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ENVIRONMENTAL RADIATION MONITORING DURING EMERGENCY

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Presented in Follow-up Training Course on
Nuclear & Radiological Emergency Preparedness 2025

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Self-introduction

Organization: National Research and Innovation Agency (BRIN)

Department: Directorate of Nuclear Facility Management

Division: Quality Assurance

Training experience :

1. On the Job Training Environmental Radiation Monitoring, JAEA-Tsuruga, Japan, 2011
2. Instructor Training Course on Environmental Radiation Monitoring, JAEA-Tokai, Japan, 2014
3. Online Training Course on Nuclear and Radiological Emergency Preparedness, JAEA, 2020
4. Advanced Instructor Training Course on Environmental Radioactivity Monitoring, Online, JAEA, 2021
5. Advanced Instructor Training Course on Environmental Radioactivity Monitoring JAEA-Tokai, Japan, 2023

Experience as an instructor:

1. Follow-up Training Course on Environmental Radioactivity Monitoring, 2014-2024
2. Instructor Training Course on Environmental Radioactivity Monitoring, 2019 & 2021 (Guest Lecturer)
3. Follow-up Training Course on Nuclear/Radiological Emergency Preparedness 2022-2024
4. Radiation Protection Officer Course 2023 - 2024

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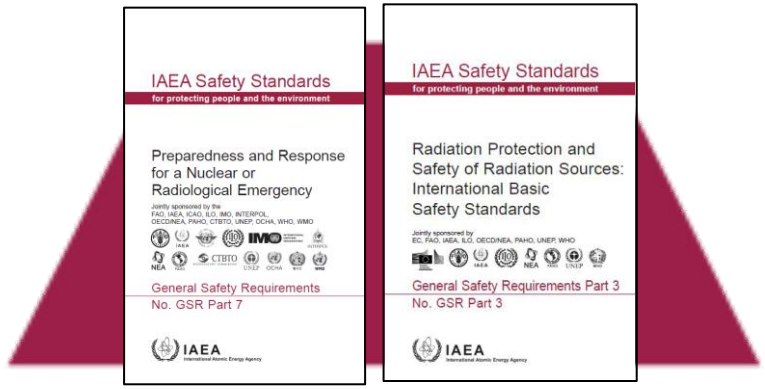
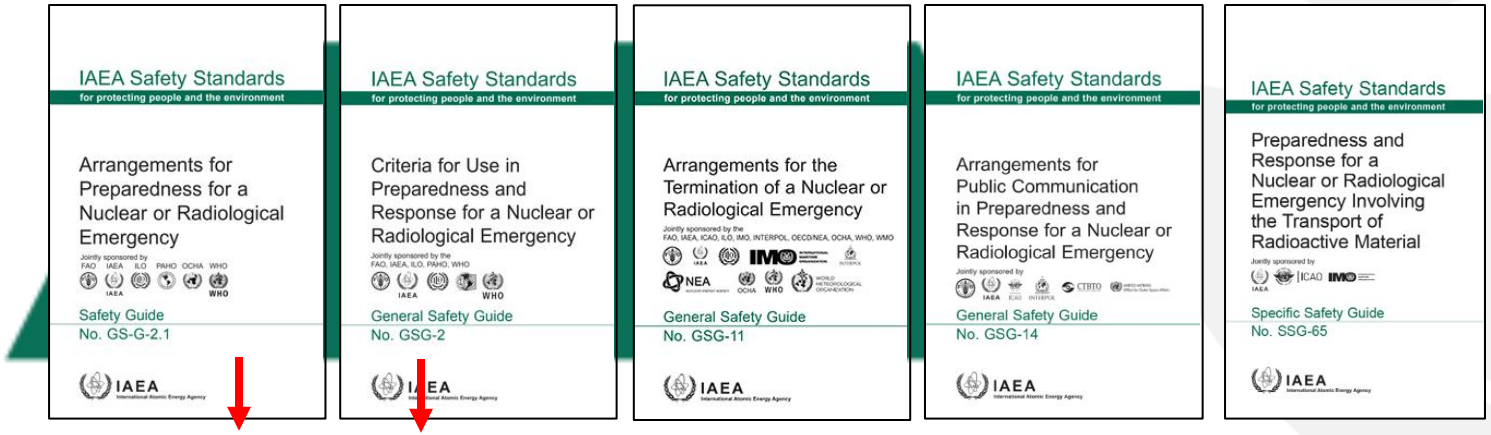
IAEA Hierarchy on EPR

Safety Fundamentals

Safety Requirements

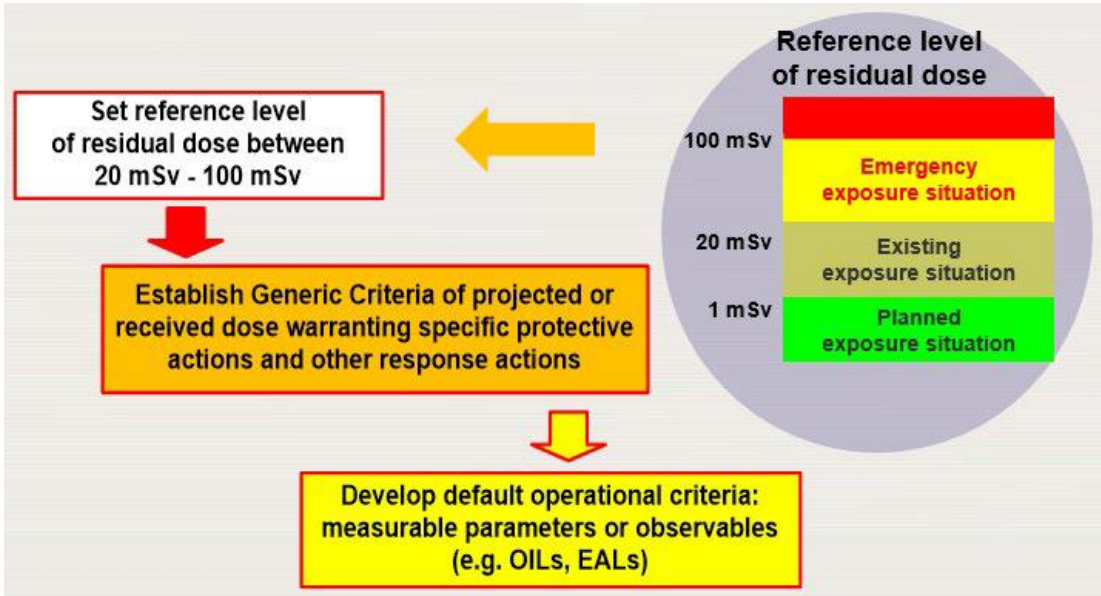


Safety Guides



Under revision

Principle 9: *"Arrangements must be made for emergency preparedness and incidents response for nuclear or radiation"*



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Goals of Emergency Response (GSR Part 7)

- **To regain control of the situation and to mitigate consequences**
  Provide real-time data and radiation/contamination maps to help decision-makers determine effective mitigation measures (evacuation, sheltering, decontamination).
- **To save lives**
- **To avoid or minimize severe deterministic effects**
  Identify and isolate high-dose areas promptly to prevent acute exposures that could cause immediate health effects.
- **To render first aid, to provide critical medical treatment and to manage the treatment of radiation injuries**
- **To reduce the risk of stochastic effects**
  Collect long-term exposure data (dose rate, food and water contamination) to minimize the risk of cancer and other delayed health effects.
- **To keep the public informed and to maintain public trust**
  Share transparent, verifiable monitoring results with the public to reduce panic, misinformation, and rumors.
- **To mitigate, to the extent practicable, the non-radiological consequences**
- **To protect, to the extent practicable, property and the environment**
  Identify contaminated areas to prioritize decontamination efforts and prevent the spread of contaminants to clean areas.
- **To prepare, to the extent practicable, for the resumption of normal social and economic activity**
  Provide validated data to support the lifting of restrictions, reopening of affected areas, and safe recovery of economic activities.

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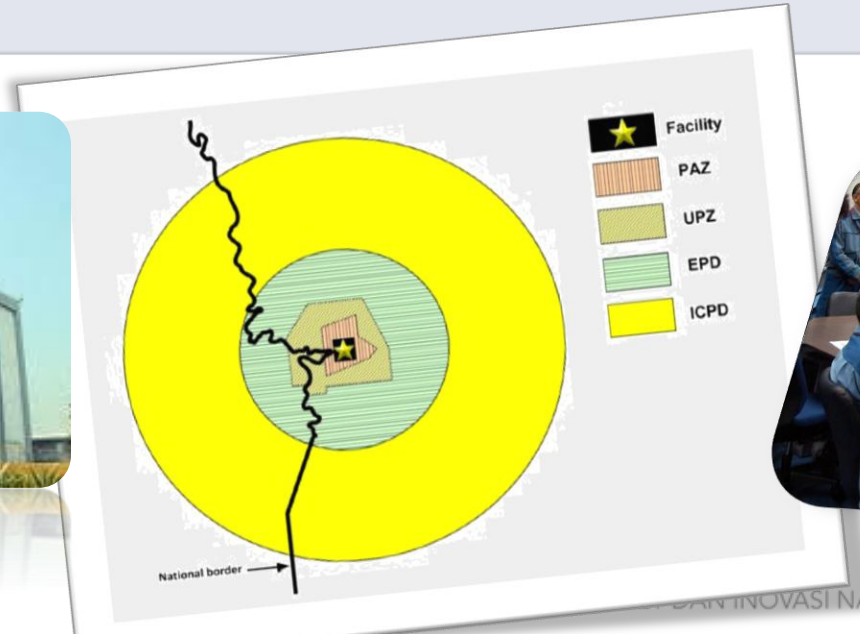
Background

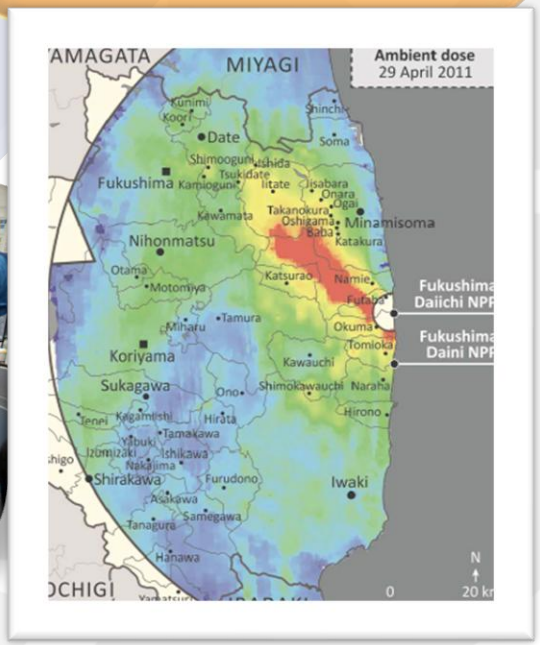
Probability of accident in nuclear/radiation utilization

Ability to promptly and adequately assess the need for protective actions

Protective action emergency management must make use of the key relevant information available

Emergency monitoring is one of the main sources for obtaining the needed information





Benefit

Participants can understand technical requirements and procedures for radiation monitoring in response to a nuclear or other radiological emergency

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Purpose

Participants are expected to explain strategy and equipment needed in monitoring during a nuclear or radiological emergency

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Success Indicator

Participants are able to:

- explain objectives of emergency monitoring;
- explain emergency monitoring organization;
- explain emergency monitoring design and program;
- explain instrumentation of emergency monitoring;
- explain QA/QC checks

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Content

- Objectives of emergency monitoring
- Emergency monitoring organization
- Emergency monitoring design and program
- Instrumentation of emergency monitoring
- QA/QC checks

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Objectives of Emergency Monitoring

Part-1

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Key Concepts

Environmental radiation monitoring:

Measurement and assessment of radiation levels in the environment.

Normal vs Emergency monitoring:

Normal: Routine measurements to detect trends.

Emergency: Rapid, targeted measurements to guide urgent protective actions.

Principles: Rapid – Accurate – Safe – Coordinated.

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Main Purpose (Tecdoc-1092)

Primary purpose of emergency monitoring is

to provide timely information on which decisions on protective actions can be confirmed or revised

This requires detection of

radioactive material	**determination of its location**	**determination of its nature**

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Objective (Tecdoc-1092)

The objectives of emergency monitoring are to:

- assist decision makers on the need to take protective actions and interventions on the basis of operational intervention levels (OILs);
- assist in preventing the spread of contamination;
- provide information for protection of emergency workers;
- provide accurate and timely data on the level and degree of hazards resulting from a radiological emergency;
- determine the extent and duration of the hazard;
- provide detail of the physical and chemical characteristics of the hazard, and
- confirm the efficiency of remedial measures such as decontamination procedures,

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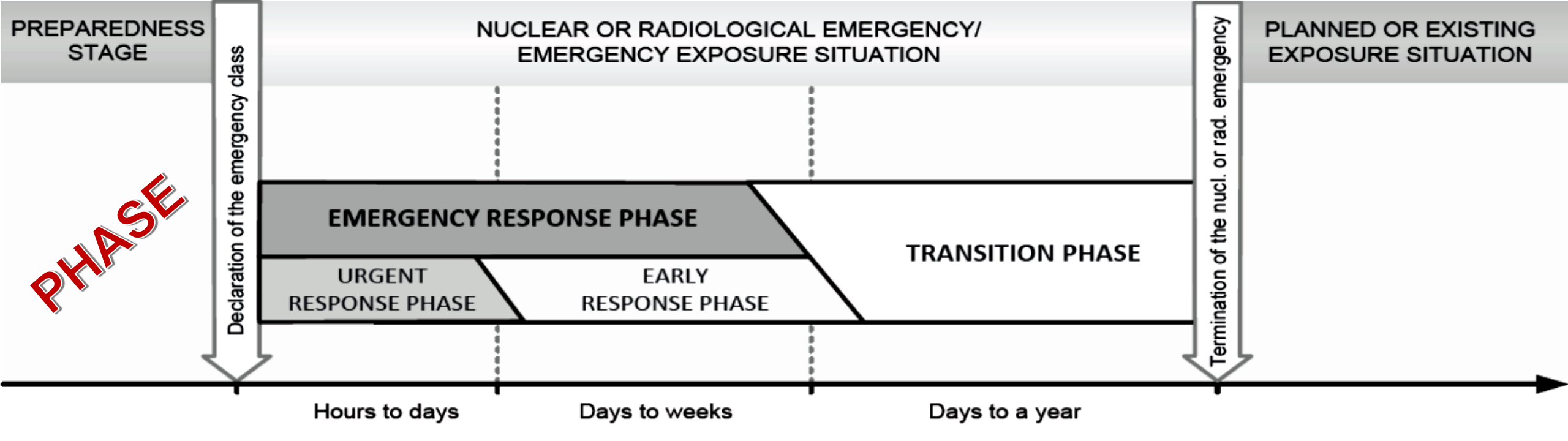
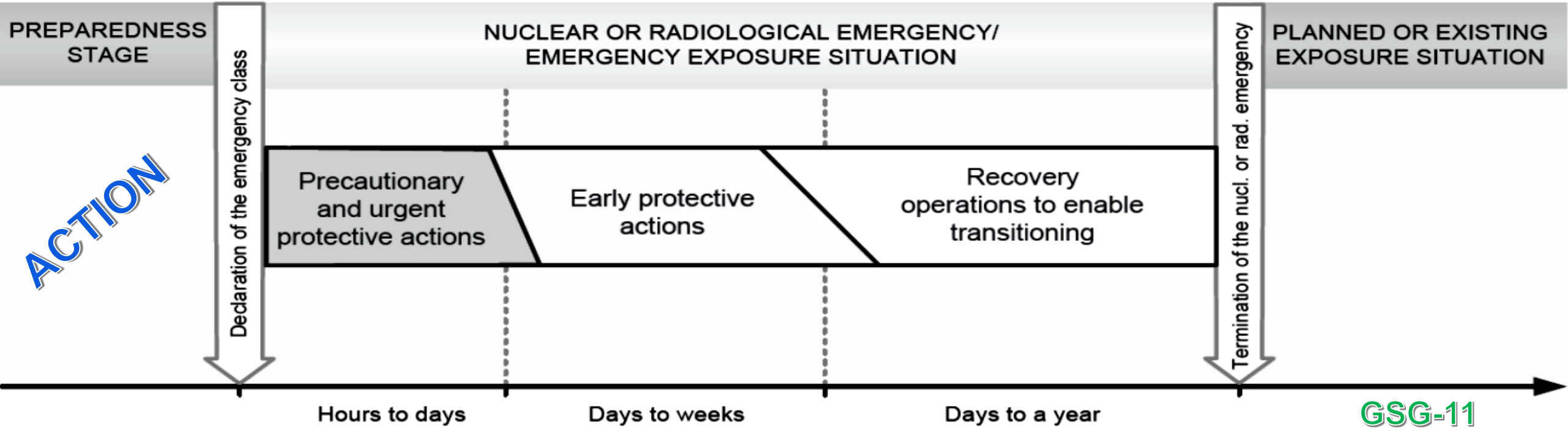
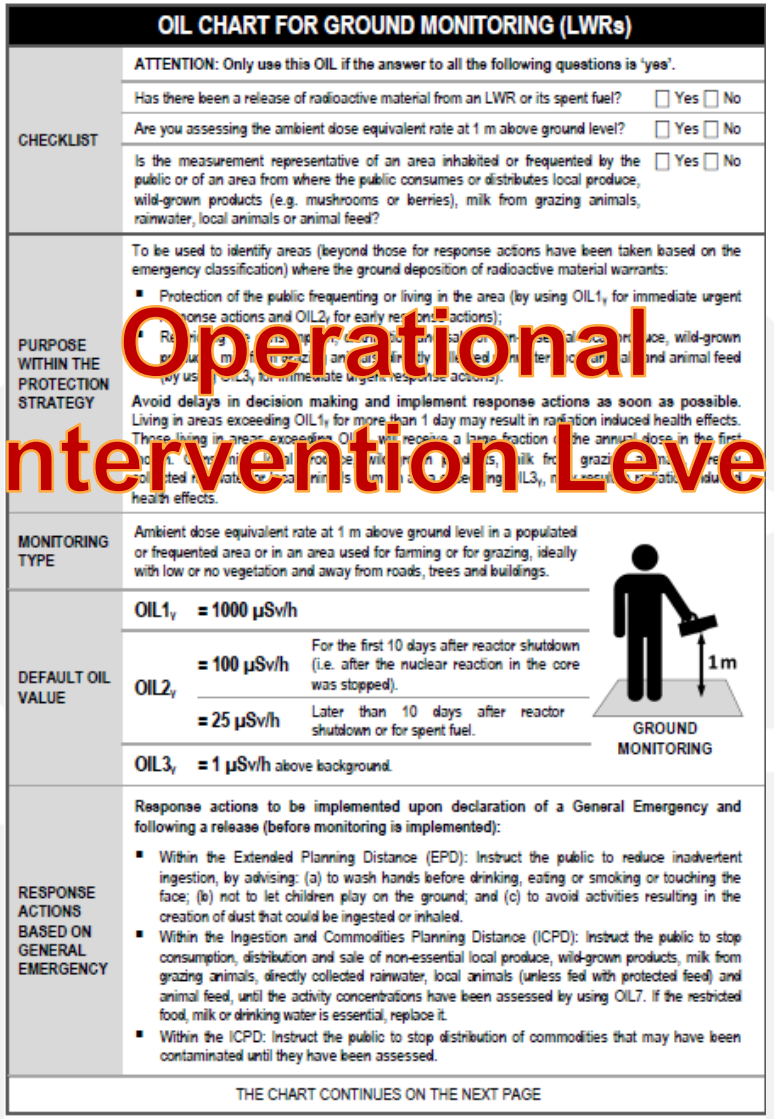

PREPAREDNESS STAGE
NUCLEAR OR RADIOLOGICAL EMERGENCY/ EMERGENCY EXPOSURE SITUATION
PLANNED OR EXISTING EXPOSURE SITUATION
PHASE
Declaration of the emergency class
Termination of the nucl. or rad. emergency
EMERGENCY RESPONSE PHASE
TRANSITION PHASE
URGENT RESPONSE PHASE
EARLY RESPONSE PHASE
Hours to days
Days to weeks
Days to a year


PREPAREDNESS STAGE
NUCLEAR OR RADIOLOGICAL EMERGENCY/ EMERGENCY EXPOSURE SITUATION
PLANNED OR EXISTING EXPOSURE SITUATION
ACTION
Declaration of the emergency class
Termination of the nucl. or rad. emergency
Precautionary and urgent protective actions
Early protective actions
Recovery operations to enable transitioning
Hours to days
Days to weeks
Days to a year
GSG-11

Purposes in Each Phase

Phase	Purpose	Monitored Parameter
1st	- Measure air concentration & dose rate - Estimating public dose - Take decisions on countermeasures (sheltering, evacuation, stable iodine)	- Met data - Release rate from facility - Gamma dose rate - Activity concentration in environmental sample
2nd	- Monitoring over a wider area - Public dose study - Restrictions on consumption of food products - Estimate the impact of accidents on the environment	- Met data - Release rate from facility - Gamma dose rate - Activity concentration in environmental sample - Cumulative dose
Recovery	- Termination of restrictions - Detailed effective dose calculation	- All parameters periodically



OIL CHART FOR GROUND MONITORING (LWRs)

CHECKLIST

ATTENTION: Only use this OIL if the answer to all the following questions is 'yes'.

Has there been a release of radioactive material from an LWR or its spent fuel? ☐ Yes ☐ No

Are you assessing the ambient dose equivalent rate at 1 m above ground level? ☐ Yes ☐ No

Is the measurement representative of an area inhabited or frequented by the public or of an area from where the public consumes or distributes local produce, wild-grown products (e.g. mushrooms or berries), milk from grazing animals, rainwater, local animals or animal feed? ☐ Yes ☐ No

PURPOSE WITHIN THE PROTECTION STRATEGY

To be used to identify areas (beyond those for response actions have been taken based on the emergency classification) where the ground deposition of radioactive material warrants:

- Protection of the public frequenting or living in the area (by using $OIL1_\gamma$ for immediate urgent [illegible] actions and $OIL2_\gamma$ for early [illegible] actions);
- [illegible] local produce, wild-grown [illegible] and animal feed [illegible] $OIL3_\gamma$ for immediate urgent response actions).

Avoid delays in decision making and implement response actions as soon as possible. Living in areas exceeding $OIL1_\gamma$ for more than 1 day may result in radiation induced health effects. Those living in areas exceeding OIL [illegible] will receive a large fraction [illegible] the annual dose in the first [illegible] local produce, wild-grown [illegible] milk from grazing [illegible] collected rainwater, local animals [illegible] $OIL3_\gamma$, [illegible] health effects.

MONITORING TYPE

Ambient dose equivalent rate at 1 m above ground level in a populated or frequented area or in an area used for farming or for grazing, ideally with low or no vegetation and away from roads, trees and buildings.

DEFAULT OIL VALUE

$OIL1_\gamma$ = 1000 µSv/h

$OIL2_\gamma$ = 100 µSv/h — For the first 10 days after reactor shutdown (i.e. after the nuclear reaction in the core was stopped).

$OIL2_\gamma$ = 25 µSv/h — Later than 10 days after reactor shutdown or for spent fuel.

$OIL3_\gamma$ = 1 µSv/h above background.

GROUND MONITORING

RESPONSE ACTIONS BASED ON GENERAL EMERGENCY

Response actions to be implemented upon declaration of a General Emergency and following a release (before monitoring is implemented):

- Within the Extended Planning Distance (EPD): Instruct the public to reduce inadvertent ingestion, by advising: (a) to wash hands before drinking, eating or smoking or touching the face; (b) not to let children play on the ground; and (c) to avoid activities resulting in the creation of dust that could be ingested or inhaled.
- Within the Ingestion and Commodities Planning Distance (ICPD): Instruct the public to stop consumption, distribution and sale of non-essential local produce, wild-grown products, milk from grazing animals, directly collected rainwater, local animals (unless fed with protected feed) and animal feed, until the activity concentrations have been assessed by using OIL7. If the restricted food, milk or drinking water is essential, replace it.
- Within the ICPD: Instruct the public to stop distribution of commodities that may have been contaminated until they have been assessed.

THE CHART CONTINUES ON THE NEXT PAGE

Operational Intervention Level

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OILs Development

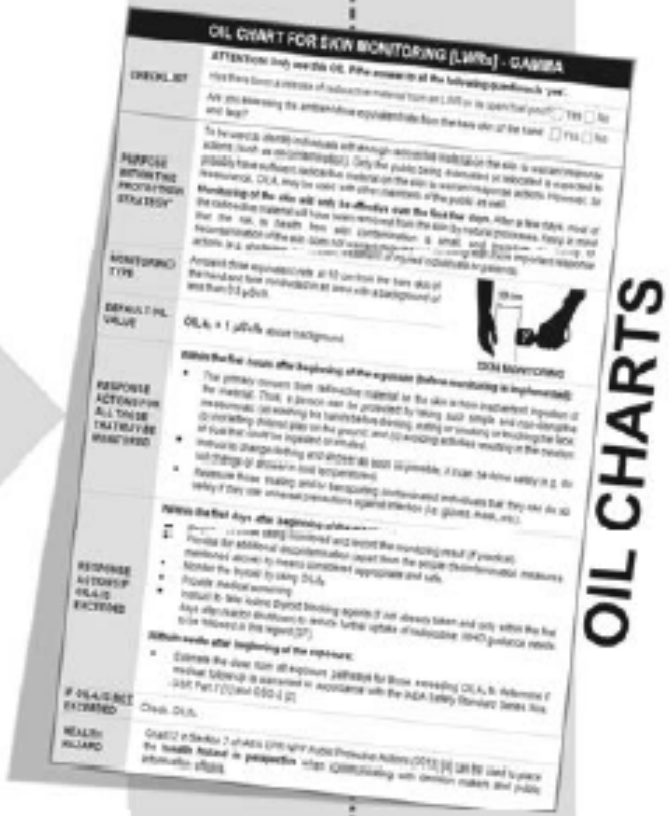
EPR_NPP_OILs_2017

AT THE PREPAREDNESS STAGE

	SECTION
Establish generic criteria at which to implement response actions	3.2
Consider all relevant radionuclide mixes	3.3
Consider all individuals being exposed	3.4
Consider all relevant exposure scenarios and associated pathways	3.4
Consider the behaviour of the radionuclides	3.5
Determine the dose conversion factors to perform the relevant organ dose calculations	3.6
Consider the instrument response	3.7
Calculate the time and mix dependent OIL(t,mix) functions and select a default OIL value	3.8
Develop a set of response actions within a justified and optimized protection strategy	3.9
Prepare to communicate with decision makers and public information officers	2.3

DURING THE RESPONSE

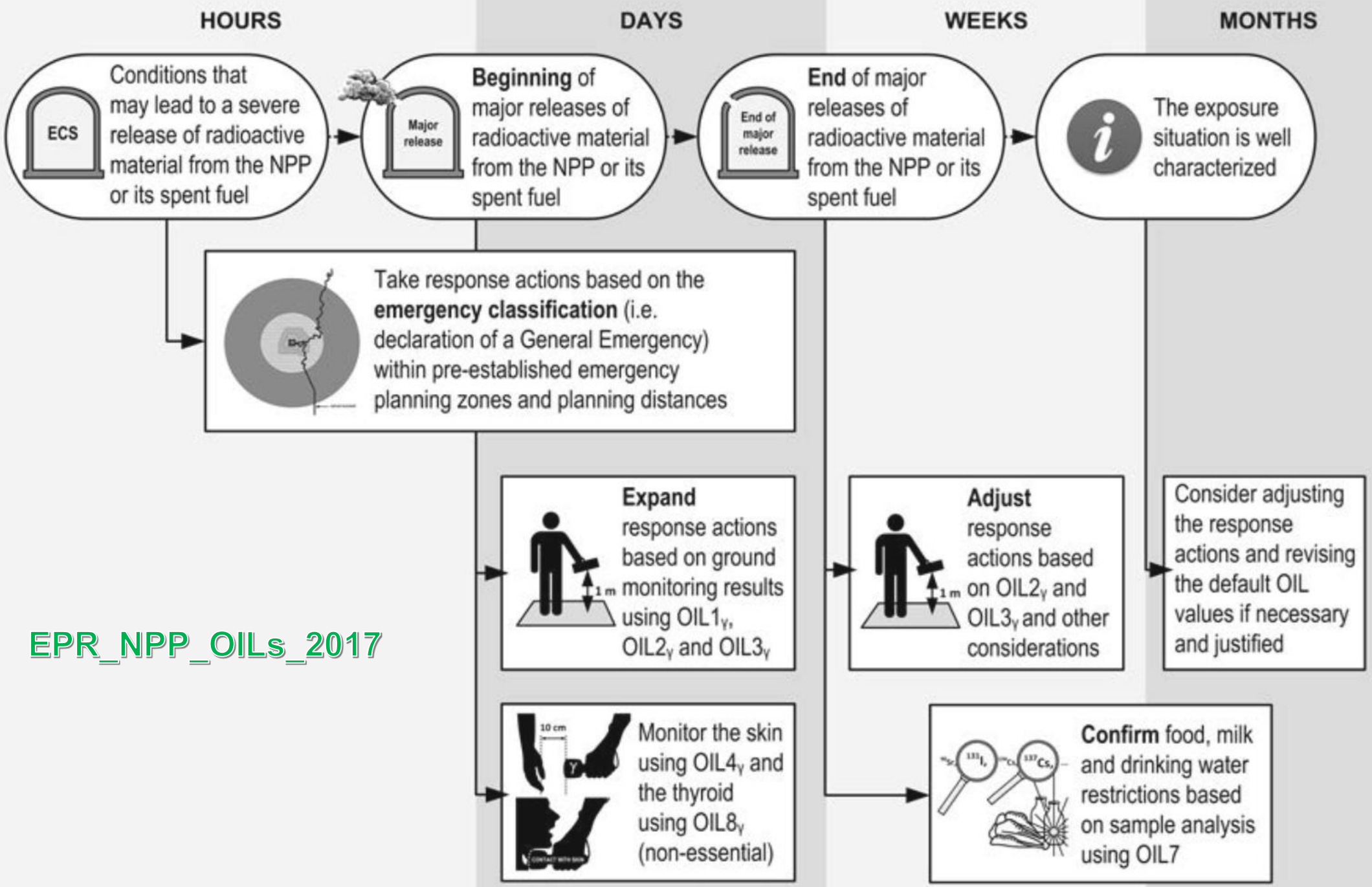
MEASURED QUANTITY



OIL CHARTS

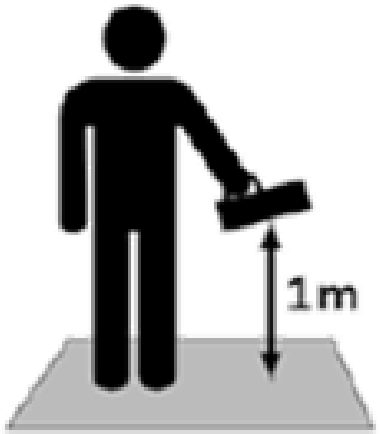
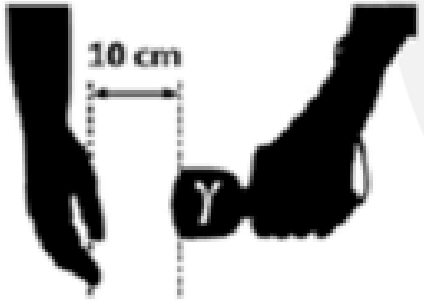
RESPONSE ACTION

Role of OILs



EPR_NPP_OILs_2017

OILs (EPR_NPP_OILs_2017)

OIL	Default OIL value	Monitoring type
$OIL1_{\gamma}$	1000 µSv/h	 GROUND MONITORING Ambient dose equivalent rate at 1 m above ground level
$OIL2_{\gamma}$	100 µSv/h (for the first 10 days after reactor shutdown[a])	
	25 µSv/h (later than 10 days after reactor shutdown[a] or for spent fuel)	
$OIL3_{\gamma}$[b]	1 µSv/h	
$OIL4_{\gamma}$[c]	1 µSv/h	 SKIN MONITORING Ambient dose equivalent rate at 10 cm from the bare skin of the hand and face

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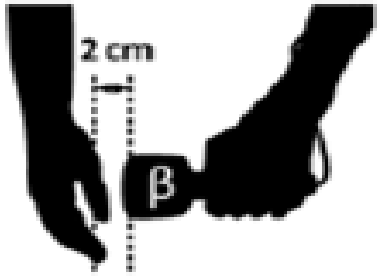
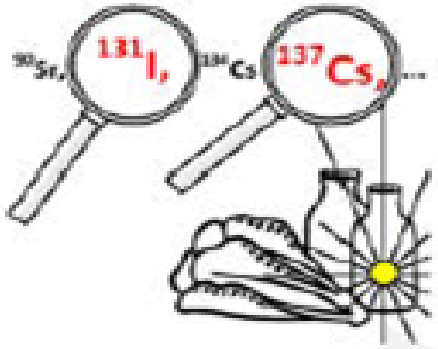
OILs (EPR_NPP_OILs_2017)

OIL	Default OIL value		Monitoring type
$OIL4_{\beta}$[c]	1000 cps[d]		SKIN MONITORING Beta count rate at 2 cm from the bare skin of the hand and face (The use of $OIL4_{\gamma}$ is preferable over $OIL4_{\beta}$)
OIL7	1000 Bq/kg of I-131 and 200 Bq/kg of Cs-137		MONITORING OF FOOD, MILK[e] AND DRINKING WATER SAMPLES Activity concentration of I-131[f] and Cs-137[f] in food, milk and drinking water samples
$OIL8_{\gamma}$	0.5 µSv/h		THYROID MONITORING Ambient dose equivalent rate in front of the thyroid in contact with the skin

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Organization

Part-2

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Generic Monitoring Organization

Emergency Manager

Responsible for overall emergency response

Protective Action Manager

Determines protective actions based on monitoring

Environmental Analyst/ Radiological Assessor

Manages field monitoring and sampling

Sample Analyst

Manages laboratory analyses

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Generic Monitoring Organization

Environmental Analyst/ Radiological Assessor

Environmental Survey Team

Measurements of gamma/beta dose rates, evaluation of unknown situations

Air Sampling Team

Collects air samples, measurements of gamma/beta dose rates

In-situ Gamma Spectrometry Team

Measurements of radionuclide ground concentrations and composition

Environmental and Ingestion Sampling Team

Collects samples of potentially contaminated soil, food and water

Personal Monitoring and Decontamination Team

Personnel and equipment monitoring, decontamination of people

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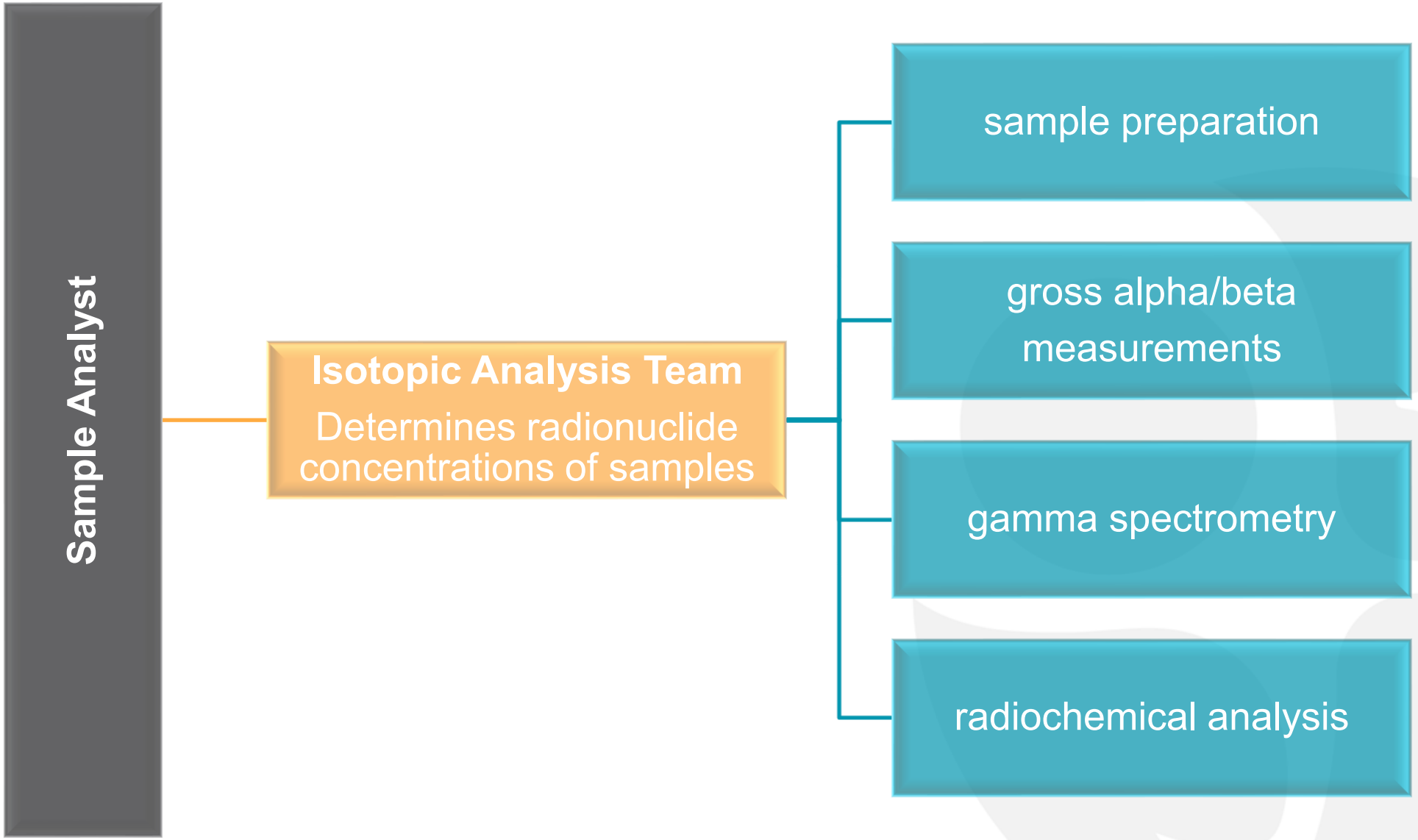
Generic Monitoring Organization



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Design and Program

Part-3

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Design of EM Programme

The design of the emergency monitoring and sampling programme will be determined:

- **By the primary objectives for which it has been established**
- **By the scale of the accident envisaged**
- **The availability of qualified teams to respond to radiological emergency**

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General Priorities in Designing EM Response

In the initial response, the determination of affected areas which are truly “dirty” and where people can be affected should be the first priority

The priority for monitoring and sampling should then take into account the composition of the affected area: residential, agricultural, rural, commercial, and industrial activities, public services and infrastructure elements

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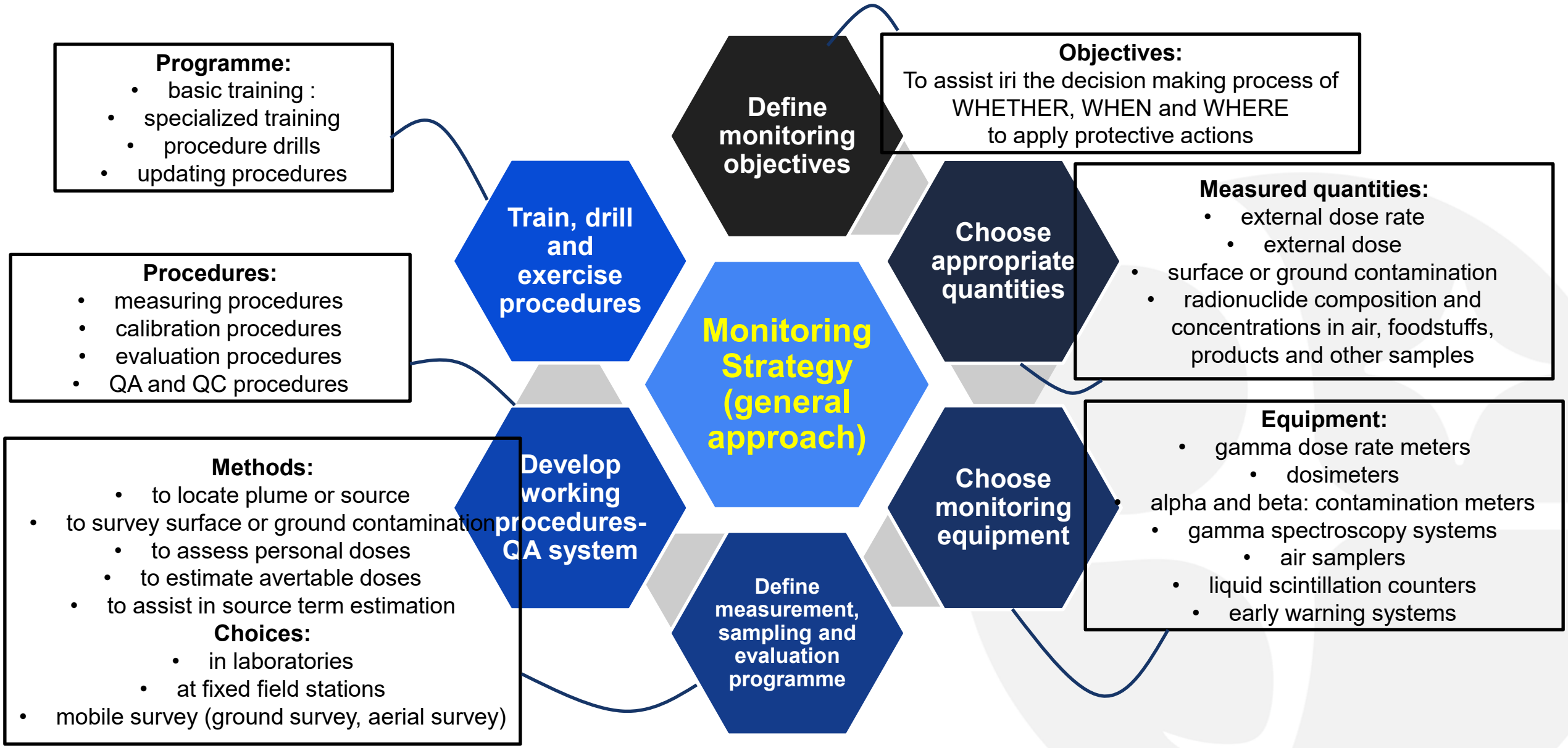
Monitoring Strategy



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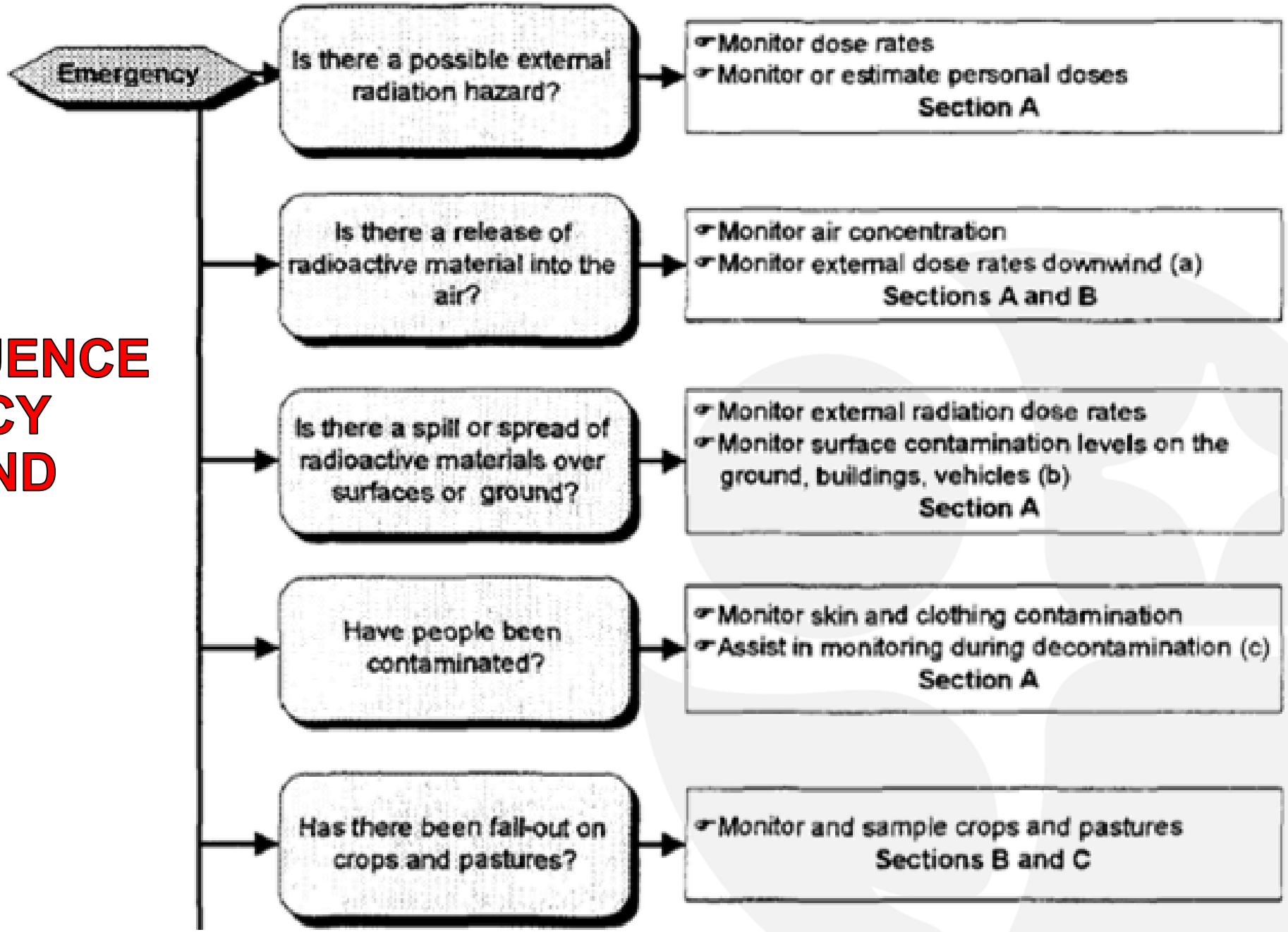
DECISION SEQUENCE FOR EMERGENCY MONITORING AND SAMPLING



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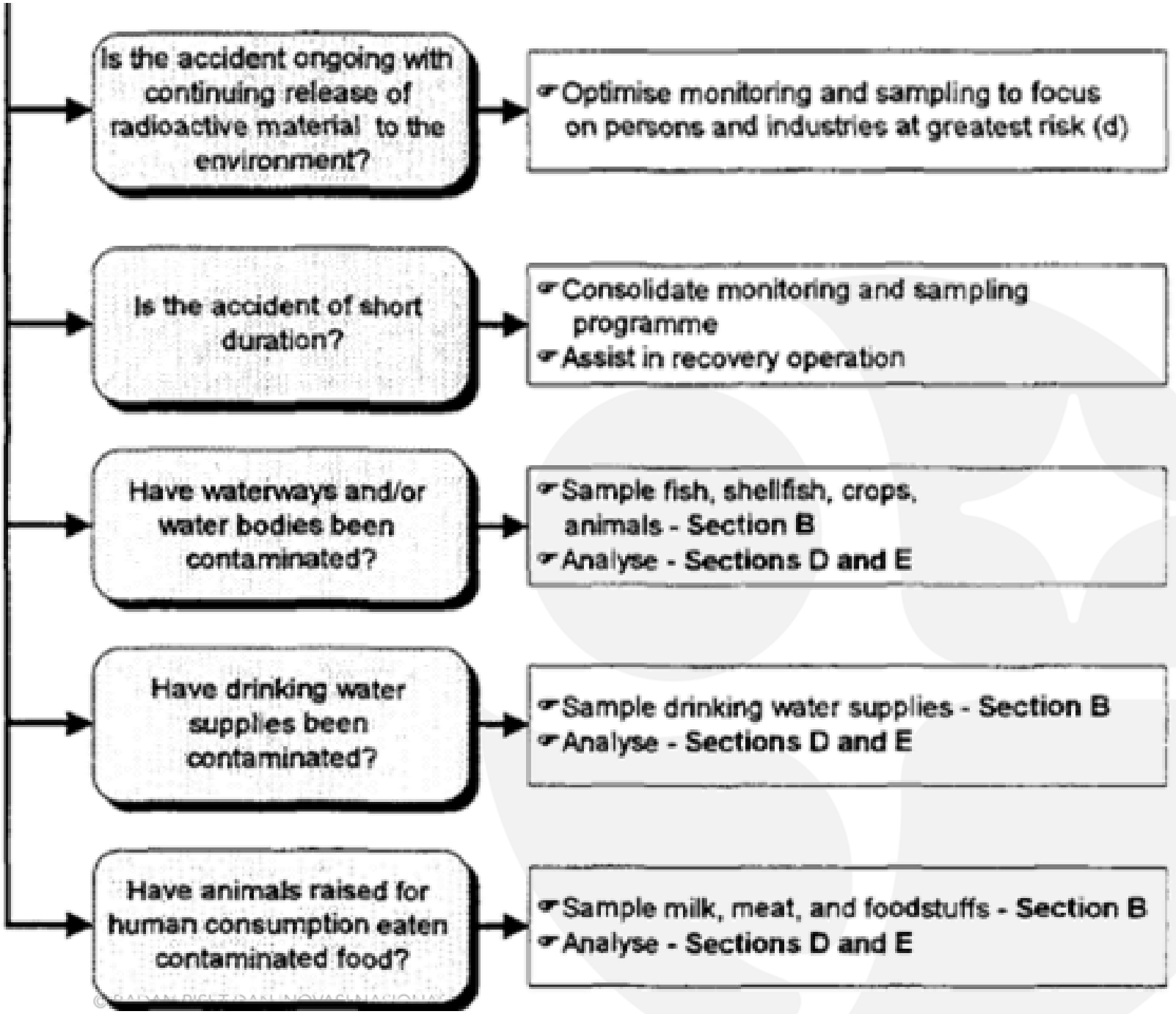
DECISION SEQUENCE FOR EMERGENCY MONITORING AND SAMPLING



Instrumentation

Part-4

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General Guidance

Choose appropriate equipment

Properly calibrate equipment

Maintain equipment readiness

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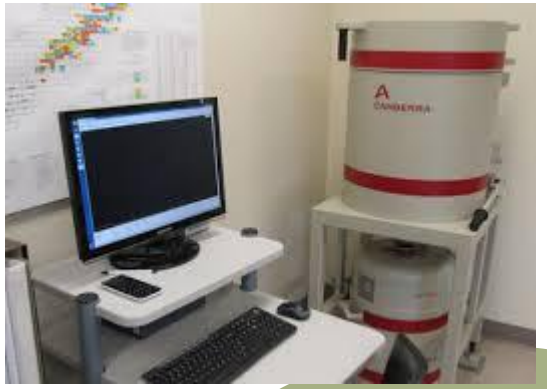
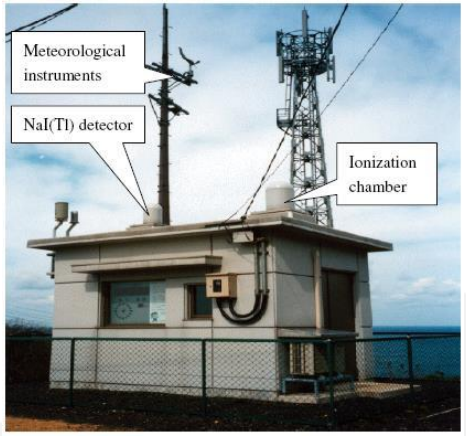
Types of Instrumentation





Installed

Laboratory

Radiation monitoring equipment

Transportable/ portable

Personal

Installed Instrumentation

Element	radiation fields	contamination	
		on surfaces	airborne
Quantity	• dose rates • dose	• contamination level • radionuclide identification • radionuclide concentrations	
Type	• dose rates meters • dosimeters	• Contamination monitor • Smears + contamination monitors or lab measurement	• Air samplers+ contamination monitors or lab measurement
Detects	beta, gamma, X-rays neutrons	alpha, beta, gamma, X-rays	

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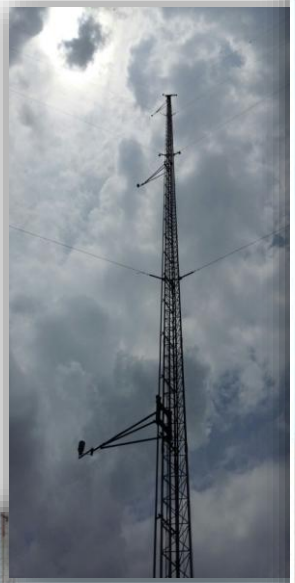
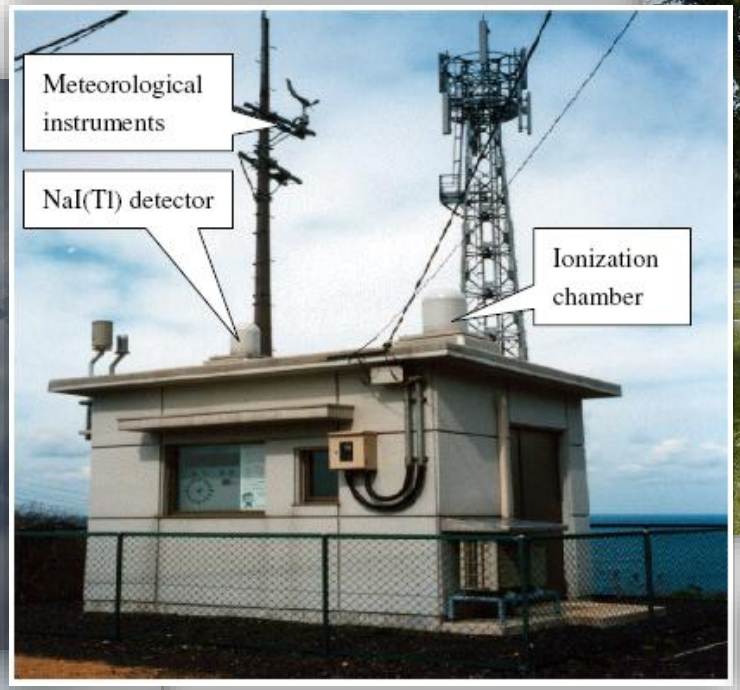
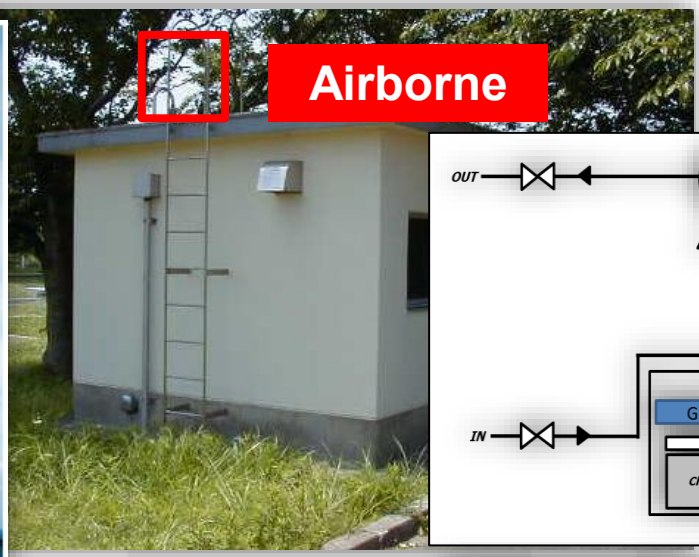
Installed Instrumentation

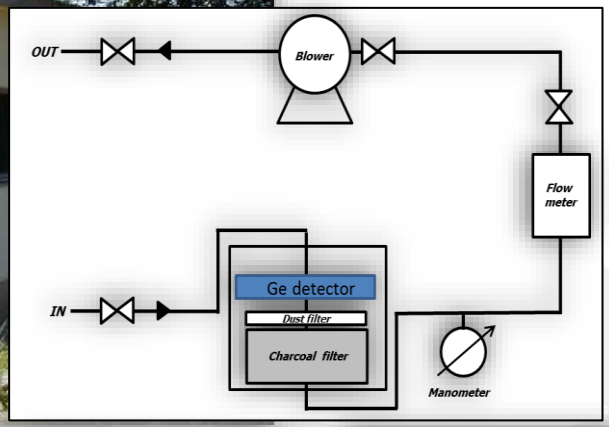
Ambient radiation





Airborne





Meteorology

Dosimeter

Surface contamination

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Portable/Transportable Instrumentation

Element	radiation fields	contamination	
		on surfaces	airborne
Quantity	• dose rate monitoring • dose survey	• contamination level • radionuclide identification • radionuclide concentrations	
Type	• dose rates meters • dosimeters	• Contamination monitor • In-situ gamma spectrometer	• Air samplers+ contamination monitors or lab measurement
Detects	beta, gamma, X-rays neutrons	alpha, beta, gamma, X-rays	

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Portable/Transportable Instrumentation

Emergency Kit

Contamination

Air sampler

Portable Iodine Monitoring

Identifinder

Personal Instrumentation

Element	external radiation	internal radiation
Quantity	• external dose to personal	• radionuclide identification • radionuclide concentrations
Type	• dosimeters (TLD, etc)	• whole body counter • thyroid counter • lung counter
Detects	gamma, X-rays, neutrons	gamma, X-rays

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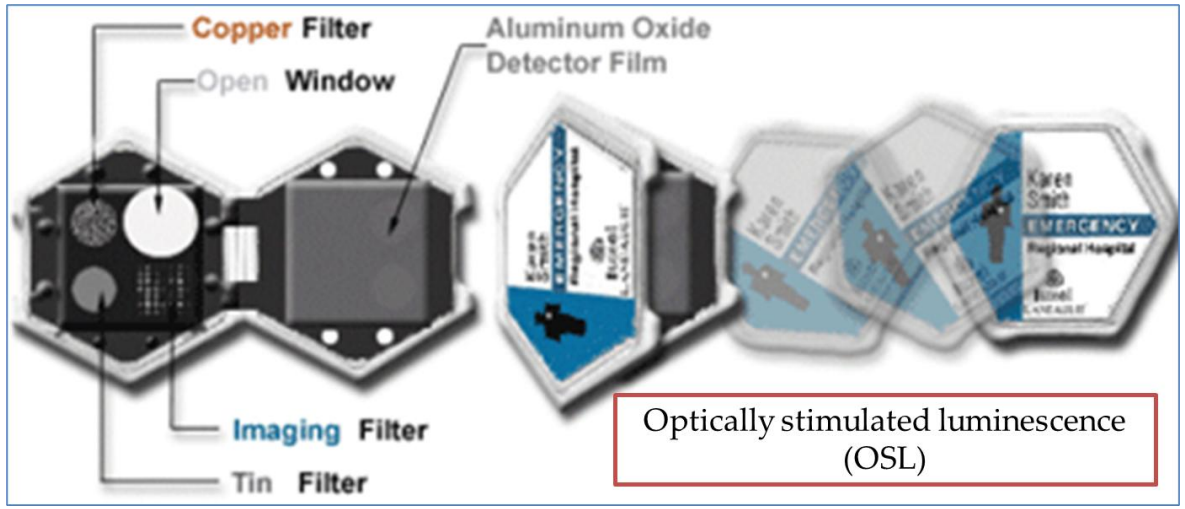
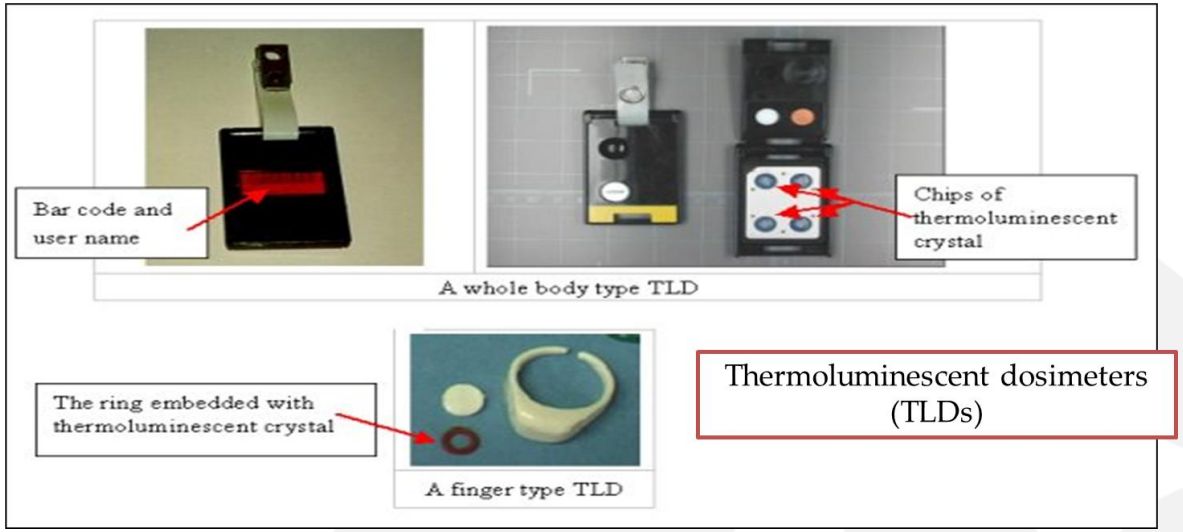
Personal Instrumentation



Optically stimulated luminescence (OSL)



Thermoluminescent dosimeters (TLDs)

EPD

WBC

Thyroid Monitor

Laboratory Instrumentation

Element	samples
Quantity	• gross alpha beta level • radionuclide identification • radionuclide concentrations
Type	• liquid scintillation counter • gas-flow proportional counter • alpha spectrometer • gamma spectrometer
Detects	alpha, beta, gamma, X-rays

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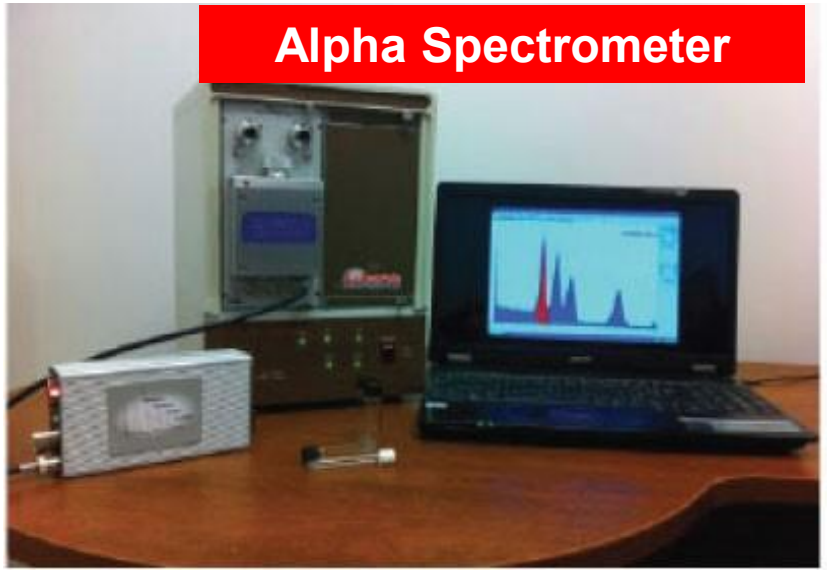
Laboratory Instrumentation

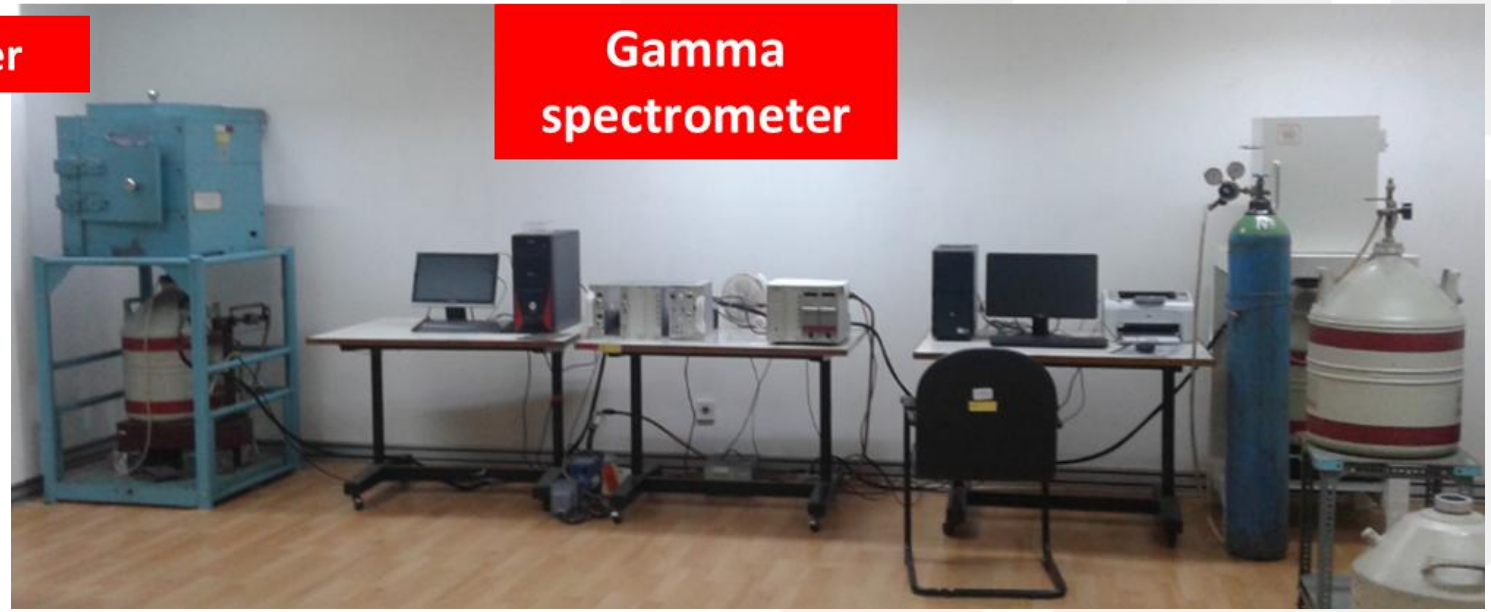
Alpha Beta counter



Alpha Spectrometer

Liquid Scintilation Counter

TLD reader



Gamma spectrometer

Mobile Radiological Laboratories

To perform rapid analyses at or near an emergency site an appropriate equipped mobile radiation laboratory can be the best solution

Vehicles range in size from van or lorry based to commercial semi-trailer or articulated lorry

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Equipment of the MRL

Common equipment placed inside mobile laboratories:

- **gamma spectrometers**
- **gross alpha/beta counters**
- **liquid scintillation systems**
- **other detection equipment**

The choice of equipment for a mobile laboratory is crucial to ensure that samples can pass through the laboratory quickly

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Environmental monitoring vehicle

Emergency vehicles

Body surface contamination-monitoring vehicle

Command vehicle

Whole body counting vehicle

Personal protective equipment vehicle

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Aerial Survey

Aerial monitoring can be regarded as an appropriate method for a rapid survey

- **To provide information on large area surface contamination (ground contamination survey) or**
- **To search, detect localize and identify gamma emitting source(s) over large areas in order to render the source safe**

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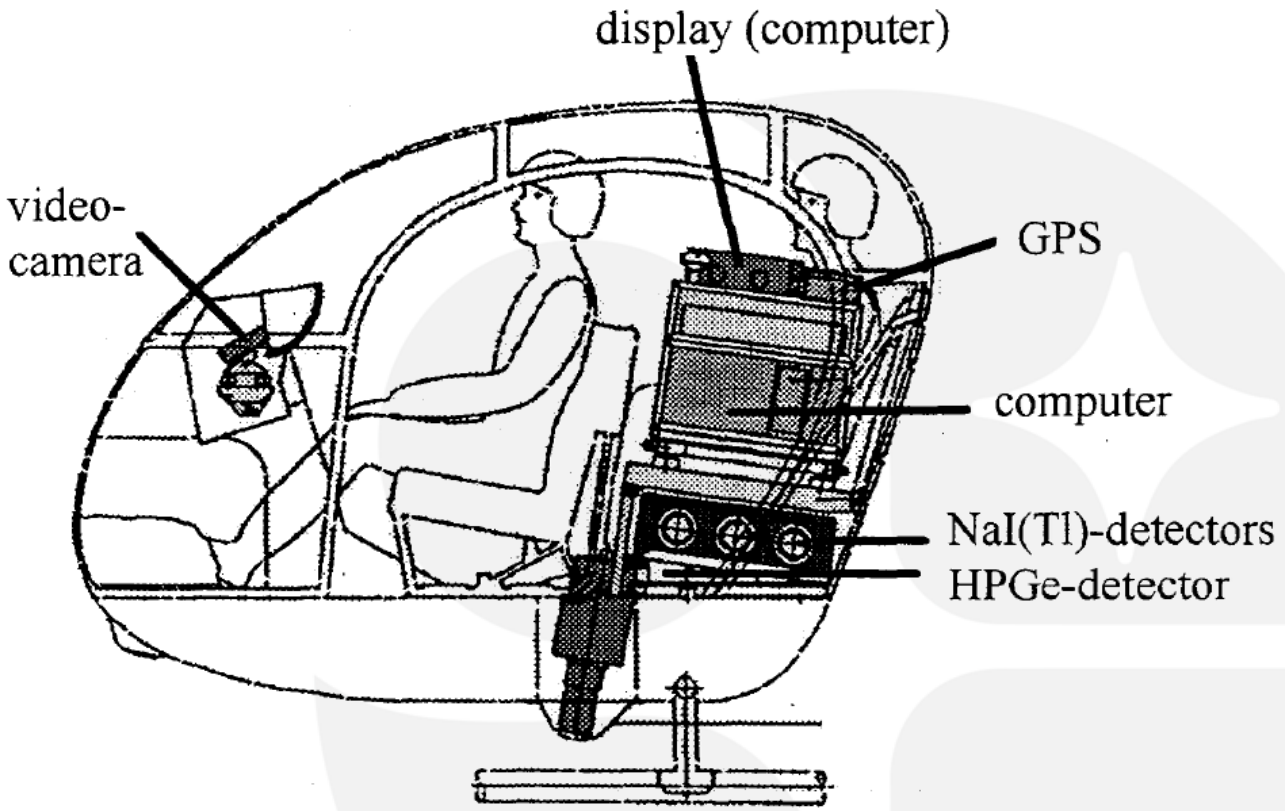
Equipment of Aerial Survey

For aerial surveys high HPGe detectors or Na(I) detectors are the favorite detectors

Systems based on pressurized ionization chambers, proportional counters, GM detectors or other suitable dose rate meters may be also used



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QA/QC Checks

Part-5

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Confidence in the Monitoring Results

Confidence in the monitoring results and international acceptability can be achieved only by implementing effective quality assurance system

The system basically consists of

- **Quality assurance (QA) programme**
- **Quality controls (QC) and**
- **Audits / appraisals**

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Field Measurements and Sampling

Techniques

- A field measurement or a collected sample must be representative

Preparation and storage of samples

- pre-treatment before they can be analyzed.
- minimize the possibility of cross-contamination
- reference state of the samples that will be used in reporting the results (dry or wet weight)

Coding and record keeping

- code numbers for sample identification
- record data for the possible future uses that may be made of the final analytical results

Chemical and radiochemical analyses

- Chemical and radiochemical analyses should be performed using approved procedures

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Sampling

Take representative samples to enable the level and extent of contamination of air, ground, water, foodstuffs, vegetation etc. to be accurately and rapidly determined

Sampling techniques should be consistent between sampling teams

Samples should be taken at locations representative for the area and where contamination is more likely rather than at the most accessible sampling sites

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Sample Analysis

Samples can either be assessed in the field or returned to a specialist laboratory

Standard analytical procedures may need to be replaced by rapid methods to cater for larger numbers of samples and the need for results as soon as possible

Sample screening techniques may be employed

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Instrumental Analyses

Instruments	• preventive maintenance • a record of instrument performance and modifications
Calibrations	• appropriate standards, calibration procedures, frequency of calibration, and traceability of standardization.
Background evaluations	• a record of measured backgrounds and analyze it statistically so that variations resulting from instrument problems or from contamination can be detected and eliminated.
Checks of the stability of the instruments	• changes in environmental factors, such as temperature and humidity
Field and laboratory records	• A record of field measurement or sampling and sample preparation and analysis for possibility on affect the outcome of the analysis.
Data reporting	• Uncertainty, table, graph for comprehensive understanding

Summary

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Key points

Monitoring organization and emergency team protective guides should be adapted to reflect site specific system in emergency response.

Monitoring is essential for protecting the public during emergencies.

Success depends on speed, accuracy, and safety.

Long-term monitoring supports recovery and public trust.

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Thank You for Your Attention

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