International Atomic Energy Agency

Radiological Monitoring during Decommissioning

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Objectives

- Discuss goals of a monitoring at a facility in decommissioning
- Describe the process of conducting a Historic Site Assessment
- Describe the process of characterizing a facility/site
- Describe the process of decommissioning radiological support monitoring
- Describe the environmental monitoring process
- Review possible post-decommissioning surveillance activities

Goals of a monitoring program

- Decommissioning Scope
  - What has to be done?
- Safety
  - What are the hazards to be encountered?
- In-Process
  - Is the decommissioning process effective?
- Disposition of Material
  - Is it radioactive waste, or can it be released? (See also 26.14)
- Final Status
  - Does the facility meet release criteria? (See also 26.14)

Monitoring Phases

- As the decommissioning project progresses the role of the monitoring staff will shift:
  - Initially - their work focuses on Site and Facility Characterization
  - Then as field activities start their focus shifts onto ensuring safe work practices and work progress
  - Finally – their focus shifts to documenting that the project is ready for Clearance of the Site for Release

Historical Site Assessment

- Design drawings and as built drawings
- Construction materials
- Facility modifications
- Facility operating records
- Production schedules
- Routine surveys
- Interviews with operators and support personnel
- Interviews with retirees
- Event log- accidents and unplanned events
- Review of security files for classified projects
- Photographs
- QA document review

Confirm unexpected revelations with Scoping Survey

Characterization

- Based on Historical Site Assessment
- Confirms HSA conclusions
- Develops scaling factors by area
- Can be used to release potentially non- impacted areas
  - Consideration of instruments and techniques
- Use of GPS greatly simplifies sampling
- Serves as a guide for the Final or Release Survey
- Characterization used as basis for Job Safety Analysis for each decommissioning task
- Regulatory agency may request copy of the Characterization Plan and Report

Characterization - Process

- Process consists of:
  - Planning the Characterization and defining requirements
  - Performing Sampling and Measurements
  - Analyzing the Data
  - Documenting the Results
  - Interpretation of the data
- Use of the data by Engineering (design) and Operations (performance)

Characterization - Uses of Data

- Data is used to:
  - Determine Scope of Work
  - Plan and Engineer Decommissioning
  - Select Decommissioning Techniques
  - Develop Waste Disposal Strategies
  - Refine of Cost Estimates and Schedules
  - Provide Input into Decommissioning Plan
  - Data needed for Approval Process
  - Assess Health and Safety Impacts to Workers and Public
  - Development of H&S Programs
  - Development of Radiological End - Point Criteria
  - Input for Planning Final Survey

Characterization - Identify Conditions

- Radiological
  - Contaminated and Activated Structures and Equipment
  - Spills and Leaks to Environment
  - Build-up of Routine Deposition
- Hazardous Materials
  - Contained in equipment
  - Spills in Structures and Environment
  - Building Materials
- Other Personnel Hazards
  - Potential Physical Hazards Expected
  - Hazardous Atmosphere / Confined Spaces
  - Stored Energy Sources- electrical, mechanical, etc
  - Building / Equipment Defects

Characterization - Preparation

- Gather existing data (Historical Site Assessment) focus on two types of information
  - Existing radiological / hazardous material data
    - Obtain “acceptable knowledge”
    - Construct conceptual site model
    - Clues for what, where and how to monitor/ sample
  - Data required to conduct characterization
    - Survey Maps
    - Access Points
    - Safety Issues

Characterization - Preparation

- Conduct Staff Interviews (current and retired)
  - Anecdotal information related to spills, missing sources and operational practices
- Research and Review of Documentation
  - Licenses, permits, authorizations
  - Notices of inspections and violations
  - Documented incidents and accidents
  - Routine monitoring data
  - Maps, construction photographs, plot plans
  - Geological / Hydrogeological, meteorlogical data

Characterization - Preparation

- Tour / Observe Facilities and Operations
  - Look for stains, leaks and defects
  - Possible scoping measurements
- Determine Characterization Objectives
- (What information do we want to derive from the characterization data?)
  - Identify radionuclide mixtures
  - Volume soil requiring excavation and disposal

Characterization - Goals

- Estimate volume of structural material requiring dismantling and disposal
- Determine structural surface areas requiring decontamination
- Prepare a list and volume of equipment requiring dismantling and disposal
- Document work and environmental hazards

Characterization - Preparation

Examples of Hazardous Material Data

- Presence of lead, chromium and other heavy metals, asbestos and PCBs and the depth of penetration of these contaminants into concrete, structural surfaces, subsurface soil, and other media
  - Areas of concern include:
    - Paints and other surface coatings
    - Site soil, sediment or groundwater
    - Systems or components

Characterization - Preparation

- Determine Data Quality Considerations
  - (What will make the data usable?)
  - Ability to detect contaminants present
    - Appropriate analytical methods and equipment
    - Background masking
  - Ability to detect contaminanants at relevant concentrations
    - Clean-up criteria

Characterization - Preparation

- Ability to assure quality of data
  - How will documentation errors be detected and corrected?
  - What are the Data Quality indicators?
  - Are personnel experienced and qualified?
  - Are characterization processes controlled?
- Not unknowingly change the facility
  - Will sampling cause contamination to migrate?

Characterization - Formulate the Plan

- Formulate and Document Plan
  - Determine What Raw Data is Needed
    - Examples of Radiological Data
    - Locations, spatial distribution, radioisotopic makeup, and contamination levels on structural surfaces
    - Depth of radioactive contamination penetration into surfaces

Characterization - Formulate the Plan

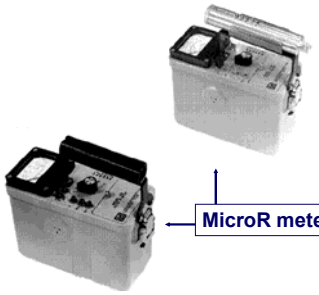
- Monitor and sample to confirm location, distribution, radioisotopic makeup, and radioactivity levels in or on contaminated equipment, ducts, fixtures, etc.
- Document radiation exposure rates from equipment and general area
- Confirm induced radioactivity from neutron irradiation in reactor components and associated structures through monitoring and sampling
- Use drawings, calculations and information from HSA to determine number and locations of samples and montoring. Consider radiological, hazardous materials, and industrial safety

Characterization - Formulate the Plan

- Select Analytical Techniques
  - Many techniques are a carry over from operations (Health Physics, Environmental Monitoring, Waste Assay)
    - Gamma exposure rates
    - Beta dose rates
    - Removable gross beta and alpha surface contamination
    - Surface soil and water sampling and analysis
    - Isotopic analysis

Characterization - Monitoring Instruments

Portable gamma spectroscopy



MicroR meters

Characterization - Direct Reading Instruments

Characterization - Formulate the Plan

- Others may be new or different from operations (methods and / or levels encountered)
  - Paint sampling and analysis
  - Direct measurement of contamination on surfaces
  - Bulk sediment sampling in equipment
  - Subsurface water, soil and bedrock sampling
  - Surface / substrate (concrete) depth sampling

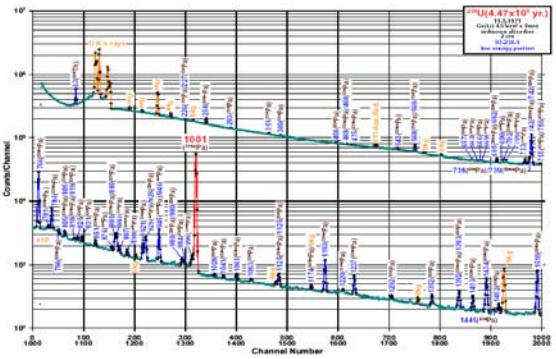
Characterization - Laboratory Instruments

Low background alpha-beta counters

Gamma spectroscopy

Characterization - Laboratory Liquid Scintillation Detectors

Example of Data – Gamma Spectroscopy



Characterization - Analytical Techniques

- Some items cannot be sampled or may not be directly measurable
  - Inaccessibility (buried duct)
  - High or lethal radiation levels (Reactor core)
  - Risk of contamination spread (floor of Hot Cell)

Characterization – Preparing the Plan

- Locate Measurement and Sampling Locations
  - Contaminated Structures
    - Unbiased Survey
      - Homogeneous areas
      - Unique mode of deposition, surface and material
      - Statistical representation (random / systematic sampling)
      - Scanning to locate anomalies
      - Classify area (or sub areas) as clean or contaminated

Characterization – Preparing the Plan

- Biased Survey (suspected worst case single point locations)
  - High likelihood of hot spot contamination (Scans / Historic Site Assessment results / Professional Judgment)
  - Spill locations, sumps, drains, floor of hot cell
  - Investigation to bound area , volume and concentrations

Characterization – Measurement & Sampling Locations

- Contaminated Systems and Equipment
  - Determine isotopic concentration and inventory
  - Correlate concentration / inventory to gross gamma / in-situ gamma spec.
  - Access for sampling representative equipment on system basis for complete isotopic / benchmarking (safety / practicality considerations)

Characterization - Measurement & Sampling Locations

- Environmental
  - Soil, sediments, water and bedrock
  - Similar basis as structures (biased and unbiased approaches)
  - Surface deposition vs. Under buildings leaks

Characterization - Measurement & Sampling Locations

- Background (Reference areas)
  - Unaffected by site
    - Up wind
    - Up ground water gradient
    - Certain of isolation
    - Similarity of conditions and materials
  - Same geological parameters as on-site characterization
  - Statistical comparison to site data
- Consider: Is contaminant in background?

Work Area Requirements - Information

Current data, on a task by task basis, is required to:

- Specify where and what to remove or decontaminate
- Gauge effectiveness of D&D techniques
- Determine readiness for final surveys

What about old data?

- Prior Characterization Data is Only a Starting Point
- Will Change as soon as work starts
- Data may have been limited or have a high uncertainty
  - Characterization provides a statistical picture
  - Interference from high background (precludes effective scanning to locate anomalous "hot spots")
- Full access may have been unavailable until "opened up" by decommissioning activities
  - Subsurface soil under structures or equipment
  - Buried/embedded equipment
  - Flooded pools/canals or equipment
  - Surfaces behind/under equipment

Work Area Requirements - Accident Scenarios

- Possible consequences -
  - Release of airborne particulates outside of controlled areas and off site
  - Contaminate clean surfaces and soil around the facility
  - Increase radiation levels at uncontrolled and offsite locations

Work Area Requirements – Accident Scenarios

- Continue with a modified Environmental Monitoring Program
- Following regulator requirements, evaluate and delete non-existing pathways (e.g., noble gases after fuel is removed)
- Stress additional monitoring requirements for routine and accident D&D release scenarios

Work Area Requirements

- Start with largest radiation sources and areas with greatest contamination and work toward clean areas
- First remove equipment, then structural contamination, then subsurface soil
  - Reduces facility radiation levels
  - Reduces potential for re-contamination
  - Opens up work areas to provide access

Work Area Requirements

- Specify structural surfaces to be decontaminated
- Sort equipment as contaminated or potentially able to be cleared with subsequent certification
- Specify soil to be:
  - Directly removal as contaminated
  - Removed as potentially clean with subsequent certification

Work Area Requirements

- Keep process moving - must be rapid to keep work going but be efficient
  - Give preference to 'In-the-Field' analysis
  - Use gross qualitative indicators of contamination/activation (levels many times release criteria)
  - Gross beta or gamma scans of surfaces or sample media (ion chamber to GM or NaI)
- Use same basic techniques as characterization survey
  - Contaminated surfaces (concrete, metallic and other building materials)
  - Contaminated concrete volumes (cracks, joints, diffusion)
  - Contaminated soil (surface, under structures, and sub-surface plumes

Work Process Photos

High radiation field probe measurement of waste item

Work in progress measurement

Work Area Requirements

- Assess Effectiveness of Work Performed via Iteratively check contamination levels after each decontamination or removal evolution

Note: Contamination depth may vary by location, especially if cracks, seams or expansion joints are present

Example of an Iterative Process

Scabble a 1 cm layer of contaminated concrete from a surface and survey newly exposed surface. Repeat process until entire surface meets release criteria.

Work Area Requirements

- Activated volumes (concrete bio-shields, reactor components)

Remember:

Monitoring techniques should evolve as working conditions change from high levels to very low levels of radiation and contamination

Work Area Requirements

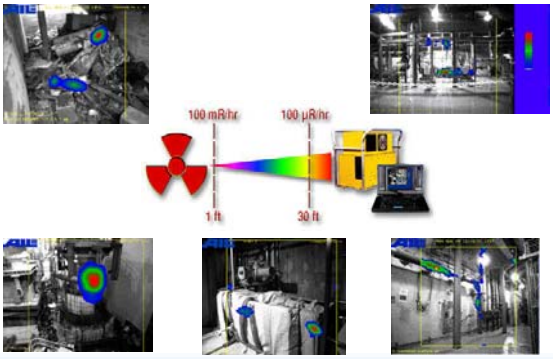
- Progress toward in-situ/in-field quantitative determinations (1-3 times release criteria)
  - ❖ Direct beta (systematic locations)
  - ❖ Collimated gross gamma scans (NaI)
  - ❖ In-situ gamma spectroscopy (background issues)
  - ❖ Field laboratory screening

Portable Gamma Instrument

Sample Locations

- The exact location must be recorded properly each time a sample is taken
- Use of traditional map-spotting techniques are slow and require trained personnel
- Modern positioning techniques: global positioning system (GPS) and microwaves, ultrasound and laser ranging systems are preferable

GammaCam (Gamma Camera)



Hazard Evaluation

- Initial static conditions may not be the same conditions encountered during decommissioning work
  - Generate airborne dust and fumes, loose contamination, and hot particles
  - Stir up existing dust
  - Expose or build up unforeseen sources of radiation

Hazard Evaluation

- Potential hazards unique to each task or work area must be identified
  - Depend on radiation sources
  - Decommissioning work scope
  - Location of personnel and their expectations
- Active work areas
- Support areas

Radiation Protection

- Airborne dust and dispersible contamination
  - Cutting of contaminated/activated materials
  - Surface decontamination
- Frequent breaching of building containment
  - Removal of contaminated structures
  - Need to access contamination
- Progressive removal of protective systems and barriers
  - Breaching equipment
  - Disabling radiation and criticality alarms
  - Removing shielding

Radiation Protection

- Movement of large volumes of dispersible waste materials
- Outdoor work and handling of radioactive materials
- Potential for rapid and unexpected changes of radiological conditions in work areas
  - Dropped/Breached waste containers
  - Unshielded or moved sources
  - Fires or explosions
- Need immediate data at any time
  - How to best evacuate personnel
  - Where to impose protective measures

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Radiation Protection

- Appropriate worker controls are in place, considering existing/potential conditions
  - Anti-Contamination clothing
  - Respirators
  - Multiple TLDs, SRDs, alarming dosimeters

Radiation Protection

Quartz filament dosimeters

Electronic dosimeters

Radiation Protection

- Required monitoring in active areas
  - Work area dose rates
  - Particulate airborne radioactivity
  - Contamination

* Provides direct and intentional monitoring by experienced D&D HP technicians
* Monitors and controls the work activity
* Provides warning of unforeseen or inadvertent un- shielding of a source or movement of radioactive materials

* Install low volume air samplers (area/breathing zone) to measure/evaluate internal exposures over a work shift
* Take large volume grab sample to evaluate short-duration tasks/peak concentrations

* Monitor for build-up of loose contamination after generating activities
* Monitor generation/migration of hot particles (cutting activated components)

Radiation Protection - Monitoring

Personnel alpha monitor

Hand and foot monitor

Manual method

Other Areas

- Hazards are minimal but could be affected by activities within active work areas if controls should fail
  - Waste storage & equipment staging areas or support zones
  - Inactive decommissioning work areas
  - Areas adjacent to active areas with recognized hazards (outside a containment tent)

Other Areas

- Required monitoring in other areas
  - Area exposure rates
    - Alarming exposure rate devices for notification of high radiation conditions in general area
    - Periodic or alarming exposure rate measurement devices on equipment where radioactivity build-up could occur (HEPA or water filtration units)
    - Periodic general area exposure rate surveys to identify trends or non-ALARA conditions
  - Particulate airborne radioactivity
    - Alarming continuous air monitors to provide immediate notification of a release from active work area
    - Consider need to monitor for containment equipment failure
  - Contamination
    - Monitor for build-up of loose contamination
    - Monitor generation/ migration of hot particles

Potential Airborne Particulate Releases

- Continue permitted building air discharge vents and stacks (particulate filter sample with alarming rate meter and dose rate monitors)
- Inside buildings, install continuous low volume particulate air samplers near doorways and other potential building openings (degraded negative pressure due to multiple openings, wind effects)

Potential Airborne Particulate Releases

- On site outdoors, install continuous long-term low volume particulate air samplers near outdoor work areas (up- and down-wind) where loose or large amounts of packaged materials are handled
- Off site, install continuous long-term low volume particulate air samplers near down-wind receptor locations and up-wind

Waste Processing

- Sort and Release Clean Waste Materials (Clearance)
  - Support packaging, transportation, and disposal
  - Concrete rubble and slabs
  - Waste equipment and furniture
  - Contractor equipment
  - Soil
  - Other (wood, plaster, pipe)

Waste Processing

- Direct sampling of every package
  - Multiple laboratory analyses (U, Gamma spec, H-3, Sr-90, etc)
  - Very time consuming and expensive
- Estimation based on easily measured variables
  - Correlation to dose rate or gamma energy flux
  - By homogeneous waste stream

Waste Processing

- Identify individual waste streams
  - Homogeneous radionuclide mixture and ratio
  - Homogeneous matrix composition
  - Examples:
    - ❖Activated biological shield concrete
    - ❖Soil under hot cell
    - ❖Primary reactor water equipment

Waste Processing

- Characterize waste streams
  - Select sample media
  - Determine complete radionuclide identities
  - Determine average ratio
- Support packaging, shipment and disposal

Waste Processing

- Determine correlation factors
  - Determine waste geometries (drums, boxes, bags, intermodal containers)
  - Select easily measured indicator variable (gamma dose, Co-60 gamma energy flux)
  - Model using shielding codes/calculations to correlate measured variable to individual radionuclide concentrations, for each waste stream and geometry

Environmental Monitoring

- Surface and Soil Contamination
  - Continue permitted building air discharge vents and stacks (particulate filter sample with alarming rate meter)
  - Perform periodic surface contamination surveys (loose contamination and hot particles)
  - Waste material, equipment, and personnel exit locations
  - Waste material and contaminated equipment storage locations
  - Perform soil sampling for exposed soil (as above)

Environmental Monitoring

- Dose Rates
  - TLDs at property line
  - TLDs at off-site occupied locations (close houses)
  - Periodic dose rate surveys of fence line
  - Periodic surveys of radioactive material area boundaries (waste staging yard)

Final or Verification Survey

- Follows the remedial action effort
- Requires strict controls are in place from the conclusion of the remedial action until the survey is performed and results are known
- The underlying assumption is that the remediated area is contaminated above release guides. The analysis of the results of the Final Survey will prove it is not.
  - More details on final facility surveys to support site release from regulatory control are given in Lesson 26.14

Summary

- Environmental restoration is an integral part of the decommissioning process
- Environmental restoration planning requires input from a number of sources
- End use of the site determines the degree of environmental restoration activities
- Restricted end-use versus unrestricted end-use has both short-term and long-term cost consequences
- Changing standards and regulatory requirements may affect long-term strategies

References

- IAEA WS-R-2
- IAEA DSS 332
- IAEA DSS 333
- IAEA WS-G-2.1, -2.2 and -2.4
- IAEA IAEA RS-G-1.1
- IAEA Safety Series #115
- IAEA TRS #334
- IAEA TRS #389
- IAEA Fundamental Safety Principles, DS298 – approved to be published, 2006