Environmental Radiological Monitoring for Nuclear Power Reactors (Nuclear Facility)

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Overview

• Provide a General Overview of the Major Requirements of a Typical Emergency Radiological Environmental Monitoring Program for Nuclear Power Plant
• Discuss Monitoring Program:
  – Accident, Abnormal, or Emergency Operations
• Discuss Monitoring Plans
  – Sources monitoring
  – Environmental monitoring
  – Person (receptor) monitoring
General Objectives -
Emergency Environmental Radiological Monitoring Program

• Determine and Mitigate Radiological Impact of the Accident, Abnormal, or Emergency releases on the Public and the Environment
  – Characterize trends in the physical, chemical, and biological condition of effluent and environmental media;
  – Identify potential environmental problems and evaluate the need for remedial actions or measures to mitigate the problems;
  – Detect, characterize, and report unplanned releases;
  – Evaluate the effectiveness of effluent treatment and control, and pollution abatement programs.

• Verify and support compliance with applicable federal, state, and local environmental laws, regulations, permits, etc.

• Determine compliance with commitments made in environmental impact statements, environmental assessments, safety analysis reports, or other official documents.

Reference: IAEA Environmental and Source Monitoring for Purposes of Radiation Protection; Safety Guide No. RS-G-1.8

Program Objectives and Exposure Pathways

Reference: IAEA Environmental and Source Monitoring for Purposes of Radiation Protection; Safety Guide No. RS-G-1.8
Types of Monitoring –

For Emergency Monitoring Planning

- RADIATION MONITORING
- Source monitoring
- Environmental monitoring
- Individual monitoring
- Source related monitoring
- Person related monitoring

Reference: IAEA Environmental and Source Monitoring for Purposes of Radiation Protection; Safety Guide No. RS-G-1.8

Exposure Pathways, Design of Monitoring, and Data Collection Objectives –

- similar to routine monitoring –
- difference is potentially higher radiation or contamination

- Direct external radiation exposure to radiation from the source;
- Internal dose from inhalation of airborne radionuclides from the Source
- Internal dose from ingestion of
  - Plant foods grown in the contaminated soil and irrigated with contaminated water,
  - Meat and milk from livestock fed with contaminated fodder and water,
  - Drinking water from a contaminated well or water body,
  - Fish or shellfish from a contaminated water, and
  - Contaminated soil.
Data Quality Objectives and Dose Limit

- ICRP recommendation
  - limit the long-term average effective dose equivalent to 100 mrem (1 mSv) per year, or less

- A higher dose limit, not to exceed 500 mrem effective dose equivalent recommended by ICRP as an occasional annual limit, may be authorized for a limited period, if it is justified by unusual operating conditions.

ICRP: The International Commission on Radiation Protection

Non-radiometric Assay – A Note

- Even though U & Pu are radioactive, they have LONG half-lives and LARGE atomic numbers

- LARGE atomic number lends itself to ICP-MS (or other non-radiometric assay)

- Advantages: Low detection limits and accurate isotope ratios for long-lived isotopes

ICP-MS: Inductively coupled plasma mass spectrometry
Data Validation - Purpose
Procedure for Chemical and Radiochemical Data

similar to routine monitoring –
difference is this must be done very quickly and decision will have a
significant impact on all aspects of operation (health, safety, economics, ….)

• To identify, through the evaluation of supporting
documentation, those data that do not meet the
expected precision and accuracy of an analytical
method

• Not intended to eliminate the need for professional
judgment in evaluating the data quality

• Data validator may be more or less stringent in
evaluating the results based on experience and
familiarity with the analytical techniques, historical
data, sample matrices, or intended use of the data.

• Product of procedure is a data validation report that
includes information regarding the overall quality of
the data and the resulting data qualifiers.

Design of Monitoring Program
Conditions to Take into Account

• Radioactive inventory and radionuclide
composition at the source;
• Space and time features of the radiation
fields around the source;
• Authorized discharges and discharge rates;
• Possible contributions from any nearby
practices or sources, discharge pathways,
exposure pathways, environmental features
at the site, and features and habits of the
population involved;
• Significance of the annual average doses of
the critical group(s) and the environmental
radiation levels from planned radioactive
releases and possible releases.
• Depending on the severity of an accident, all three types of radiation monitoring — source monitoring, environmental monitoring, and individual monitoring — may have to be performed;

• The overall strategy for emergency monitoring should be preplanned to address the needs of assessors, decision makers and responders over time and geographical location, and as a function of the type of decision on protective actions and response actions that might be necessary to protect the public and responders or to mitigate the consequences of the emergency.

Reference: IAEA Environmental and Source Monitoring for Purposes of Radiation Protection; Safety Guide No. RS-G-1.8
Accident, Abnormal, or Emergency – Monitoring Program Design

- Automatic measuring stations that will continuously measure and transmit to an emergency center the dose rate in the environment should generally be installed around major facilities for the purposes of early monitoring and plume tracking (early warning system);

- It is advantageous if the measuring stations are also capable of measuring concentrations of airborne particles, gaseous iodine and any other radionuclide of particular concern;
  - For example, if a facility may contain large amounts of tritium, some special device to measure tritium may as well be installed.

- A map with preselected sampling locations should be prepared;

- Computer modeling of the dispersion of the radioactive plume with the source term, meteorological conditions and other factors taken into account can help to clarify monitoring priorities;

- However; computer models should not be used as the sole basis for protective actions.
Accident, Abnormal, or Emergency – Monitoring Program Design

- The effects of a protracted radioactive release and of the overwhelming of local resources for monitoring should be considered in relation to emergency preparedness;
- Thus arrangements should be made in the planning process for receiving help from other organizations if needed;
- In the event of a severe accident, provision should be made for the establishment of a radiological monitoring and assessment center at which the efforts of all the groups conducting monitoring and assessment will be coordinated:
  - The effectiveness of these arrangements should be evaluated in exercises that simulate response conditions.

Reference: IAEA Environmental and Source Monitoring for Purposes of Radiation Protection; Safety Guide No. RS-G-1.8
Accident, Abnormal, or Emergency Planning - Source monitoring

- The primary purpose of source monitoring under emergency conditions is to determine the magnitude of the releases that might occur, that are occurring or that have occurred;
- Such data, in combination with meteorological data and the results of predictive dose assessment models, would often be the first line of information available to intervention authorities.

Accident, Abnormal, or Emergency Planning - Source monitoring

- Personnel conducting monitoring, sampling and assessments during an emergency should be designated as emergency workers and should be subject to the requirements established for emergency workers
- Arrangements should be made to continually assess and record the doses received by emergency workers.
Environmental Monitoring:

- Often is the most informative source of data under emergency conditions;
- Prioritized on whether the area is residential, agricultural, rural or commercial, and whether it features industrial activities, public services and infrastructural elements;
- Priority given to significantly contaminated areas – those areas in which radiation levels are at or above the levels at which intervention is required to avoid the immediate potentially harmful exposure of people.

Early measurements should be made with simple instruments and should be made rapidly with the purpose of defining the nature of the emergency;

Locations for measurements should include some that have been predefined for that purpose on the basis of the expected locations of maximum impact.

Site specific and emergency specific interpretation of these simple measurements should be considered in the process of developing emergency preparedness.
Accident, Abnormal, or Emergency Planning - Environmental Monitoring

• Priorities for severe accident involving airborne contamination:
  – Rapid measurements of external gamma dose rates in air over areas – helps define whether limits have been reached or exceeded
  – In-plume air sampling during a release for the measurement of concentrations and compositions of radionuclides, which provide necessary data for the evaluation of inhalation hazards

• Priorities for severe accident involving airborne contamination:
  – Measure the external dose rate in air due to ground deposition to detect locations where limits have been reached or exceeded
  • Perform immediately after the release and deposition have stopped
  • Identify areas for public relocation or restrictions on the consumption of foodstuffs,
  • Perform field gamma spectrometry in the deposition area - would provide an opportunity to define which gamma emitting radionuclides have been released to the area
Accident, Abnormal, or Emergency Planning - Environmental Monitoring

- Priorities for severe accident involving airborne contamination:
  - Soil sampling after the end of the release or after passage of the plume for the measurement of radionuclide concentrations to give values for ground deposition to supplement the deposition values determined by field gamma spectrometry.
  - If there is a possibility that radionuclides were released that cannot be detected by means of field gamma spectrometry, these samples should be processed for the detection of pure beta (e.g. $^{90}$Sr) and alpha (e.g. $^{239}$Pu) emitters.

References

- IAEA Environmental and Source Monitoring for Purposes of Radiation Protection; Safety Guide No. RS-G-1.8
References

- http://www.icrp.org/
- http://www.epa.gov/rpdweb00/marssim/
- IAEA, Preparedness and Response for a Nuclear or Radiological Emergency, No.GS-R-2

References on Data Quality Objectives

- NRC Regulatory Guide 4.1, “Programs for Monitoring Radioactivity in the Environs of Nuclear Power Plants”
- EPA Data Quality Objective (DQO) process (EPA QA/G-4-2006)
- The Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)
- Multi-Agency Radiological Laboratory Analytical Protocols Manual (MARLAP)
- Mixed Analyte Performance Evaluation Program (MAPEP)
- DOE Order 485.1 “Radiation Protection of the Public and the Environment”
For planning purposes emergency time phases can be specified, which are then used for guiding the prioritization of emergency monitoring actions;

The phases used here are designated as the pre-release and early phase (release), the post-release or intermediate phase and the recovery or remediation phase.
Accident, Abnormal, or Emergency Planning
Design (Supplemental slide 2)

• The scale of the emergency envisaged will determine the design of the environmental monitoring and sampling program.

• While the nature and extent of an emergency cannot be anticipated, it is important that advance arrangements be made to prepare for a range of possible emergencies.

• Arrangements should be made for instrumental measurements, sample collection, sample analysis, dose assessment, interpretation of results, communication and the receipt of assistance from other organizations, if needed.

Accident, Abnormal, or Emergency Planning
Design (Supplemental slide 3)

• Facilities in threat category I, such as nuclear power plants, could give rise to releases that result in severe deterministic health effects off the site;

• Facilities in threat category II, such as research reactors, could give rise to releases resulting in doses to people off the site that warrant taking protective action in accordance with international standards.
During and immediately after a nuclear or radiological emergency, monitoring resources are likely to be heavily overtaxed, and it is essential to ensure that such resources are utilized as effectively and efficiently as possible until additional assistance can be secured.

At the outset, all available meteorological information and modeling predictions should be used to determine the geographical area in which people could be affected by the release of radioactive material.

Sources of Tritium
- **Natural Sources:**
  - $^{14}\text{N}(n,t)^{12}\text{C}$ and $^{16}\text{O}(n,t)^{14}\text{N}$ in Atmosphere
  - Almost exclusively HTO
  - Ave Concentration in Env water: 100 – 600 Bq/m³
- **Man-Made Sources:**
  - Nuclear Industry: ~ 4x10⁴ TBq/y
    - HWR: 3x10² – 2x10³ TBq
    - LWR: 30 TBq/y per Reactor

Uses of Tritium
- Luminising Industry: 10 – 100 TBq/y
- Research and Teaching: 1 – 100 GBq/y
• H$^3$
• I$^{131}$
• Xe$^{133}$
• Co$^{60}$
• Sr$^{90}$
• Cs$^{137}$
• U$^{235}$
• U$^{238}$
• Pu$^{239}$