IAEA Post Graduate Educational Course in Radiation Protection and Safety of Radiation Sources

Intervention for Chronic and Emergency Exposure Situations

Monitoring in a Nuclear or Radiological Emergency

Field Radiation and Contamination Monitoring

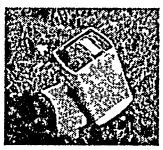
Lecture

Introduction

- The lesson presents an overview of basic methods and techniques in field radiation and contamination monitoring
- It explains generic procedures from Section A of the IAEA technical document *Generic procedures for monitoring in a nuclear or radiological emergency* (IAEA-TECDOC-1092)

Content

- Objectives of field radiation and contamination monitoring
- Radiation instrument QC checks
- Basic survey procedures:
  - Plume survey
  - Ground deposition survey
  - Environmental dosimetry
  - Source monitoring
  - Surface contamination survey
  - Aerial survey
- Summary



Overview

- One of the most important aspects of managing a radiological emergency is the ability to promptly and adequately estimate the consequences of an accident
- In order to assess the radiological hazards involved during all stages of the management of the accident, the emergency monitoring is required
- Field radiation and contamination monitoring represents one of the components of emergency monitoring

Objectives of Field Radiation and Contamination Monitoring

- To locate the plume
- To measure ambient dose rates from deposition
- To evaluate radiation levels in the environment
- To detect, localize and possibly identify the radioactive source
- To assess ambient dose rates in the vicinity of the radioactive source
- To provide information on contaminated areas, objects, tools, equipment and vehicles
- To locate hot spots

Monitoring Procedures

- Procedure steps are structured as follows:
  - Prior to being dispatched
  - Measurements and analysis
  - Data recording and reporting
  - Contamination control
  - Cautions and notes

General Precautions/Limitations



- Always be aware of the hazards that you may encounter in the field and take the necessary precautions
- Never attempt any field activities without the appropriate safety equipment; always know how to use it
- All monitoring activities shall be conducted so that exposures are maintained as low as reasonably achievable
- Team members shall be aware of turn back levels

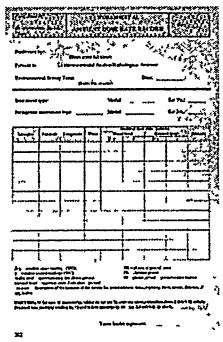
Prior to Being Dispatched

- Receive an initial briefing and initial assignments
- Obtain appropriate equipment using checklists
- Check the instruments
- Conduct the radio check when leaving for the assignment
- Conduct a GPS check when leaving for the assignment
- Wrap the instruments in plastic to prevent contamination
- Set the alarms of self-reading dosimeters
- Wear appropriate personal protective equipment

Data Recording and Reporting

- Make every effort during field measurement to record all aspects of the procedure that might affect the outcome of the analysis
- Use prepared worksheets (forms) and/or any other means for data recording
- Make the notes both legible and clear in meaning, so that others who read them will be able to reconstruct the events that are referred to

An Example of a Worksheet



Contamination Control

- Survey vehicle and personnel periodically
- Document the reading, time, and location on appropriate worksheet
- At the end of the mission perform personnel and equipment monitoring (contamination check) or request assistance from Personal Monitoring and Decontamination Team

Contamination Check of Used Tools



Radiation Instrument QC Checks

- Purpose: to perform pre-operational and quality control check of each instrument that will be used in survey activities
- Method: predetermined check source counting geometry
- Performed by: all response teams
- Special precautions: none
- Equipment: instrument to be checked, an appropriate check source and worksheets

Pre-operational Check

- Inspect the instrument for apparent physical damage
- Inspect the calibration tag or calibration certificate
- Check the batteries of the instrument to ensure that they are acceptable
- Zero any instrument having a manual or electronic "ZERO" function

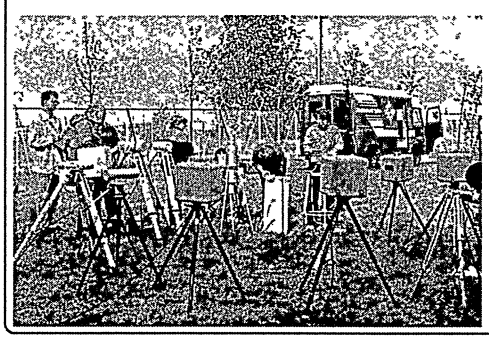
Pre-operational Check – Cont'd

- Check the high voltage settings if applicable
- Set the instrument to the lowest range that will give an on-scale reading; observe the normal operation of the meter
- Record readings and findings
- If required return the instrument for repair

Quality Control Check

- Use the appropriate check source to detect and confirm the expected reading for the predetermined check source counting geometry
- Check each instrument at the beginning and ending of each shift
- Replace defective equipment and repeat QC checks on replacement
- Record all instrument data in worksheet

An Example of QC Check of the Instruments



Basic Survey Procedures

- Plume survey
- Ground deposition survey
- Environmental dosimetry
- Source monitoring
- Surface contamination survey
- Aerial survey

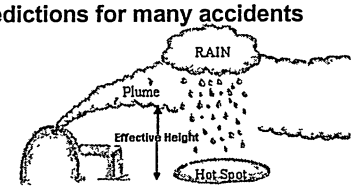
Caution

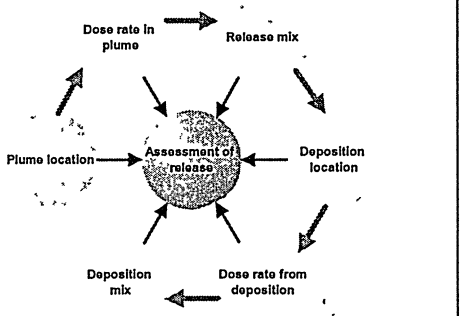
- Generic procedures should be revised to reflect conditions and capabilities for which they will be applied



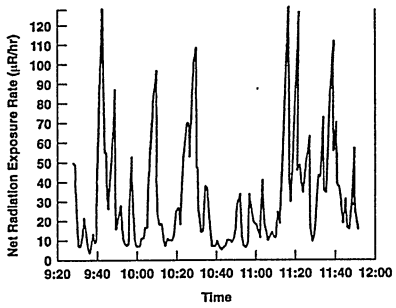
Plume

- Dose rates in the plume will be variable
- Deposition will be complex
- Models cannot provide accurate predictions for many accidents

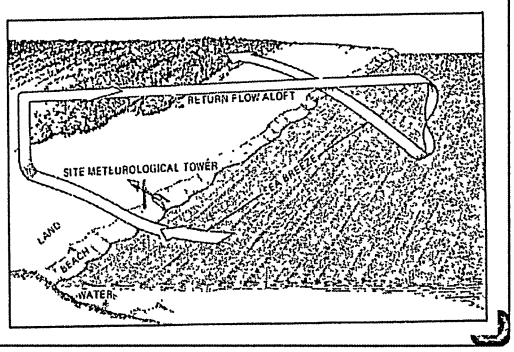




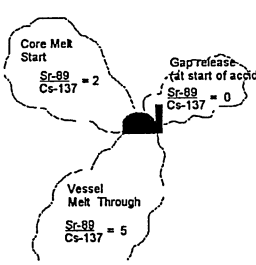
FIELD EXPOSURE RATES MEASUREMENTS (WITH CONSTANT WIND DIRECTION)



Complex Plume Movement



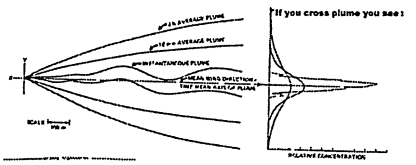
Isotopic Mixture in Plume May Change During Release



- Different depending upon core damage state and route
- Confirm by monitoring
- Can change during release with wind direction

Measurements in Plume

- Plumes meander even if the wind direction is steady
- Models and assessments based on averages (10 -15 min.)



Plume Survey

- Purpose: to conduct plume transverse/tracking and to identify plume boundaries
- Method: based on ambient dose rate measurements
- Performed by: Environmental Survey Team
- Special precautions: team members shall be aware of possible contamination from radionuclides washed out by rain within a plume
- Equipment: low and medium range gamma dose rate meters equipped with the detector window, contamination monitor and worksheets

Survey

- While in transit to the monitoring locations, observe the ambient dose rate using the most sensitive instrument and scale to provide the first radiation measurements
- Using the instrument with window for taking open (β+γ) and closed (γ) readings perform a radiological survey
  - at waist level and
  - at ground level
- Record the readings on the worksheet

Plume Survey Drill



Analysis

- By comparing readings against the table determine if the plume is elevated, at ground level or has passed

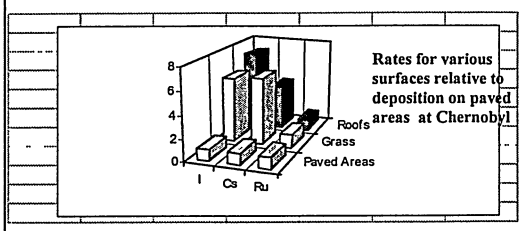


WO – window open; WC – window closed

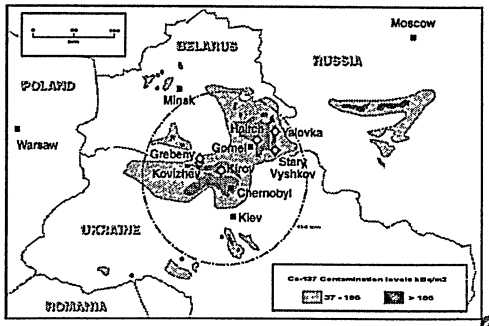
If at waist level: WO	WC		If at ground level: WO	WC	Then:
β+γ	≈ γ	AND	β+γ	≈ γ	Plume is elevated
β+γ	> γ		β+γ	> γ	Plume is at ground level
β+γ	≈ γ		β+γ	> γ	Plume has passed – ground contamination

Deposition

- Expect deposition rates to vary



Deposition Could Cover a Large Area



Ground Deposition Survey

- Purpose: to identify where protective actions are indicated; to locate hot spots
- Method: based on measurements of ambient dose rate from deposition
- Performed by: Environmental Survey Team
- Special precautions: Try to avoid resuspension of ground contamination
- Equipment: low and medium range gamma dose rate meters, contamination monitor and worksheets

Survey

- Travelling along each roadway toward the contaminated area and starting with the meter on the lowest range, taking measurements from within the vehicle (with detector window closed), record the location where the ambient dose rate is twice background
- Record the location where the ambient dose rate is ten times background (approximately 1 μSv/h) and locations for each 10 μSv/h increase up to 1 mSv/h
- Record the results

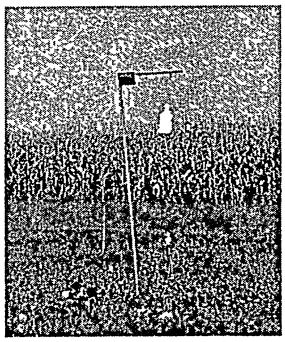
Measuring Ambient Dose Rate From Deposition



Environmental Dosimetry

- Purpose: to evaluate any potential increase(s) in radiation levels in the environment; to reconstruct the plume trajectory and/or radiation fields
- Method: TLD dosimetry
- Performed by: Environmental Survey Team
- Special precautions: all TLDs should be shielded from exposure during storage, deployment and retrieval
- Equipment: TLDs for environmental dosimetry, contamination monitor and worksheets

An Example of TLD in the Environment



Deploying Environmental Dosimeters

- Go to the location(s) requested and find a place in an open area
- Identify the position and mark it on the map and record it
- Take ambient dose rate at the location and record it
- Place two TLDs in a sealable plastic bag and firmly secure them to a post or structure (approximately one meter above the ground)
- Record the TLD numbers and the date/time when the TLD is placed in the field
- Return worksheet(s) to the Environmental Analyst/Radiological Assessor after deployment

Retrieval

- All TLDs that were deployed are to be retrieved
- Survey the TLDs for contamination prior to removal from the field
- Package each set of TLDs collected in a second appropriate-size plastic bag
- Note on the bag and worksheet if contamination was detected
- Assure that the identifying numbers of the collected TLDs match the numbers recorded
- Record the date and time of collection for these TLDs
- Return all the collected TLDs along with the completed worksheet

Source Monitoring

- Purpose: to assess dose rates in the vicinity of a radioactive source; to provide timely information to initiate protective actions; to render the source safe
- Method: based on gamma dose rate measurements
- Performed by: Environmental Survey Team
- Special precautions: periodically check dosimeter
- Equipment: medium and high range gamma dose rate meters, contamination monitor and worksheets

Searching for Sources



Monitoring - Part 1

- Switch instrument on before entering the area of suspected elevated dose rate
- Measure the dose rate from the source
- Note the distance from the source
- For mixed beta+gamma fields, measure the dose rate with the beta window open and the beta window closed
- If betas or alphas are suspected, monitor close to the surface of the source (take care not to contaminate your dose rate meter)
- Record all the data

Monitoring - Part 2

- If the source is not visible, use one of the following methods to locate the source:
  - Hold the instrument away from the body and rotate the body until the minimum reading; a line from the instrument through the centre of the body will give the direction of the source (very approximately)
  - Alternatively a circle of same dose rate points can be measured around the source and the source is assumed at the approximate centre of the circle
  - A crude guess of a distance can be obtained by measuring dose rates at two distances in line of "sight" and using the inverse square law

Surface Contamination Survey

- Purpose: to provide information on contaminated areas, objects, tools, equipment and vehicles, cleanup operations or decontamination
- Method: direct monitoring method, indirect – smears
- Performed by: Environmental Survey Team
- Special precautions: refrain from eating, drinking, or smoking where monitoring activities are being conducted
- Equipment: contamination monitors and worksheets

Direct Method of Surface Monitoring - Part 1

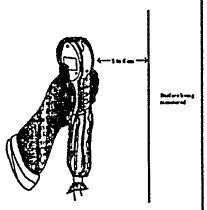
- Select appropriate contamination monitor for the radionuclide contamination in question
- Switch the instrument on and select the appropriate time constant (if possible) before entering suspected contamination area or approaching suspected contamination surface
- Measure and record background radiation level; recheck this level periodically to ensure that the detector has not become contaminated

Searching for Possible Surface Contamination



Direct Method of Surface Monitoring - Part 2

- Using the audio response of the contamination monitor, sequentially sweep the area with the contamination monitor moving it at a steady rate across the suspect surface
- Start monitoring from periphery and move to the centre



Direct Method of Surface Monitoring - Part 3

- For alpha and soft beta contamination monitoring, monitor close to the surface
- Record readings indicating alpha, beta+gamma, beta and/or gamma and where and when taken and any special circumstances regarding the reading
- Measurements data on equipment and materials should be affixed to the particular equipment or material and documented

An Example of Surface Contamination Monitoring



Contamination Survey of Vehicles - Part 1

- Perform a general gross beta-gamma survey of the vehicle, initially surveying the grille, wheel wells, bumpers, and tires
  - If exterior contamination is detected at or above the action level, record the reading and direct the vehicle to a designated area for decontamination or secure isolation

Contamination Survey of Vehicles - Part 2

- If contamination above background, but below the action level, is detected during the exterior survey of the vehicle:
  - Survey the surface of the air filter housing, if practical, for gross gamma activity
  - Survey interior surfaces of the vehicle such as the seats, floorboards, armrests, steering wheel, and gearshift to determine if there is contamination above the action level within the interior of the vehicle

Contamination Survey of Vehicles - Part 3

- After initial decontamination is attempted, re-survey the areas where contamination was detected
  - If the levels have been significantly reduced, but remain above the action level, repeat the decontamination procedure and re-survey
  - If the readings still remain above the action level, advise the vehicle operator that the vehicle should be isolated in a secure area pending further evaluation
- Record all information regarding the vehicle and the extent of contamination found

Smear Method of Surface Monitoring - Part 1

- Select a sampling location representative of the area
- Mark off a known area – approximately plot for a 100 cm^2 (10 cm by 10 cm) if possible
- With two gloved fingers, carefully rub smear over the pre-marked area; try not to apply so much pressure as to wear a hole or to roll the smear
- Use portable contamination monitor to assess level of contamination on the smear
- Record the reading

Smear Method of Surface Monitoring - Part 2

- Label a plastic bag with the appropriate information about the sample, including sample location, date, time, collector's initials, and the approximate location of the smear so that the sampling location can be found again, if needed
- Record all data
- Deliver the smear samples to the Sample Analyst
- At the end of the survey, do contamination check of all tools and equipment used; document the readings and the time of check

Aerial Survey

- Purpose: to provide information on large area surface contamination, to search for gamma-emitting source(s) over large areas
- Method: aerial gamma spectrometry and/or dose rate measurements
- Performed by: In-situ Gamma Spectrometry Team
- Special precautions: weather conditions
- Equipment: airborne gamma spectrometer system, system based on suitable dose rate meters, helicopter or fixed wing aircraft and worksheets

Preparing for Aerial Survey



Aerial Contamination Survey

- To provide information on large area surface contamination by radionuclide specific measurements in order to initiate protective actions and/or cleanup operations

Aerial Contamination Survey – Cont'd

- MDA: 1-5 kBq/m^2 (depending on the detector efficiency, flying altitude, radionuclide and its distribution in soil)
- Measuring time: 10-300 s per cycle (depending on the detector efficiency, flying altitude, radionuclide, its concentration and distribution in soil)
- Accuracy: ± 30 to ± 50 % (depending on the distribution of radionuclides in soil, the structure of the terrain, calibration accuracy, measuring time)

Pre-flight Checks - Part 1

- Inspect the airborne spectrometer system for apparent physical damage
- Select an appropriate location for the installation of the detector to minimize shielding by the fuel tank and/or other components of the helicopter or aircraft
- Check the appropriate mechanical installation of the airborne spectrometer system in the helicopter or fixed wing aircraft
- Check the electrical connection of the airborne system including radar altimeter and GPS

Pre-flight checks - Part 2

- When HPGe-detectors are used, check liquid nitrogen in the detector dewar
- Switch on the measurement system, check its basic functionality
- Set the appropriate measuring parameters, e.g. measuring time, data configuration for storage cycle
- Conduct the radio check
- Check the GPS, the radar altimeter
- Keep records of all relevant data

Measurement

- Fly to the area to be surveyed, start the measurement sequence and follow the predetermined flying routes
- Depending on the situation and national authority requirements, recommended flight parameters are as follows:
  - Flying altitude: typically 90 – 120 m above ground (when helicopters are used) depending on landscape (trees, buildings, power lines etc.); the flying altitude should be kept as constant as possible
  - Flying speed: for helicopters, flying speed is recommended between 60 km/h and 150 km/h in most cases

After Final Landing

- Re-check basic functionality of measurement system
- Record all the relevant data in the logbook
- Ensure that the data are in a readily available format
- Make back-up copies of all measured data
- Check the contamination of the helicopter or aircraft and equipment
- Analyse data and prepare fallout maps for individual radionuclides

Aerial Source Monitoring

- To detect, localize and identify gamma-emitting source(s) over large areas in order to render the source safe, to initiate protective actions and/or cleanup operations

Aerial Source Monitoring – Cont'd

- MDA: several hundred MBq (depending on the detector efficiency, flying altitude, radionuclide and line spacing)
- Measuring time: 1-5 s per cycle (depending on the detector efficiency, flying altitude and radionuclide)
- Accuracy: ±30 to ±50 % of activity under favorable conditions (depending on the structure of the terrain, calibration accuracy, measuring time, environmental conditions, radionuclide, natural background radiation, line spacing)

Search

- Fly to the area to be surveyed, start the measurement sequence and follow the predetermined flying routes
- Observe continuously the output of the measurement system
- If the count rate or instrument reading exceeds the predefined level return to location of anomaly and reduce the searching grid pattern to find the location more precisely
- Inform the EA/RA about the probable location of the source
- Continue search pattern until all sources are located

Summary

- This lecture has presented survey methods covered in Section A of the IAEA document
  GENERIC PROCEDURES FOR MONITORING IN A NUCLEAR OR RADIOLOGICAL EMERGENCY
- The following generic procedures for field radiation and contamination monitoring have been covered: plume survey, ground deposition survey, environmental dosimetry, source monitoring, surface contamination survey and aerial survey

Summary

- The procedures are written in a form compatible with QA requirements
- Procedures must be reviewed and revised to reflect specific conditions and capabilities for which they will be applied
- Procedures are intended to be used only by personnel who have been trained and drilled in their use