

**Follow-up Training Course (FTC)
on Environmental Radioactivity Monitoring 2025
13 – 17 October 2025**

Designing an Environmental Monitoring Program for Nuclear Facility Decommissioning

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WORK EXPERIENCES

1990 – 2018 Center for Technology of Radiation Safety and Research, National Nuclear Energy Agency (BATAN)

- Researcher on environmental radiation safety
- Head of Radioecology Division 2014 – 2017
- Head of Safety and Health Division 2011 – 2014
- Head of Environmental Safety Section 2006 – 2011
- Contact Person for IAEA ALMERA Network 2006-2018

2018 – 2021 Center for Radioactive Waste Technology, National Nuclear Energy Agency (BATAN)

- Researcher on radioactive waste disposal
- Regional Coordinator for Asia Pacific of IAEA ENVIRONET with Tim Payne (Australia)

2022–Now Research Center for Nuclear Material and Radioactive Waste Technology, National Research and Innovation Agency (BRIN)

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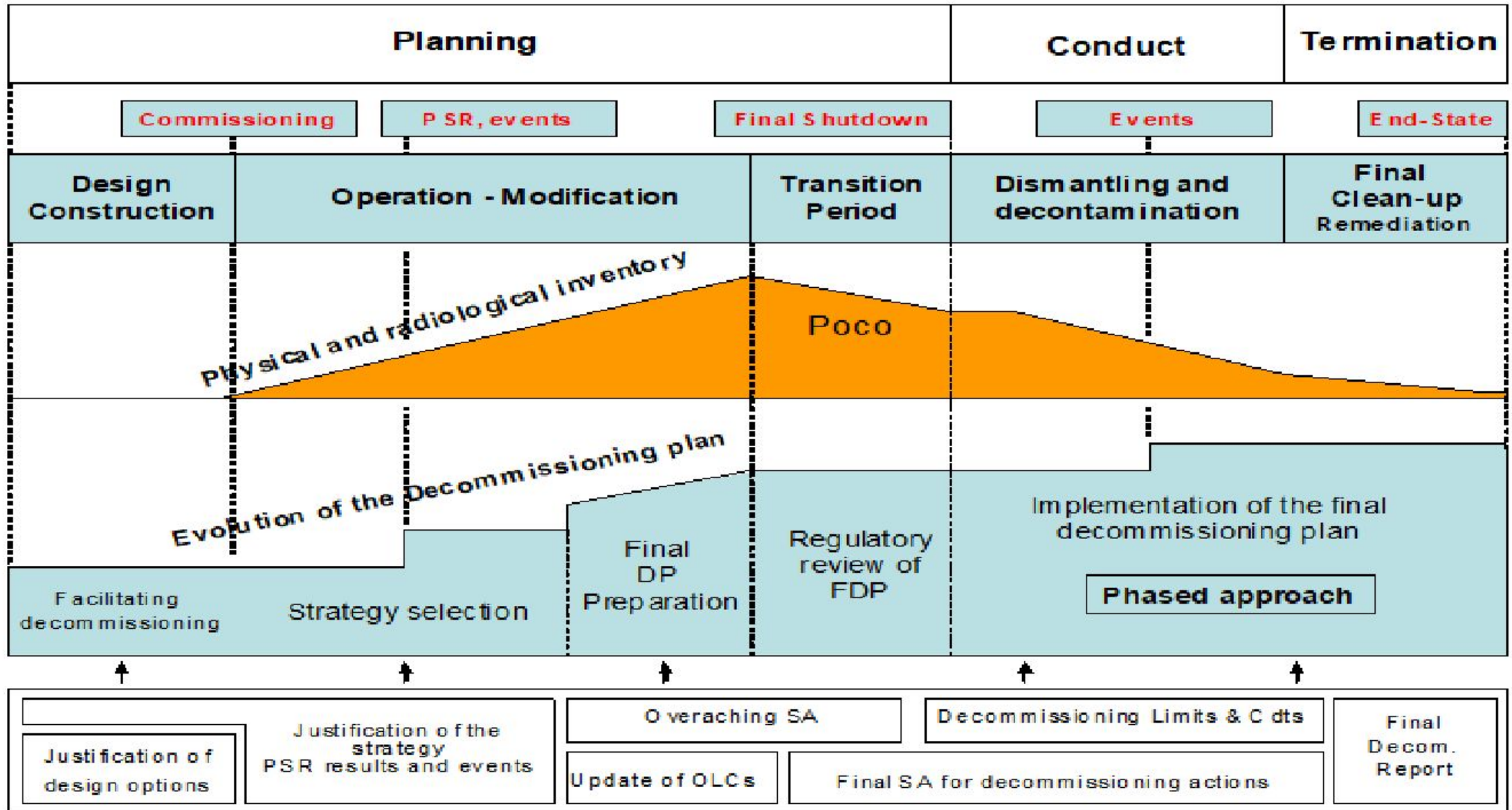
EDUCATION

Nuclear Engineering (Doctor of Engineering),
Nagoya University, Japan

1. Introduction
2. Development of an environmental baseline data;
3. Determination of release paths from site activities and their associated exposure pathways in the environment;
4. Selection of appropriate sampling locations and media
5. QA/QC
6. Radiation and Radioactivity Measurement
7. Conclusion

INTRODUCTION

Safety Assessments and Decommissioning Plan: Evolution throughout the lifecycle of a facility

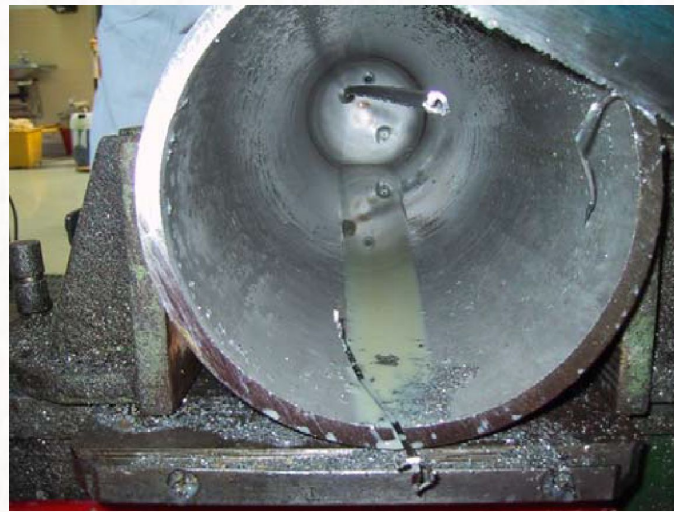


	Decontamination & dismantling	Demolition of buildings	Site clean-up	Site restoration
Main actions	Decontamination, removal of structures, systems and components	Clean-up of buildings Partial demolition of contaminated parts of structures and underground structures	Clean-up of contaminated land (on-site, off site)	Backfilling with appropriate materials
Objectives	Removal of radioactive waste to disposal facilities Removal of hazardous materials	Conventional demolition of concrete buildings	Removal, excavation of contaminated land, treatment of ground water	Assurance that no contaminated materials are re-introduced in the site

Why is it necessary to conduct environmental monitoring?



Demolition of the control rod house



The Fuel Drain Tank cut apart



The nibbler and the half-cut reflector tank



Cutting the four experimental channels



Channel being drilled out



Circular saw cutting away the activated inner slab

The decommissioning environmental monitoring plan must be consistent and complete to ensure the detection and mitigation of off-site impacts caused by radioactive or hazardous materials released from decommissioning activities at nuclear facilities.

- **Regulatory compliance** – ensuring emissions are below authorised limits.
- **Risk assessment** – evaluating potential public and environmental exposure.
- **Public reassurance** – demonstrating environmental safety and transparency.
- **Release criteria verification** – confirming areas are eligible for release from regulatory control.

Environmental Monitoring Plans for Decommissioning of Nuclear Facilities should include:

- (1) development of an environmental baseline prior to commencement of decommissioning activities;
- (2) determination of release paths from site activities and their associated exposure pathways in the environment; and
- (3) selection of appropriate sampling locations and media to ensure that all exposure pathways in the environment are monitored appropriately.

DEVELOPMENT OF AN ENVIRONMENTAL BASELINE DATA

- Importance of pre-decommissioning environmental characterisation as a reference baseline:
 - Review of historical environmental data, previous monitoring results, and current data.
 - Analysis of background levels and spatial/temporal trends.
 - Identification of key radionuclides based on facility operation history.
 - Gap analysis for incomplete or missing monitoring coverage.
- The environmental monitoring program links to radiation safety regulations, public protection, and site release criteria.

DETERMINATION OF RELEASE PATHS FROM SITE ACTIVITIES AND THEIR ASSOCIATED EXPOSURE PATHWAYS IN THE ENVIRONMENT

- Identifies how contaminants leave the site (release paths)
- Describes how contaminants move through the environment (transport pathways)
- Explains how humans or biota may be exposed (exposure pathways)

- Airborne emissions: dust, aerosols, or gases during dismantling
- Liquid discharges: leaks, spills, or drainage to surface/groundwater
- Solid waste: contaminated materials, debris, or soil
- Direct radiation: gamma rays escaping from contaminated structures

- **Air** : dispersion and deposition onto soil or vegetation
- **Surface water** : movement via rivers, drainage systems, or lakes
- **Groundwater** : migration through soil and aquifers
- **Soil and sediment** : accumulation or resuspension of contaminants

- **Inhalation** : breathing contaminated air or dust
- **Ingestion** : consuming contaminated food or water
- **External exposure** : gamma radiation from contaminated areas
- **Dermal contact** : direct contact with contaminated water or soil

- **Source** : Reactor dismantling □ Potential contaminant release
- **Release Path**: Airborne dust □ Material leaves the facility
- **Transport**: Air □ Soil □ Water □ Food chain
- **Exposure** : Inhalation or ingestion by humans or biota

SELECTION OF APPROPRIATE SAMPLING LOCATIONS AND MEDIA

1. Identify potential contamination sources and pathways.
2. Collect baseline data (topography, drainage, wind, historical info).
3. ***Choose an appropriate sampling design (radial, transect, or grid).***
4. Include background and quality assurance sampling points.
5. Select media (soil, water, air, biota) and appropriate sampling depths.
6. Determine spacing and number of samples according to risk and area size.
7. Accessibility, safety, and representativeness are considered in the site selection process.

- **Radial Pattern**

From the source centre outward at multiple distances (e.g., 10m, 25m, 50m).

- **Transect Pattern**

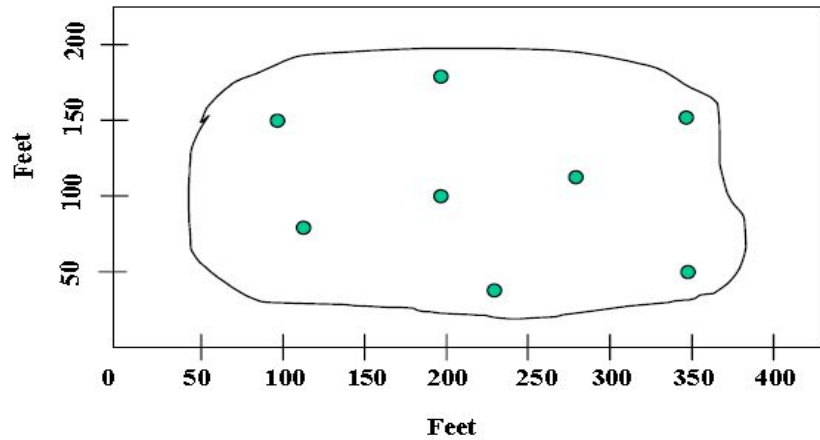
Along the wind or water flow direction with fixed intervals.

- **Grid Pattern**

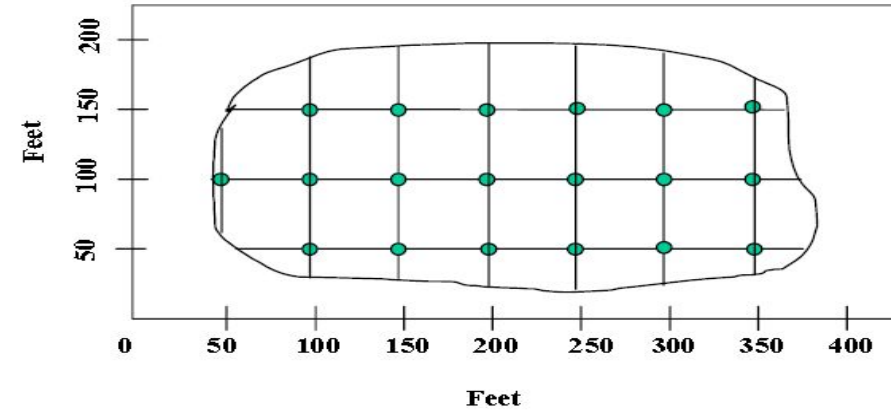
Uniformly spaced points for diffuse or unknown contamination.

- **Targeted Sampling**

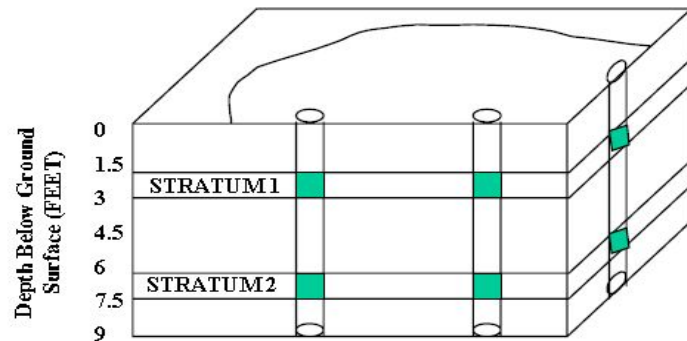
Visual hotspots, drainage lines, or low-lying accumulation areas.



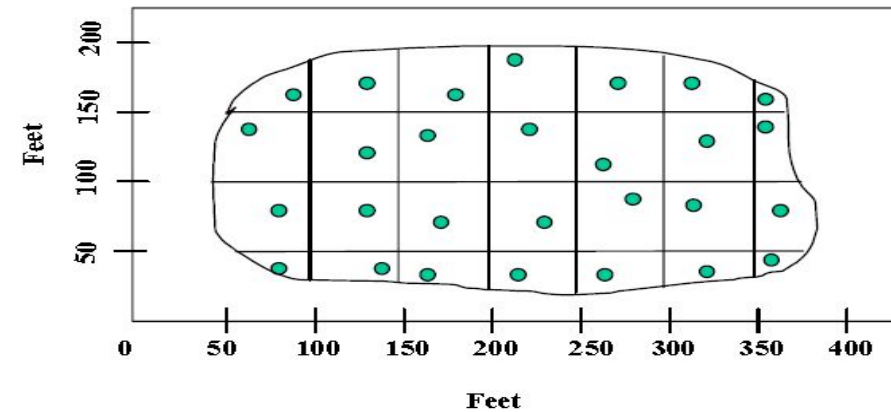
a) Random Sampling



a. Systematic Grid Sampling



b) Stratified Random Sampling

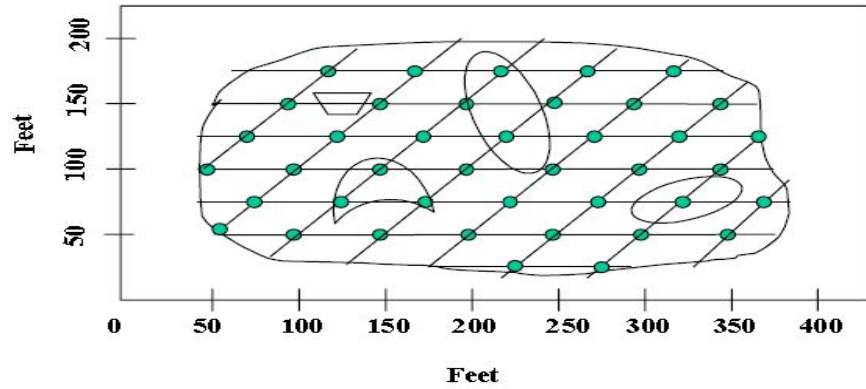


b. Systematic Random Sampling

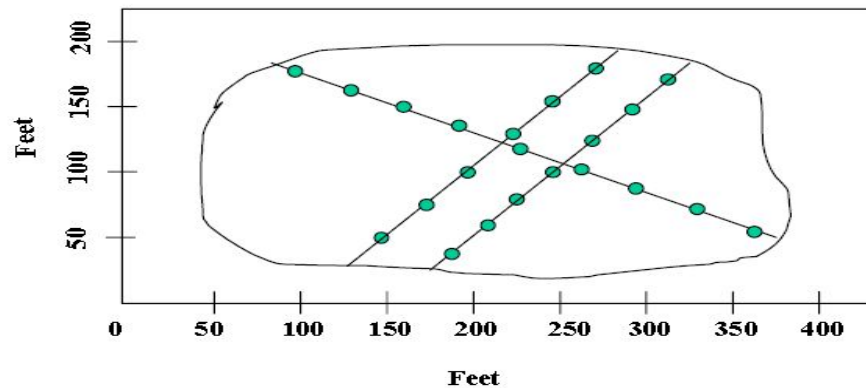
● Selected Sample Location

● Selected Sample Location

Sampling Design Patterns



a. Search Sampling



b. Transect Sampling

● Selected Sample Location
○ Hot Spot

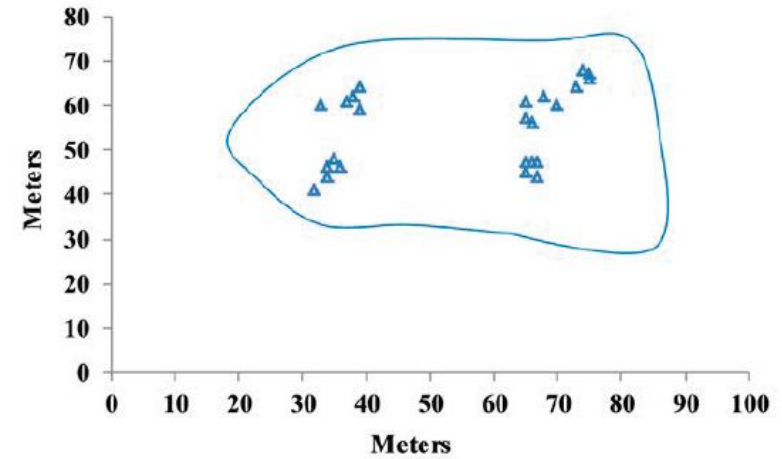
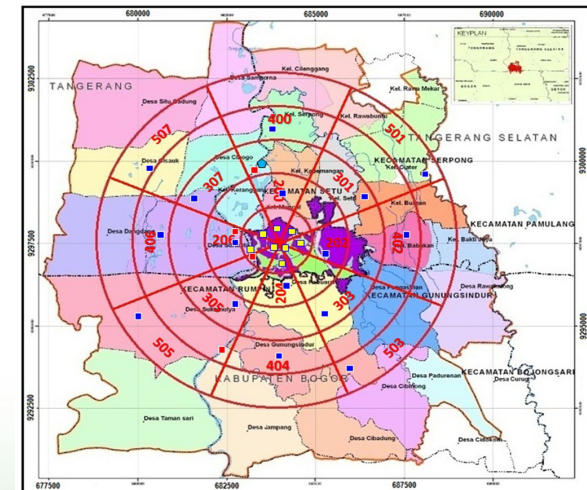


FIG. 2.7. Cluster sampling.



Radial Pattern

Example scheme for soil or air monitoring:

- **Near field** : 0–10 m (immediate vicinity) – 1–3 points.
- **Intermediate** : 25–50 m – along main transect.
- **Far field** : 100–250 m – to detect contamination gradient.
- **Background** : >300 m upwind or upstream.

All points should be georeferenced (GPS) and documented for repeat monitoring.

- Frequency depends on site radioactivity level, radionuclide behaviour, and seasonal variations.
- Duration planned to capture long-term trends and decay characteristics.
- Graded approach – higher frequency at start, adjusted after stable trends are established.

Location, Frequency, Method(1)

Component	Parameter	Monitoring station	Sampling Frequency	Measurement Method
External radiation	ambient dose rate	6 (cont') 24 (temporal)	Continuous, 6 months	GM, NaI(Tl) detector (surveymeter)
	accumulated dose	8	3 months	TLD (Thermoluminescent dosimeters)
Air	Iodine & particulate radioactivity	4	1 month	Alpha/beta low background counter (LBC), gamma spec.
Rain water	Radioactivity in rain water	2	1 month	Alpha/beta LBC, gamma spec.
Soil	Radioactivity in surface soil	24	6 months	Alpha/beta LBC, gamma spec.

Location, Frequency, Method(2)

Component	Parameter	Monitoring station	Sampling Frequency	Measurement Method
Surface water	Radioactivity in surface water	2 (lake) 3 (small river) 4 (big river)	1 month	Alpha/beta LBC, gamma spec
Drinking water	Radioactivity in drinking water	16 (settlement) 2 (drinking water inst.)	6 months 1 month	Alpha/beta LBC, gamma spec
Sediment	Radioactivity in sediment	2 (lake) 3 (small river) 4 (big river)	6 months	Alpha/beta LBC, gamma spec
Plant (grass)	Radioactivity in plant (grass)	24	12 months	Alpha/beta LBC,
Meteorology	Rainfall, solar rad., wind, temperature, humidity, pressure	1	continuous	Rain gauge, pyranometer, automatic weather system

Quality Assurance / Quality Control

- ❖ Standard operating procedures (SOP) for sampling and analysis.
- ❖ Instrument calibration, blank and spike samples, and external audits.
- ❖ Chain of custody documentation and data validation before reporting.

- ❖ Record coordinates, sample type, depth, weather, and chain of custody.
- ❖ Include duplicates, blanks, and background samples for QA/QC.
- ❖ Ensure sample labelling, preservation, and transport integrity.
- ❖ Plan statistical analysis to compare impacted vs. background levels.

- ❑ Compare results to background values and regulatory limits.
- ❑ Statistical evaluation: mean, median, and trend analysis.
- ❑ Spatial mapping and exposure pathway modelling.
- ❑ Reports include tables, charts, and summaries for regulators and stakeholders.

- ❖ Adjust monitoring scope and frequency based on results.
- ❖ Conduct additional surveys if anomalies or hotspots are detected.
- ❖ Implement long-term post-release monitoring and automated sensor systems.
- ❖ Promote continuous improvement and transparency in environmental safety.

RADIATION AND RADIOACTIVITY MEASUREMENT

- ❖ **Field/in-situ:** gamma dose rate mapping, portable spectrometry, continuous air monitoring.
- ❖ **Laboratory:** sample preparation, gamma spectrometry (HPGe/NaI), alpha/beta counting, radiochemical analysis.
- ❖ QA/QC ensures data integrity: calibration, blanks, duplicates, traceability.

Field/in-situ: gamma dose rate mapping, portable spectrometry, continuous air monitoring.



**Gamma Radiation Exposure
Micro R Meter Model 19 with NaI(Tl) Detector**



**Surface Contamination
Monitor Model 6000**



Insitu Gamma Spectrometer

- ❖ **Laboratory:** sample preparation, gamma spectrometry (HPGe/NaI), alpha/beta counting, radiochemical analysis



Gamma Ray Spectrometer



Alpha Beta Low Background Counter

MAPPING METHODOLOGY



1. Systematic grid sampling has been used for sampling \square grid size 60 km x 60km for five main islands and 20km x 20km for other islands.

2. Environmental gamma dose rate was performed continuously in the car during the trip in the grid; also in the soil sampling point – outside of the car.



MAPPING METHODOLOGY



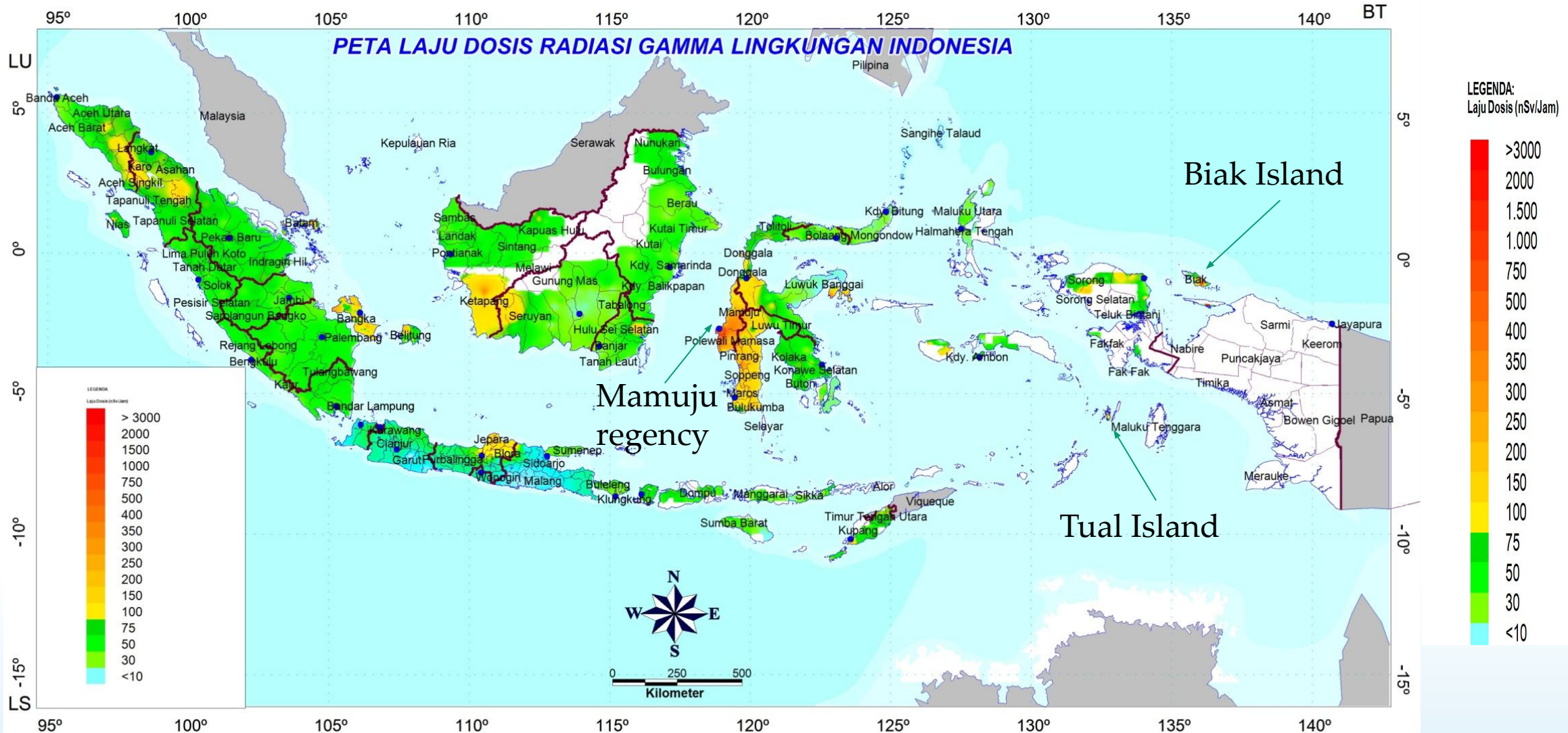
3. Soil samples were taken at each grid with a depth of 0-5 cm and 5-20 cm;
4. Radionuclide concentrations were measured by Gamma Spectrometer with HPGe Detector.



5. The maps were made using MapInfo Software.



ENVIRONMENTAL GAMMA DOSE RATES (nSv/h) IN INDONESIA



	Range(nSv/h)	Geometric average (nSv/h)	Highest area
Gamma Dose Rates	10 - 8,000	56 ± 2	Mamuju, West Sulawesi

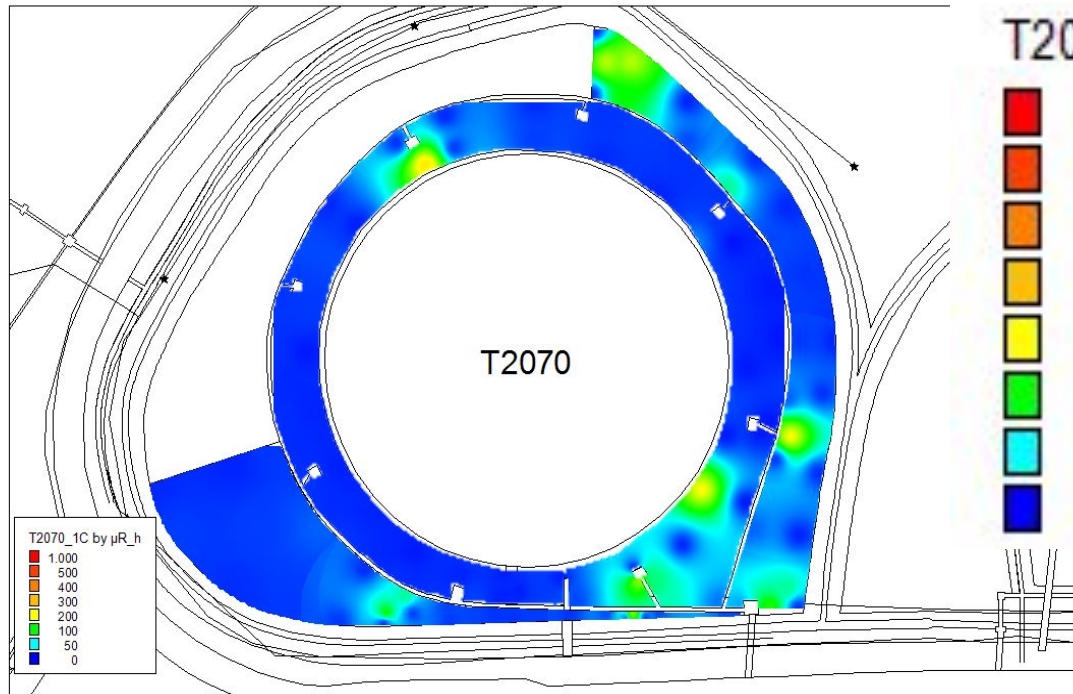
FTC on ERM 13-17 October 2025

Process of NORM Clean Up



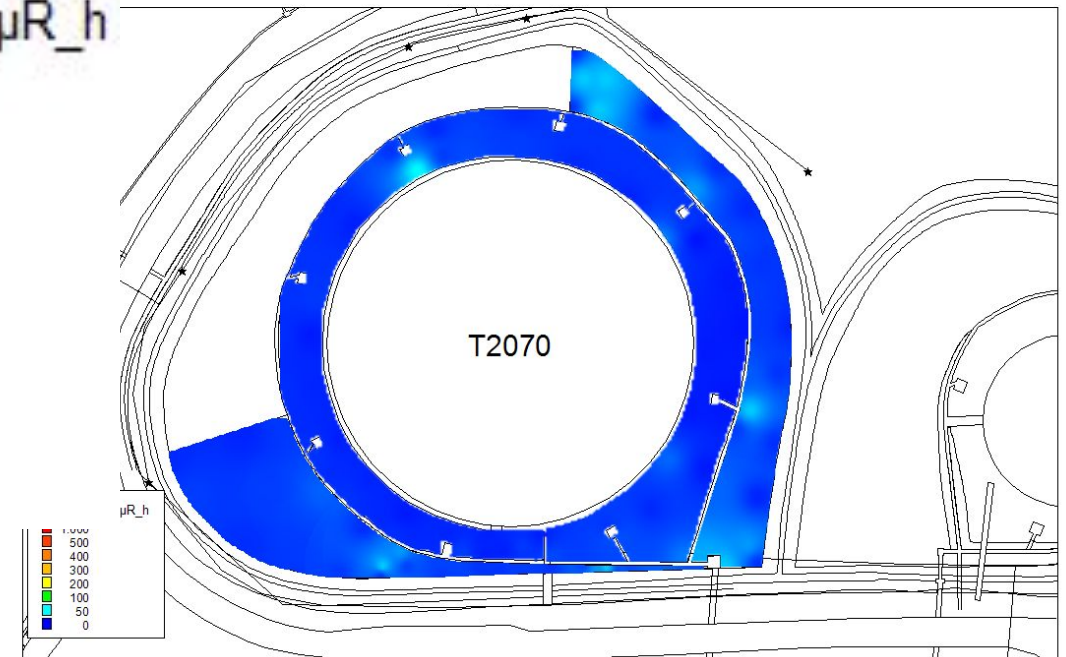
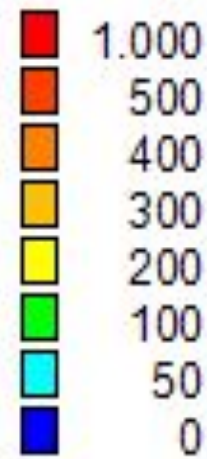
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Determination of NORM Contamination Level before and after Clean Up



Before clean up

T2070_1C by μR_h



After clean up

Environmental monitoring programs from nuclear facility decommissioning are intended to ensure that there are no radionuclide releases exceeding the permitted limits and to protect the environment and the public.



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