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DECONTAMINATION OF STEEL AND CONCRETE FOR THE DECOMMISSIONING AND DISMANTLING OF EUROPEAN DEMO

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framatome

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Outline

- Introduction
- Assessment of existing decontamination techniques
- Development of a characterization plan
- Technology gaps & new developments for DEMO
- Summary & Outlook

Introduction

- EUROfusion WPSAE Radioactive Waste Management Task 3.1.3-T02 (2019, FP8)
- Contribution of Framatome as subcontractor
- Radioactive wastes FPP (Fusion Power Plant) vs. NPP: large quantities, huge amount of tritium, different radio-isotopes
- Dominant fusion wastes from structure materials: EUROFER, stainless steel, concrete
- EU DEMO: Helium Cooled Pebble Bed (HCPB) & the Water Cooled Lithium Lead (WCLL) breeding blanket (BB) concept
- Handling & treatment of radioactive metallic waste & the concrete structures

EU DEMO		Mass (kg)
EUROFER (in-vessel components)	HCPB	3.69E+06
	WCLL	4.19E+06
SS 316L (vacuum vessel, piping, etc.)		2.17E+07
Concrete (bioshield, building rooms, etc.)		2.50E+07

Assessment of existing decontamination techniques (LWR)

- Decontamination techniques have been developed for conventional industry and adapted for the nuclear industry. **Main objectives**:
  - to reduce radiation exposure of personnel and tools;
  - to salvage equipment and materials;
  - to reduce the volume of equipment and materials requiring storage and disposal in licensed disposal facilities;
  - to restore the site and facility, or parts thereof, to an unconditional-use condition;
  - to remove loose radioactive contaminants and fix the remaining contamination in place in preparation for protective storage or permanent disposal work activities;
  - to reduce the magnitude of the residual radioactive source in a protective storage mode for public health and safety reasons

Assessment of existing decontamination techniques

- **Chemical decontamination** is mainly used for surface decontamination of metallic surfaces to remove contamination in the form of fouling and metallic oxides (e.g. rust). Chemical processes/reactions in nuclear industry:

  - **Chelation & Organic Acids** (oxalic acid, citric acid, gluconic acid, ethylenediaminetetraacetic acid (EDTA), hydroxyethylenediaminetriacetic acid (HEDTA), Ethylenediaminedisuccinic acid (EDDS), Oxyethylidenediphosphonic acid (OEDPA), and Diethylenetriaminepentaacetic acid (DTPA))

  - **Strong mineral acids and related material** (Hydrochloric acid (HCl), Nitric acid (HNO_3), Sulfuric acid (H_2SO_4) and Phosphoric acid (H_3PO_4));

  - **Oxidizing & reducing (Redox) agents** (a metal oxide transformed into a different oxidation state for more solubility with a redox reaction);

  - **Electrochemical processes** a chemical decontamination assisted by an electrical field.

Chemical decontamination is best suited for water carrying piping systems outside bioshield, Chemical and Volume Control System (CVCS), liquid waste treatment systems.

Assessment of existing decontamination techniques

- **Physical decontamination** can be divided into surface cleaning techniques and surface removal techniques:
  - **Wet or dry abrasive blasting**
    - dry abrasive systems: minerals (magnetite or sand) are blasted with a compressed air stream onto the contaminated surface.
    - wet abrasive systems: high pressure water jet is used in combination with additional abrasive media and often also pressurized air.
  - **Scarifying Techniques** (Grinding / planing, scaling, scabbling, milling/shaving);
  - **Decontamination as part of the decommissioning & dismantling works** (Drilling/spalling, hammering, sawing);
  - **Further processes** (microwaves, laser ablation, electro-hydraulic scabbling, bio-decontamination, electrokinetic decontamination, melting, plasma-melting)

Assessment of existing decontamination techniques

- **Combined physical/chemical decontamination processes**
  - Foams, gels, pastes
  - Ultrasonic cleaning
  - Emerging technologies (hybrid technologies with chemical, electrochemical, biological, mechanical, laser or sonic methodologies)
- **Handling of decontamination techniques**
  - manual techniques (most, ALARA, low dose rate)
  - remote-controlled or automatized versions (less effort)
  - automatized process with regard to cost-effectiveness (highly activated / contaminated structures / components in smaller volumes & dimensions)
  - Remote-controlled demolishing machines with robotic appendages

Assessment of existing decontamination techniques

- **Criteria of decontamination techniques used in a LWR for the application in DEMO**
  - **Handling –** Manual - remote operated - automatized
  - **Destructive technique** (yes / no)
  - **Treated surface type**
  - **Treated material** (EUROFER, SS 316L, heavy/ordinary concrete)
  - **Applicability for blanket type** (HCPB, WCLL)
  - **Detritiation in combination**
  - **Optimum recycling step** (reuse, disposal, plasma melt)
  - **Safety** (safety measures)
  - **Efficiency** (high/low decontamination factor)
  - **Nuclear Waste Minimization** (high / low volume)
  - **Secondary Waste**
  - **Advantages / Disadvantages**

Decontamination matrix

Category	Process	Handling	Destructive	Surface	Eurofer	SS 316L	Heavy concrete	Ordinary concrete	WC LL	HC PB	Detritiation	Optimum recycling step	Safety	Efficiency	Nuclear Waste minimisation	2^{nd} Waste	Advantages	Disadvantages
Chemical	See Section 2	remote	no	Piping systems (internal), large areas	x	x	/	/	x	/	/	Direct reuse of system/component	o	o	-	Water, Chemicals, Reaction Products, IX resins	– "in situ" on closed systems – reuse of components and systems – May remove contamination from internal and hidden surfaces – Minor problems regarding airborne cross-contamination	– Chemicals generate additional 2^{nd} waste – Ineffective on porous surfaces – Treat corrosive and toxic reagents – Additional heating to 70-90°C
Physical	Wet Abrasive Blasting	manual, remote, automatized	yes	Large areas	x	x	/	x	x	x	Surface Abrasion; or subsequent detritiation	reuse of abrasive medium, disposal of debirs	o	o	o	Water, Abrasive particles, Filter cartridges	– Low guiding & reset forces – Individual cutting forms – No vibrations	– Demand of water – Aerosols emissions – Very large amount of 2^{nd} waste – Need of water/sludge treatment installation – Risks of cross-contamination
Physical	Dry Abrasive Blasting	manual, remote, automatized	yes	Large areas	x	x	/	x	x	x	Surface Abrasion; or subsequent detritiation	reuse of abrasive medium, disposal of debirs	o	o	o	Dust, Abrasive particles, Filter Cartridges	– High to very high yield – High performance – Highly versatile technique – hard to reach surfaces (air powered configuration) – Collection of dust and debris by default – Insensitive for metal inserts – rough surfaces – Low abrasive cost – Continuous recycling of abrasives	– – 2^{nd} waste – Risk of cross-contamination (abrasives recycling) – High personal safety requirements – High dust formation – Deep abrasion produces rather rough surface finish
Physical	Dry Abrasive Blasting (SIVABLAST)	remote	yes	Piping systems (internal), large areas	x	x	/	/	x	/	/	Direct reuse of system/component	+	+	o	Dust, Abrasive particles, Filter Cartridges	– "in situ" on closed systems – remote control – reuse of components and systems – – low 2nd waste	– 2nd waste – Risk of cross-contamination (abrasives recycling) – High dust formation – not applied to tubes with large internal diameter

Assessment of existing decontamination techniques

- **Mechanical decontamination process SIVABLAST (Framatome)**
  - For steam generator tube decontamination with a closed circuit technique
  - contaminated tubes with internal diameters of up to 30mm
  - Tube inlet side: connect the recirculation blast unit (RBU) of the blasting equipment using a remotely controlled manipulator
  - Tube outlet side: collect grit & scales at a suction header / suction funnel and convey back to the blasting unit
  - A waste collection system (covered by a tent / cabin) is placed separately from the RBU, and it is connected to the vacuum pump.
  - A dust collector / waste drum equipped with a filter
  - The whole process is controlled remotely

Development of a characterization plan

- **Four main types of contamination in DEMO for steel and concrete structures**
  - structural activation of steel components incl. tritium permeation
  - structural activation of concrete structures incl. tritium permeation
  - spread of loose contamination in steel components and piping systems through contaminated medium: activated corrosion products (ACPs), tungsten dust, tritium
  - spread of loose contamination to concrete structures through leakages
- **A characterization plan is required as a part of facility decommissioning planning (the nature, extent and location of contaminants, sampling locations and protocols, quality assurance objectives for characterization, documentation requirements)**
- **The outcome of generating a characterization plan should be the determination of the necessity and applicability of decontamination, used type of decontamination method and decontamination effectiveness after performance**

Development of a characterization plan

- **Characterization methods**
  - **theoretical calculations** (activation)
  - **contamination measurements**
  - **Destructive assay** (all radionuclides, radioactive waste inventories, etc.)
  - **Investigation of documentation**
    - a data collecting & documentation system during DEMO plant operation
    - detailed material specification & samples of the used material

Development of a characterization plan

- **The main irradiation and contamination measurements**
  - dose rate measurements
  - loose contamination measurements
  - surface counting
  - spectrometry measurements (**gamma spectrometry** is the one most commonly used for concrete in situ measurement)
  - Current developments
    - Gamma spectroscopy with video feed / 3D camera
    - Laser scanning
    - Position determination in combination with a layout drawing/ model of the plant
    - design and program the robots to perform wipe tests

Development of a characterization plan

- **A characterization plan for concrete structures of DEMO requires**
  - initial material composition of the used concrete
  - non-homogeneous concrete
  - the activation of concrete and the spreading of contamination due to different breeding blanket concepts
  - local hotspots and a general overview of locations of radiation sources

Technology gaps & new developments for DEMO

- **PbLi loop (WCLL BB concept)**
  - distribution & spreading of the ACPs
  - After draining PbLi the loop should be cleaned & decontaminated to remove solidified PbLi, any lose contamination of ACPs, to reinstate the protective Al_2O_3 coating
- **Tokamak dust:** collection, treatment and disposal, as well as investigation of subsequent decontamination activities
- **Combined decontamination & detritiation**
  - To perform detritiation either prior to decontamination or subsequently
  - analyse the existing detritiation matrix for compatibility with the decontamination techniques
  - New decontamination techniques e.g. multistage chemical decontamination with an additional detritiation step
- **Prohibition of contamination** reduce the risk of contamination, e.g. no airborne contamination (sawing dust or aerosols from laser cutting) by cutting BB pipe during the replacement

Summary & Outlook

- At the current stage, it is not possible to determine the best available practice for decontamination of steel & concrete structures within the DEMO project.
- The final characterization plan can only be created when operational data & materials samples of DEMO / FPP will be available.
- The decontamination paths of NPP are not directly transferrable to the FPP
- For the WCLL and its PHTS, the DIV- and VV-PHTS with water coolant, the extensive experience from the LWR in terms of contamination of piping systems through distribution of diluted ACPs in cooling water is considerable for DEMO.
- Dust for the WCLL and HCPB, ACPs in PbLi loop have to be analysed

Further waste management study in FP9 with Framatome (2024 – 2025)

- Steel waste treatment: test of technologies for activated steel treatment
- DEMO decommissioning plan outline

Thank you!

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