Influence of Decontamination

Michael Knaack
18th February 2016
Decontamination

- Overview of reasons for decontamination
- Different methods
- Advantages / Disadvantages
- Influence on decommissioning planning and radiological characterization
- Criteria to choose a decontamination
- Conclusions
• Decontamination reduces the dose rate what is helpful especially for the dismantling work, when many workers spent a lot of hours in radiation field → reducing the collective dose.
• In most countries it is required by law to minimize the amount of generated radioactive waste.
• A main point are the costs: often it is cheaper to decontaminate than to bring waste to the disposal facility.
• Decontamination leads to more material for the clearance process.
• More materials could be recycled or used directly.
• It helps to save space in the repository.
Masses expected during decommissioning

Decontamination Costs for Clearance are cheaper than Conditioning Costs for RadWaste
(experience from other German decommissioning projects)

Clearance / Exemption (several paths are possible)
- Unrestricted release
- Recycling
- Land filling

Radioactive waste
Reuse (under defined circumstances)

The fractions are valid for BWR and PWR
But experience also has shown, that the mass distribution as displayed above needs:

- Fine decontamination techniques;
- The conditions for clearance should be stable for long terms;
- A good path for concrete / building rubble;
- An interim storage, or
- A repository.

The advantages, disadvantages and experiences may lead to a situation where single strategy fit with all requirements, but mixed strategies can be more effective.
Use of Different decontamination techniques

- **Small parts**
  - Same procedure as in operation

- **Components**
  - Same procedure as in operation

- **Systems**
  - Same procedure as in operation

- **Full System Decontamination**
  - Decontamination of the primary circuit together with the auxiliary systems
  - Reducing the radiation level in the whole controlled area
  - Preparing good conditions for the dismantling works as well as for clearance
Use of Different techniques

- Cleaning by wiping with or without ingredients
- Cleaning by pressurized water – cold / hot / steam cleaning
- Mechanical cleaning
  - Blasting with hp water, abrasives, CO$_2$-Ice
  - Polishing, Drilling, Milling, for concrete Needling
- Strippable coatings
- Melting
Decontamination

Measuring concrete
Demolishing concrete

Measurement by $\gamma$-in situ

- Averaging over some square meter
- Fast decision for great parts or buildings
- Geometrical factors could be calculated
- Penetration of nuclides in the concrete could be evaluated / calculated
Broken concrete could be used after clearance for

- Worst case: landfill (waste site)
- Road construction
- New buildings constructions
Decontamination of structures
Decontamination of buildings
Removal of contaminated concrete from floors and walls
Use of Different Techniques

- Chemical cleaning
  - Decontamination in chemical bathes
  - Decontamination in ultrasonic bathes
  - Electro polishing

- Full System Decontamination
A very powerful kind of decontamination

- Cleaning the primary circuit and the auxiliary systems
- Decreases the dose rate: important for dismantling works
- Allows easier conditioning procedures
- But terminates the operational history
- But possible shifts the nuclide vector

Of which amount of activity inventory we talk?

Activity inventory without nuclear fuel: \( \text{ca. } 1 \times 10^{17} \text{ Bq} \)

Formed by activation: \( \text{ca. } 95 + \% \)

Cleanout per FSD: \( \text{ca. } 1 \times 10^{14} \text{ Bq} \)
Influence of Decontamination

How to decontaminate?

The Contamination Brusher

Chemical Decontamination

Mechanical Decontamination

Outer layer, containing Chromium (2 – 10 μm)

Oxide layer, CRUD, ferritic (1 – 5 μm)

Diffusion layer (< 20 μm)

Base material
Influence of Decontamination

Full System Decontamination

Principle Picture of the Range of a FSD (PWR)
• Which are the results?

The success of the decontamination is described by the decontfactor:

\[
\text{Decontamination factor} = \frac{\text{Dose rate prior decontamination}}{\text{Dose rate after decontamination}}
\]

Typical decontamination factors are between 10 and 75 (in some cases up to 100), this depends on different factors like the operation, the material, the surface, the decontamination fluid flow…

A decontfactor of 10 means a 90% discharge of the contamination!!
Full System Decontamination

Measuring the success of the FSD
Dose rate during FSD

Dosisleistung [μSv/h]

Legende:
- TA Leitung
- Sprühleitung
- Pumpenschleife
- Loop "kalt" Austritt HKMP
- Loop "kalt" Mitte
- Loop "heiß" Mitte
- Surgeline Bogen
- Surgeline waagerecht
- Surgeline diagonal

Zyklus 1        Zyklus 2        Zyklus 3         Zyklus 4        Zyklus 5

Quelle: E.ON KKU

Influence of Decontamination ~ February 2016 ~ 20
Doserate in the middle of the primary chamber (SG)
before: 150 mGy/h  ➔  after: 3 mGy/h

Quelle: E.ON KKU
Full System Decontamination

Impact on waste management

• Direct dismantling of big components
Impact on waste management

- Easier dismantling of components like steam dryer or water separator without need in under water remote techniques
But what is left if the chemical metering is too high or the procedure is not steered in the right way?
• Because of the high cleanout of contamination it is necessary to do the radiological characterization for waste management and clearance after the FSD. The possibility of shifting the nuclide vector must be considered.

• The cleanout per FSD has no impact on the activated nuclides!
Radiological Characterization in different phases of decommissioning / dismantling

Details, which shall be evaluated **before** licensing:

<table>
<thead>
<tr>
<th>Intended purpose</th>
<th>System</th>
<th>Grade of investigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decommissioning Strategy (Application of dismantling steps)</td>
<td>Facility (all systems, buildings, area)</td>
<td>Operational History, Sum of Activity, Activation calculations, Key Nuclides of the contamination (Dose)</td>
</tr>
<tr>
<td>Accident examination, if occurred</td>
<td>Primary circuit (non destructive), Wastewater treatment, Waste package</td>
<td>Inventory in Systems, Tanks, etc Key Nuclides, (Dose)</td>
</tr>
<tr>
<td>Full System Decontamination (corresponding to the application)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Radiological Characterization in different phases of decommissioning / dismantling

Details, which shall be evaluated after licensing:

<table>
<thead>
<tr>
<th>Intended Purpose</th>
<th>System</th>
<th>Grade of investigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiological Work Protection, Work Permission</td>
<td>System- / Components demanding on the work progression</td>
<td>nuclide specific contamination, Focus on alpha-contamination, Dose; Detailed definition of the previous findings of the RC</td>
</tr>
<tr>
<td>Clearance procedure, Validation of calculated activities of radioactive waste</td>
<td>All systems demanding on the work progression</td>
<td>Complete Characterization incl. hard to measure nuclides; Detailed definition of the previous findings of the RC</td>
</tr>
<tr>
<td>Free release of the buildings, Free release of the site</td>
<td>Surface of the buildings, Site, buried Systems and Components</td>
<td>Surface contamination, Penetration behavior, Covered Areas</td>
</tr>
</tbody>
</table>
As shown above in the reasons:

- Better radiation protection for staff
- Decreasing dose rate
- Lower amount of radioactive waste
- More possibilities for dismantling
- Better transport conditions
- Easy conditioning / simple container
Some disadvantages:

- Production of secondary waste, in case of using organics it is difficult to dispose
- Increasing collective dose rate for the decontamination work
- Handling with hazardous agent
- Risky work (e.g. blasting)
- Shifting in the nuclide vector
- Complete removal of nuclides → which nuclide vector could be used? Taking a general one can build up fictive contamination.
- Cost / benefit analysis is necessary (especially for FSD)
Decontamination shift the nuclide vector to some extent

• Some nuclides are more adherent than other

• During mechanical decontamination like blasting some nuclides are hammered into the base material

• During cutting, especially thermal cutting, it occurs with the molten material

• Recombination during a chemical process is nuclide specific
In Numbers:

- During operation the relationship between $\beta/\gamma$ and $\alpha$-nuclides: approx. 3000 / 1

- Shifting by decontamination: approx. 1000 / 1

- And in case of Co-60 after 5 years: approx. 500 / 1

This is in the region of limits for the measurements of airborne nuclides for radiation protection.
Radiation protection

- Decrease dose rate
  - For “Old” NPP
  - Short time after shut down
  - Especially by FSD

- Seal the contamination
  - Cleaning also below clearance levels
  - Reduce the amount of nuclides released in the environment
Handling of material

- Easily possible after decontamination
  - Especially dismantling works on secondary treatment places

- Transport
  - Less shielding required
Minimize the waste

- More material for clearance and recycling
  - Possible recycling even of parts from the primary circuit
  - Melting for shielding
  - Further use of concrete

- Immediate dismantling vs. deferred dismantling
  - Less decontamination effort due to decay
Conclusions

• Decontamination is good practice

• Planning, waste management and radiological characterization are influenced

• “Old” NPP’s with more Co-60 in the components structure materials and/or with fuel damages more benefits from decontamination

• Concrete is not so easy to decontaminate (geometry, penetration depth, activation) but due to the masses the benefit is high

• Decontamination shifts the nuclide vector → problems for the radiation protection

• Clearance measurement need a nuclide vector but some decontamination leave nothing (milling, electropolishing)

• Otherwise a “best estimate” nuclide vector will be chosen with the build up of activities
The difference between theory and praxis is mostly in the praxis greater than in the theory!!!