



# **L5: Dispersion of Radionuclides in the Environment During Decommissioning**

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**Follow-up Training Course on Environmental Radioactivity Monitoring  
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# Background

Decommissioning of nuclear facilities involves dismantling, decontamination, and waste management, which may release radionuclides.

Radionuclides can be released through mechanical, chemical, and thermal processes.

Released radionuclides can travel via air, soil, groundwater, and surface water.

Mitigation and Control Measures are essential to limit dispersion.



# Objective – Basic Competency

Participants will be able to understand the **release scenarios**, **environmental pathways**, **influencing factors**, and **mitigation measures** of radionuclide dispersion during decommissioning, enabling them to assess environmental risks and implement appropriate control strategies



# Objective - Success Indicators

Participants can identify and describe types of release scenarios and their potential environmental impact

Participants can explain the main pathways (air, soil, groundwater, surface water) and provide examples of contamination routes

Participants can discuss how meteorological, hydrological, geochemical, and operational factors influence dispersion

Participants can propose appropriate engineering, administrative, and environmental protection measures for a given decommissioning scenario



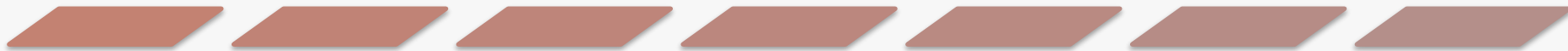
## Release Scenarios During Decommissioning



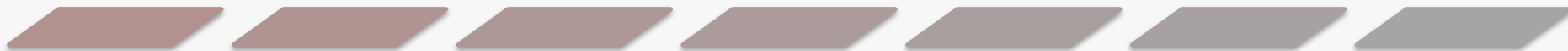
## Potential Environmental Pathways



## Environmental Factors Affecting Dispersion



## Mitigation and Control Measures



# Release Scenarios During Decommissioning

Session-1





## Mechanical Dismantling and Cutting



## Decontamination



## Waste Packaging and Transfer

# Mechanical Dismantling and Cutting

Mechanical dismantling involves physically taking apart structures, equipment, or components of a nuclear facility using tools such as saws, shears, plasma cutters, or robotic arms.

## Purpose:

- Remove contaminated structures safely.
- Prepare the site for decommissioning or repurposing.

## Common Operations:

- Dismantling of reactor internals, piping systems, and structural steel.
- Removal of contaminated floors, walls, or equipment housings.



# Potential Release of Radioactive Dust and Particles

## Mechanism

- Cutting, grinding, or shearing can generate fine dust or aerosols containing radionuclides.
- Dust can become airborne, settle on surfaces, or infiltrate soil and water.

## Environmental Concerns

- Airborne radionuclides may spread beyond the immediate work area.
- Settled dust can contaminate soil, drains, or groundwater if not controlled.

## Health and Safety Considerations

- Exposure risk to workers and the public.
- Requires monitoring and protective measures.

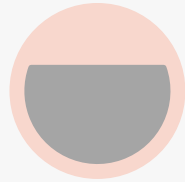
## Reactor or Piping System Dismantling



### Reactor Dismantling:

Cutting of reactor pressure vessel internals, biological shields, and other components.

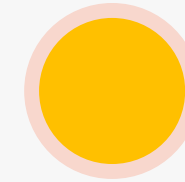
Use of remote-operated cutting tools to reduce radiation exposure.



### Piping System Dismantling:

Removal of contaminated pipes, valves, and supports.

Potential for localized dust release during cutting or scraping.



### Mitigation Measures:

Containment (plastic sheeting, gloveboxes, or temporary enclosures).

Local ventilation and HEPA filtration.

Wet cutting methods to reduce airborne dust.

Continuous monitoring of air and surface contamination.

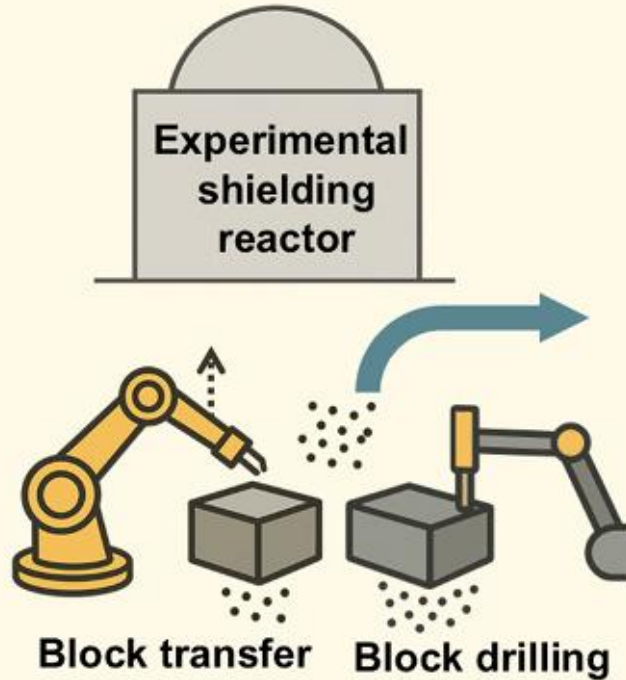


Fei Zhou , Xiaotong Chen , Hao Wang , Zhenzhong Zhang

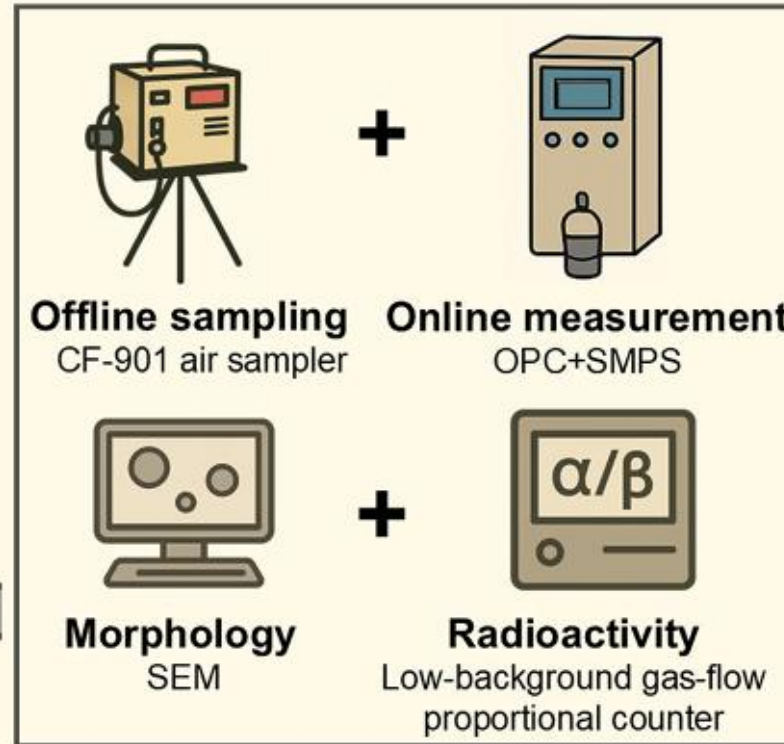
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## Characterization and mitigation of radioactive dust during graphite retrieval process of nuclear decommissioning

### Graphite retrieval

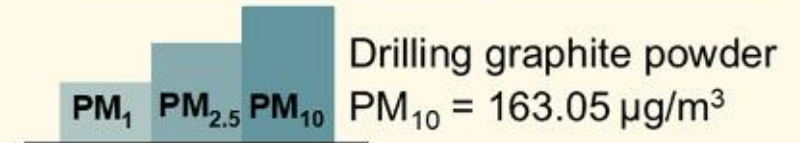


### Particulate characterization



### Findings

**Mircon-sized particulates dominate**



**Low radioactivity detected**

$\alpha$ : 0.40-0.48  $\text{mBq}/\text{m}^3$   
 $\beta$ : 3.37-4.89  $\text{mBq}/\text{m}^3$

**Effective dust mitigation**

**High-flow ventilation system**

Mitigation efficiency  
91.05%

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The graphite retrieval process can generate radioactive dust that poses occupational and environmental safety concerns during decommissioning.

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Most released particulates are micrometer-sized, with PM10 concentrations peaking around 163  $\mu\text{g}/\text{m}^3$  during drilling of powdered samples.

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On-site high-flow ventilation (3300  $\text{m}^3/\text{h}$ ) achieved over 90% reduction in aerosol dispersion, significantly limiting airborne radioactivity.

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Localized dust extraction near the source further suppresses coarse particulates and supports overall dust control.

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Airborne aerosol radioactivity remained low ( $\alpha$  0.40–0.48  $\text{mBq}/\text{m}^3$ ;  $\beta$  3.37–4.89  $\text{mBq}/\text{m}^3$ ), largely due to effective dust containment.

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Drilling powdered samples generates substantially more aerosols than drilling cylindrical samples, suggesting that sample preparation methods influence emission risk.

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The study provides practical, field-based guidance for improving radiation protection and environmental safety in graphite decommissioning via combined ventilation and source-focused dust extraction strategies.





## Chemical Decontamination

## Abrasive Methods

## Thermal Methods

# Chemical Decontamination

Use of chemical agents to remove or reduce radioactive contamination from surfaces of structures, equipment, or materials.

## Common Agents:

- **Acids:** e.g., nitric acid, citric acid – dissolve surface oxides and radionuclides.
- **Chelating agents:** e.g., EDTA – bind radionuclides to facilitate removal.

## Applications:

- Decontamination of metal surfaces, piping, tanks, and reactor components.

## Advantages:

- Effective for complex surfaces and inaccessible areas.
- Can significantly reduce surface activity levels.

## Considerations:

- Generates secondary radioactive waste (e.g., contaminated liquids).
- Requires neutralization and safe disposal.



# Abrasive Methods

Mechanical removal of contaminated layers from surfaces using physical abrasion.

## Techniques:

- **Sandblasting:** High-pressure abrasive media to remove surface contamination.
- **Scabbling:** Chiseling or grinding of concrete or other surfaces.

## Applications:

- Removal of contamination from concrete floors, walls, and structural surfaces.

## Advantages:

- Rapid removal of surface layers.
- Minimal chemical waste generation.

## Considerations:

- Generates airborne dust, requiring containment and ventilation.
- May damage surfaces if not carefully controlled.



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Use of heat to remove, decompose, or immobilize radioactive contamination.

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**Techniques:**     **Heating:** Surface heating to volatilize certain contaminants.  
                          **Melting:** Smelting or controlled burning to concentrate radionuclides for easier removal.

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**Applications:**     Decontamination of metallic scrap, ash, or specialized components.

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**Advantages:**     Can achieve high decontamination factors.  
                              Reduces volume of contaminated material.

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**Considerations:**     Requires strict emission controls to prevent airborne release.  
                                  Energy-intensive and may require specialized facilities.



# Waste Packaging and Transport

The process of safely containing and moving radioactive waste from decommissioning sites to storage, treatment, or disposal facilities.

## Packaging Types:

- **Drums and barrels:** For solid low- and intermediate-level waste.
- **Shielded containers:** For high-level waste or highly radioactive components.
- **Specialized liners or bags:** For liquid or soft contaminated materials.

## Transport Considerations:

- Compliance with national and international regulations (e.g., IAEA Safety Standards, ADR/RID).
- Labeling, documentation, and radiation monitoring during transport.

## Purpose:

- Prevent contamination of personnel, equipment, and environment during movement.
- Facilitate long-term management of radioactive waste.

# Temporary Storage Procedures

Safe holding of radioactive waste at the decommissioning site before final disposal or treatment.

## Key Aspects:

- Segregation by waste type and radioactivity level.
- Use of secure storage facilities with shielding and ventilation.
- Regular monitoring for radiation levels, leaks, or structural integrity.

## Purpose:

- Minimize risk to workers and environment.
- Ensure regulatory compliance while awaiting treatment or disposal.



# Risk of Accidental Releases During Handling

## Potential Sources:

- Spills or leaks during packaging.
- Dropping or damage to containers during transport.
- Improper handling or human error.

## Environmental and Safety Impacts:

- Contamination of surfaces, soil, or water.
- Airborne radionuclide release.
- Worker exposure exceeding safe limits.

## Mitigation Measures:

- Use of appropriate PPE (personal protective equipment).
- Remote handling and automation where possible.
- Secondary containment systems and spill response plans.
- Continuous monitoring of radiation levels during handling and transport.

# Identifying Critical Points in Decommissioning Processes

Critical points are stages or operations in decommissioning where the likelihood of radionuclide release is highest.



## Typical Critical Points:

- **Mechanical Dismantling and Cutting:** Cutting reactor internals, pipes, and structural components can generate dust and aerosols.
- **Decontamination Operations:** Chemical, abrasive, or thermal methods may mobilize radionuclides.
- **Waste Handling and Packaging:** Improper containment can lead to leakage or spillage.
- **Transport and Temporary Storage:** Movement of waste containers or temporary storage areas may pose risk if not properly controlled.



## Assessment Methods:

- Process hazard analysis (PHA) to map potential release points.
- Radiation surveys and sampling to identify contamination hotspots.
- Review of operational procedures to identify weak points in containment.

# Early Mitigation Strategies

**Purpose:** Reduce the likelihood and impact of radionuclide release before significant contamination occurs.

## Engineering Measures

- Containment of work areas using plastic sheeting, gloveboxes, or enclosures.
- Local ventilation and HEPA filtration systems to capture airborne particles.
- Wet methods (e.g., water sprays) to suppress dust generation.

## Administrative Measures

- Standard operating procedures (SOPs) for high-risk operations.
- Worker training and supervision for critical tasks.
- Scheduling of operations to minimize cumulative exposure.

## Monitoring and Verification

- Continuous air and surface contamination monitoring.
- Regular environmental sampling around the facility.
- Early warning systems for accidental release.

# Potential Environmental Pathways

Session-2



Airborne dispersion refers to the transport of radionuclides through the air as dust particles, aerosols, or gases released during decommissioning activities.

## Sources of Airborne Contamination:

- **Mechanical Dismantling:** Cutting, grinding, or shearing of contaminated components.
- **Decontamination Processes:** Abrasive or chemical cleaning that generates fine particles.
- **Waste Handling and Transfer:** Spillage, handling, or movement of contaminated materials.

## Characteristics of Airborne Radionuclides:

- Particle size affects transport distance and deposition.
- Volatile radionuclides (e.g., iodine, tritium) may travel long distances as gas.
- Settling occurs depending on particle size, weight, and air currents.



# Meteorological Factors

## Wind

- Speed and direction determine the spread and concentration of radionuclides downwind.

## Temperature and Atmospheric Stability

- Temperature inversions can trap contaminants near the ground.
- Thermal gradients affect vertical dispersion.

## Humidity and Precipitation

- Rain or snow can remove particles from the air (wet deposition).

## Topography and Obstacles

- Buildings, terrain, and vegetation influence local airflow and deposition patterns.

## Airborne radionuclides can:

- Settle on soil, water, and surfaces, contributing to secondary contamination.
- Be inhaled by workers or nearby populations, posing health risks.

## Mitigation Measures:

- Containment and enclosures around high-risk operations.
- Local exhaust ventilation with HEPA filtration.
- Use of wet cutting or suppression techniques to reduce dust.
- Continuous air monitoring around work areas.



Deposition occurs when airborne radionuclides settle on soil, surfaces, or structures, leading to surface contamination.

## Mechanisms of Deposition:

- **Gravitational settling:** Larger dust particles fall to the ground naturally.
- **Impaction:** Particles collide and adhere to surfaces.
- **Adsorption:** Radionuclides chemically bind to soil or organic matter.

## Common Affected Areas:

- Ground surfaces around decommissioning operations.
- Building roofs, floors, and nearby equipment.



# Runoff and Erosion Effects

Movement of radionuclides from contaminated surfaces via water flow.

## Mechanisms:

- **Surface runoff:** Rainwater or cleaning water carries particles into drains or nearby water bodies.
- **Soil erosion:** Contaminated soil particles are displaced, spreading contamination to new areas.

## Factors Influencing Movement:

- Slope of terrain and soil permeability.
- Rainfall intensity and frequency.
- Vegetation cover and land use patterns.



# Impact on Local Ecosystems

## Soil:

- Accumulation of radionuclides may alter soil chemistry and microbiota.

## Plants and Crops:

- Uptake of radionuclides through roots or surface deposition can lead to bioaccumulation.

## Animals and Humans:

- Contaminated plants and soil may enter the food chain.

## Environmental Monitoring:

- Regular soil sampling and contamination mapping.
- Measures to prevent spread through water or dust.



# Mitigation Measures

Containment of contaminated soil during dismantling.

Surface cleaning using wet methods or vacuum systems with HEPA filters.

Erosion control measures such as mulching, sediment traps, or temporary barriers.

Groundwater infiltration refers to the movement of radionuclides through soil and into aquifers, potentially contaminating groundwater resources.

## Factors Affecting Infiltration:

- **Soil Type and Permeability:** Sandy soils allow faster infiltration; clay soils slow down radionuclide movement.
- **Hydraulic Gradient:** Direction and rate of groundwater flow determine how contaminants spread.
- **Depth to Water Table:** Shallow groundwater is more vulnerable to surface contamination.

**Significance:** Understanding soil and aquifer characteristics is critical to predict potential contamination and plan mitigation.

# Radionuclide Transport Modeling in Aquifers

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**Purpose:** Predict the movement and concentration of radionuclides in groundwater over time.

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**Key  
Processes  
Modeled:**

**Advection:** Movement of radionuclides with flowing groundwater.

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**Dispersion:** Spreading of radionuclides due to variations in flow paths.

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**Sorption:** Binding of radionuclides to soil or rock surfaces, reducing mobility.

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**Decay:** Radioactive decay reduces radionuclide concentration over time.

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**Applications:** Risk assessment for nearby wells, rivers, or ecosystems.

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Designing containment and remediation measures.

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Regulatory compliance and safety case development.

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# Environmental Implications

Contaminated groundwater can affect drinking water sources, irrigation, and ecosystems.

Early identification of high-risk zones allows timely implementation of barriers or treatment systems.

# Mitigation Measures

Installation of impermeable liners or barriers to prevent infiltration.

Monitoring wells to detect radionuclide movement.

Pump-and-treat systems or in-situ immobilization of radionuclides if contamination occurs.



Radionuclides can enter surface water bodies through direct discharge, runoff, or leaching from contaminated soil.

## Common Pathways:

- **Surface Runoff:** Rainwater carries contaminated soil particles or decontamination liquids into rivers, lakes, or ponds.
- **Drainage Systems:** Effluents from decommissioning facilities may enter streams or retention ponds.
- **Erosion:** Contaminated sediment can be transported downstream.

## Transport Factors:

- Flow rate and volume of the water body.
- Seasonal variations (floods, droughts) affecting dilution and deposition.
- Sediment deposition and resuspension processes.



# Impact on Water Quality & Aquatic Life

- Increased radioactivity levels in water can exceed regulatory limits for human use and ecological safety.
- Contaminants may persist in sediments, acting as secondary sources.

## Water Quality Implications:

- Bioaccumulation of radionuclides in fish, plants, and microorganisms.
- Disruption of aquatic ecosystems and food chains.
- Potential long-term ecological consequences.

## Effects on Aquatic Life:

- Regular sampling of water, sediment, and biota.
- Assessment of radionuclide concentration trends over time.
- Evaluation of cumulative effects on ecosystem health.

## Monitoring and Assessment:



# Mitigation Measures

Containment of effluents before discharge into water bodies.

Use of sediment traps or retention basins to prevent downstream contamination.

Continuous environmental monitoring and early warning systems.

Remediation strategies for contaminated sediments if needed.



# Environmental Factors Affecting Dispersion

Session-3



# Meteorological Factors

## Wind Speed and Direction

Wind plays a key role in the horizontal and vertical transport of airborne radionuclides.

### Influences:

- **Wind Speed:** Higher wind speeds can transport particles over longer distances.
- **Wind Direction:** Determines which areas downwind may be affected by airborne radionuclides.

### Implications:

- Critical for planning work schedules and containment strategies.
- Helps predict deposition patterns and identify potentially impacted areas.



# Meteorological Factors

## Temperature and Humidity

### Temperature

- Influences atmospheric stability and vertical dispersion.
- Temperature inversions can trap contaminants near the ground, increasing local exposure.

### Humidity

- High humidity can enhance deposition of airborne particles through condensation.
- Moist conditions may reduce dust generation but can also facilitate surface adherence of radionuclides.



## Precipitation and Weather Patterns

### Precipitation (Rain, Snow)

- Promotes **wet deposition**, removing airborne particles and depositing them on surfaces or soil.
- Heavy rainfall can lead to runoff, transporting contaminants into soil and water bodies.

### Weather Patterns

- Seasonal changes affect dispersion, dilution, and deposition rates.
- Storm events can resuspend settled radionuclides, temporarily increasing airborne contamination.

Meteorological conditions are critical for risk assessment and planning of decommissioning operations.

Monitoring weather conditions helps optimize timing of high-risk activities, reducing environmental and public exposure.

Predictive modeling of radionuclide dispersion relies heavily on meteorological data.



# Mitigation Measures

Schedule high-risk operations during favorable weather conditions (low wind, dry periods).

Use temporary containment structures or tents to minimize dispersion during strong winds.

Continuous meteorological monitoring to support decision-making and emergency response.



# Hydrological & Geochemical Factors

## Soil Type and Permeability

Soil characteristics influence the movement and retention of radionuclides in the environment.

### Influences:

- **Sandy or gravel soils:** High permeability allows faster infiltration into groundwater.
- **Clay or compacted soils:** Low permeability slows movement but may allow accumulation near the surface.

**Implications:** Determines how quickly radionuclides migrate and where contamination may concentrate.

# Hydrological & Geochemical Factors

## Groundwater Depth & Hydrological Flow

### Groundwater Depth

- Shallow aquifers are more susceptible to contamination from surface releases.
- Deep aquifers may provide natural attenuation but are harder to remediate.

### Hydrological Flow

- Flow direction and rate determine contaminant transport pathways.
- Interaction with rivers, lakes, and other surface water bodies can spread contamination.



# Radionuclide Interactions with Environmental Media

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**Sorption:** Radionuclides may bind to soil or sediment particles, reducing mobility.

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**Desorption:** Changes in pH, ionic strength, or redox conditions can release bound radionuclides.

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**Chemical Speciation:** Influences solubility, mobility, and bioavailability of radionuclides.

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**Sedimentation and Resuspension:** Contaminated sediments in rivers or ponds can act as secondary sources



Understanding hydrological and geochemical factors is critical for:

Predicting migration of contaminants.

Designing effective containment and remediation strategies.

Assessing risks to water resources and ecosystems.

# Mitigation Measures

Installation of impermeable liners or barriers to limit infiltration.

Groundwater monitoring wells to detect early contamination.

Remediation strategies such as sorbent materials or pump-and-treat systems.

Controlling erosion and sediment transport from contaminated surfaces.



## Operational Practices and Work Procedures

- The way decommissioning activities are planned and executed can influence the likelihood of radionuclide release.
- **Key Points:**
  - Strict adherence to Standard Operating Procedures (SOPs) reduces accidental releases.
  - Scheduling high-risk tasks during favorable conditions minimizes environmental impact.
  - Use of checklists and supervisory oversight ensures consistent application of safety measures.

## Facility Maintenance

- Proper upkeep of equipment, containment systems, and ventilation is critical to controlling radionuclide dispersion.
- **Influences:**
  - Well-maintained ventilation and filtration systems prevent airborne contamination.
  - Regular inspection and repair of waste storage containers reduce leaks and spills.
  - Preventive maintenance of decontamination and cutting equipment ensures safe operation.



## Human Errors:

- Mishandling of radioactive materials.
- Incorrect operation of containment or ventilation systems.
- Failure to follow established protocols.

## Mitigation Measures:

- Comprehensive training and certification programs for workers.
- Implementation of remote handling and automation for high-risk tasks.
- Safety culture promotion to encourage reporting and corrective actions.
- Continuous monitoring and auditing to detect deviations early.

Human factors can significantly influence the release and spread of radionuclides during decommissioning.

Effective management of operational practices and human errors reduces risk to workers, public, and the environment.

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### Aerosol deposition and dispersion during nuclear reactor decommissioning

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#### ABSTRACT

The study of aerosol particle deposition and dispersion has gained increasing importance in a range of applications such as aerosol monitoring, air pollution management, and industrial gas cleaning. In the nuclear industry, it plays a critical role in the assessment of aerosol behavior and the potential release of radioactive materials during severe accidents or decommissioning processes. However, due to the complexity of the and varying model precision, producing completely repeatable experimental results remains challenging. Significant research efforts have been made to simulate and evaluate dispersed particles in turbulent boundary layers and model particle deposition in turbulent duct flows. This review article aims to serve as a reference for future studies in the field, covering topics such as particle dispersion and deposition, deposition processes, thermal-hydraulic impacts on particle behavior, and experimental validation studies for nuclear applications.



# Case Study

## Objective

- Explain **how fine particles (aerosols)** spread and stick to surfaces during reactor decommissioning.
- Provide **practical guidance** to researchers and practitioners to improve safety and policy.

## Methodology

- Reviewed a range of experimental studies that looked at **aerosol behavior in different spaces** (straight pipes, bends, enclosed rooms).
- Compared experimental results **with computer simulations** (CFD models and simplified lumped-parameter models).
- Used particle size and key measures ( $V_d$  = deposition velocity,  $\tau_p$  = particle relaxation time) to understand **how aerosols deposit**.
- Described several ways particles stick: **diffusion** (random motion), **inertial impaction** (hitting surfaces as they fly), **thermophoresis (movement)** due to temperature differences), and **electrostatic forces**; also considered **surface roughness**.

## Key Findings

- **Tiny** particles deposit mainly by diffusion; **medium** particles by a mix of diffusion and impaction; **large** particles mainly by inertial impaction.
- **Surfaces and air flow** (surface roughness, bends, how the air moves) make deposit predictions hard.
- Mathematical models work differently depending on **particle behavior and size**; some models are accurate in some situations but not all.
- **Thermophoresis** is important near hot surfaces or in two-phase environments (air plus moisture/steam).
- **Validation** across many experiments is essential to ensure predictions are reliable for real facilities.

# Mitigation and Control Measures

Session-4



# Engineering Controls

## Ventilation and Filtration Systems

Systems designed to control airborne radionuclides by directing airflow and removing contaminants.

### Key Components:

- **Local Exhaust Ventilation (LEV):** Captures dust and aerosols at the source.
- **High-Efficiency Particulate Air (HEPA) Filters:** Remove fine particles from exhaust air.
- **Controlled Airflow Patterns:** Maintain negative pressure in contaminated areas to prevent spread.

### Benefits:

- Reduces airborne exposure to workers and the environment.
- Minimizes deposition on surfaces and surrounding soil.



# Engineering Controls

## Physical Barriers and Containment

Structural measures to isolate radioactive materials from the environment.

### Examples:

- Enclosures or gloveboxes for high-risk dismantling operations.
- Temporary tents, plastic sheeting, or partition walls around work areas.
- Secondary containment for waste storage and transfer.

### Purpose:

- Prevents accidental release of dust, aerosols, or liquids.
- Provides controlled access and reduces spread of contamination



## Monitoring and Detection Technologies

Systems to detect radionuclide presence and concentration in real time.

### Examples:

- Continuous air monitors for airborne radionuclides.
- Surface contamination monitors for floors, equipment, and walls.
- Radiation detectors at waste packaging and storage areas.

### Benefits:

- Early detection of accidental releases.
- Supports corrective actions and regulatory compliance.
- Provides data for environmental impact assessment and safety reporting.



# Administrative Controls Standard Operating Procedures

Written instructions that define safe and consistent methods for performing decommissioning tasks.

## Key Points:

- Step-by-step guidance for high-risk activities, such as dismantling, decontamination, and waste handling.
- Includes emergency procedures for accidental releases or equipment failures.
- Regularly reviewed and updated based on lessons learned and regulatory requirements.

## Benefits:

- Ensures uniformity in operations.
- Reduces the likelihood of human error.
- Supports regulatory compliance.



# Administrative Controls Personnel Training and Certification

Structured programs to equip workers with knowledge and skills for safe operations.

## Key Elements:

- Radiation protection principles, including ALARA (As Low As Reasonably Achievable).
- Proper use of PPE (personal protective equipment).
- Handling of radioactive waste and emergency response procedures.
- Certification to verify competency before assignment to high-risk tasks.

## Benefits:

- Enhances worker safety.
- Improves awareness of potential environmental impacts.
- Supports a strong safety culture within the facility.



## Access Restrictions and Controlled Zones

Measures to limit personnel exposure and prevent unauthorized entry to high-risk areas.

### Examples:

- Designated controlled zones with clear signage and barriers.
- Security protocols for entry and exit.
- Zoning based on radiation levels to apply appropriate protective measures.

### Benefits:

- Minimizes accidental exposure to radionuclides.
- Protects both workers and the public.
- Facilitates monitoring and containment of contamination.



# Environmental Protection Measures Environmental Monitoring Programs

Systematic observation and measurement of radionuclide levels in air, soil, water, and biota to assess environmental impact.

## Key Components:

- Continuous monitoring of airborne radionuclides near decommissioning operations.
- Regular sampling of soil, surface water, and groundwater.
- Monitoring of plants and animals to detect bioaccumulation.

## Benefits:

- Early detection of contamination or accidental releases.
- Supports decision-making for corrective actions.
- Provides data for regulatory reporting and safety verification.



## Waste Management and Ecosystem Restoration

### Waste Management:

- Proper segregation, packaging, and storage of radioactive waste.
- Safe transport to treatment or disposal facilities.
- Minimization of secondary environmental contamination.

### Ecosystem Restoration:

- Remediation of contaminated soils and sediments.
- Rehabilitation of affected water bodies, vegetation, and habitats.
- Long-term monitoring to ensure recovery and ecological stability.

### Purpose:

- Reduce environmental impact of decommissioning activities.
- Ensure sustainable restoration of affected areas.

# Mitigation Measures Summary

Integration of engineering and administrative controls with environmental monitoring ensures comprehensive protection.

Early planning and continuous oversight minimize the spread of radionuclides.

Coordination with local authorities and stakeholders supports environmental safety and compliance.



# Summary

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Decommissioning involves dismantling, decontamination, and waste management; radionuclide release can occur via mechanical, chemical, and thermal processes.

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Air, soil, groundwater, and surface water are potential transport media; deposition can lead to secondary contamination.

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Mechanical dismantling, cutting, decontamination, and waste handling can generate dust, aerosols, and gases.

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Meteorological (wind, temperature, humidity, precipitation), hydrological (soil type, groundwater depth, flow), geochemical (sorption/desorption), and human factors influence dispersion.

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Containment enclosures, LEV/HEPA, local ventilation, wet cutting, containment around waste handling.

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SOPs, training, scheduling, continuous monitoring, risk assessments.

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Surface/soil containment, erosion control, groundwater monitoring, sediment traps, and containment of effluents.

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*Thank You for  
Your Attention*

