Chemical decontamination in nuclear systems
Radiation protection issues during planning and realization
Introduction

- Corrosion product
- Activation product
- Insoluble activity
- Soluble activity
- CRUD
- Fission product
- Ionic activity
- Dose rate
Introduction

- Dose rate of systems and components rises with the operation of nuclear power plants

Increase of collective doses

Example: Dose rate – primary circuit loop

Protection objective
Reduction of occupational exposure during maintenance
Introduction

- Dose rate of systems and components rises with the operation of nuclear power plants

![Increase of collective doses]

**Example: Dose rate – primary circuit loop**

<table>
<thead>
<tr>
<th>Operating time [yr]</th>
<th>Dose rate [mSv/h]</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
</tr>
<tr>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td>25</td>
<td>4</td>
</tr>
<tr>
<td>30</td>
<td>5</td>
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<td>35</td>
<td>5</td>
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<tr>
<td>40</td>
<td>5</td>
</tr>
<tr>
<td>45</td>
<td>6</td>
</tr>
<tr>
<td>50</td>
<td>7</td>
</tr>
</tbody>
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**Protection objective**
Reduction of occupational exposure during maintenance

**Decontamination**
Decontamination techniques

- High-pressure water jet decontamination
- Mechanical decontamination
- Chemical decontamination
  - Chemical process by means of oxidation and reduction
  - Multi cycle process
  - Example process: CORD (Areva)
    (Chemical, Oxidizing, Reduction, Decontamination)
Decontamination techniques

- Mechanical decontamination
- Chemical decontamination
- High pressure Water jet

Outer layer, Iron rich (1 – 5 µm)
Oxide layer, CRUD, Chromium rich (2 - 10 µm)
Loose deposits
Diffusion layer (< 20 µm)
Base material
# Decontamination techniques

## Closed systems:

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<tr>
<th>High-pressure water</th>
<th>Mechanical</th>
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<td>- Well established</td>
<td>- Small waste volume</td>
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**EUROSAFE**
Chemical decontamination / Overview

- deionised water
- chemcials
- off gas
- liquid waste
- solid waste
- mixing unit
- equalising tank
- releasing unit
- pump
- heating unit
- ion exchanger
- contaminated system
Chemical process

Oxidation $\rightarrow \text{Fe}^{2+}$

Reduction $\rightarrow \text{CrO}_4^{2-}$

Outer layer, Iron rich (1 – 5 $\mu$m)

Oxide layer, CRUD, Chromium rich (2 - 10 $\mu$m)

Diffusion layer (< 20 $\mu$m)

Base material
Activity: inventory, flow and enclosure

- Prior to decontamination the activity is fixed to the system/components
- During decontamination the activity
  - is dissolved
  - distributed throughout the system and decontamination equipment
  - higher levels of mobile activity than before decontamination
- Activity removed by ion exchange resins in each decontamination cycle, or by discharge of process water
Activity: inventory, flow and enclosure

Example:
Activity inventories for part-system decontamination of
- volume control system after 30 years of operation
- volume: 4.0 m³; surface: 328 m²
- activity prior to decontamination: 1.7E 05 Bq / cm²

Removed activity - volume control system

<table>
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<th>Activity [1E10 Bq]</th>
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<td>Cycle 1</td>
</tr>
<tr>
<td>25</td>
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EUROSAFE
Residual radioactive materials and waste

Types of waste generated by chemical decontamination:

- Process water
- Off gases
- Ion exchange resins

Volume and activity depending on system

**Example:**
Waste generated by decontamination of volume control-system

Ion Exchange resins: 0.4 m³; 3E11 Bq
Radiation protection issues

During planning:

- Limitation of direct radiation during decontamination
  1) Separation of “high activity areas” and “low activity areas“
  2) Shielding
  3) Restriction of access

- Limitation of contamination / internal dose uptake
  - Prevent spread of contamination

- Limitation of impact of accidents (environment and operators)

During decontamination process:

- Monitoring of dose rates
- Monitoring of activity containment
Limitation of radiation exposure

Limitation of direct radiation during decontamination

1) Separation of “high activity areas” and “low activity areas”

Schematic display of installation of decontamination equipment, separated according to activity levels
Limitation of radiation exposure

Limitation of direct radiation during decontamination

2) Shielding

- Separation of “high activity”/“low activity” areas
- Reduction of dose rates an workplaces and walkways (<10 µSv/h)
- Reduction of dose rate at adjacent operations
Limitation of radiation exposure

Limitation of direct radiation during decontamination

3) Restriction of access

- High dose rates near piping that contains decontamination materials
- Closing of walkways may be necessary
- Main components of decontamination equipment have to be installed in closed off areas
Limitation of radiation exposure

Limitation of contamination / internal dose uptake

- Prevent spread of contamination

- Inspection of leak tightness / minimize spread
  - Whole system:
    decontamination equipment & system to be decontaminated
  - Prior to start up (multiple checks)
  - During decontamination (periodic checks)
  - Compartment air monitoring
Limitation of radiation exposure

Analysis of the radiological impact of accidents in the environment and operators

Events usually to be considered:

- Leakages (e.g. from components containing the decontamination liquid)
- Failure of the circulation pump
- Malfunction of the heating
- Falling of components during transport (e.g. containers containing ion exchange resins)
Monitoring of radiation exposure

Monitoring of direct radiation

Dose rates have to be monitored for the duration of decontamination

Especially at:

- working places
- walkways
- waste containers
Quantifying decontamination results

Decontamination Factor = \frac{\text{Dose rate before decontamination}}{\text{Dose rate after decontamination}}

Typical decontamination factors range from 5 to 50, depending on many factors such as geometry, material, surface characteristics ...

Example:
Achieved decontamination factor after decontamination of the volume control system: 10
Dose reduction

Example:

Feasibility study to compare doses for the 2010 to 2014 planned shutdowns in a pressurized water reactor with and without full system decontamination (primary circuit):

<table>
<thead>
<tr>
<th>Estimated collective dose for future maintenance without decont.</th>
<th>Estimated collective dose for future maintenance with decontamination</th>
<th>Estimated collective dose of the chemic. decontamination</th>
<th>Estimated saved collective dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>4780 mSv (100%)</td>
<td>1570 mSv</td>
<td>250 mSv</td>
<td>4780 mSv - 1570 mSv - 250 mSv</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2960 mSv (62%)</td>
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Role of the TSO during planning and realisation

Technical support organisations are involved in each phase of the decontamination project:

- Planning
- Installation
- Commissioning
- Operation
- Dismantling
- Waste treatment
Role of the TSO during planning and realisation

Technical support organisations are involved in each phase of the decontamination project:

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- Consultation
- Accompanying inspections
Summary

Chemical decontamination

- Rising number of applications
- Proven and tested method
- Wide range of radiation protection issues
- Very good decontamination results
- Large potential for reduced dose uptake to operators
Thank you for your attention