Introduction to Environmental Radiation Monitoring

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Follow-up Training Course on Environmental Radioactivity Monitoring
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SHORT CV

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*) TC on Radiological Assessor
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*) TOT on Nuclear Emergency
*) TC on Radiological Emergency Preparedness
*) Regional Workshop on Occupational Radiation Protection, South Korea
*) Security Transport of Nuclear Material, Germany
*) Instructor Training Course on Environmental Radioactivity Monitoring, Japan
*) Workshop on Monitoring during a Nuclear or Radiological Emergency, Japan
*) TC on Monitoring of terrestrial radioactivity in the nuclear emergency system, Ukraine
*) Interregional Training Course on Design and Implementation of Decommissioning and Environmental Remediation, USA

OUTLINE

1. Introduction
2. Sources of Environmental Radioactivity
3. Monitoring Phases
4. Exposure Pathways
5. Concept of Public Dose Evaluation
6. Key Environmental Media
7. Monitoring System Architecture
8. Challenges in Environmental Monitoring

INTRODUCTION

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Utilization of Atomic Energy

- Medic
- Industries
- Agricultural
- Nuclear Reactor

Safety and Security

OBJECTIVES AND SCOPE

Objectives:

- Understanding the basic concepts of environmental radiation monitoring.
- Being able to identify sources of radioactivity and relevant environmental media.
- Understanding the architecture of monitoring systems and implementation challenges in the field.

Scope:

- Environmental monitoring for nuclear installations and/or radiation facilities.
- Monitoring stages from pre-operation to post-closure.
- Environmental media: air, water, soil, plants, and external dose.
- Manual & automatic monitoring systems, fixed & mobile

SOURCES OF ENVIRONMENTAL RADIOACTIVITY (1 of 6)

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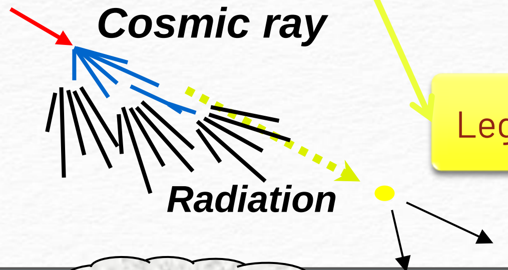
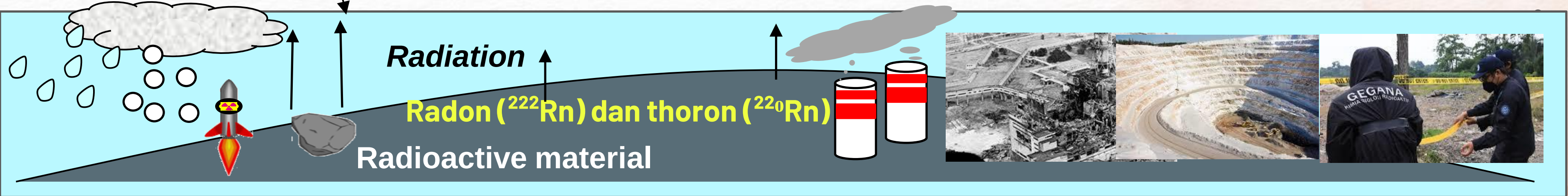
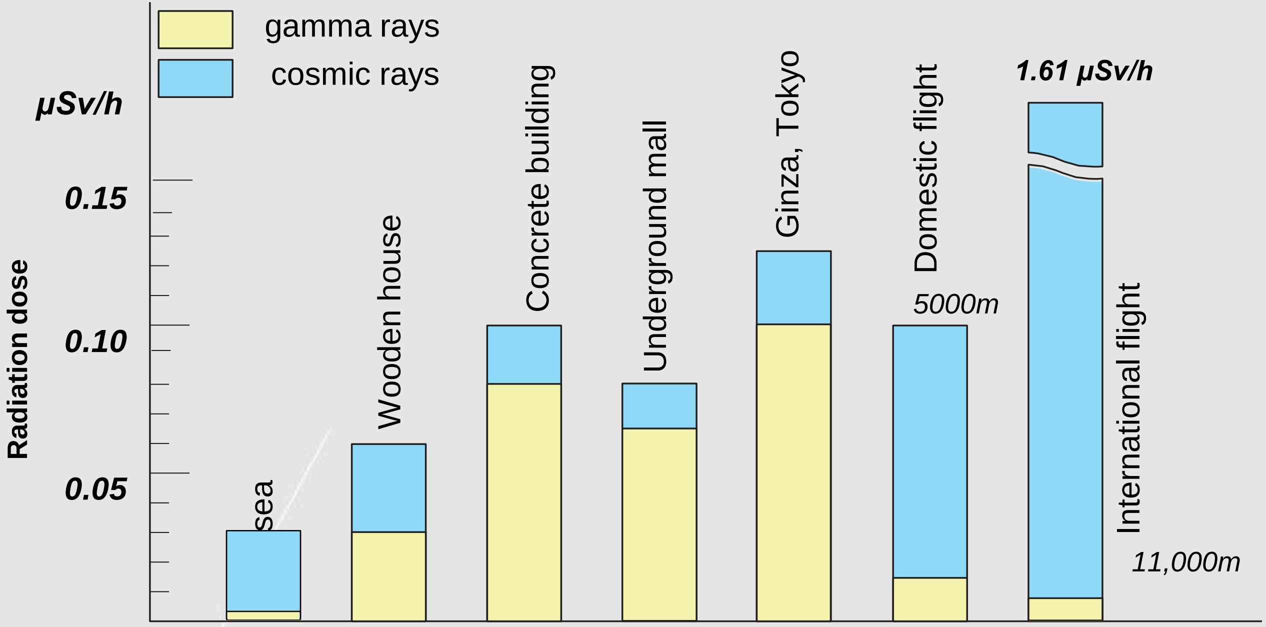
Radiation Sources

- Natural Radiation
  - Radioactive materials formed by the action of cosmic ray
  - Radioactive materials contained in the ground (Terestrial, radionuklida primordial: U-238, Th-232, K-40)
- Man-Made Radiation
  - Radioactive from atmospheric nuclear weapons tests
  - Radioactive from nuclear facilities (NPPs, radioisotope facilities)
  - Nuclear accidents (Chernobyl, Fukushima, etc.)
- Legacy Contamination
  - Former nuclear facilities, uranium mines, or TENORM industries
  - The waste being dumped does not meet standards.





SOURCES OF ENVIRONMENTAL RADIOACTIVITY (2 of 6)

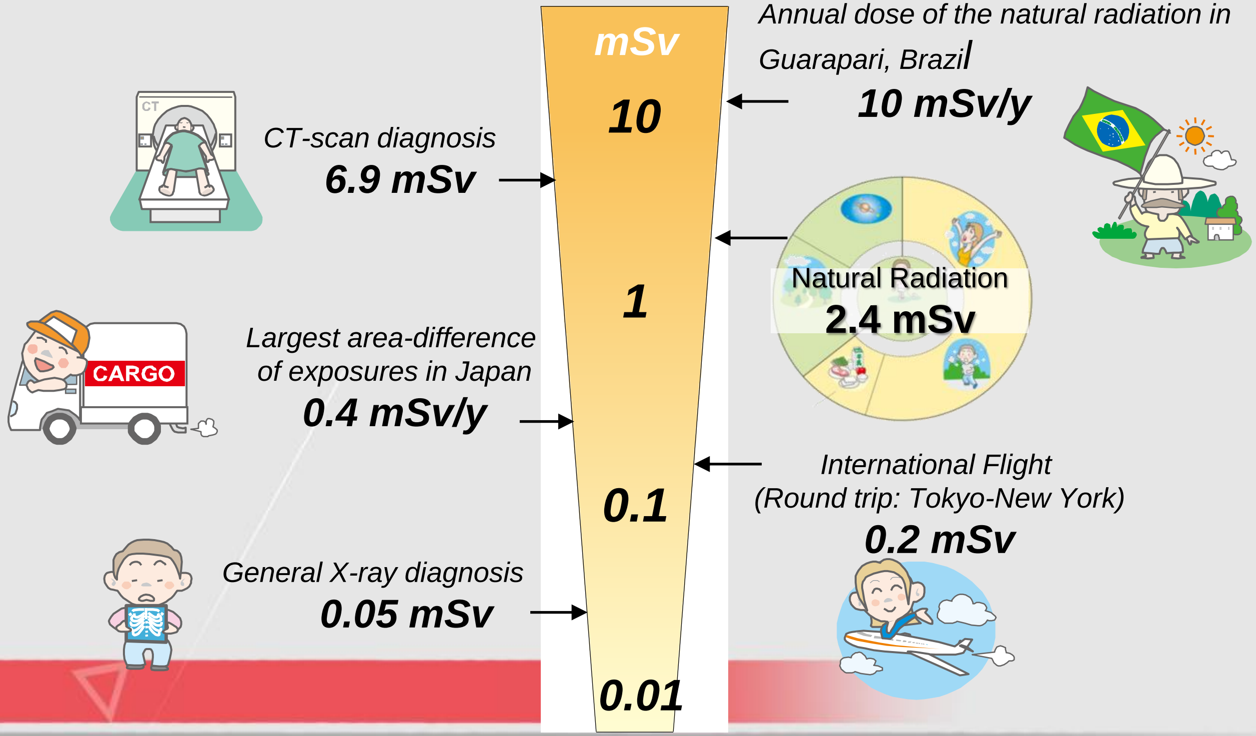


Difference of radiation dose in location

Source: Radiation Science Center, High Energy Accelerator Research Organization "Handbook for radiation in daily life" (2005)

SOURCES OF ENVIRONMENTAL RADIOACTIVITY (3 of 6)

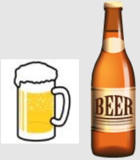
Radiation Exposure in Daily Life



SOURCES OF ENVIRONMENTAL RADIOACTIVITY (4 of 6)

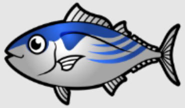
Natural radioactive material (^{40}K) is contained in various foods

Milk
10Bq (**200ml**)

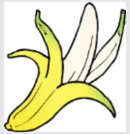


Beer
5Bq (**500ml**)

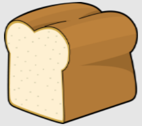
Meat
20Bq (**200g**)



Fish
10Bq (**100g**)

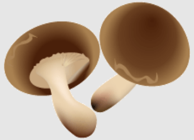


Banana 13Bq
(120g)



Bread 4.2 Bq
(140g)

Crisps 36Bq
(90g)



Dried mushroom
14Bq (**20g)**

Seaweed
20Bq (**10g)**

Rice
6Bq **(200g)**

Sweet potato
13.8Bq **(100g)**

SOURCES OF ENVIRONMENTAL RADIOACTIVITY (5 of 6)

Radioactivity in Your Body

^{40}K and ^{14}C are practically harmless

Radioactive materials in the body

Potassium-40	***4,000 Bq***
Carbon-14	***2,500 Bq***
Rubidium-87	***500 Bq***
Lead-210 & Polonium-210	***20 Bq***

(for an average Japanese weighing 60 kg)

Source: Lets' start learning radiation

SOURCES OF ENVIRONMENTAL RADIOACTIVITY (6 of 6)

🦐 Cs-137 Contaminated Shrimp

- Test Results from AS: Cs-137 in Indonesian shrimp **68 Bq/kg** → far below the national limit (**500 Bq/kg**).
- 1 serving of shrimp (200 g) ≈ 0.18 μSv, (1 Bq Cs-137 = 0.013 μSv (ICRP standard)).
- **Dose comparison:**

  🍌 1 banana ≈ 0.1 μSv
  ✈️ 1 hour of flying ≈ 2–3 μSv
  🦷 Dental X-ray ≈ 4–100 μSv
  💻 Chest CT scan ≈ 5,000–7,000 μSv
  🌍 Natural radiation ≈ 2,400 μSv/year

👉 **0.18 μSv ≈ 2 bananas** – far below daily activity and public safety limits (1,000 μSv/year).

👉 Eating contaminated shrimp every day for a year ≈ 65 μSv/year, still very safe.

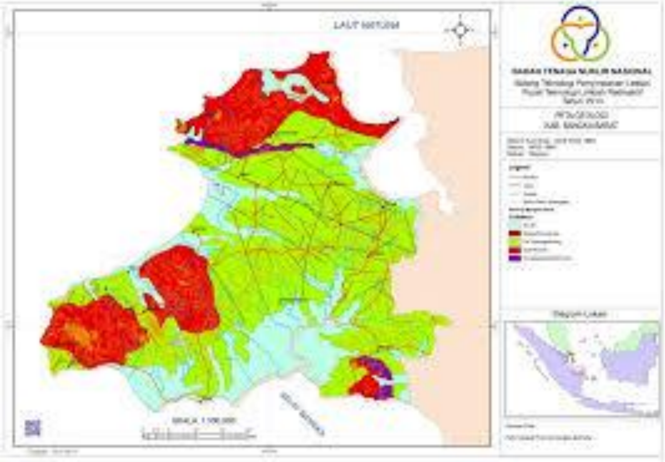
Sumber: https://ilhamvariansyah.substack.com/p/udang-radioaktif-dan-risiko-radiasi?utm_campaign=post&utm_medium=web&triedRedirect=true

MONITORING PHASES (1 of 5)

Pre-Operation (Baseline)	• Objective: To determine the initial conditions (background). • Baseline data is used as a comparison for the impact of the operation.
Operation	• Objective: Verify compliance with emission limits & public dose limits • Routine & incidental monitoring
Decommissioning	• Objective: To assess residual contamination & decontamination effectiveness
Post-Closure / Post-Remediation	• Objective: Long-term monitoring to ensure environmental safety

MONITORING PHASES (2 of 5)

Pre-Operational Monitoring



- Purpose: baseline data, initial environmental characterization
- Types of media: air, water, soil, biota
- It's important to evaluate the changes after surgery.

MONITORING PHASES (3 of 5)

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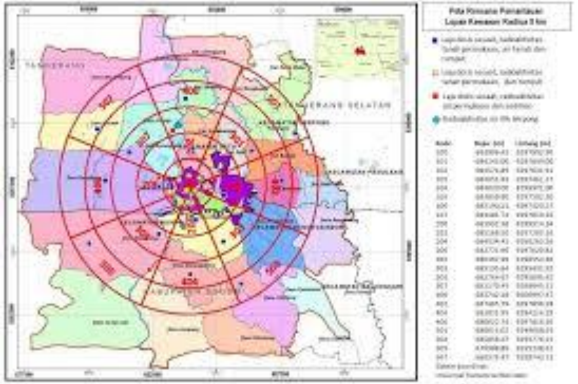
Operational Monitoring

- Focus: detection of routine & abnormal releases
- Real-time monitoring and surveillance program
- To be the basis for calculating public doses

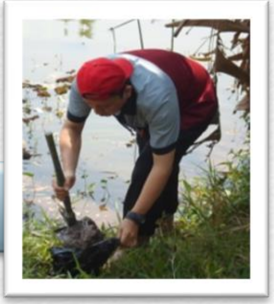


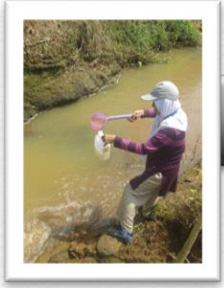
MONITORING PHASES (4 of 5)

ERM at Serpong Nuclear Area

Air samples, 4 points / month

Sediment samples, 7 points / 6 month





Surface water samples, 12 points / month

Grass samples, 24 points / year

Soil samples, 24 points / 6 month

Drinking water samples, 16 points / 6 month

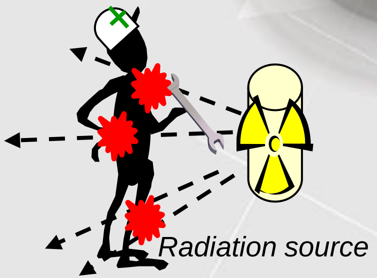
MONITORING PHASES (5 of 5)

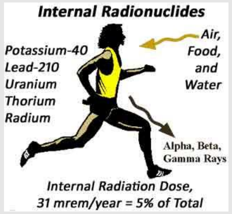
Decommissioning & Post-Closure Monitoring

- Monitoring to ensure no contamination remains
- Long-term, frequency gradually decreases.
- Focus on long-term safety & environmental remediation

EXPOSURE PATHWAYS (1/7)

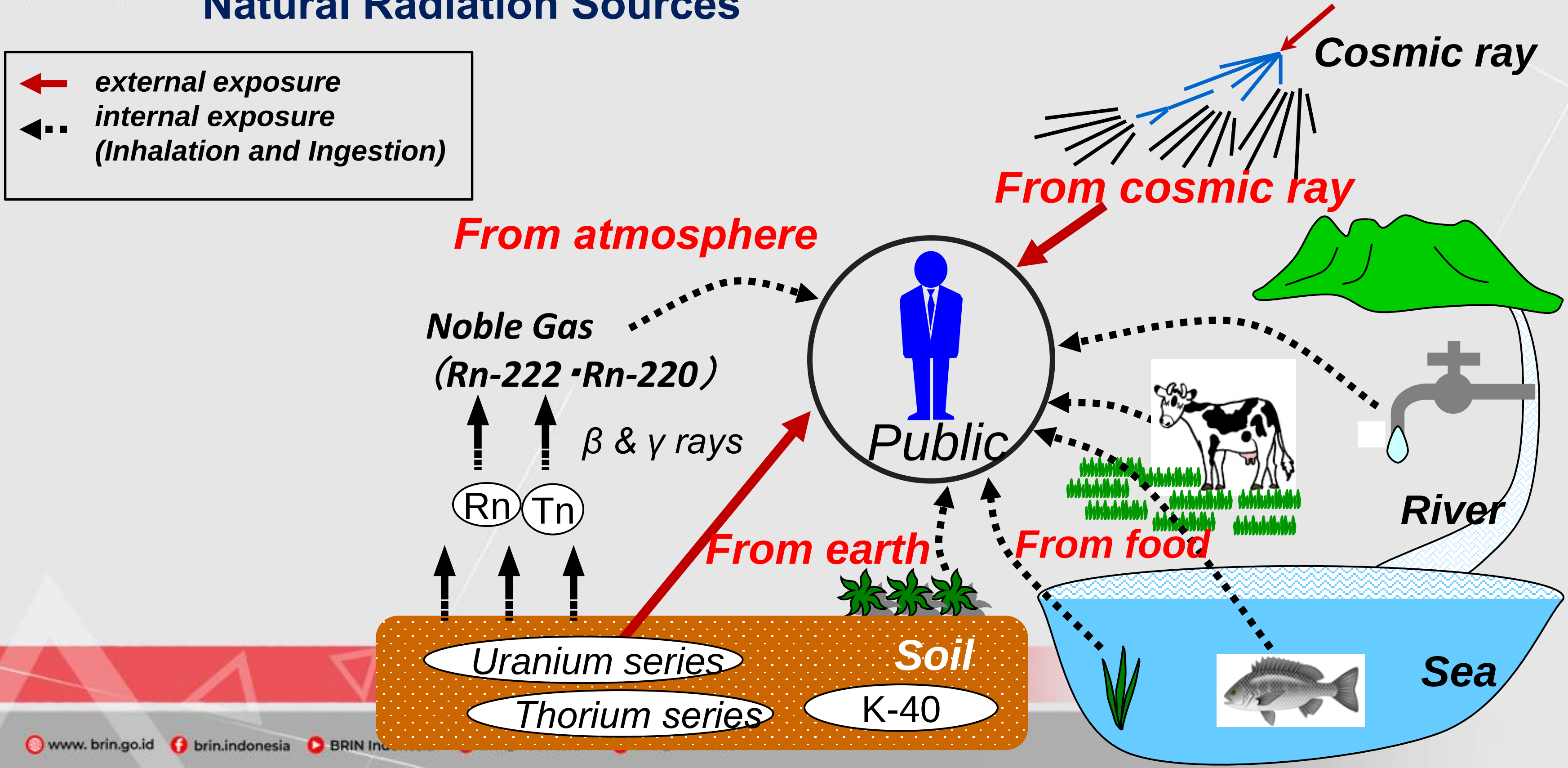
- Exposure Pathways
  - External Exposure
    - Direct from radiation sources
    - Radiation from plume, contaminated ground surface and water
  - Internal Exposure
    - Inhalation of contaminated air
    - Ingestion (Intake of contaminated water & foodstuffs)
    - Absorption (Skin defects)





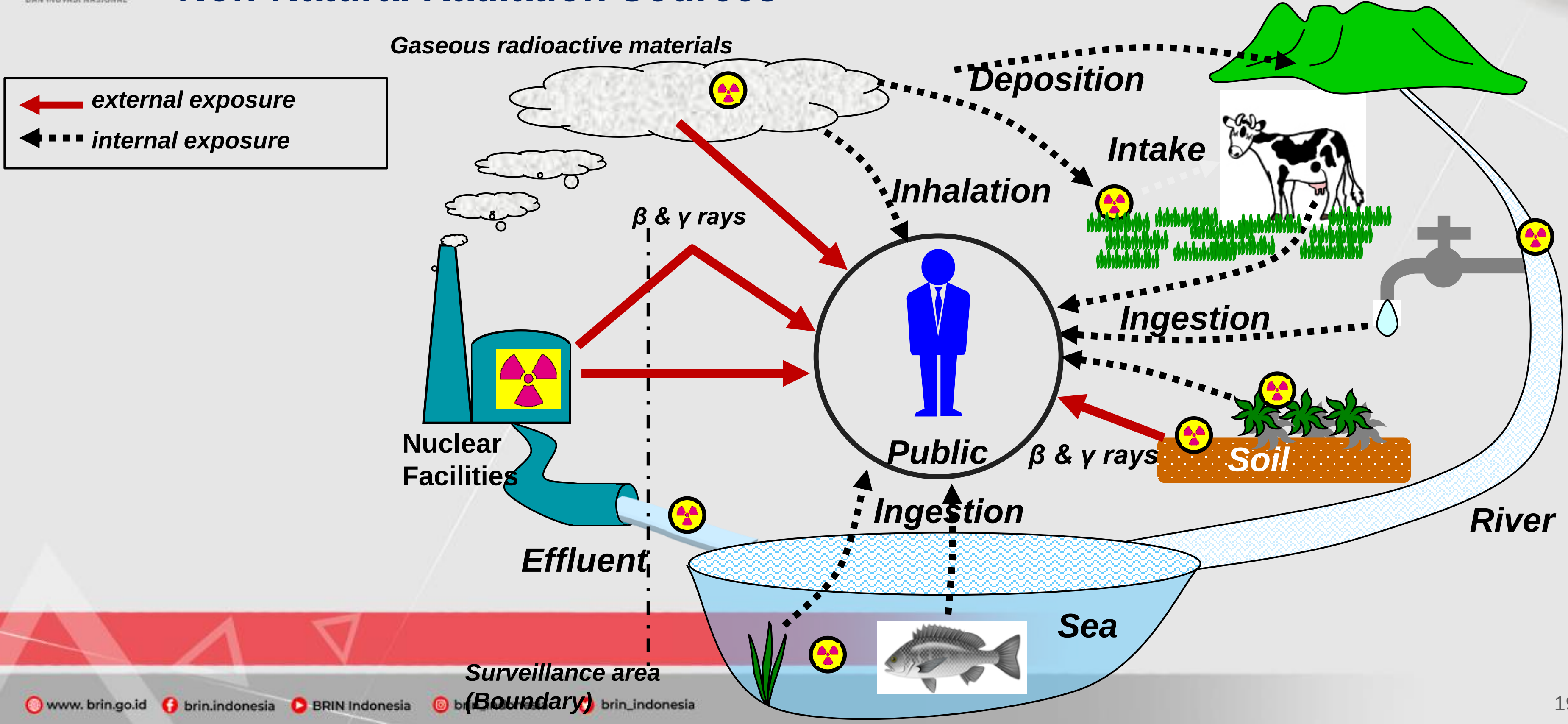
EXPOSURE PATHWAYS (2/7)

Natural Radiation Sources



EXPOSURE PATHWAYS (3/7)

Non-Natural Radiation Sources

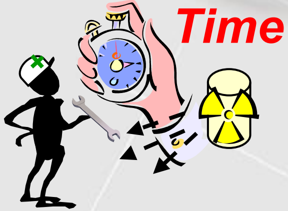


EXPOSURE PATHWAYS (4/7)

PRINCIPLES OF RADIATION PROTECTION

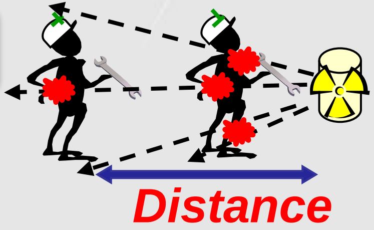
Time

- The time principle is related to minimizing the duration of radiation exposure as much as possible.
- The longer an individual is exposed to radiation, the greater the potential for harm to the body's cells.



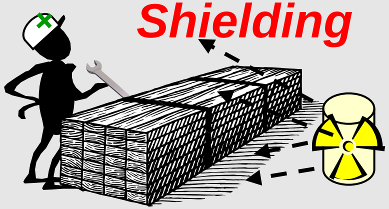
Distance

- The distance principle refers to the concept that the farther an individual is from the radiation source, the less radiation exposure they will receive.
- Radiation follows the inverse square law, meaning that radiation exposure decreases exponentially with increasing distance from the source



Shielding

- The shielding principle involves using appropriate shielding materials to reduce radiation exposure.
- Shields can also be used to protect specific organs or body areas that do not need to be exposed to radiation



EXPOSURE PATHWAYS (5/7)

Prevention against Internal Exposure


- Prohibit smoking, eating, drinking, and make-up in controlled areas
- Use rubber gloves when using radioactive materials
- Wear respiratory masks
- Use in a glove box or a fume hood
- Frequent contamination check with survey meters
- Continuous measurements of the radioactive concentration in the air



EXPOSURE PATHWAYS (6/7)

Estimation of Internal Exposure

Whole-body counter

Standing type

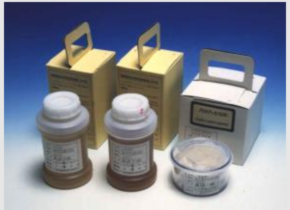
Bed type

EXPOSURE PATHWAYS (7/7)

Estimation of Internal Exposure

Bioassay

Containers for excretions



Urine Sample

Chemical Analysis

Gross Alpha Analysis

CONCEPT OF PUBLIC DOSE EVALUATION (1 of 4)

Critical Group → Representative Person

CONCEPT OF PUBLIC DOSE EVALUATION (2 of 4)

Critical Group

- Groups of people who are potentially exposed to radiation doses significantly exceeding the average dose values for other population groups.
- Based on: location, activity, consumption habits
- Data obtained from field surveys and socioeconomic data

Example

- Fishermen living near the discharge canal may represent the critical group for ingestion of contaminated fish.
- Farmers using groundwater for irrigation may be representative for ingestion and external exposure pathways

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Representative Person

- A fictional individual who realistically represents the group of people with the highest exposure.
- Used for evaluation and dose limitation to the public.
- This approach is more realistic and conservative, ensuring protection for individuals most likely to receive the highest doses.

CONCEPT OF PUBLIC DOSE EVALUATION (4 of 4)

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Core Comparison

Aspect	Critical Group	Representative Person
Database	Field & local socioeconomic surveys	National/regional statistical data + conservative modeling
Individuals	Real community groups	Representative fictional (hypothetical) individuals
Objective	Assess the dose to the most exposed group	Assess conservative & realistic individual doses for public protection
Example	Fishermen near the waste discharge channel	Hypothetical individual living downwind of the air discharge location

KEY ENVIRONMENTAL MEDIA (1 of 6)

Environment samples

- Air
- Water
- Soil
- Sediment
- Surface Water
- Drinking Water
- Grass/Plant

Air & Atmospheric Monitoring

- Parameter: gamma, particulates, noble gasses, Iodine
- Technique: air sampler, aerosol filter, stack monitoring

KEY ENVIRONMENTAL MEDIA (3 of 6)

Water & Sediment

- Focus: rivers, wells, lakes, seas
- Technique: grab sampling, composite sampling
- Analysis: gross alpha-beta, gamma spectrometry



Soil & Terrestrial Media

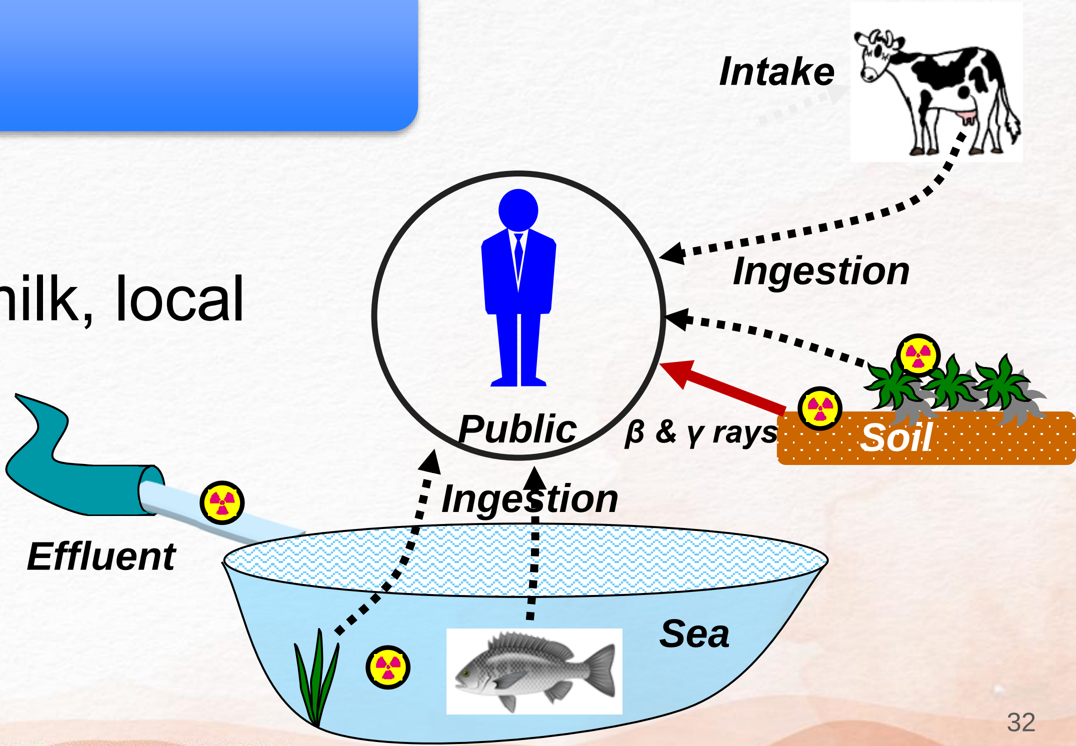
- Long-term accumulation, baseline is important
- Systematic sampling & depth stratification





Biota & Foodstuff

- Main ingestion pathway
- Monitoring fish, plants, milk, local food



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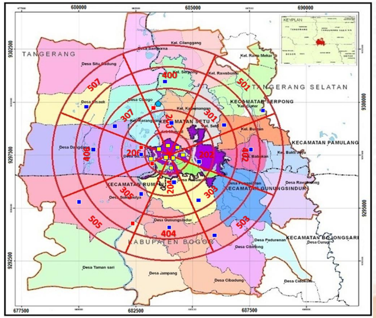
External Dose Monitoring

- Environmental dosimeter, TLD, fixed gamma station
- Real-time data for early warning

MONITORING SYSTEM ARCHITECTURE (1 of 7)

Monitoring

- Fixed Monitoring Stations
  - Permanent monitoring posts:
    1. Manual (sampling & lab analysis)
    2. Automatic (real-time gamma dose rate)
- Mobile Monitoring
  - Vehicle surveys, drones, portable dose rate meters ➔ incidental surveys or difficult areas

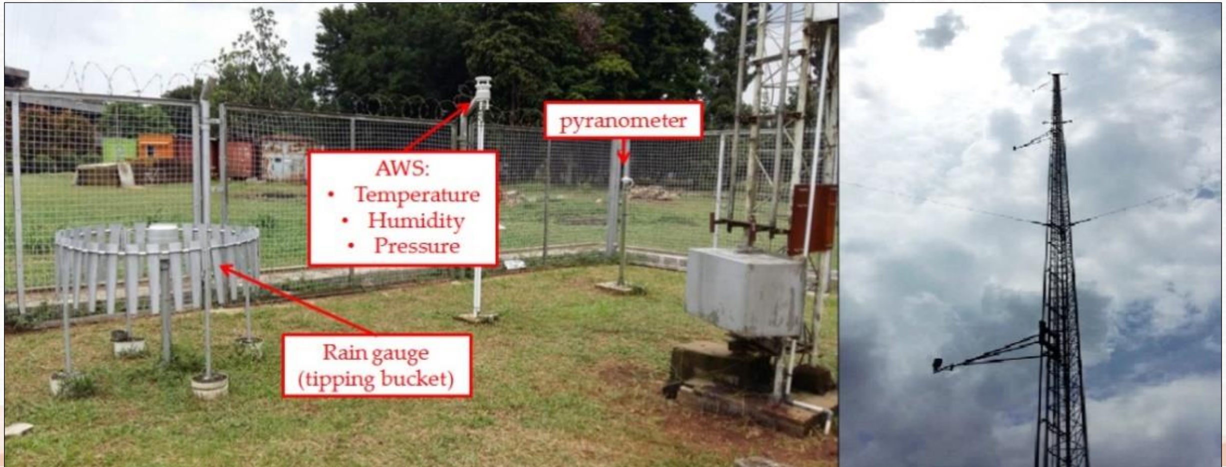




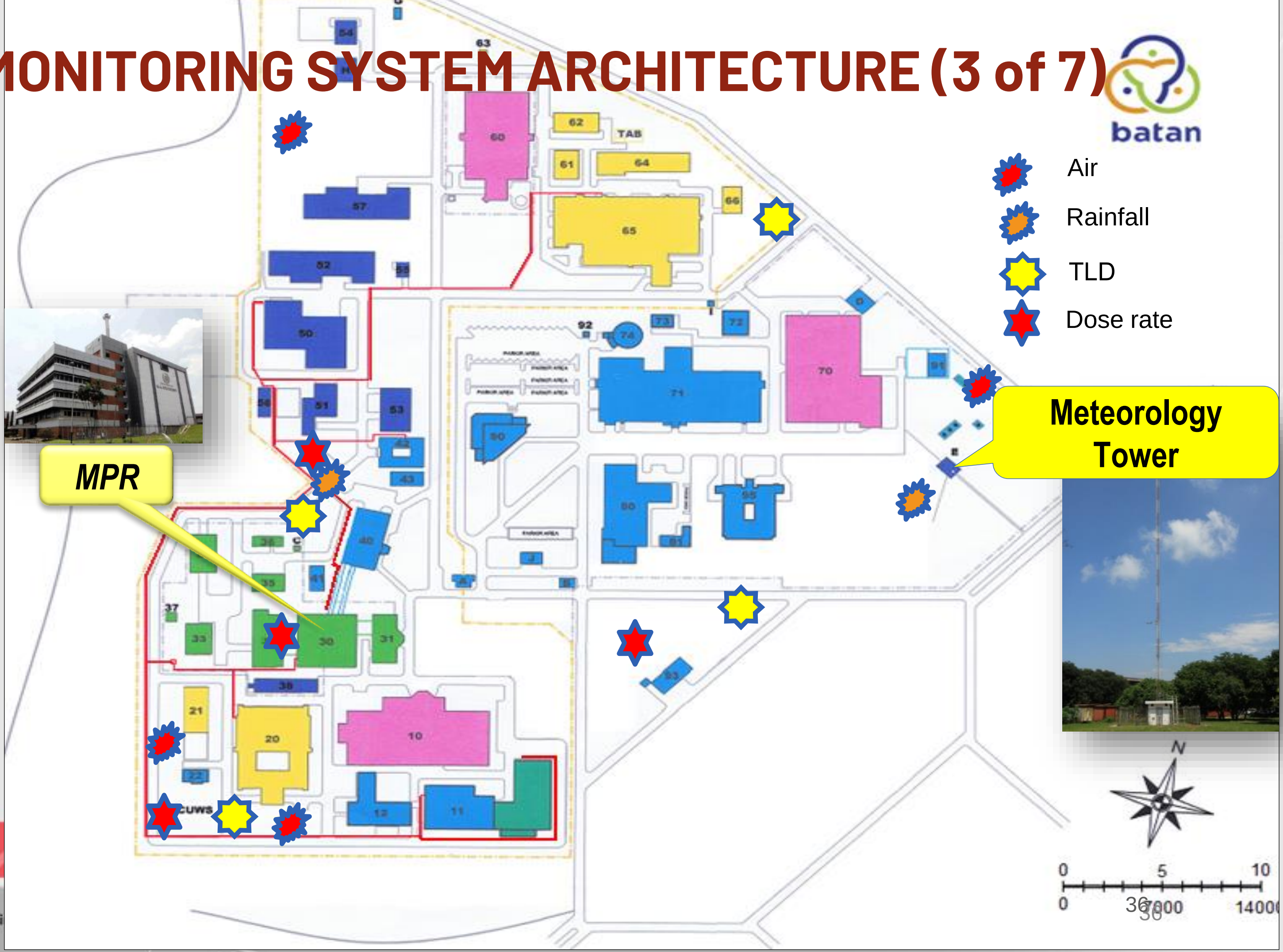
MONITORING SYSTEM ARCHITECTURE (2 of 7)

Fixed Monitoring Systems

- Permanent installation, continuous data, early detection
- Gamma sensor, meteorology, real-time transmission
- Fixed monitoring station (tower with sensors & antenna).



MONITORING SYSTEM ARCHITECTURE (3 of 7)



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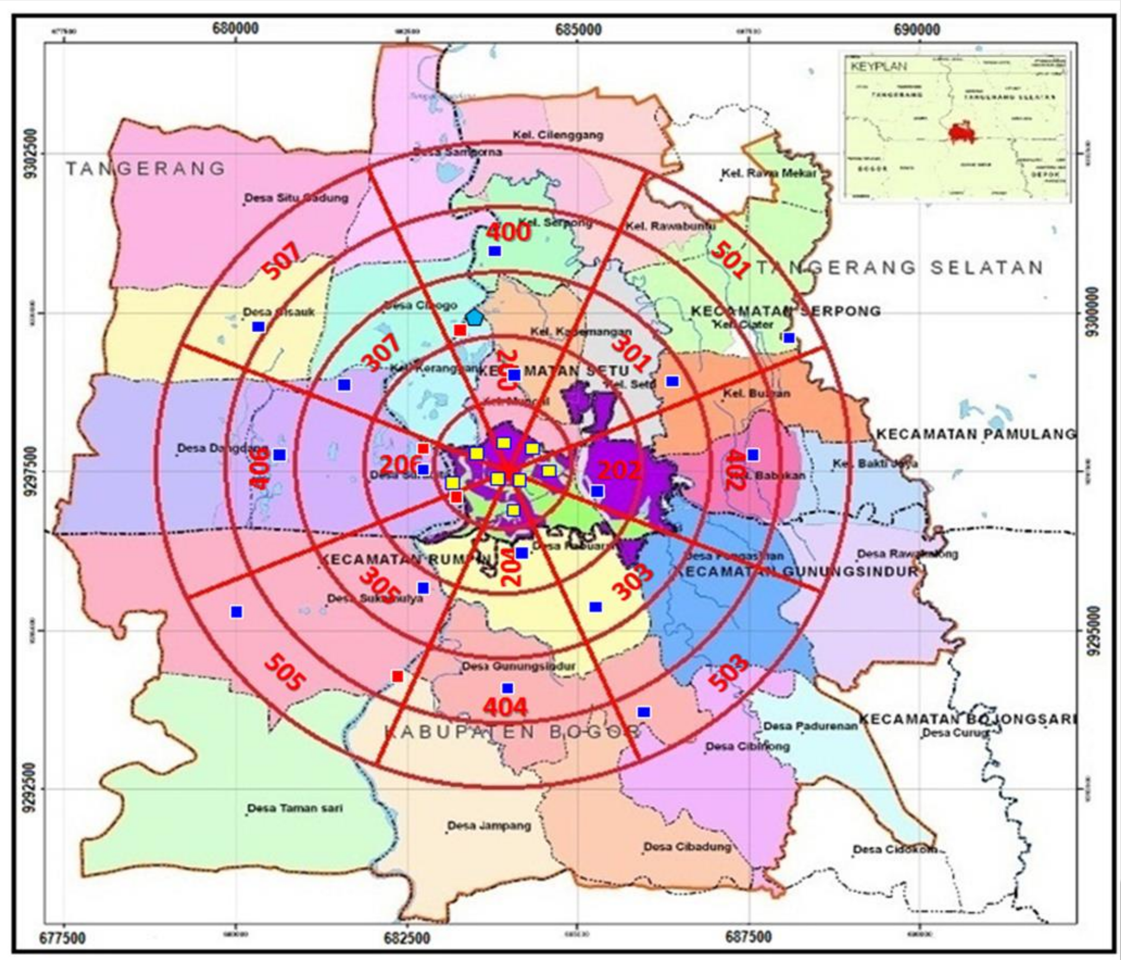
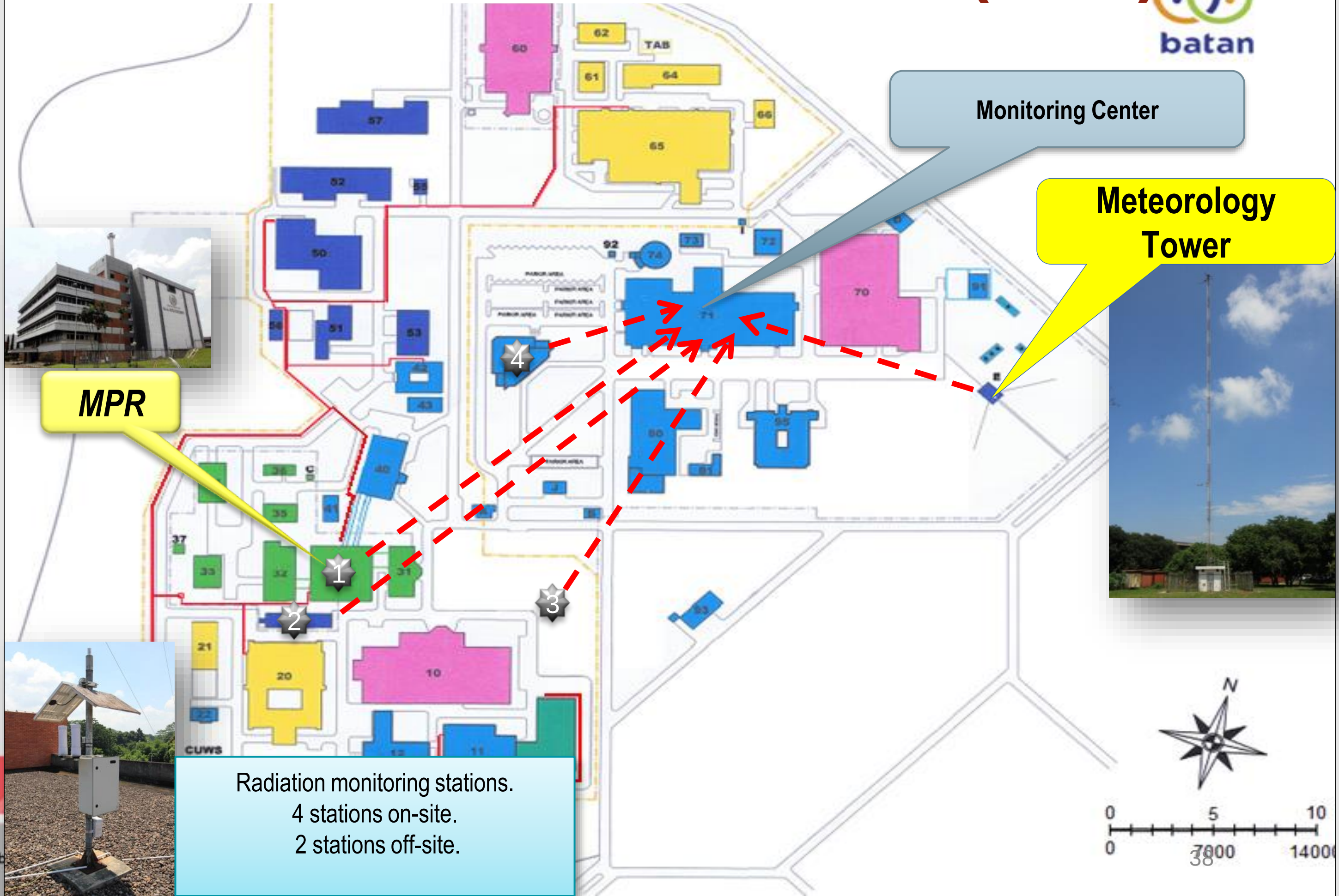
MONITORING SYSTEM ARCHITECTURE (4 of 7)



- Dose rate, soil, grass, drinking water
- Dose rate, soil, grass
- Dose rate, surface water, sediment
- Drinking water

MONITORING SYSTEM ARCHITECTURE (5 of 7)



MONITORING SYSTEM ARCHITECTURE (6 of 7)

Monitor Display

Alarm panel

Telegram bot

Mobile Monitoring Systems

- Flexible, hotspot investigation & emergency conditions
- Survey vehicles, drones, portable instruments

CHALLENGES IN ENVIRONMENTAL MONITORING (1 of 5)

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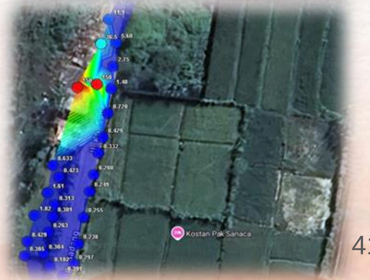
Challenges

- Detection limit
- Environmental heterogeneity
- Weather & accessibility
- Representativeness



CHALLENGES IN ENVIRONMENTAL MONITORING (2 of 5)

Challenge 1: Detection Limits & Sensitivity

- The concentration of radionuclides in the environment is generally very low, approaching or falling below the detection limit of the instruments.
- Sensitive analysis methods are needed (e.g., gamma spectrometry with long counting times).
- Environmental matrix factors can affect the accuracy of measurements.
- Regular calibration and the use of blanks are crucial for maintaining data quality.

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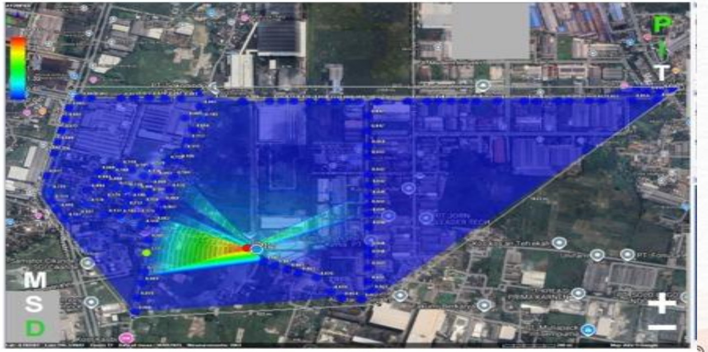
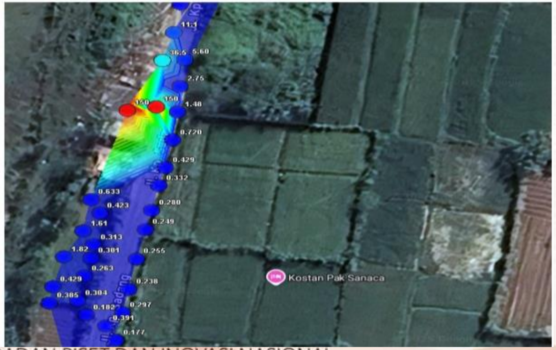
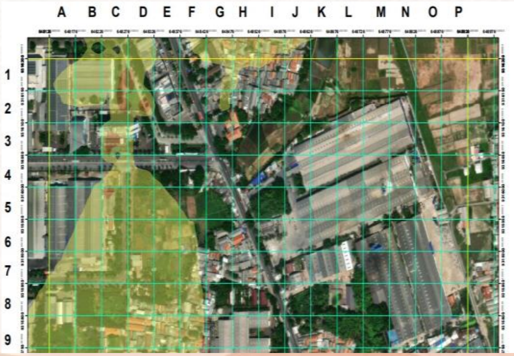
Challenge 2: Environmental Heterogeneity

- The distribution of radionuclides is not uniform in environmental media (soil, water, air).
- Differences in topography, geology, vegetation, and human activity → high spatial variation.
- A representative network monitoring design strategy and location stratification are needed.
- Composite sampling or multiple sampling points are often used.







Challenge 3: Weather & Accessibility

- Extreme weather (heavy rain, storms, high temperatures) affects data collection and quality.
- Remote locations, forested areas, or regions with limited infrastructure make access difficult

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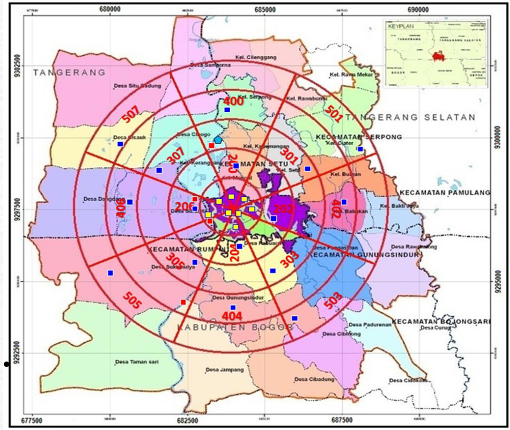
Challenge 4: Representativeness & Data Quality

- Monitoring data must be representative of actual public exposure and environmental conditions.
- Faulty sampling design → invalid data interpretation.
- Strict SOPs, result validation, and multi-layered QA/QC (including inter-laboratory comparison) are required.
- Choosing monitoring points that truly reflect public exposure.



Summary

1. **Introduction** – Environmental radiation monitoring ensures public and environmental safety around nuclear installations and radiation facilities, covering all operational phases.
2. **Sources of Environmental Radioactivity** – Radioactivity comes from natural sources (cosmic rays, terrestrial radionuclides, radon) and human activities (nuclear facilities, accidents, legacy contamination, food).
3. **Monitoring Phases** – Monitoring is conducted in four stages: pre-operation (baseline), operation, decommissioning, and post-closure, each with specific objectives.
4. **Exposure Pathways** – Radiation exposure occurs externally (plume, contaminated surfaces) and internally (inhalation, ingestion, absorption); protection follows time, distance, and shielding principles.
5. **Concept of Public Dose Evaluation** – Critical groups and representative persons are used to realistically estimate public exposure and ensure regulatory compliance.
6. **Key Environmental Media** – Air, water, soil, biota, and external dose are the main monitoring targets, using various sampling and measurement techniques.
7. **Monitoring System Architecture** – A combination of fixed and mobile monitoring systems provides real-time data and flexible coverage for both routine and emergency situations.
8. **Challenges** – Main challenges include low detection limits, environmental variability, weather and access constraints, and ensuring data representativeness and quality.

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SOAL PRE-POST TEST

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1. What is the main purpose of baseline environmental radiation monitoring (pre-operation phase)?

A. To measure the dose received by workers
B. To detect accidental releases from the facility
C. To determine natural background levels before operation
D. To control waste management activities

Answer: C. To determine natural background levels before operation

SOAL PRE-POST TEST

2. Which of the following is NOT a natural source of environmental radioactivity?

A. Cosmic radiation
B. Radionuclides from nuclear power plant emissions
C. Primordial radionuclides (U-238, Th-232, K-40)
D. Radon gas and its progeny

Answer: B. Radionuclides from nuclear power plant emissions

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3. Which environmental media is most suitable for assessing long-term accumulation of radionuclides?

A. Air
B. Surface water
C. Soil and sediment
D. Foodstuffs

Answer: C. Soil and sediment

4. The "representative person" concept is used to:

A. Estimate the average radiation dose for all workers
B. Identify the individual in the population receiving the highest realistic exposure
C. Determine the limit of detection for environmental samples
D. Design automated monitoring systems

Answer: B. Identify the individual in the population receiving the highest realistic exposure

5. Which of the following is a key challenge in environmental radiation monitoring?

A. Easy access to all monitoring points
B. Homogeneous distribution of radionuclides in the environment
C. Low detection limits required for environmental samples
D. Unlimited resources for monitoring networks

Answer: C. Low detection limits required for environmental samples

Thank You for Your Kind Attention

Arigato Gozaimashita

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Thank You for Your Kind Attention

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