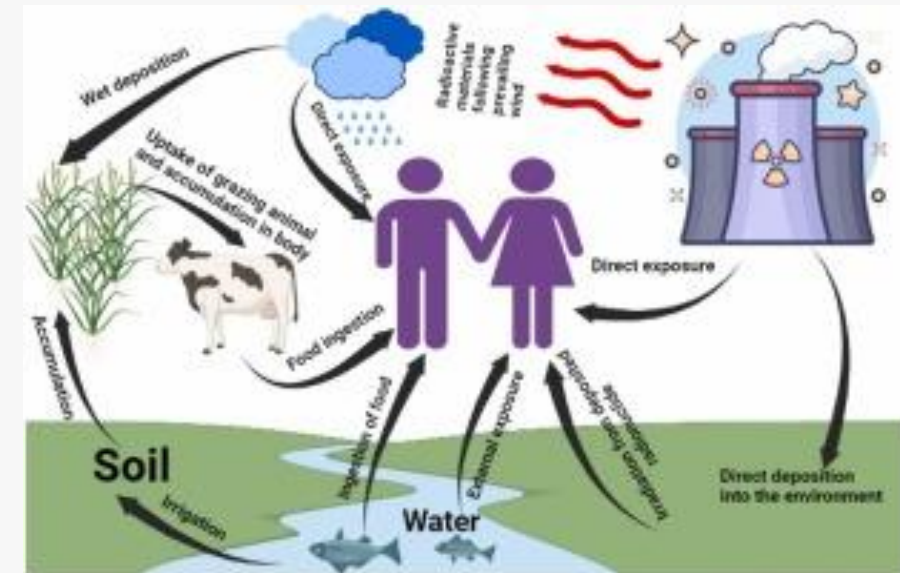
Development of dosimetry methods and procedures for nuclear and radiological emergency mitigation.



# Introduction

- What is Environmental Radiological Risk Assessments?

Environmental radiological risk assessment is a quantitative process that estimates the potential harm to humans and wildlife from radiation exposure due to contaminated sites.



# Environmental Radiological Risk Assessments

- modeling the transport of radionuclides through the environment (air, water, soil),
- estimating doses to people and ecosystems,
- evaluating the associated risks to inform decision-making for remediation and control.



# Key components

- identifying sources,
- modeling transport,
- assessing exposure pathways,
- estimating dose and risk,
- analyzing uncertainties



# Radiological assessment

Radiological assessment is the quantitative process of estimating the consequences to humans resulting from the release of radionuclides to the biosphere.

It is a multidisciplinary subject requiring the expertise of a number of individuals in order to predict source terms, describe environmental transport, calculate internal and external dose, and extrapolate dose to health effects.



# For what?

Facilities and activities needing a radiological environmental impact assessment are those in which radioactive material is produced, processed, used, handled, or stored in such a form and on such a scale that consideration of the possible impact on the public and the environment is required.



# What Facilities need it?

- nuclear installations (including nuclear power plants, research reactors, radioisotope production facilities, source production facilities, spent fuel storage facilities, reprocessing facilities, facilities for the enrichment of uranium, nuclear fuel fabrication facilities, predisposal radioactive waste management facilities, disposal facilities during the operational period, and nuclear fuel cycle-related research and development facilities);
- some mining and raw material processing facilities, such as open pit uranium mines; and
- facilities for the milling or processing of uranium ores.



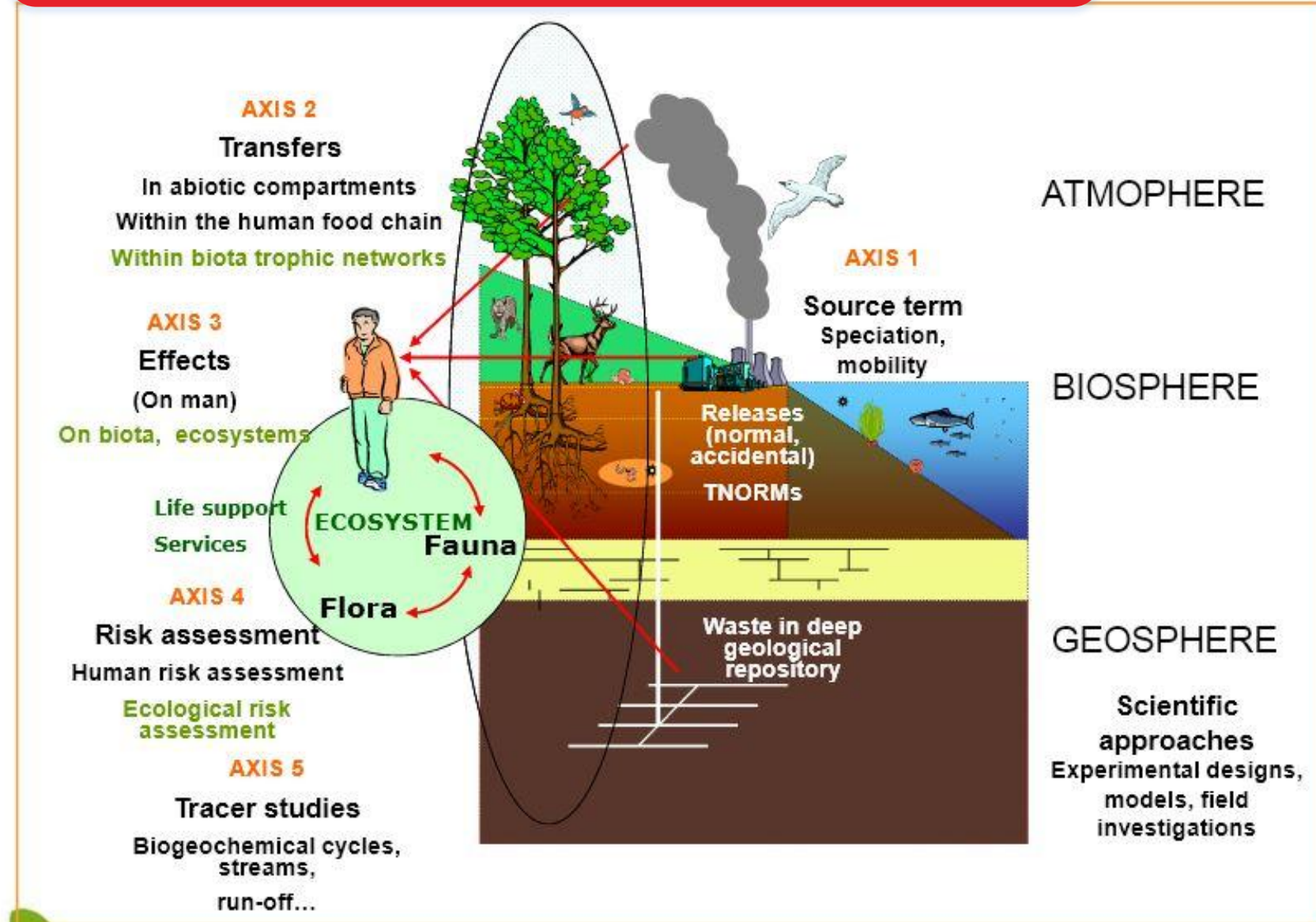
## What activities need it?

the use of unsealed radiation sources for industrial




research and medical purposes




the decommissioning of certain facilities





# TYPES OF RADIATION

**Alpha Rays**  $\alpha$  **2 Protons and 2 Neutrons**  
Ionisation   

**Beta Rays**  $\beta$  **High Energy Electrons**  
Ionisation   

**Gamma Rays**  $\gamma$  **High Energy EM Radiation**  
**X-Rays**  $X$   
Ionisation   

**Neutron Rays**  $n$  **Free Neutrons**  
Ionisation   



**How Penetrating?**

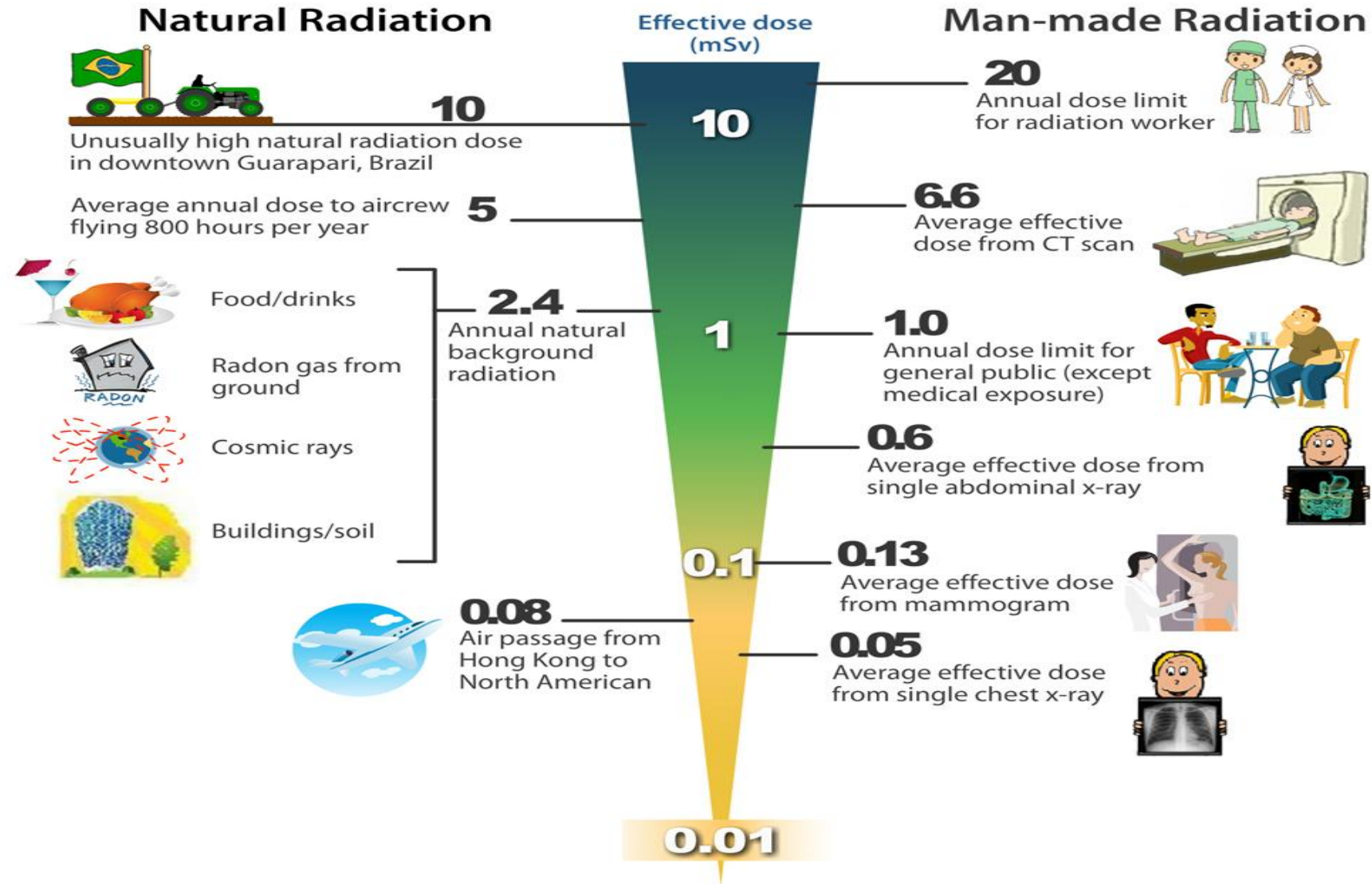
**Paper**  
Stops  $\alpha$  rays

**Thin Aluminum**  
Stops  $\beta$  rays

**Thick Lead**  
Stops  $\gamma$ , X rays

**Water or Concrete**  
Stops neutron rays

# Radiation in Daily Life



# RADIATION EFFECTS

Measurements in millisieverts (mSv). Exposure is cumulative.

- **Potentially fatal radiation sickness. Much higher risk of cancer later in life.**

**10,000 mSv:** Fatal within days.

**5,000 mSv:** Would kill half of those exposed within one month.

**2,000 mSv:** Acute radiation sickness.

- **No immediate symptoms. Increased risk of serious illness later in life.**

**1,000 mSv:** 5% higher chance of cancer.

**400 mSv:** Highest hourly radiation recorded at Fukushima. Four hour exposure would cause radiation sickness.

**100 mSv:** Level at which higher risk of cancer is first noticeable

- **No symptoms. No detectable increased risk of cancer.**

**20 mSv:** Yearly limit for nuclear workers.

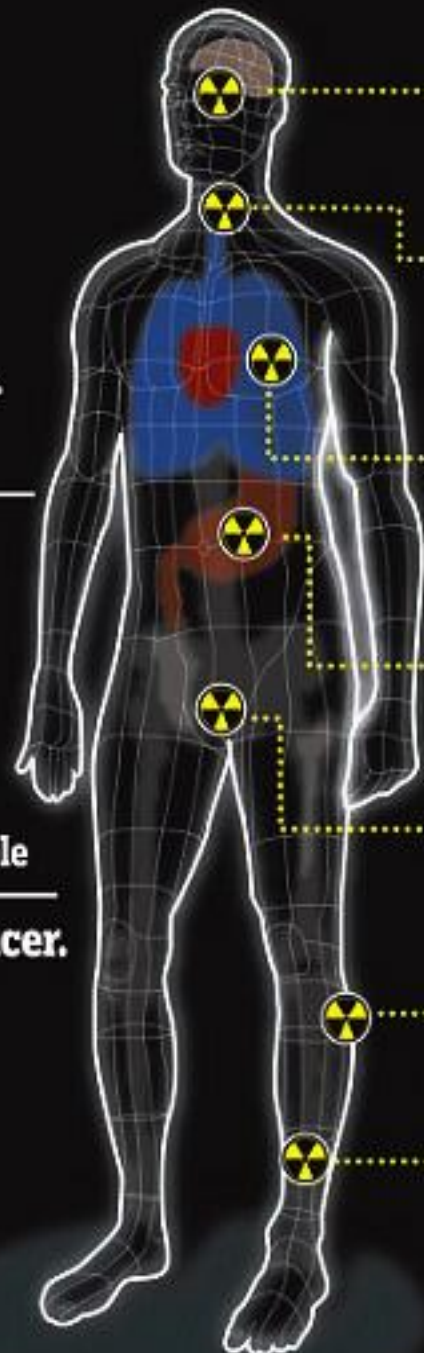
**10 mSv:** Average dose from a full body CT scan

**9 mSv:** Yearly dose for airline crews.

**3 mSv:** Single mammogram

**2 mSv:** Average yearly background radiation dose in UK

**0.1 mSv:** Single chest x-ray



**EYES** High doses can trigger cataracts months later.

**THYROID** Hormone glands vulnerable to cancer. Radioactive iodine builds up in thyroid. Children most at risk.

**LUNGS** Vulnerable to DNA damage when radioactive material is breathed in.

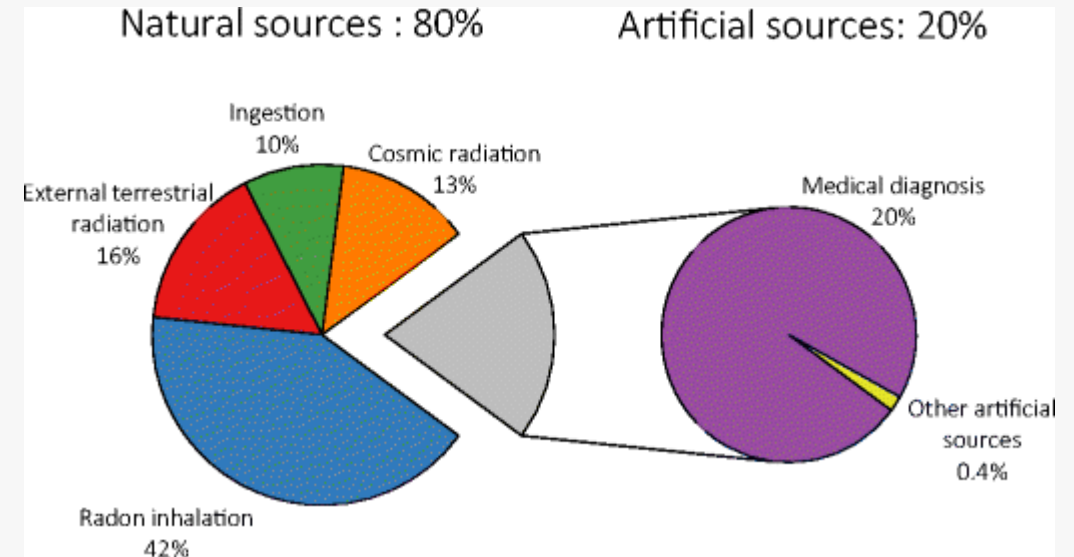
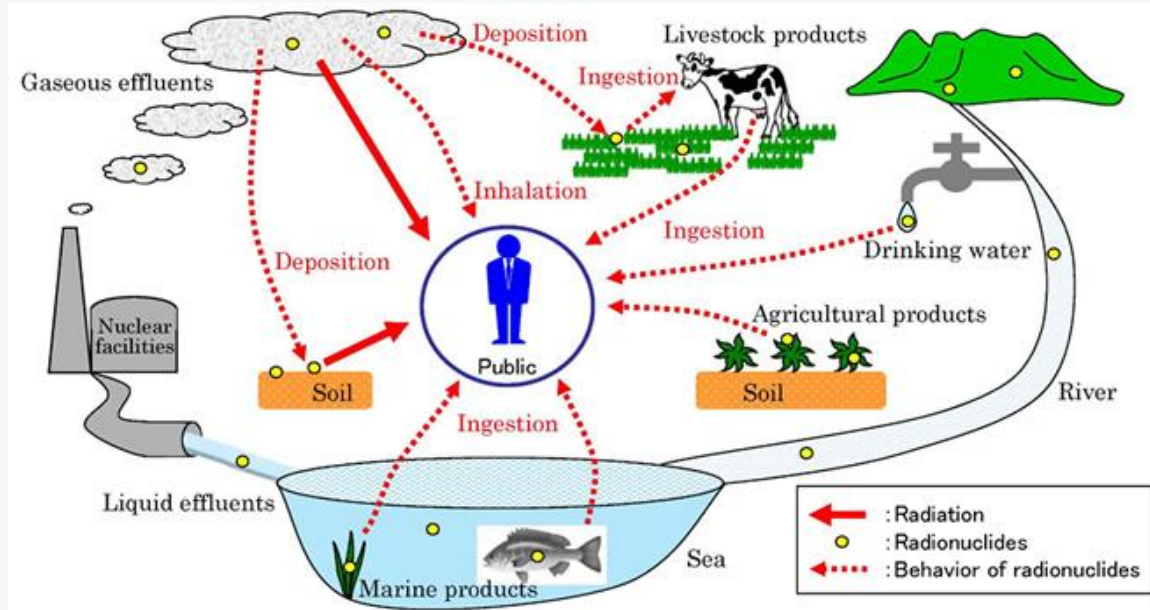
**STOMACH** Vulnerable if radioactive material is swallowed.

**REPRODUCTIVE ORGANS** High doses can cause sterility.

**SKIN** High doses cause redness and burning.

**BONE MARROW** Produces red and white blood cells. Radiation can lead to leukaemia and other immune system diseases.

# Radiation Around Us



- Radiation is an inherent part of human daily life.
- Natural radiation contributes to the human radiation dose.
- Some places around the world exhibit background radiation anomalies, with dose values exceeding the global average of 3 mSv per year.

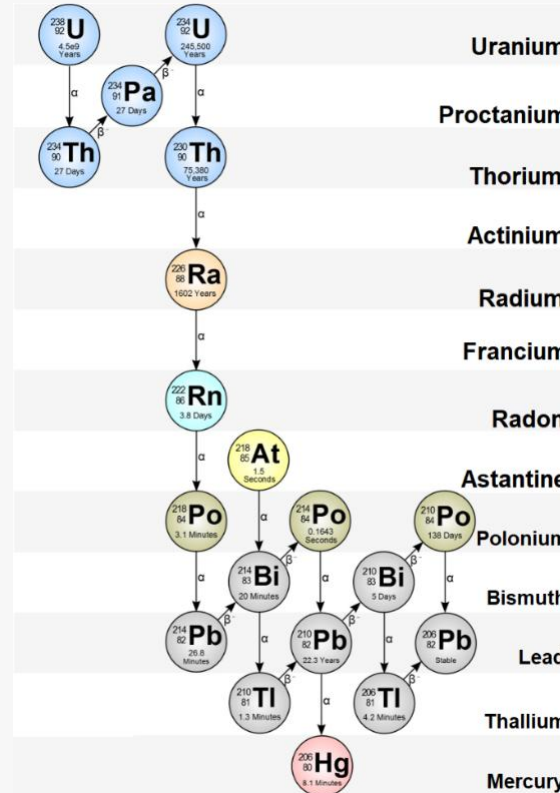
a. [https://www.jaea.go.jp/english/04/ntokai/houkan/houkan\\_02.html](https://www.jaea.go.jp/english/04/ntokai/houkan/houkan_02.html)

b. UNSCEAR. (2010). 2008 Report to the General Assembly: Annex B Exposures of the Public and Workers from Various Sources of Radiation. In United Nations: Vol. I.

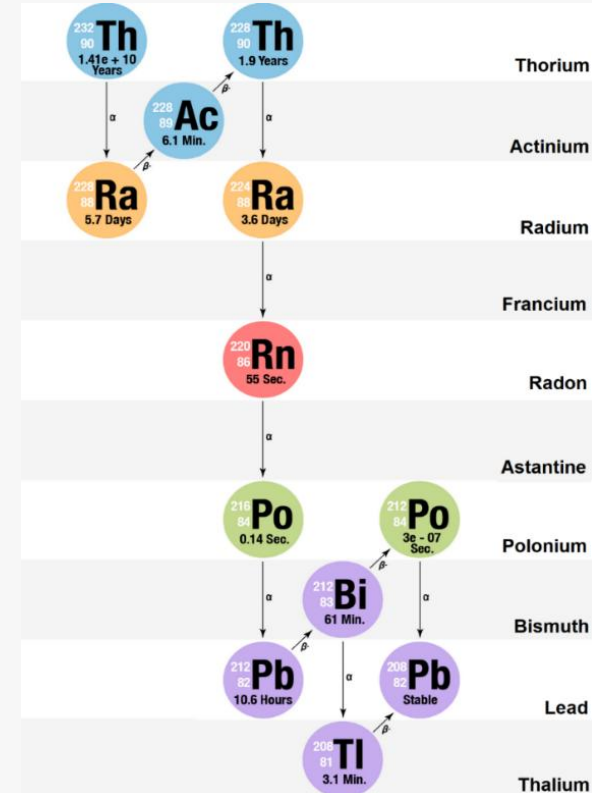


# Radionuclide in The Environment

Cosmogenic Radionuclide	Primordial	Artificial
$^{14}\text{C}$ , $^{35}\text{S}$ , $^{38}\text{S}$ , $^7\text{Be}$ , $^{10}\text{Be}$ , $^3\text{H}$ , $^{34}\text{Cl}$ , $^{36}\text{Cl}$ , $^{38}\text{Cl}$ , $^{32}\text{P}$ , $^{22}\text{Na}$ , etc	$^{238}\text{U}$ , $^{234}\text{U}$ , $^{232}\text{Th}$ , $^{230}\text{Th}$ , $^{228}\text{Ra}$ , $^{226}\text{Ra}$ , $^{222}\text{Rn}$ , $^{220}\text{Rn}$ , $^{210}\text{Pb}$ , $^{210}\text{Po}$ , etc	$^{241}\text{Pu}$ , $^{239}\text{Pu}$ , $^{241}\text{Am}$ , $^{243}\text{Am}$ , $^{131}\text{I}$ , $^{129}\text{I}$ , $^{137}\text{Cs}$ , $^{134}\text{Cs}$ , $^{90}\text{Sr}$ , $^{89}\text{Sr}$ , etc



Uranium decay series,



Thorium decay series



# Risk vs dose Concept

Risk assessment is the process of identifying, analyzing, and evaluating the likelihood and impact of events that threaten the achievement of objectives. Meanwhile, dose assessment is a subset of risk assessment (specifically in toxicology and health) that measures the relationship between the magnitude of exposure to a substance and its resulting health effects, which is then used to determine a safe exposure level.

## Risk

**Purpose:** Assess the likelihood and impact of events that could threaten the achievement of an organization's or project's objectives.

**Process:** Involves the identification, analysis (determining likelihood and severity), and evaluation of risks.

## Dose

**Purpose:** Understand how the dose of a substance (such as a chemical or radiation) correlates with its health impacts.

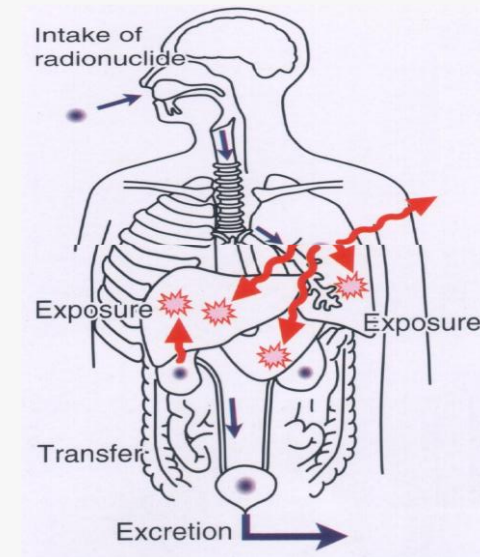
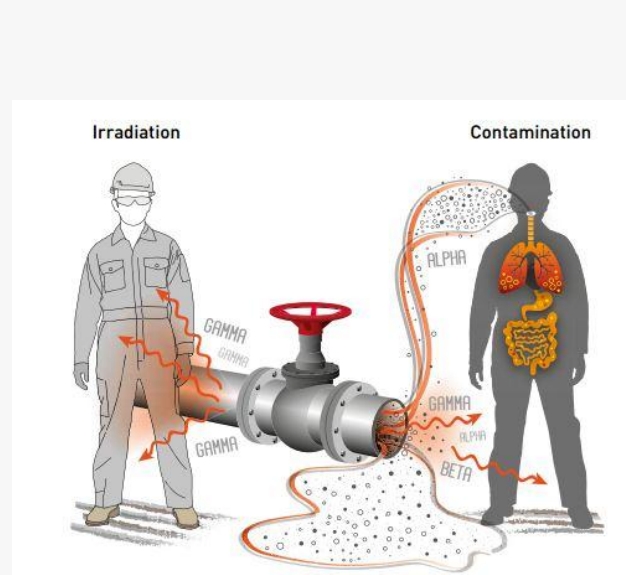
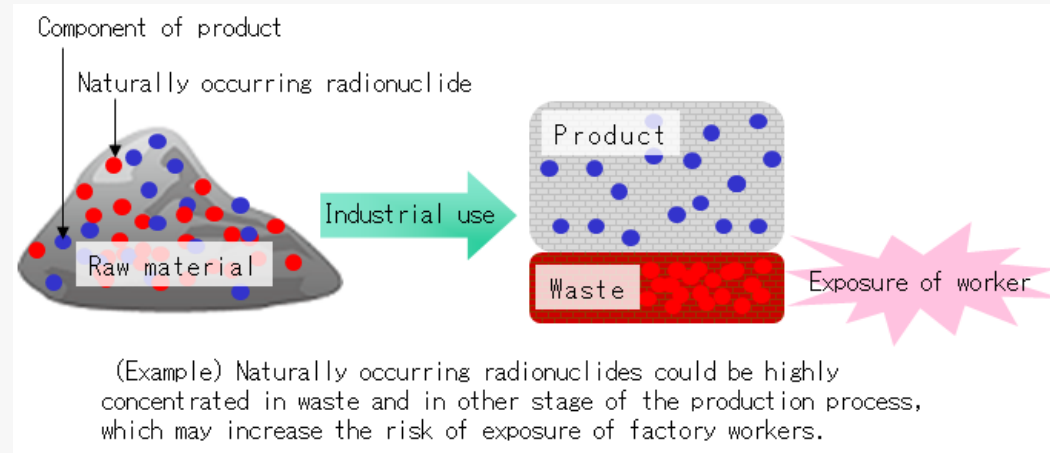
**Process:** Study the dose-response relationship to identify safe exposure levels, such as a "reference dose" or daily exposure tolerance.



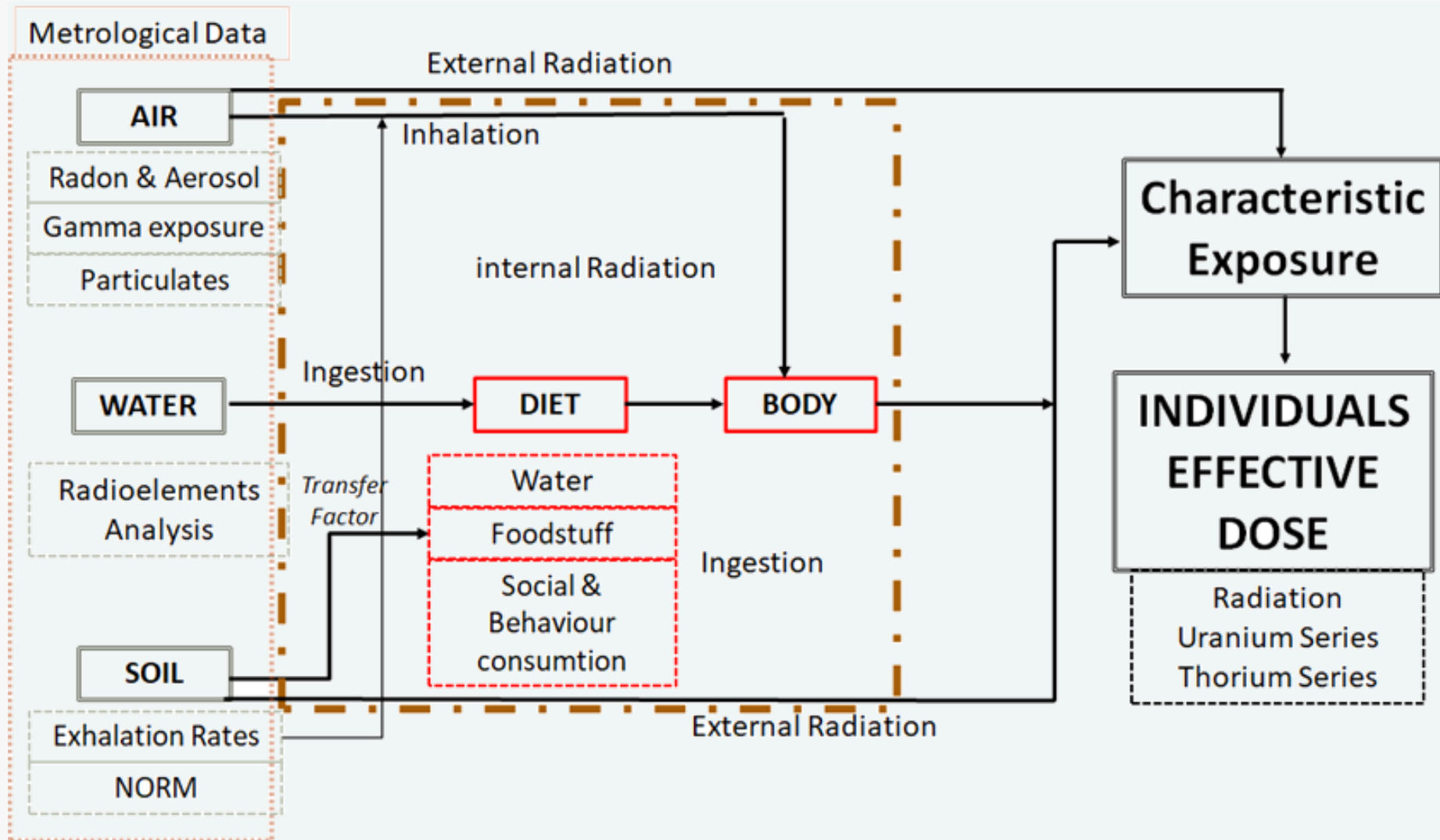
# Source Identification of TENORM

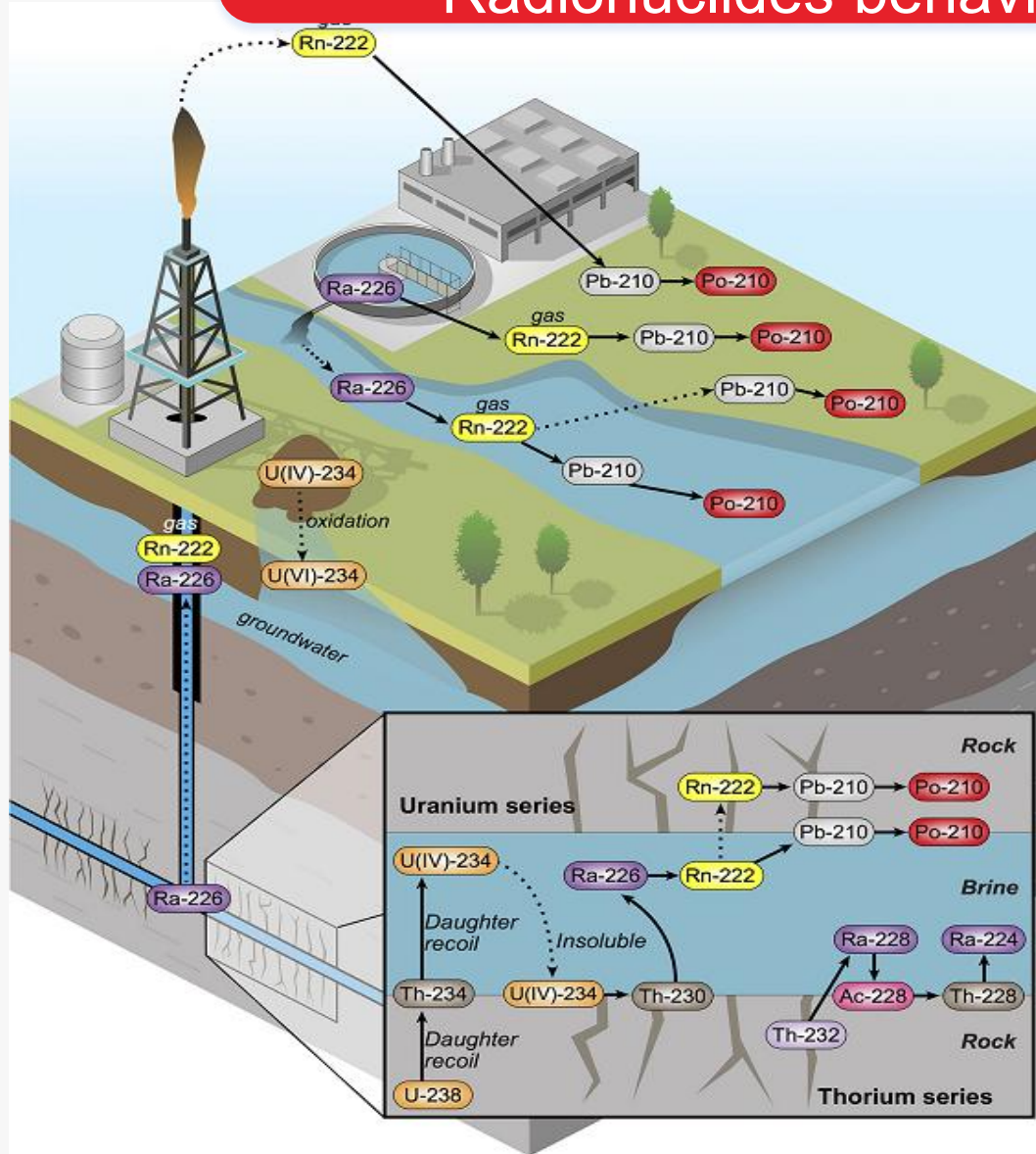
**External exposure**  
(radiation  $\beta$ ,  $\gamma$ )  
operational

**Internal** (inhalation,  
ingestion, absorption  
of TENORM dust and  
radon/thoron gas) →  
maintenance /  
decomisioning



# Source Identification: example from mining industries



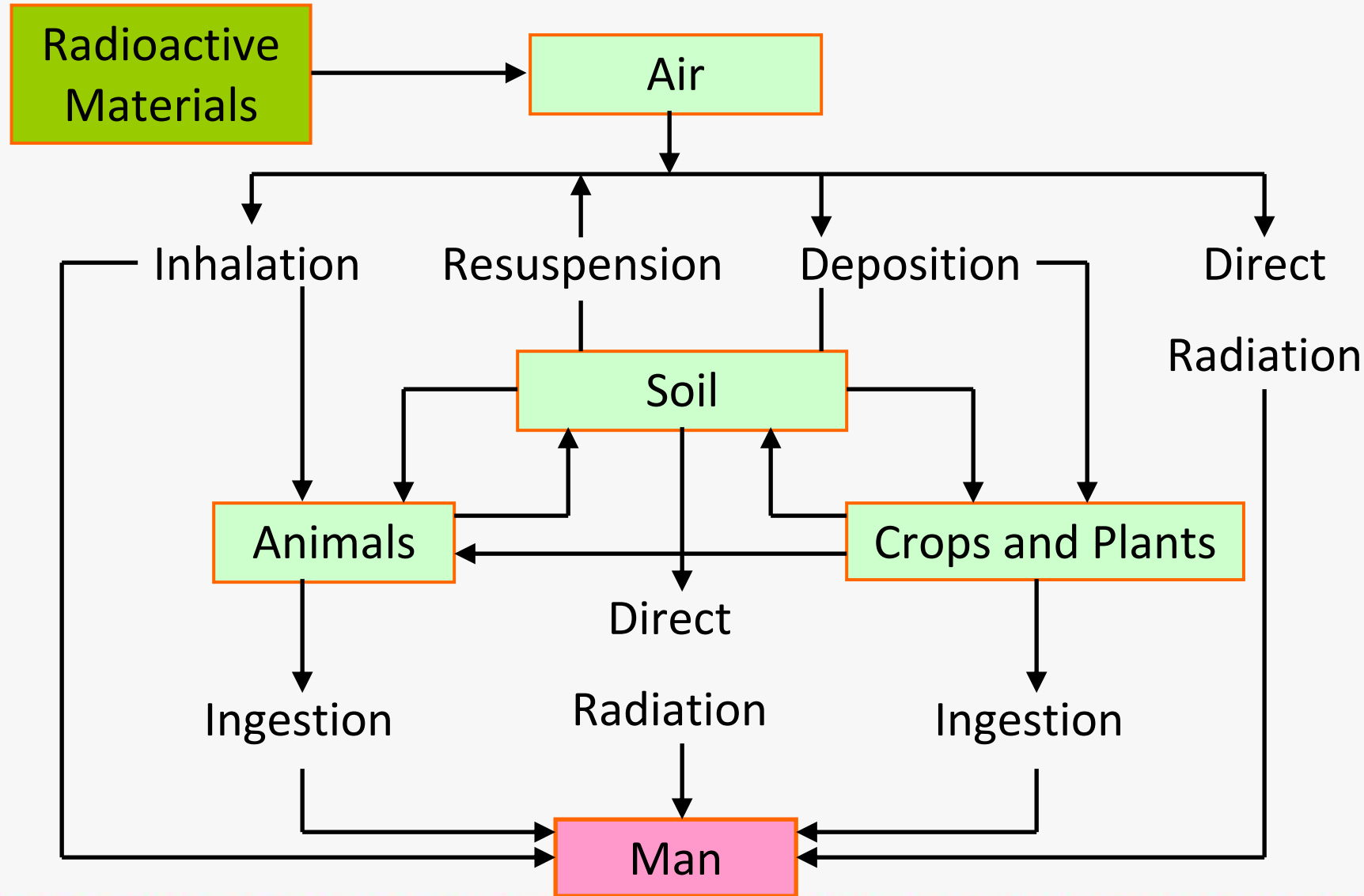


## Radionuclides TE/NORM

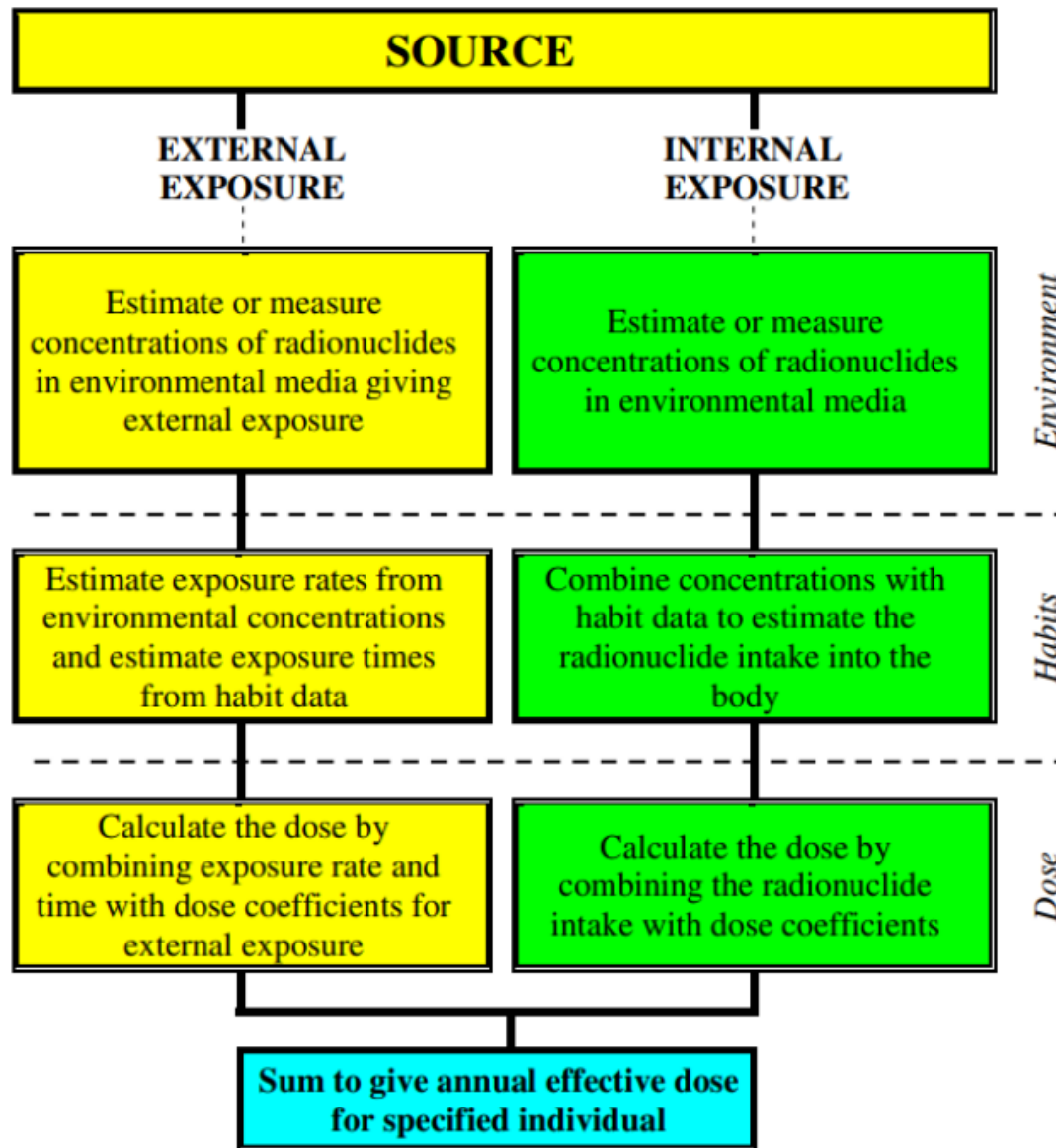
- U-238
- Th-232
- Ra-228
- Ra-226
- Rn-222
- Rn-220
- Pb-210
- Po-210
- K-40



# The Simple pathway of Radionuclides



# Dose Assessment Process



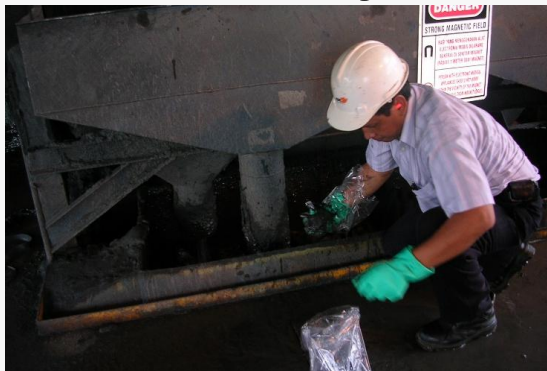
- Stage 1 : The source of the exposure should be Characterised
- Stage 2 : environmental concentrations at various locations are obtained by measurements, by modelling the dispersion, deposition, and transport of radionuclides
- Stage 3 : combination of concentrations of radionuclides in environmental media with habit data and other information defined by exposure scenarios.
- Stage 4 : application of dose coefficients and related quantities
- Stage 5 : Summation of the contributions from internal and external exposure results in a total annual dose



# NORM Survey Activities



**Sampling NORM in Oil and Gas Industry, On-Shore**



**Sampling of Bottom Ash, Coal Power Plant**



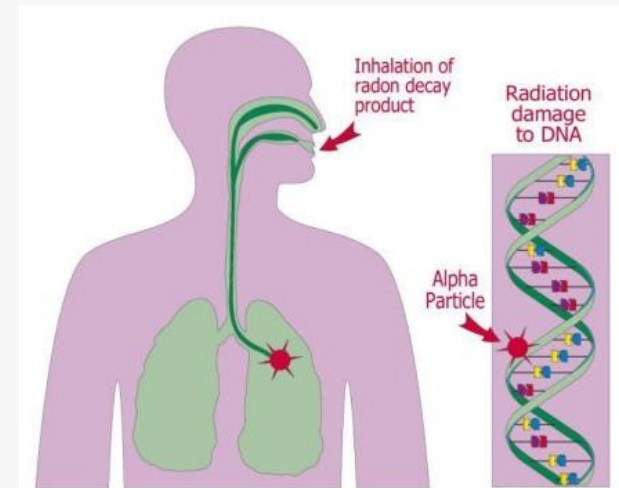
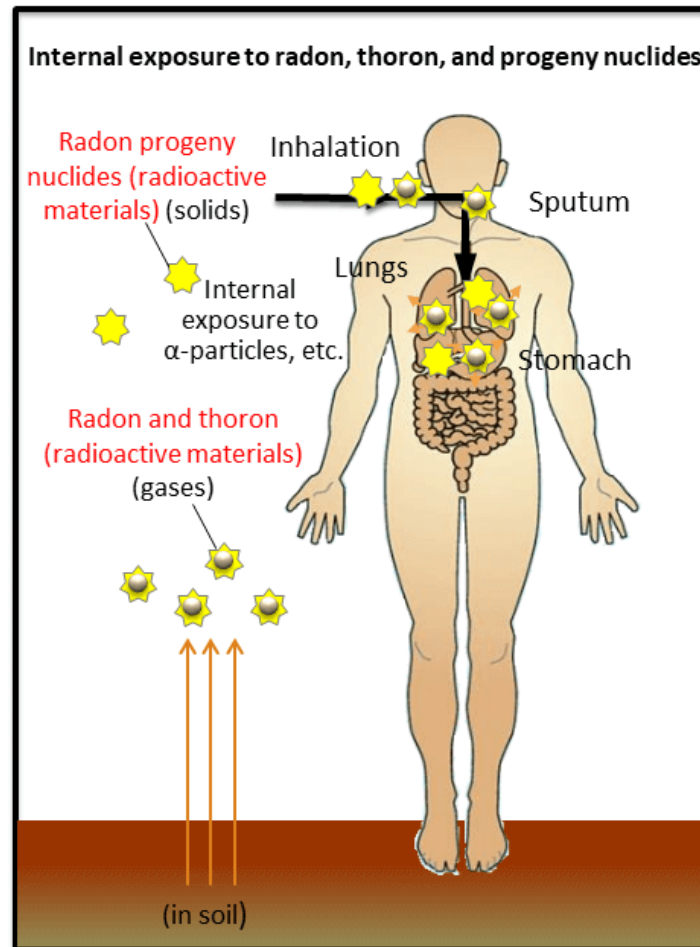
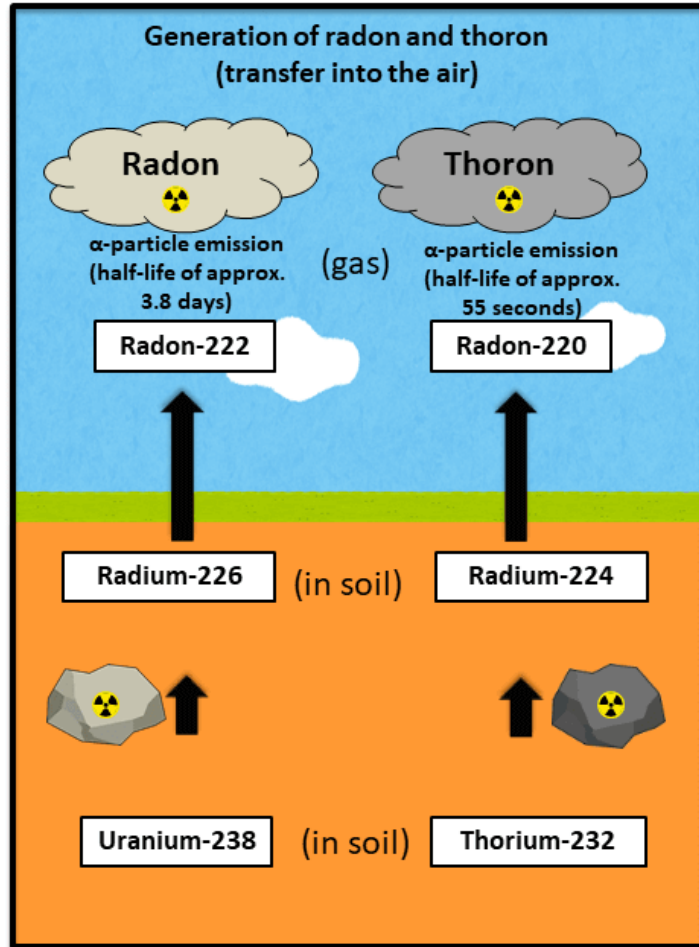
**Monazite at tin smelter**



**Installing radon, thoron, EETC/EERC monitor at tin**

Radiation around Us

## Internal Exposure to Radon and Thoron through Inhalation



**Radon** is the **#1** environmental cause of cancer deaths and the **#2** cause of lung cancer deaths.

† AMERICAN LUNG ASSOCIATION.

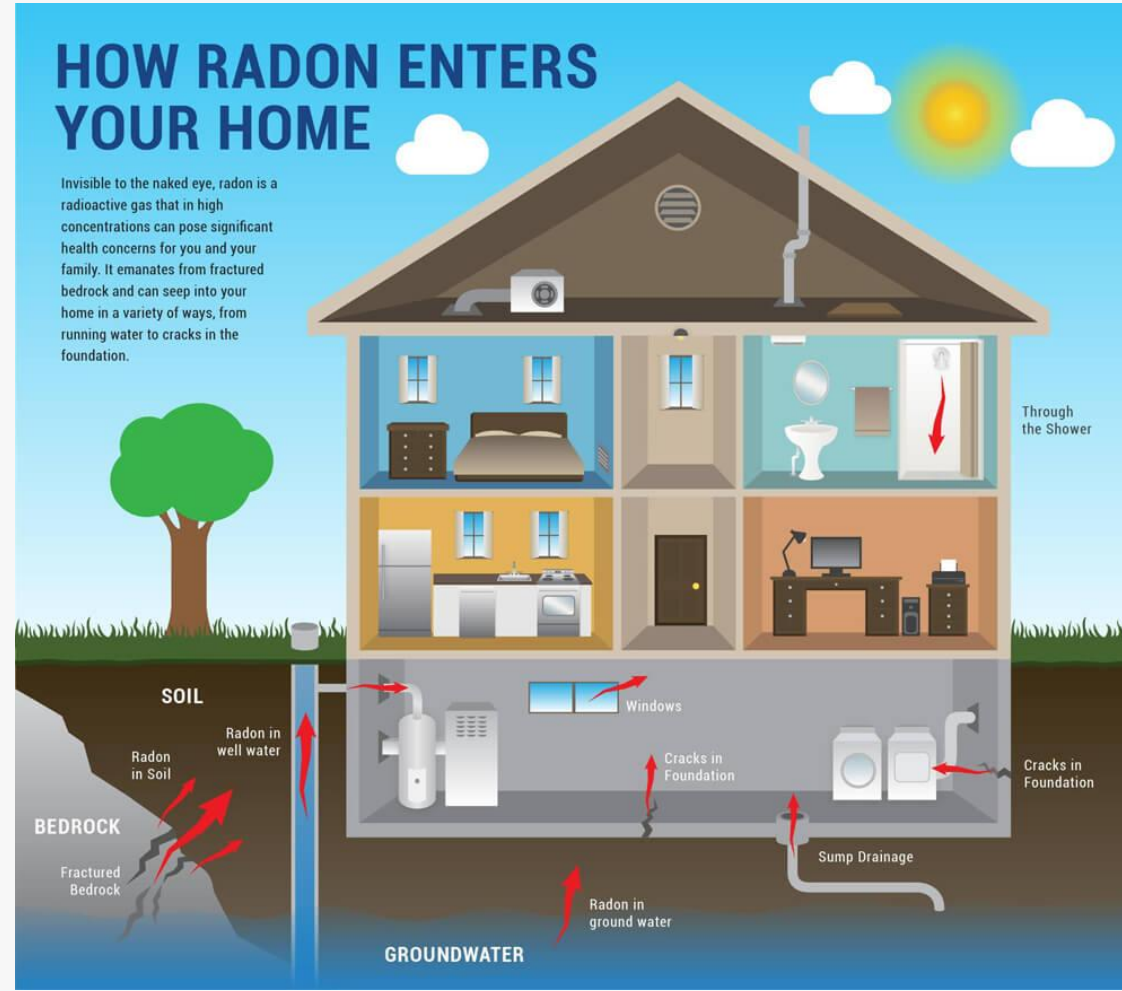
a. <https://www.env.go.jp/en/chemi/rhm/basic-info/2018/02-05-08.html>

b. <https://aaqr.org/articles/aaqr-20-01-0a-0037>

c. <https://www.lung.org/clean-air/indoor-air/indoor-air-pollutants/radon>

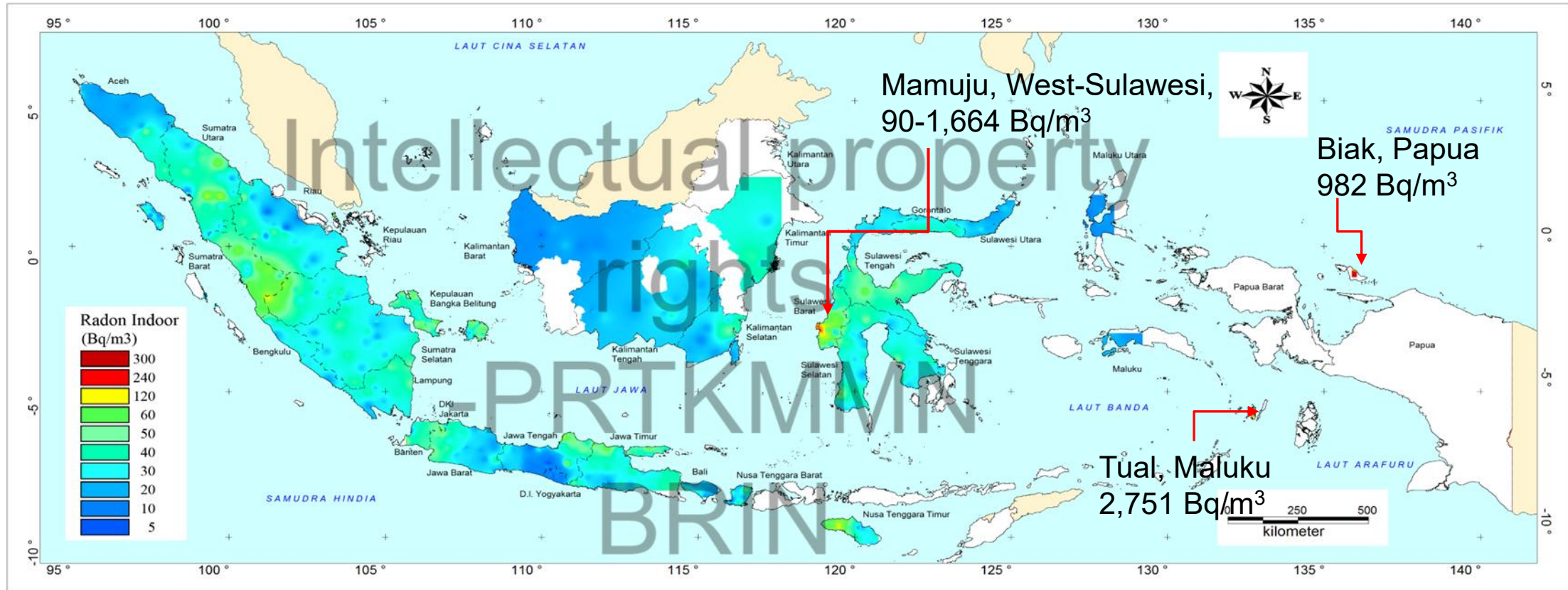


# Distribution of Natural Radionuclides in The Environment Scheme



<https://www.cdc.gov/radon/radon-facts-ld.html>

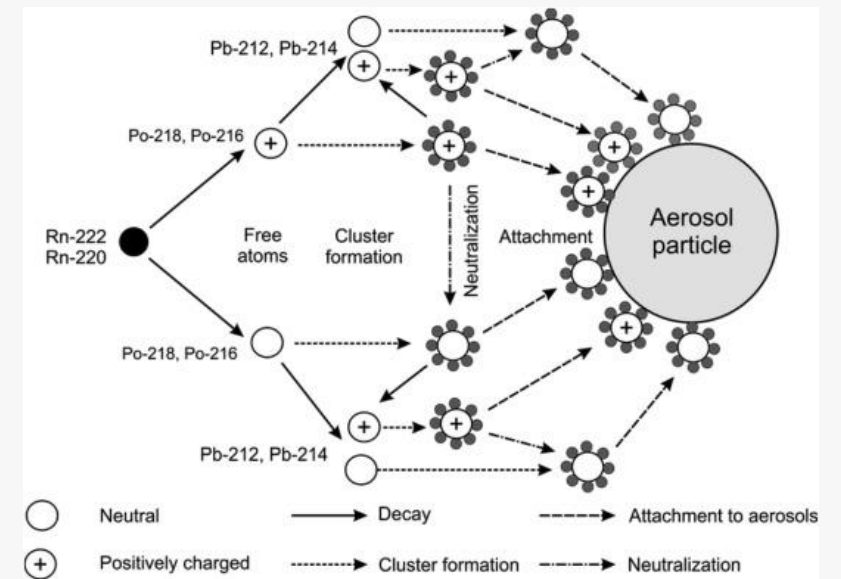
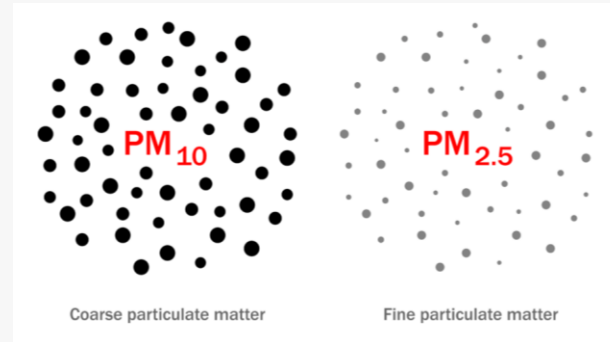
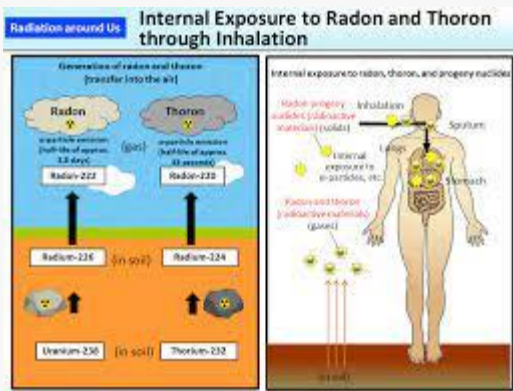




Radon indoor	Range, Bq/m <sup>3</sup>	Geometric mean, Bq/m <sup>3</sup>	Highest Area
Activity concentration	8 to 2751	32	Mamuju, Biak, Tual



# Studies on Noble Gas and Particulate Interaction



# Dose Calculation

$$E_T = H_E + \sum_j e(ing)_{j,ing} \cdot I_{j,ing} + \sum_j e(inh)_{j,inh} \cdot I_{j,inh}$$

external dose      Internal dose from Ingestion      Internal dose from Inhalation

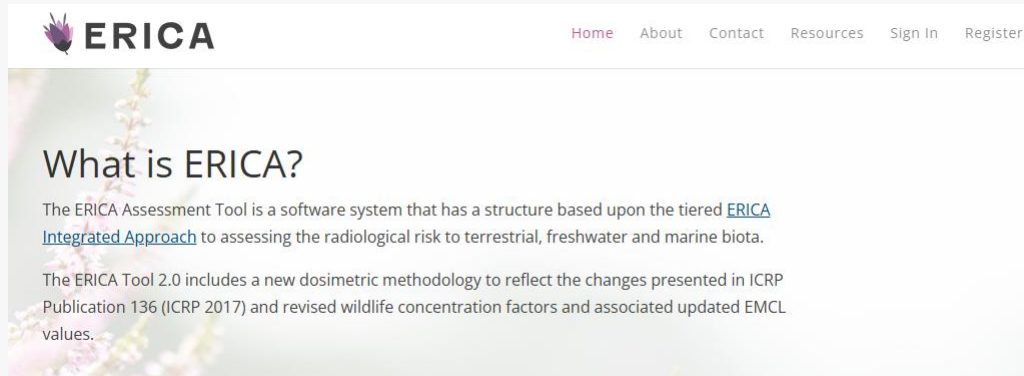
- E is the effective dose (Sv), H is the dose of external exposure (Sv),  $e(g)_{j,ing}$  is the coefficient of ingestion dose (Sv Bq<sup>-1</sup>) per unit input through digestion for radionuclide (j) by age group (g),  $e(g)_{j,ing}$  the coefficient of inhalation dose (Sv Bq<sup>-1</sup>) per unit of respiratory input for radionuclides (j) by the age group (g),  $I_{j,ing}$   $I_{j,inh}$  is the ingestion and inhalation intake (Bq)
- To calculate Ingestion intake ( $I_{j,ing}$ ) using data from BPS 2014 was used where the rice, meat, and vegetable+fruit daily consumption is 270.4, 64.6 and 36.8 gram with one year equaling 365 days. The daily consumption of drinking water based on the questionnaire survey was around 1.6 L d<sup>-1</sup> (WHO reference is 2 L d<sup>-1</sup>), the dose conversion factor <sup>226</sup>Ra for adults is 2.8 × 10<sup>-7</sup> Sv Bq<sup>-1</sup>, for <sup>238</sup>U 4.5 × 10<sup>-8</sup> Sv Bq<sup>-1</sup> and 1.2 × 10<sup>-6</sup> Sv Bq<sup>-1</sup> for <sup>232</sup>Th
- To inhalation contributor factor ( $I_{j, inh}$ ) using new dose conversion factor (ICRP 137) for radon is 17×10<sup>-6</sup> mSv (Bq h m<sup>-3</sup>)<sup>-1</sup>, the dose conversion factor for thoron is 1.07×10<sup>-4</sup> mSv (Bq h m<sup>-3</sup>)<sup>-1</sup>, 7000 h for occupancy factor in dwellings

Source : UNSCEAR, 2010



# Modelling Tools

## ERICA

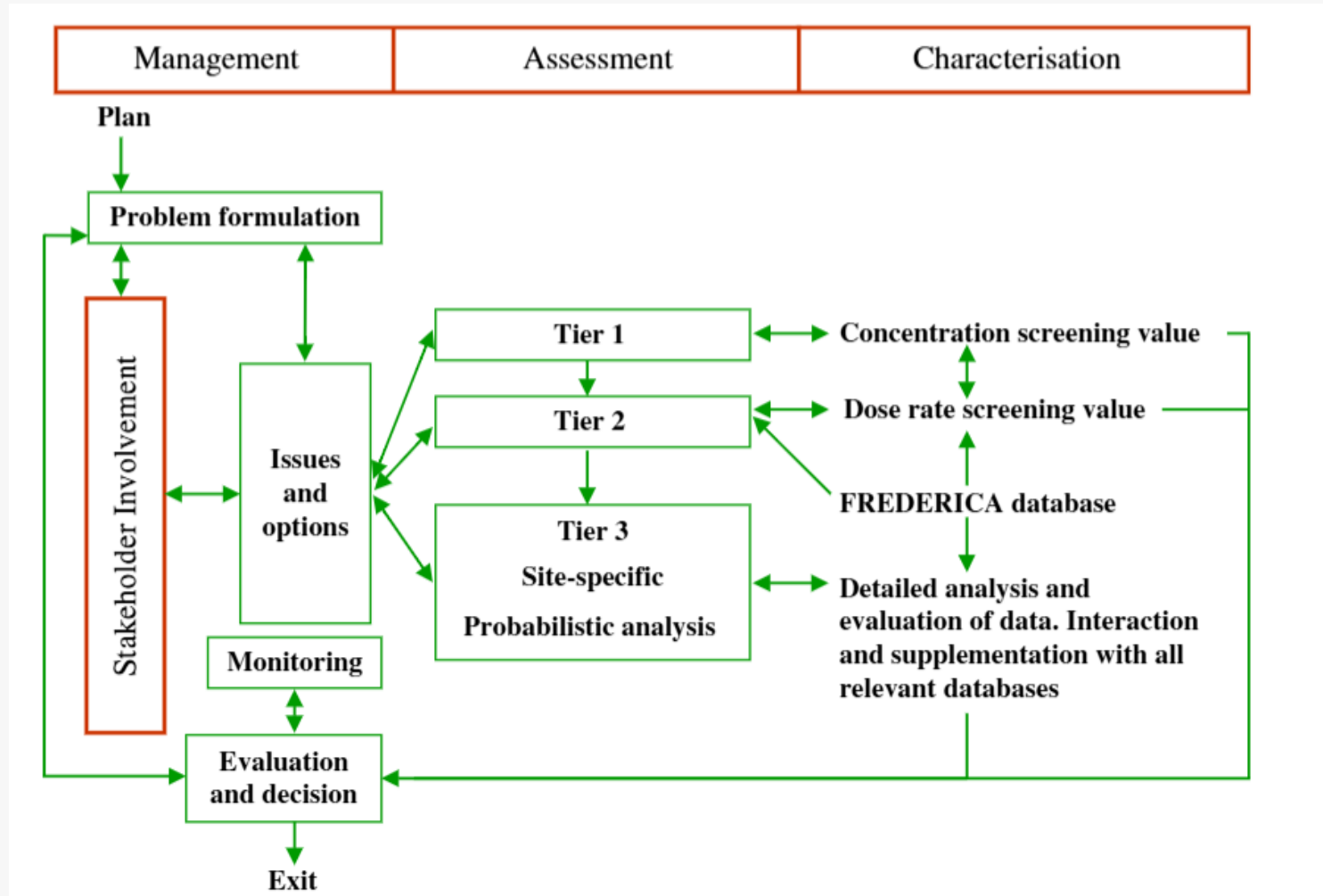


The screenshot shows the ERICA website header with navigation links: Home, About, Contact, Resources, Sign In, Register. The main content area features the heading "What is ERICA?" followed by two paragraphs of text. The first paragraph states: "The ERICA Assessment Tool is a software system that has a structure based upon the tiered [ERICA Integrated Approach](#) to assessing the radiological risk to terrestrial, freshwater and marine biota." The second paragraph states: "The ERICA Tool 2.0 includes a new dosimetric methodology to reflect the changes presented in ICRP Publication 136 (ICRP 2017) and revised wildlife concentration factors and associated updated EMCL values."

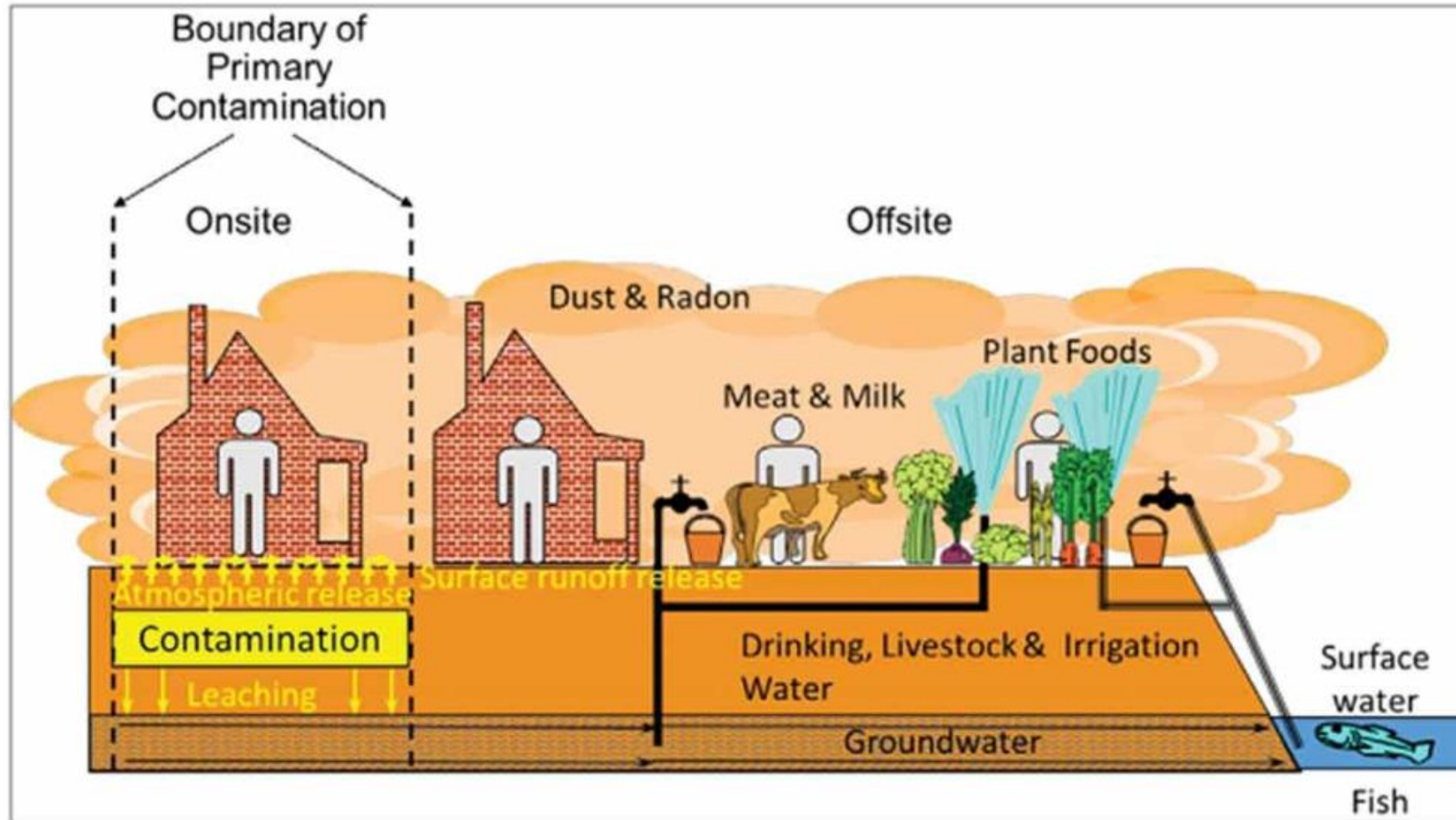
## RESRAD



# ERICA



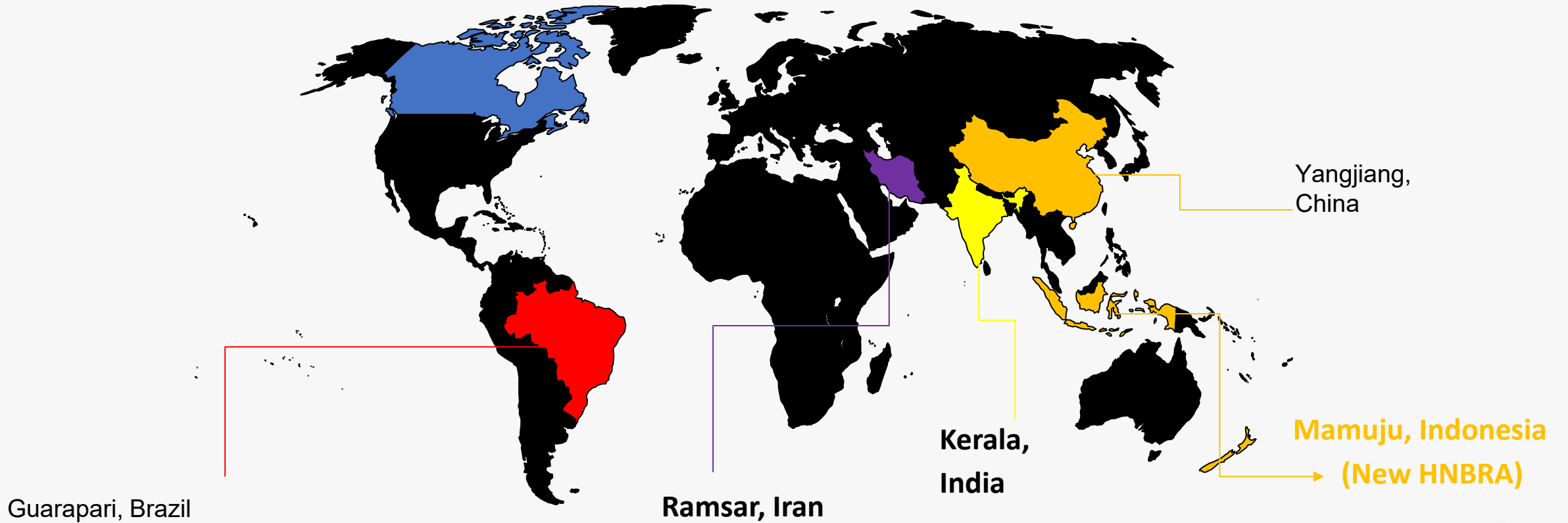
# RESRAD



# Study case : Comprehensive dose assessments in HNBRA Mamuju



# The high natural background radiation area in the world



# Estimation of annual effective dose

$$E_T = H_E + \sum_j e(ing)_{j,ing} \cdot I_{j,ing} + \sum_j e(inh)_{j,inh} \cdot I_{j,inh}$$

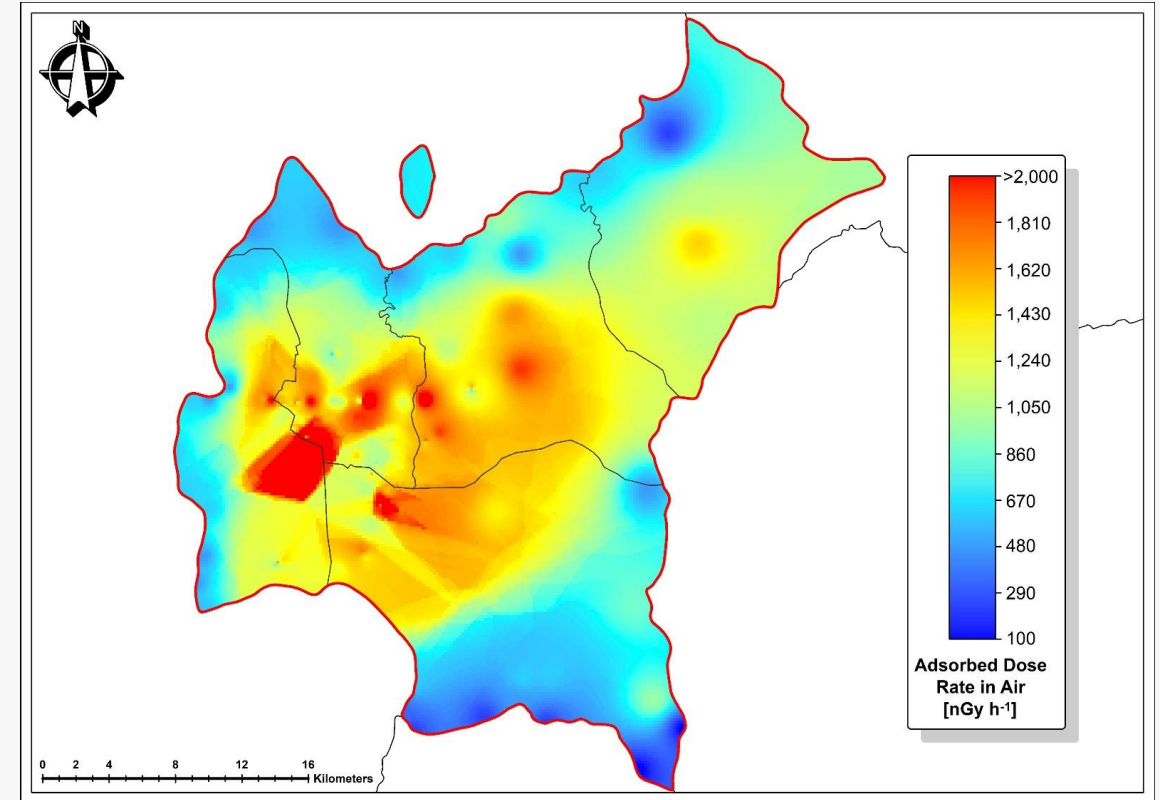
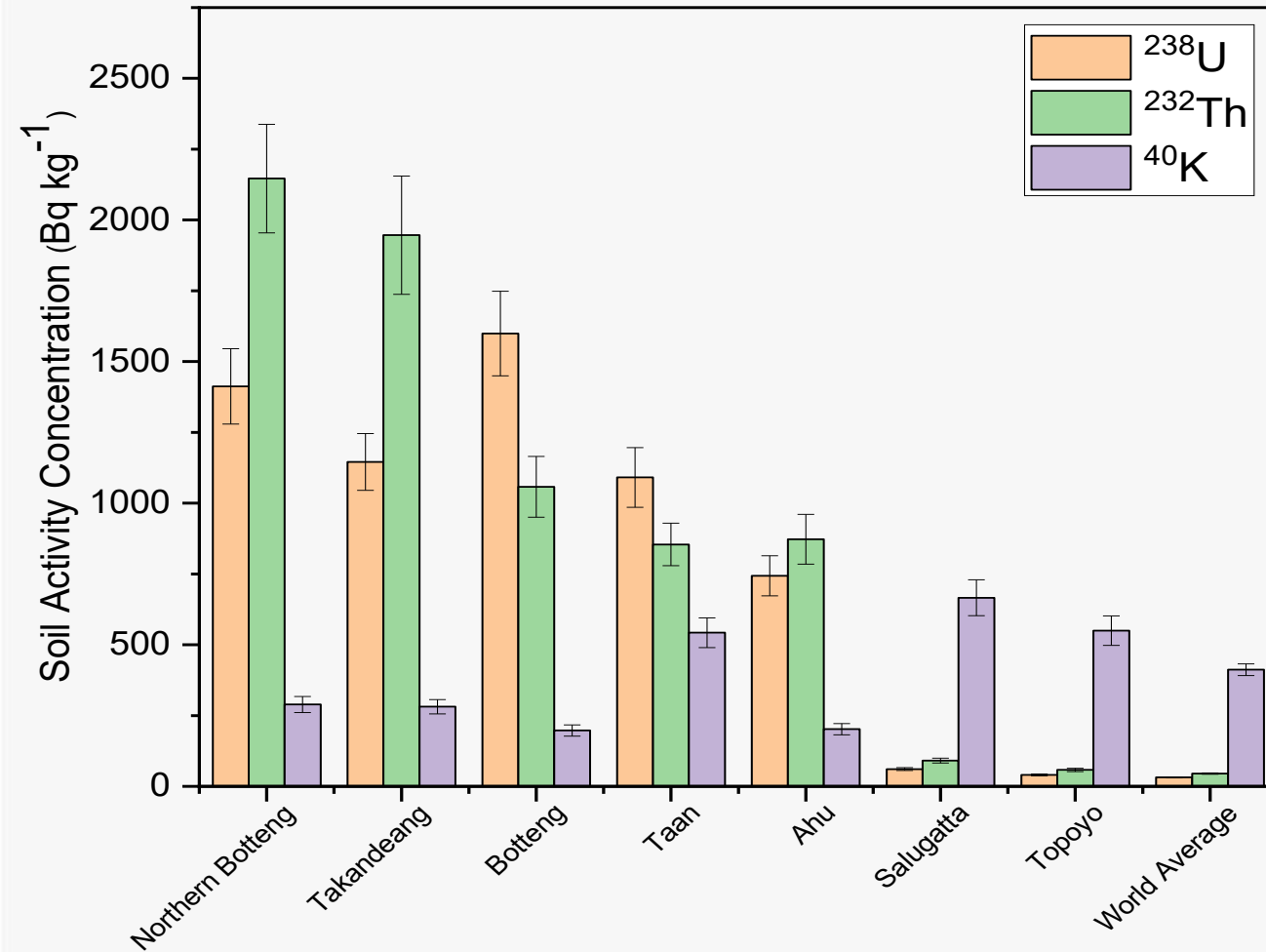
external dose
Internal dose from Ingestion
Internal dose from Inhalation

- E is the effective dose (Sv), H is the dose of external exposure (Sv),  $e(g)_{j,ing}$  is the coefficient of ingestion dose (Sv Bq<sup>-1</sup>) per unit input through digestion for radionuclide (j) by age group (g),  $e(g)_{j,inh}$  the coefficient of inhalation dose (Sv Bq<sup>-1</sup>) per unit of respiratory input for radionuclides (j) by the age group (g),  $I_{j,ing}$   $I_{j,inh}$  is the ingestion and inhalation intake (Bq)
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Source : UNSCEAR, 2010



# Radiation Exposure Characteristic

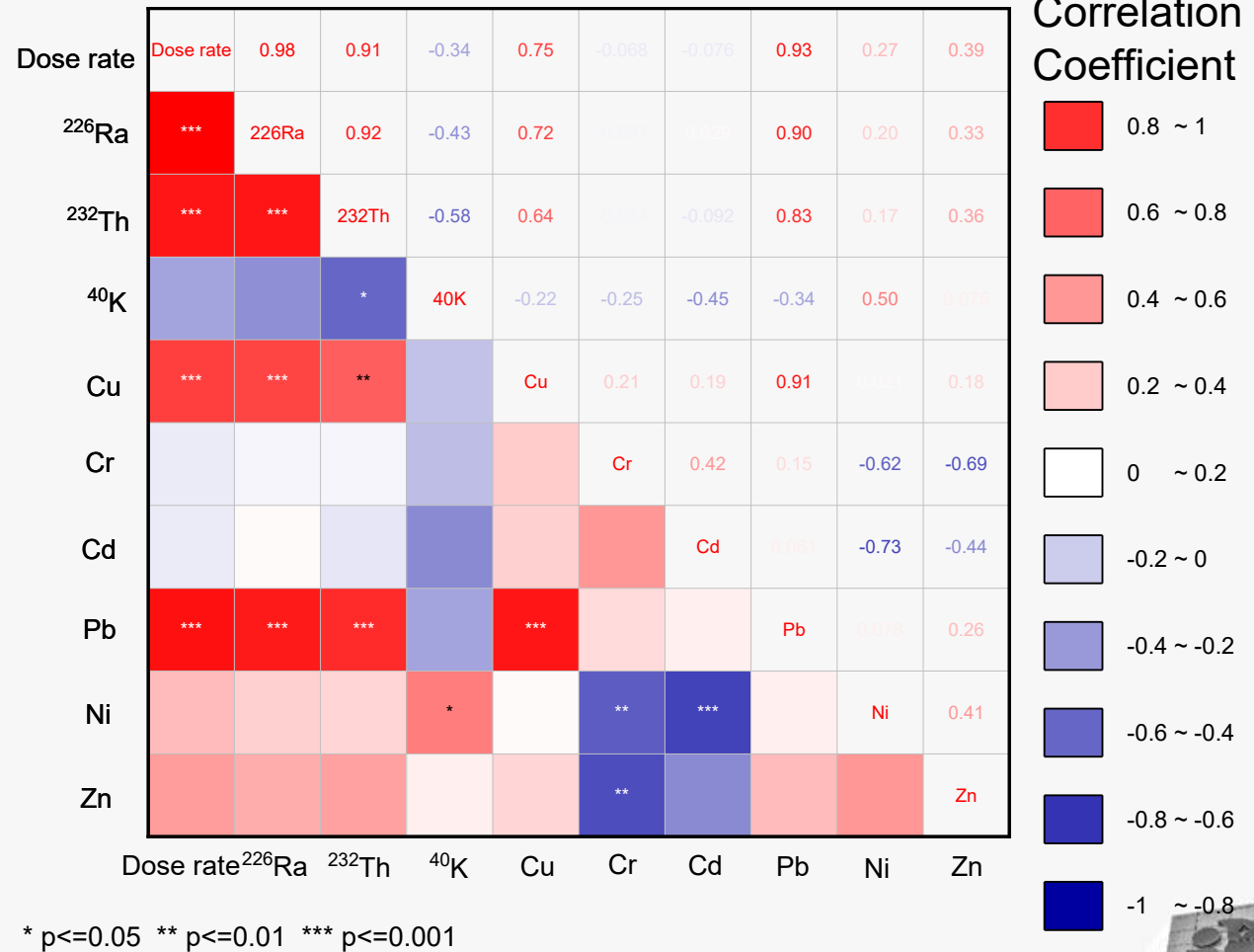


Nugraha, E.D., et al. Comprehensive exposure assessments from the viewpoint of health in a unique high natural background radiation area, Mamuju, Indonesia. *Sci Rep* 11, 14578 (2021). <https://doi.org/10.1038/s41598-021-93983-2>



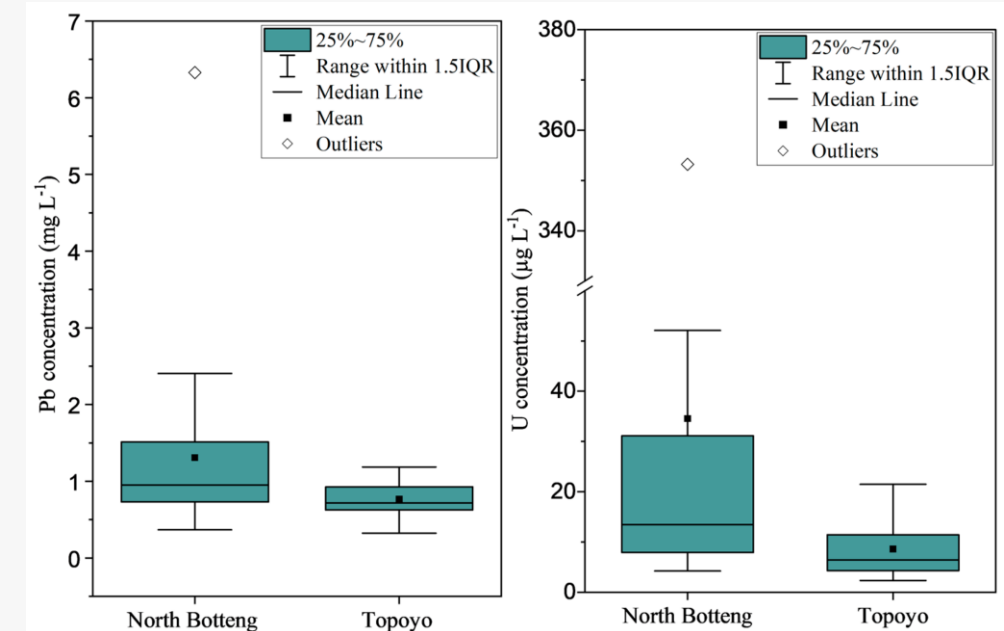
# Heavy Metals and Radioactivity in the Soil in Mamuju

A strong positive correlation was found between  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ , ambient dose equivalent rate, Cu and Pb



**Table 1.** Comparison of Pb concentrations in urine across different studies.

Location	Urine Sample	N	Pb Concentration (mg L <sup>-1</sup> )	Reference
Tanzania industrial area	School children	240	Mean: 0.55 ± 0.46 Max: 1.92	[32]
Ghana mining area	Mine workers	22	Mean: 0.29 ± 0.08	[33]
Kasanda, Zambia mining area	Children near Pb-zinc mine	88	Range: 0.002–2.914 Mean: 0.207	[34]
Makululu, Zambia mining area	Children near Pb-zinc mine	94	Range: 0.003–1.113 Mean: 0.081	[34]
Mamuju	HNBRA residents	22	Mean: 1.31 ± 1.22 Max: 6.33	The present study
Topoyo	Residents	21	Mean: 0.77 ± 0.23 Max: 1.19	The present study

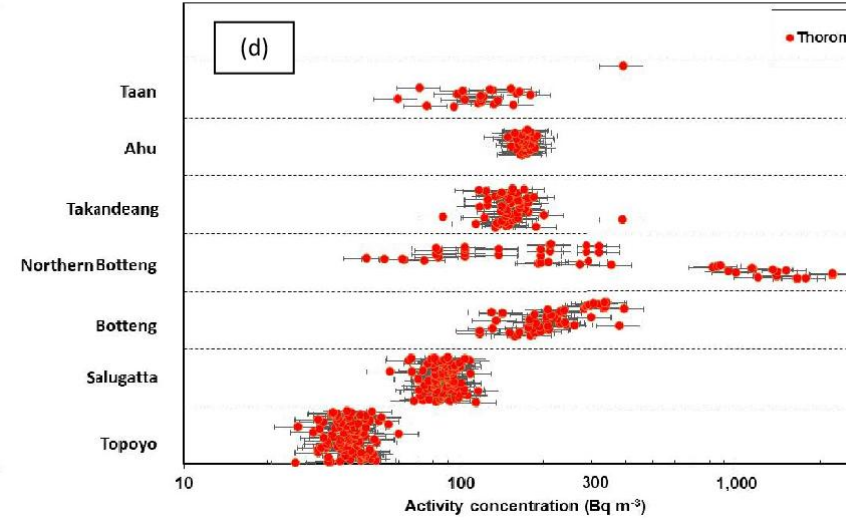
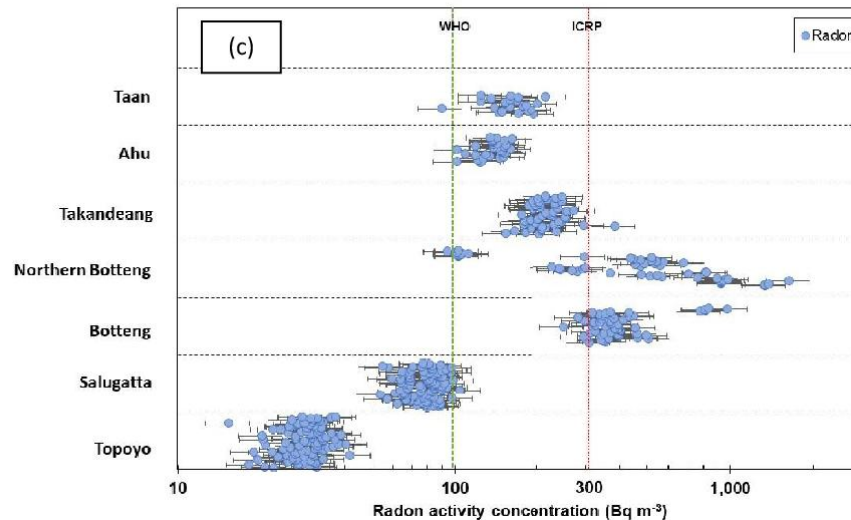
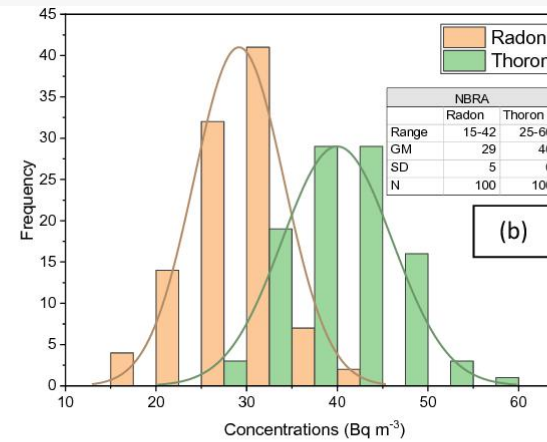
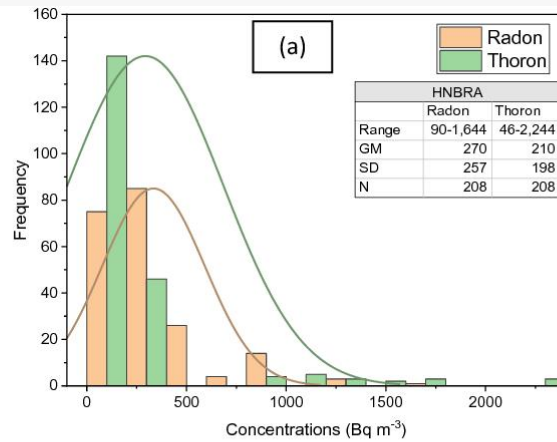


**Table 2.** Comparison of uranium (U) concentrations in urine samples across different studies.

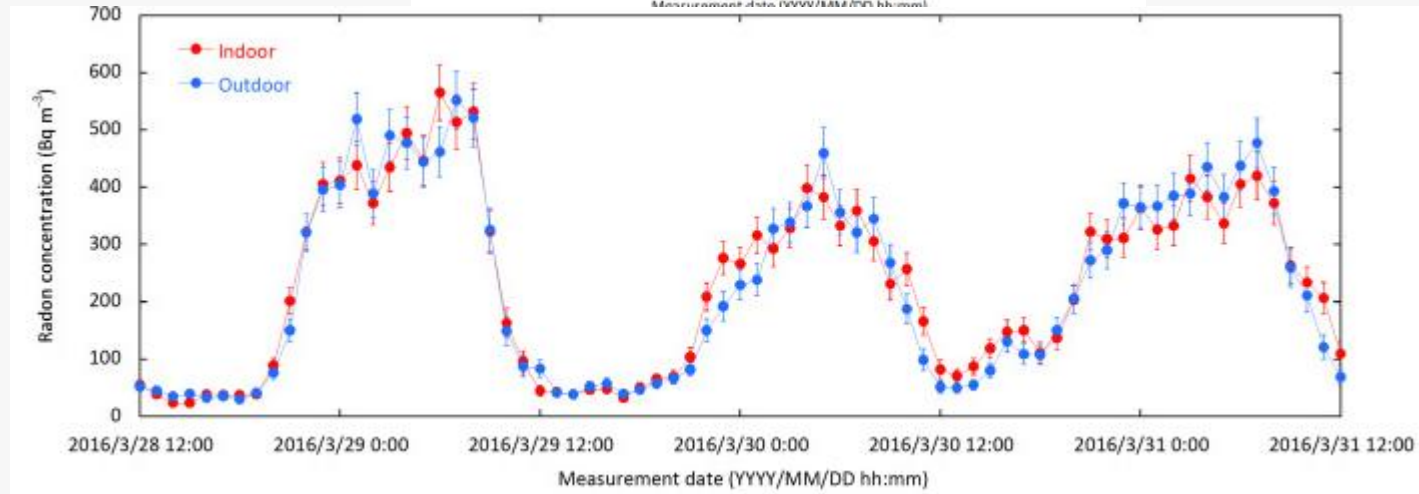
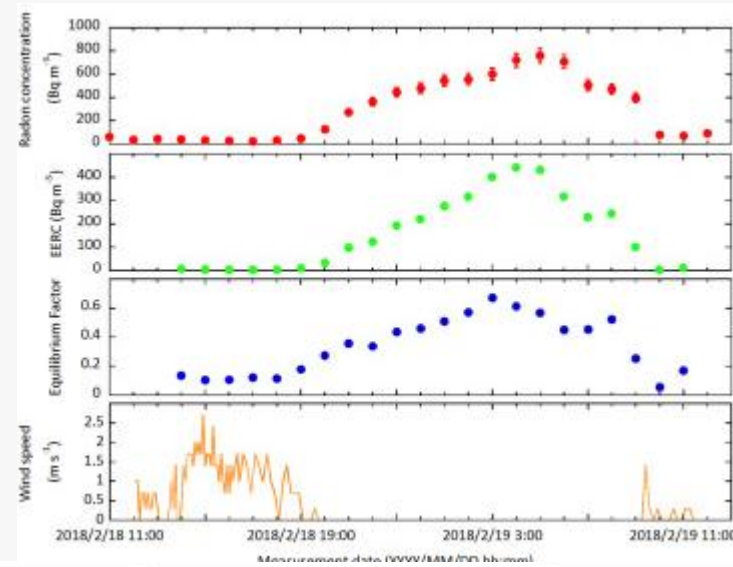
Location	Urine Sample	N	U concentration (µg L <sup>-1</sup> )	Reference
Xinjiang, China	Residents near a coal mine	16	Mean: 0.20 Max: 0.76	[35]
Southern Finland	Residents	951	Mean: 0.016 Max: 3.70	[36]
Mamuju	HNBRA residents	22	Mean: 35 ± 72 Max: 350	The present study
Topoyo	Residents	21	Mean: 9 ± 5 Max: 21	The present study

## Pb and <sup>238</sup>U concentrations in urine samples





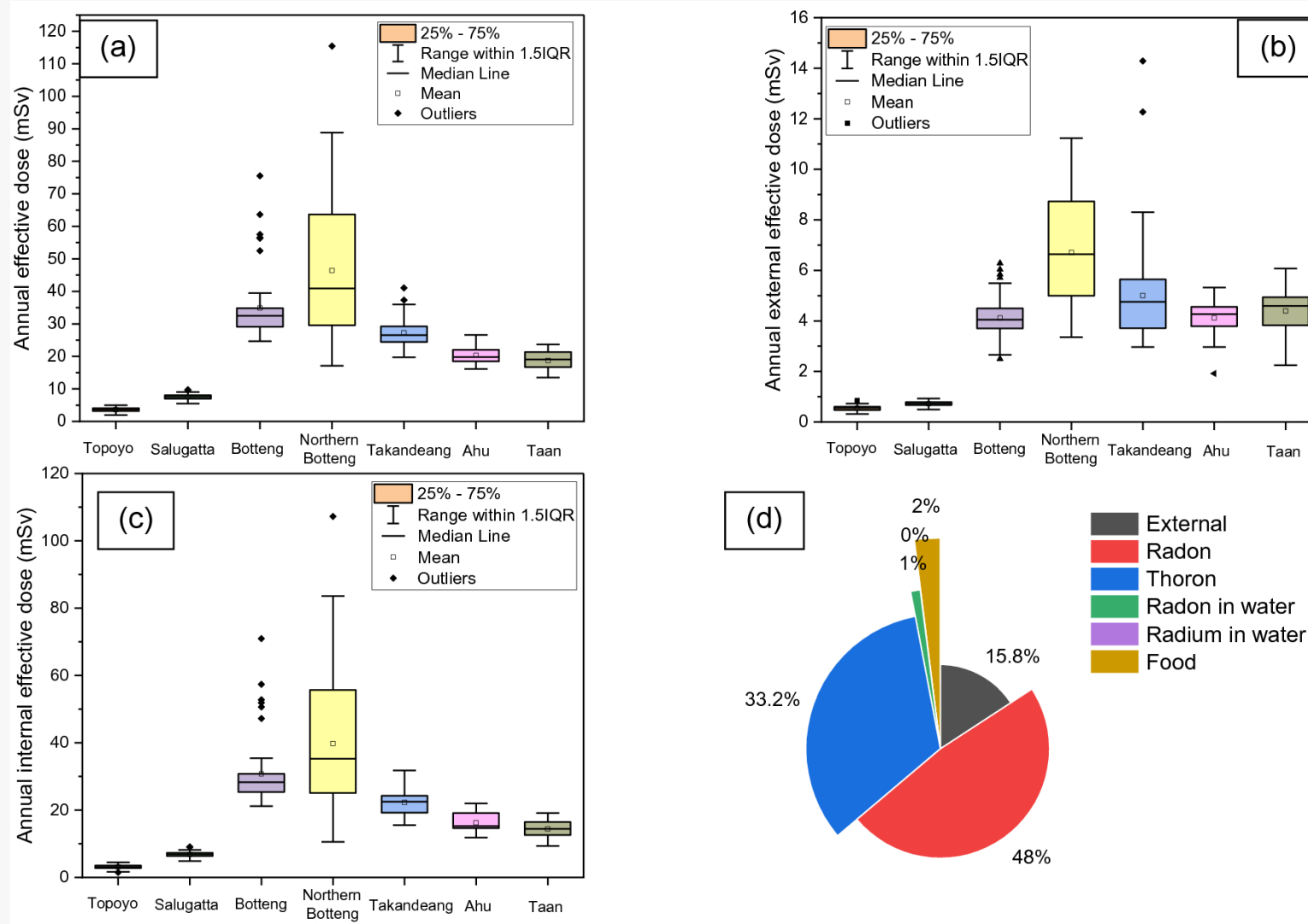
# Radon Thoron in Mamuju (active monitor)



Hosoda, M., Nugraha, E.D., Akata, N., Yamada, R., Tamakuma, Y., Sasaki, M., Kelleher, K., Yoshinaga, S., Suzuki, T., Rattanapongs, C.P. and Furukawa, M., 2021. A unique high natural background radiation area—Dose assessment and perspectives. *Science of the Total Environment*, 750, p.142346.



# Annual Effective Dose



Nugraha, E.D., et al. Comprehensive exposure assessments from the viewpoint of health in a unique high natural background radiation area, Mamuju, Indonesia. *Sci Rep* 11, 14578 (2021). <https://doi.org/10.1038/s41598-021-93983-2>



# Comparison Mamuju with HNBRA in the world

Country	HNBRA	Area characteristic	Average annual internal dose (mSv)	Average annual external dose (mSv)	Average annual effective dose (mSv)	Dose coefficient or dose conversion factor of radon (mSv (Bq h m <sup>-3</sup> ) <sup>-1</sup> )	Dose coefficient or dose conversion factor of thoron (mSv (Bq h m <sup>-3</sup> ) <sup>-1</sup> )	Reference
Brazil	Guarapari	Monazite sands	-	-	7	-	-	3,34
China	Yangjiang	Monazite particles	4.1	2.1	6.4	9 × 10 <sup>-6</sup>	4 × 10 <sup>-5</sup>	3,8,34
India	Kerala	Monazite sands	2.4	4.5	6.9	9 × 10 <sup>-6</sup>	4 × 10 <sup>-5</sup>	7,9,34
Iran	Ramsar	Sulfurous hot springs & <sup>226</sup> Ra	4.2	6	10.2	9 × 10 <sup>-6</sup>	-	3
Present study	Mamuju	Volcanic rocks and basalt rock type containing <sup>232</sup> Th and <sup>238</sup> U	26.9	5	32	1.7 × 10 <sup>-5</sup>	1.07 × 10 <sup>-4</sup>	Present study
World average			-	0.48	2.4	-	-	2

Nugraha, E.D., et al. Comprehensive exposure assessments from the viewpoint of health in a unique high natural background radiation area, Mamuju, Indonesia. *Scientific Reports, Nature* 11, 14578 (2021). <https://doi.org/10.1038/s41598-021-93983-2>



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**A unique high natural background radiation area – Dose assessment and perspectives**

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**scientific reports**

**OPEN** Comprehensive exposure assessments from the viewpoint of health in a unique high natural background radiation area, Mamuju, Indonesia

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Environmental Science and Pollution Research (2023) 30:89280–89292  
<https://doi.org/10.1007/s11356-023-28640-4>

RESEARCH ARTICLE

**Car-borne survey and dose assessment from external radiation exposure in Bangka Island**

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**Abstract**  
With a history of more than 200 years of tin mining, Bangka Island has brought along a byproduct of heavy minerals containing radionuclide elements. There are some concerns about this byproduct material contributing to natural radiation in the environment. In this study, a car-borne survey was conducted to accurately assess natural background radiation in Bangka Island. Indoor and outdoor ambient dose rates in 146 houses were also measured to assess the radiation dose from external



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