HERCA – Strategic review of HERCA WGE member countries national monitoring priorities in a nuclear or radiological emergency

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Contents

1. Introduction

This document provides a strategic review of the national monitoring priorities in a nuclear or radiological emergency in fourteen HERCA Member States. The information in this document, and in particular the good practices identified, can be used to support the development and review of national monitoring programmes. The information in this document reflects and compares arrangements at the time of writing in HERCA Member States.

Monitoring the environment, people and commodities is an essential element of the response to a nuclear or radiological emergency. The outputs of this monitoring will:

- inform decisions regarding the selection and implementation of public protective actions and actions to protect the environment;
- provide inputs to the assessment of the radiological consequences of the emergency; and
- be used to inform the public of the current situation and expected prognosis.
- help in the development of strategy and plans for recovery

Monitoring requirements must be considered in the planning phase based on a range of emergency scenarios and risk assessments. A monitoring strategy should be developed so that in the event of a nuclear or radiological emergency, the necessary equipment, resources and arrangements are in place to swiftly implement the monitoring needed.

Radioactive contamination following a nuclear or radiological emergency may extend over a large geographical area depending on the nature of the release and the prevailing weather conditions at the time. Therefore, the approach to monitoring must be pragmatic, taking into account available resources. The scale of the monitoring will depend on the severity of the emergency, the nature and amount of radioactivity released, the size of the affected area and the nature of the land use. The monitoring strategy should clearly specify the objectives of the different types of monitoring as this would enable the refinement of the monitoring depending on the conditions specific to the emergency.

The main purpose of monitoring is the protection of public health and the environment. Therefore, monitoring requirements are linked to the exposure pathways of significance. Immediately after an atmospheric release in a nuclear or radiological emergency, the exposure pathways of most concern are external exposure and inhalation of radioactive material in the plume. Following plume passage, other pathways will become more important, including external exposure from deposited material and ingestion of contaminated food, water and other commodities.

In the early phase of a nuclear or radiological emergency, measurement data will be required as soon as possible. Monitoring of external gamma dose rate and activity concentrations of radionuclides in air will confirm whether or not there has been a release from the site. This type of monitoring also enables a technical assessment of the extent of radioactive contamination both in terms of the concentration of radionuclides and the distance from the release site as well as an estimation of the potential doses to people and the environment affected by the emergency.

Following a release of radioactivity in a nuclear or radiological emergency, environmental monitoring can be used to determine the areas where urgent protective actions are needed. Monitoring of individuals can also be performed to verify individual radioactive contamination and decide if any treatment such as decontamination, medical treatment or long-term health monitoring is necessary.

2. Preparation of this document

A template to collect information from HERCA Member States on national monitoring strategies was prepared by the HERCA Working Group on Emergencies. The types of information requested included measured quantity, relevance for assessing the radiological situation and priority before, during and after a release. This template was completed by 14 members of the HERCA Working Group on Emergencies for their respective countries (Austria, Belgium, Czech Republic, Finland, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Slovak Republic, Slovenia, Sweden and the United Kingdom). The information gathered has been used to prepare the guidance in the following sections. A summary of the data collected is provided in Appendix 1.

3. Neighbouring countries

When developing monitoring strategies, neighbouring countries should take into consideration the HERCA-WENRA Approach in order to reduce disparity in monitoring arrangements and associated decision making on protective measures on both sides of an international border. In an emergency, the approach to monitoring in the accident country and neighbouring countries should be aligned for border regions. Implementing equivalent monitoring strategies promptly and sharing the information collected will facilitate better informed cross-border coordination of protective actions during the early phase of a nuclear or radiological emergency.

4. Monitoring before a release

Many measurements performed before a release of radioactive material are those carried out as part of routine monitoring programmes, although the frequency may be increased in the event of a perceived increased risk of an accident that could lead to a release. The objectives of monitoring before a release are to:

- confirm that ambient dose rates and activity concentrations of radionuclides in air are at normal levels;
- establish baseline data;
- provide an early warning function; and
- assess radiation exposure to people and the environment.

4.1 Priority monitoring when there is an increased risk

Before radioactive material is released, it is of high priority and a good practice to monitor

- ambient gamma dose rates in air with automatic sampling and monitoring stations; and

- activity concentrations of radionuclides in air with automatic sampling and monitoring stations.

Routine environmental monitoring plans to measure radionuclides in surface water, drinking water, milk, food, meat, fish, soil, crops and other environmental samples will continue. Samples should continue to be collected and analysed for radionuclides such as gamma-emitting radionuclides, gross beta activity, gross alpha activity, strontium-90, tritium, caesium-134/137, potassium-40 and iodine-131.

National ambient gamma dose rate monitoring networks vary among countries in terms of geographical density of monitoring stations and the frequency of reporting results (typically gamma dose rate average values are reported in a range between 10 and 60 minutes with the frequency increasing in an emergency). For nuclear countries, monitoring networks also exist around nuclear sites, sometimes in the formation of one or two rings. A good practice is to split the rings into sectors and to have a monitoring station in each sector to track the plume or the deposition in each sector in case of an emergency.

National ambient gamma dose rate monitoring networks are used to confirm that there are no elevated levels of radiation, to provide an early warning function, to indicate the start of a release and the arrival of a plume and to identify long-term trends. Good practices which should be considered for monitoring networks include:

- the use of a central database for recording data and issuing alerts;
- the availability of backup power supplies or the use of solar and mains powered gamma monitors;
- the use of multiple data transmission methods such as radio and phone networks; and
- the inclusion of a rain sensor to indicate whether or not it is raining.

Many stations in national monitoring networks also include instruments for monitoring radionuclides activity concentrations in air. These include on-line instruments and off-line instruments which require a manual filter change. As well as measuring gamma radiation, many of these stations also have the ability to measure gross beta, gross alpha and iodine concentrations in air.

The measurement of gamma dose rates and radionuclides activity concentrations in surface water, although given high priority by some countries, is less common.

4.2 Additional monitoring when there is an increased risk

The following monitoring is also carried out prior to a release but is of less priority than that described in the previous section. This monitoring includes:

- collection of meteorological data using automatic monitoring stations;
- radionuclide trace measurements in air to detect distant events;
- air kerma measurements;
- monitoring of radionuclides in the human body;
- measurements of ambient gamma dose rates by Unmanned Aerial Vehicles (UAVs);
- dose monitoring using thermoluminescent dosimeters (TLDs); and
- automatic monitoring of radionuclides activity concentration in surface water.

5. Monitoring during a release

During an atmospheric release of radioactive material in a nuclear or radiological emergency, data will continue to be available from automatic monitoring stations as described in section 4.1. The objectives of monitoring during a release are to:

- detect plume arrival and raise the alarm;
- provide information on the composition of the plume;
- confirm which areas have been affected and the activity concentration of deposition;

- estimate medium- and long-term projections of environmental radioactive contamination;
- forecast dispersion of radioactive material based on meteorological data;
- validate model assessments;
- support initial dose assessments;
- identify people who need urgent decontamination and medical attention;
- support decisions on protective actions;
- facilitate initial estimation of the source term; and
- confirm information received from neighbouring countries.

5.1 Priority monitoring

The following forms of monitoring data may be collected to support these objectives:

- ambient gamma dose rates in air;
- activity concentrations of radionuclides in air;
- activity concentrations of radionuclides in surface water, plants, and soil samples;
- meteorological data.

Some good practices include

- monitoring stations with systems that create automatic alerts which are sent to key personnel when elevated readings are detected;
- backup power supplies such as batteries;
- robust communications to ensure continued operation even during power failure or the failure of phone networks; and
- automated collection of meteorological data.

5.2 Additional monitoring

Some monitoring stations have detectors for isotope identification, and these can provide additional information such as the composition of iodine isotopes.

Radiation monitoring equipment on ships may be useful for nuclear or radiological emergencies near coastlines and for emergencies on nuclear-powered vessels in coastal waters or moored in harbour.

Taking into account country specific arrangements, availability of fixed monitoring stations and overall ALARP considerations, while it is generally not recommended that field measurement teams are deployed to take measurements or collect samples during plume passage, sufficient mobile monitoring resources should be available to ensure that measurements can be carried out where they are needed. Remote monitoring with the aid of UAVs may also be undertaken to provide rapid mapping of deposition and identifying hotspots.

In the case of a prolonged release phase, monitoring of ground radioactive contamination (complementing automatic monitoring stations) may need to start while significant releases are still ongoing, focusing on areas where radionuclide concentrations in air are lower and ground contamination levels are not likely to significantly change. Active field monitoring team members should use electronic personal dosimeters to control levels of exposure. This will ensure compliance with occupational safety for emergency responders and may help to differentiate between common medical symptoms and acute radiation injury. Personal radioactive contamination monitoring, assessment of internal exposure from inhalation or ingestion of radionuclides and decontamination of emergency workers may also need to be performed during the release phase.

The use of TLDs placed in buildings and outdoors can be useful in obtaining information about the shielding efficiency of buildings.

6. Monitoring after a release

In the early stages, after plume passage, the objectives of monitoring are to:

- confirm that the plume has passed;
- assess the current situation supported by environmental monitoring, perform mapping of the deposition and to identify hot-spots;
- support decisions on the implementation and termination of public protective actions such as evacuation and sheltering by comparing measurements with operational interventional levels or other generic criteria, such as projected doses;
- measure radionuclides concentrations in local food and drinking water to compare activity concentrations with current regulations;
- support decisions on protective actions to reduce intake of radionuclides;
- facilitate future assessments as the situation evolves and assess the effectiveness of clean-up actions; and
- identify those who need urgent decontamination, find individuals who have been exposed to high radiation doses and those who may have received organ doses justifying medical examination and exclude individuals whose symptoms are not caused by irradiation/exposure.

At this stage, monitoring may also be performed to provide reassurance to the public regarding their safety.

6.1 Priority monitoring

As well as established monitoring networks described in section 4.1, gamma dose rates can also be measured using mobile instruments which can be deployed by field response teams. This can offer increased flexibility particularly when large areas are potentially affected. Mobile devices/equipment can be used to supplement monitoring networks and increase the measurement density in areas of interest. Large area monitoring by road or air using manned vehicles or drones are used to build up a picture of the extent and severity of deposition. It is good practice to have some mobile air sampling resource to facilitate identification of radionuclides in appropriate locations. Where possible, the determination of fission products (including iodine fractions) in air at fixed monitoring stations should be made where this capability is available.

Environmental radioactivity surveillance programmes to measure activity concentrations of radionuclides in soil, grass, surface water, drinking water, milk, foodstuffs and animal should be implemented. In addition, radioactive contamination monitoring of persons, vehicles and objects should be performed to facilitate the rapid triage of persons, vehicles and objects leaving the enclosed affected area.

While the dose and contamination monitoring of first responders is very important, the large-scale monitoring of individuals in the general public is only required where there has been significant radioactive contamination. In addition, even when the actual risk for the general public is low, people may still request to be monitored for reassurance purposes. In these cases, portable monitoring units with the following capabilities should be considered:

- skin radioactive contamination monitoring to determine if decontamination is required or has been successful;
- thyroid dose monitoring to determine if medical follow up is required; and
- internal radioactive contamination monitoring by whole body counter and bioassay to determine if medical follow up is required.

While estimates of doses received by the public, workers and helpers during the release phase can be based on, or at least supported by, environmental monitoring results, thyroid dose monitoring and internal dose monitoring are also important to enable internal doses received by the public, workers and helpers during the release phase to be assessed retrospectively.

The monitoring of members of the public is very time consuming and wide scale-screening is not effective. Where radioactive contamination of people has occurred, then guidance should be provided to the public on personal decontamination. If monitoring of people is required then, where possible, environmental monitoring should be used to reduce the amount of personal monitoring and to prioritise which individuals require monitoring. People returning home from areas affected by the emergency should be monitored at the point of entry, if monitoring of people is deemed appropriate, as advised by professionals.

In accordance with International Agency for Research on Cancer's Technical Publication No. 46 'Thyroid Health Monitoring after Nuclear Accidents'[1], trained professionals should be available to perform thyroid radioiodine monitoring in individuals as soon as possible after the nuclear emergency, but within 6 weeks after the emergency at the latest. However, if the equipment's minimum detectable activity of iodine-131 in the thyroid is less than 500 Bq then the assessment may be conducted later than 6 weeks after the emergency.

6.2 Additional monitoring

Initially, the emphasis should be on the monitoring of gamma dose rates and the analysis of samples by gamma spectrometry as these measurements can be made quickly. Radiochemical procedures to measure alpha and beta emitters are time consuming and resource intensive. Consideration should be given in advance to developing and verifying rapid radiochemical techniques for alpha- and beta-emitters such as strontium-90 and plutonium-239,240.

The use of TLDs in buildings and also placed outdoors can be useful in obtaining information about the shielding efficiency of buildings. They can also be used in retrospective exposure evaluation, external dose estimation and the observation of long-term trends.

Over the longer term, monitoring will continue to be required to support recovery decisions. Information from monitoring programmes will determine where decontamination measures need to be implemented and where and when longer term protective actions such as food restrictions can be relaxed.

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[1] https://publications.iarc.fr/Book-And-Report-Series/Iarc-Technical-Publications/Thyroid-Health-Monitoring-After-Nuclear-Accidents-2018

7. Other guidance

Further guidance on radioactivity monitoring in a nuclear or radiological emergency is available elsewhere including in:

- INTERNATIONAL ATOMIC ENERGY AGENCY, Generic Procedures for Monitoring in a Nuclear or Radiological Emergency, IAEA-TECDOC-1092, IAEA, Vienna (1999).
- International Commission on Radiation Units and measurements (ICRU), Report 92 on Radiation Monitoring for Protection of the Public after Major Releases of Radionuclides to the Environment (2015).

Appendix 1 – Summary of Data Collected

This data summarises information supplied by 14 HERCA WG Emergencies members during the period 2019 to 2021.

Please note that some interpretation of responses was required since consistent terminology was not used by all countries.

Before a Release

Type of Monitoring	Priority	Comments [number of respondent countries where method recorded]
Ambient gamma dose rate in air	High	• Automatic monitoring stations [14] • Monitoring frequency between 1 and 60 mins (10 mins most common [8]) • To confirm normal situation, early warning function, start of release, cloud arrival, long-term trends
Activity concentration in air	High	• Automatic monitoring stations [10], mixture of on-line and off-line [3], manual filter exchange [4] • Monitoring frequency: between 10 and 120 mins (10 mins most common) • Radionuclides: gamma [11], gross beta [6], gross alpha [5], iodine [4]
Ambient gamma dose rate using a UAV	High	• Not very common (reported in 1 country) • Radiological investigation in specific areas via UAVs • To detect sources (act of terrorism)

Type of Monitoring	Priority	Comments [number of respondent countries where method recorded]
Environmental surveillance programme	High	• Environmental sampling and laboratory measurements in surface water [3], sea water [1], drinking water [4], milk [3] and food [3], environmental samples [2], soil [2], meat [2], fish [1] • Number of samples: between few hundreds and 10,000 per year • Radionuclides: gamma, gross beta, beta (Sr-90), H-3, Cs-134/137, natural radionuclides, K-40, I-131
Activity concentration in surface water	High	• Not very common (reported in 2 countries)
(Ambient) gamma dose rates in water	High	• Not very common (reported in 1 country)
Dose rates in air	Medium	• Field measurements [4] • Cooperation of radiation protection, defence forces and emergency services • Spectra + deployable probes [3] • Detection of source, early warning, confirm normal situation

Type of Monitoring	Priority	Comments [number of respondent countries where method recorded]
Activity in human body	Medium	• Not very common (reported in 2 countries) • Whole boy counter, excreta, monitoring programme • 30/70 individuals per year • Survey of radionuclides in the body, long-term trend observation
Meteorological data	Low	• Reported in 2 countries, located at nuclear sites to provide local meteorological data
Dose	Low	• Using TLDs [4], located near nuclear sites • Numbers varied from 50 to 300 • Monitoring frequency: continuously (integration)

During a Release

Type of Monitoring	Priority	Comments [number of respondent countries where method recorded]
Ambient gamma dose rate in air	High	• Automatic monitoring stations [14] • Mobile monitoring [4] • Monitoring frequency between 1 and 60 mins (10 mins most common [8]) • To detect arrival, extent and departure of the plume, validation of model assessment, prepare initial information ration on source term
Activity concentration in air	High	• Automatic monitoring stations [7], mixture of on-line and off-line [3], manual filter exchange [8], autonomous measuring systems [1] • Monitoring frequency: 10 mins [3], 30 mins [1] • Radionuclides: gamma and neutron detection, isotope identification, gamma dose rate measurements, gross alpha/beta, Iodine concentration, iodine fractions determination [6]

Type of Monitoring	Priority	Comments [number of respondent countries where method recorded]
Ambient gamma dose rate and deposition	Medium	• Air-borne gamma spectrometry [1], flight mapping [1], sampling and measurement of air samples via UAV [1], car-borne monitoring [2] • Mobile teams/ field measurements [5] • Radiological monitoring performed by navy ship
Meteorological data	High	• Reported in 2 countries, located at nuclear sites to provide local meteorological data, backup power supply (batteries) [1]
Environmental surveillance programme	High [5] Medium [2] Low [2]	• Environmental sampling and laboratory measurements in fallout [3], soil [3], grass [1], surface water [2], seawater [1], rainwater [1], drinking water [3], air [1], milk [3], animal feed [3], foodstuff [5], environmental samples [3] and meat [1] • Number of teams between 1 and 5 and frequency of analysis: once per day or once per site, every two hours during release, shorter than one month • Radionuclides: nuclide ratios, gamma spectrometry, alpha and beta counting, Cs-134/137, Sr-90, H-3, I-131
Ambient gamma dose rates in water	High	• Not very common (reported in 1 country) • Rivers near nuclear and monitoring frequency: 10 Minutes

Type of Monitoring	Priority	Comments [number of respondent countries where method recorded]
Dose	High/ medium	• Doses to individual persons using dosimeters and dose rate outside the working area [1] • Radioactivity in the human body [4]: thyroid measurements, whole body, excretion

After a Release

Type of Monitoring	Priority	Comments [number of respondent countries where method recorded]
Ambient gamma dose rate in air	High	• Automatic monitoring stations [13] • Monitoring frequency between 1 and 60 mins (10 mins most common [8]) • To assess the radiological situation and extent of radioactive plume, confirm that plume has passed, estimation of personal dose
Activity concentration in air	High	• Automatic monitoring stations [6], mixture of on-line and off-line [2], manual filter exchange [7], mobile aerosol laboratory [1], mobile teams [1]] • Monitoring frequency: 10 mins [1], 30 mins [1] • Radionuclides: Gross alpha and beta, gamma spectroscopy, I-131, iodine fractions determination [3] • Portable air samplers within car-born groups [5] • Movable air samplers that can be deployed as needed

Type of Monitoring	Priority	Comments [number of respondent countries where method recorded]
Ambient gamma dose rate and deposition	High	• Type: Air-borne gamma spectrometry [2], fallout samplers [1], flight mapping [4], car-borne monitoring [7] • Resources: UAV [2], moving laboratory [2], hand-held device [4], car-borne monitoring systems [6], helicopter or plane [5]
Meteorological data	Medium	• Automatic monitoring station [1] to provide local meteorological data (precipitation intensity, local wind speed and direction, relative humidity, barometric pressure and temperature)
Environmental surveillance programme	High	• Activity concentration in fallout [7], soil [12], grass [5], surface water [4], seawater [3], rainwater [3], drinking water [7], water [4], air [2], milk [8], animal feed [7], foodstuff [10], environmental samples [6], meat [4], waste sludge [1] • Lab measurements, in situ gamma-spectrometry, monitoring stations • Radionuclides: alpha/beta, gamma spectrometry, Cs-134/137, Sr-90, H-3, I-131
Ambient gamma dose rates in water	High	• Not very common (reported in 1 country) • Rivers near nuclear and monitoring frequency: 10 Minutes

Type of Monitoring	Priority	Comments [number of respondent countries where method recorded]
Dose	High	• Doses to individual persons [4] using personal dosimeters of NPP operators, emergency services, army • Radioactivity in the human body [9]: thyroid measurements, whole body, excretion, radionuclides: I-131
Contamination	High	• Contamination of persons, vehicles and objects [7] using contamination meters, portable instrumentation, for the rapid sorting of persons, vehicles and objects leaving the enclosed affected area • Radionuclides: gamma dose rate, alpha monitoring, beta monitoring