



# MANAGEMENT OF MATERIAL FROM V1 NPP´s DECOMMISSIONING PROGRAMME

## CASE STUDY

KP-JAVYS-010

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## Foreword

In 2021, the European Commission (EC) adopted a new proposal for a Council Regulation[1] establishing a dedicated financial programme for decommissioning nuclear facilities and managing radioactive waste. This instrument covers the co-funding of the decommissioning programmes of Bulgaria, Slovakia, and the decommissioning of the Joint Research Centre (JRC). A separate Council Regulation[2] was adopted for the decommissioning programme of Lithuania.

The EC JRC is mandated to foster the spread of decommissioning knowledge across all the European Union Member States and facilitate knowledge sharing arising from implementing the above-mentioned decommissioning programmes, funded by the Nuclear Decommissioning Assistance Programme (NDAP).

The decommissioning operators from the NDAP (NDAP Operators) implemented and tested a knowledge management methodology in 2021 through Project ENER/D2/2020-273. Using this methodology, the NDAP Operators can develop Knowledge Products that are currently available to share with other European stakeholders. In addition, this methodology is being implemented by the JRC Nuclear Decommissioning and Waste Management Directorate (NDWMD), which has become a knowledge generator extracting the knowledge from the ongoing decommissioning activities across the JRC´s four different sites (Geel, Ispra, Karlsruhe and Petten.

The JRC´s NDWMD aims to become a Centre of Excellence in nuclear decommissioning knowledge management and to develop a decommissioning knowledge platform which allows exchanging information building on EU best practices through executing the multi-annual financial framework (2021 – 2027) strategy. The operational phase of the project started in 2024 with the objectives to: develop ties and exchanges among EU stakeholders, document explicit knowledge and make it available through multi-lateral knowledge transfers on decommissioning and waste management governance issues, managerial best practices, technological challenges, and decommissioning processes at both operational and organisational level, as well as to develop potential EU synergies.

**This is a Knowledge Product prepared by Nuclear Decommissioning and Waste Management Directorate (NDWMD) – Directorate J of the Joint Research Centre.**

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| **Performed by** | Ing. Dana Mišovicová, Mgr. Lenka Richterová | | |
| **Revised by** | Jonathan Oliver | | |
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| | | | |
| **Sent to** | Luis Felipe Durán | | |
| **Approved by** | Andrea Piagentini | | |

[1] Council Regulation (Euratom) 2021/100 of 25 January 2021 establishing a dedicated financial program for the decommissioning of nuclear facilities and the management of radioactive waste, and repealing Regulation (Euratom) No 1368/2013

[2] Council Regulation (EU) 2021/101 of 25 January 2021 establishing the nuclear decommissioning assistance programme of the Ignalina NPP in Lithuania and repealing Regulation (EU) No 1369/2013

# PRODUCT DESCRIPTION

This Knowledge Product (KP) provides an overview of the strategies, infrastructure and outcomes related to material management during V1 NPP´s decommissioning, with a focus on Project D4.2 "*Dismantling of Reactor Coolant System Large Components*." It details how materials (particularly contaminated metallic materials) were characterised, processed and routed using on-site fragmentation and decontamination facilities. The document outlines logistics, key performance indicators (KPIs), equipment used, lessons learnt and recommendations, offering practical insights drawn from the dismantling of two VVER-440 reactor units.

# ABSTRACT

The management of materials from V1 NPP´s decommissioning comprises of a comprehensive set of activities ensuring that all materials arising during dismantling are handled in a safe, efficient and economically viable manner. These processes follow relevant legislative frameworks, internal procedures and the NPP operator´s management documentation. This KP outlines the end-to-end material management approach including characterisation, collection, sorting, packaging, transport, treatment and disposal of waste produced from the dismantling of equipment, systems and demolition of civil buildings. One of the critical areas was the logistics of materials dismantled during Project D4.2 "*Dismantling of Reactor Coolant System Large Components*" which was planned to be over 13,837 tonnes.

A major challenge was the processing of contaminated metallic materials directly on-site without the need to transport them to a storage site and subsequently process them outside the decommissioned nuclear facility. This was successfully addressed through the deployment and operation of fragmentation and decontamination (F&D) facilities within V1 NPP´s premises. Over 4,300 tonnes of metallic materials were processed across 65 months, achieving an exceptional decontamination efficiency of more than 98%, with most material cleared for release or designated for decay / remelting. The in-situ approach significantly reduced radioactive waste (RAW) volumes (with less than 2% of input remaining as RAW), cut transportation needs, as well as optimised project logistics and radiation safety in line with ALARA principles.

The study draws on operational data, internal procedures and KPIs to capture challenges encountered, solutions implemented, as well as lessons learnt and recommendations. This includes the importance of early planning, flexible infrastructure with use of F&D facilitites and KPI driven monitoring. Insights from V1 NPP´s decommissioning offer practical guidance for similar EU-based projects, emphasising the benefits of integrated on-site treatment, radiological safety and waste minimisation strategies.

# OBJECTIVE

To record, convey and explain the knowledge gained during the management of material during V1 NPP's decommissioning programme.

# APPROACH

This KP was developed through referring to the following knowledge inputs: the "*Plan for Management and Transport of Radioactive Waste from the 2nd Stage of V1 NPP Decommissioning*", JAVYS' internal directive "*Management of material from the decommissioning of the V1 NPP controlled area*", the waste management plan for Project D4.2 "*Dismantling of Reactor Coolant System Large Components*" and "*Performance Evaluation for the V1 NPP Large Capacity F&D Facility*" as key references. The document was provided to the JRC by Jadrová a vyraďovacia spoločnosť, a. s. (hereafter referred to as "JAVYS"), as a contribution to the JRC's Nuclear Decommissioning Knowledge Management (NDKM) Initiative.

The following main points are conveyed in this KP:

- general principles of effective material management employed at V1 NPP,
- radioactive waste management from decommissioning of nuclear facilities,
- challenges encountered and solutions developed, mainly with regard to Project D4.2,
- KPIs of effective material management strategies applied in the processing of contaminated metallic materials in scope of Project D4.2,
- lessons learnt and recommendations.

# RESULTS, FINDINGS AND INSIGHTS

The on-site use of F&D facilities at V1 NPP played a central role in the efficient management of contaminated metallic materials during Project D4.2 *"Dismantling of Reactor Coolant System Large Components"*. By processing the materials directly within the controlled area, the project avoided the need for off-site transport and treatment, which significantly reduced costs, improved logistics and minimised radiation exposure in line with ALARA principles. Over the course of 65 months, the F&D facilities processed more than 4,300 tonnes of contaminated metallic material, undergoing one or more decontamination cycles. Thus, a total of 6,482 tonnes of material was performed (*note, the difference between processed and performed is explained within the case study´s body of text*), averaging 1,197 tonnes per year, significantly surpassing the initial annual target of 800 tonnes.

The achieved decontamination efficiency of more than 98% allowed for the vast majority of material to be free released, directed to decay storage or remelted, with only a small fraction (2%) remaining as RAW, thus reducing final RAW volumes and associated disposal costs. Radiation exposure to workers and the public was kept well within regulatory limits through on-site processing, effective shielding, and reduced transport. The key performance indicators (KPIs), including total throughput, RAW production rate and facility-specific release ratios, confirmed the efficiency of the implemented strategy.

Key findings and insights include the importance of process flexibility, detailed planning of logistics and the strategic sequencing of decontamination tasks across multiple facilities. The availability of multiple decontamination methods (e.g. abrasive blasting, semi-dry electrochemical treatment, alkaline degreasing, etc.) enabled tailored responses to varied contamination levels and material types. The recommissioning of DKP4 and the deployment of mobile semi-dry electrochemical decontamination equipment (PODEZA) further enhanced system capacity and efficiency. This case study demonstrates how a well-planned, legally compliant and technically optimised approach to material management can produce outstanding decontamination results and contribute to the broader EU knowledge base for nuclear facility decommissioning.

# TARGET USERS

This KP is a valuable contribution to entities involved in nuclear power plant decommissioning and nuclear waste management, especially with respect to other decommissioning operators and contractors, as well as relevant research and academic institutions.

# APPLICATION, VALUE AND USE

The information contained herein offers insights into effective material management strategies, encompassing planning, handling, storage and disposal of radioactive and non-radioactive materials. It can assist in identifying and mitigating against risks, thus enabling decommissioning operators to refine their material management plans. In addition to this, showcasing best practices for waste minimisation, logistics, storage optimisation and safe disposal are all topics of interest to target users.

# KEYWORDS

Decommissioning, management of materials, radioactive waste, V1 NPP, VVER-440 reactors

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# ACRONYMS (1 / 2)

| | |
|---|---|
| **ALARA** | As Low As Reasonable Achievable |
| **CB** | Civil Building |
| **CMM** | Contaminated Metallic Material |
| **DKM** | Decommissioning Knowledge Management |
| **DKP** | Decontamination Workplace |
| **DN** | Diameter Nominal |
| **D4.2** | Project code: “*Dismantling of Reactor Coolant System Large Components*” |
| **D4.4C.01** | Project code: “Dismantling of Systems in V1 NPP Controlled Area – Part 2” |
| **EC** | European Comission |
| **ENER** | Energy Directorate project code |
| **EU** | European Union |
| **F&D** | Fragmentation and Decontamination |
| **FCC** | Fibre-Concrete Container |
| **FP** | Fragmentation Workplace |
| **HVAC** | Heat, Ventilation and Air-conditioning |
| **IBN** | Internal Bounded Neutron |
| **ILW** | Intermediate Level Radioactive Waste |
| **IS RAW** | Interim Storage of RAW |
| **JAVYS** | Jadrová a vyraďovacia spoločnosť, a. s. |
| **JRC** | Joint Research Centre (of the European Commission) |
| **KM** | Knowledge Management |
| **KNI** | Channel for measuring of neutron flux |
| **KP** | Knowledge Product |
| **KPI** | Key Performance Indicator |
| **LLW** | Low Level Radioactive Waste |
| **MCPs** | Main Coolant Pumps |
| **MIVs** | Main Isolation Valves |
| **MoE SR** | Ministry of Environment of the Slovak Republic |
| **NDAP** | Nuclear Decommissioning Assistance Programme |
| **NDWM** | Nuclear Decommissioning and Waste Management |
| **NDWMD** | Nuclear Decommissioning and Waste Management Directorate |
| **NRA SR** | Nuclear Regulatory Authority of the Slovak Republic |
| **PPE** | Personal Protective Equipment |
| **RAW** | Radioactive Waste |
| **RH** | Remote-Handled |
| **RSA** | Reactor Shielding Assemblies |

# ACRONYMS (2 / 2)

| | |
|---|---|
| **SFSP** | Spent Fuel Storage Pool |
| **TSU RAO** | Facility for Treatment and Conditioning of RAW |
| **VLLW** | Very Low-Level Radioactive Waste |
| **WCW** | Wet Cutting Workshop |
| **WWER** | Water-Water Energy Reactor |

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# 1. INTRODUCTION

## 1.1. Background and context

The **Nuclear Decommissioning and Waste Management Directorate** (**NDWMD**) of the **JRC** is running the Nuclear Decommissioning and Waste Management (NDWM) Programme for the nuclear sites of the European Commission (EC), with the majority of the activities currently focused on dormant facilities situated on the Ispra site (located in northern Italy).

In 2020 the Council of the EU issued **Council Regulations 100** and **101** in which they provided co-funding to the decommissioning programmes in three EU Member States (Slovakia, Bulgaria and Lithuania), as well as full funding to the internal NDWM Programme of the EC, run by the JRC. this initiative is commonly known as the **Nuclear Decommissioning Assistance Programme** (**NDAP**).

The same regulations also mandated the JRC to initiate a project on knowledge management in NDWM, which is commonly referred to as the **NDKM Initiative**, based on the experiences and lessons learnt running the JRC and NDAP. The primary products of the NDKM Initiative, referred to as KPs, will be disseminated to European stakeholders in order to support new operators entering NDWM activities, enabling them to profit from knowledge generated by previous experience and programmes.

**This KP** builds on the progress made by the NDWM Programme in the past years. It **documents V1 NPP´s material management process**, especially regarding **Project D4.2** "*Dismantling of Reactor Coolant System Large Components*", highlighting on-site processing of contaminated metallic materials through multiple F&D facilities. The case study captures key activities such as radiological characterisation, logistics and decontamination, along with lessons learnt and recommendations, offering practical insights for future decommissioning efforts across the EU.

**Figure 1:** Aerial view of V1 NPP in Jaslovské Bohunice

## 1.2. Purpose, scope and objectives of the case study

The **procedures** relating to **pre-dismantling** and **post-dismantling decontamination** have an impact on **safety**, and if implemented correctly may contribute to **cost reductions** and **schedule optimisation** during the **processing**, **storage** and **transportation** of **RAW** and **coventional materials**. It is also **important to document such information because it can assist in developing plans**, **procedures and technical documentation for other operators**. The process of decommissioning nuclear facilities, including its task-based nature and organisational culture changes in addition to waste management issues that occur, are bound interact with all relevant stakeholders at some stage. **Capturing findings in this format makes it easily accessible to said stakeholders**.

## 1.3. Description of the project

This case study provides an overview of the material management strategy applied during V1 NPP´s decommissioning at Jaslovské Bohunice, Slovakia. It focuses on the handling, processing, transport and disposal of both radioactive and conventional materials generated across multiple dismantling projects. Special emphasis is placed on **Project D4.2** "*Dismantling of Reactor Coolant System Large Components*", due to its scale and complexity. **The project involved the dismantling of two reactor units**, including pressure vessels, internal structures, primary circuit components, etc.

The scope also included removal of activated and contaminated concrete, dismantling of the remote-handled waste storage "*mogilnik*", on-site treatment of contaminated metallic materials at F&D facilities and eventual dismantling of temporary fragmentation infrastructure. **In addition to documenting Project D4.2**, **the study draws on relevant procedures and experiences from other related decommissioning activities**. This illustrates how JAVYS implemented effective material classification, radiological characterisation, packaging, on-site processing and performance monitoring in accordance with regulatory and safety requirements.

Supporting data, KPIs and technical diagrams, especially those illustrating F&D facility operations, are provided throughout the document. Together, they highlight key results, successful practices and lessons learnt, offering practical insight for similar large-scale decommissioning projects within the EU.

# 2. CASE STUDY

## 2.1. General principles of effective material management

Effective waste management during V1 NPP´s decommissioning was essential for ensuring the protection of human health, the environment, nuclear safety and the long-term sustainability of RAW management. This crucial process demanded management that was strictly regulated, technically accurate, and transparent, in accordance with international standards.

To achieve this, **JAVYS applies a structured set of principles for the safe**, **efficient**, and **fully compliant management of materials generated during the V1 NPP decommissioning**. These principles aimed to minimise radiological risk, optimise logistics and costs, and ensure traceability and environmental protection throughout the entire material life cycle.

### 2.1.1. Early and thorough planning, preparation and comprehensive characterisation

The management of materials generated during the decommissioning implementation process is based on thorough planning and preparation. This essential phase commences with the identification of material types, quantities and locations, which is then followed by comprehensive radiological and physical characterisation. Such characterisation is crucial for accurate classification and routing, ultimately determining the optimal management strategy for each waste stream, resource allocation and safe execution of dismantling works.

**Focus:** Preparation and analysis before dismantling begins.

**Purpose:** Planning and resource allocation. To understand what types of materials will be generated, where they are located, how much there is and what their radiological/physical properties are. This:

- helps to maintain nuclear safety,
- happens before or at the start of dismantling,
- involves, for instance, mapping, radiological surveys, sampling, and measurements to determine contamination levels,
- supports planning for scheduling, logistics, worker safety, shielding, dismantling tools, expected treatment paths, etc,
- provides baseline data for documentation and traceability.

**Example:** Knowing that a certain pipeline is surface-contaminated but structurally intact helps determine that it can be processed in a certain F&D facility or even cleared for release after simple treatment.

A critical step in this process is the **classification of materials according to their level of radioactivity**, given the diverse range of waste types with varying radioactivity generated by nuclear decommissioning. Specifically, materials from V1 NPP´s decommissioning are divided into two main groups based on their radionuclide or hazardous substance content: **RAW** and **conventional waste**.

### 2.1.2. Strict application of legal and regulatory frameworks

All material management activities related to decommissioning were carried out in strict accordance with applicable Slovak and European legislation. This ensures legal compliance, supports transparency, and guarantees that all decisions related to material handling, treatment, and disposal are properly justified and traceable.

For **RAW**, the **key legal foundation** is the **Atomic Act No. 541/2004 Coll.**, which governs the peaceful use of nuclear energy in Slovakia. This is **complemented by** the **Decree of the Nuclear Regulatory Authority (NRA SR) No. 30/2012**, which specifies the procedures and technical requirements for RAW and spent fuel management. These regulations define critical parameters, such as clearance levels, limits for radioactive content, and safety requirements for handling, transport, storage and final disposal.

**For conventional waste**, including potentially contaminated or hazardous materials that are not classified as RAW, **JAVYS must comply with the Waste Act No. 79/2015 Coll**. This is **supplemented by the Decree of the Ministry of Environment** (**MoE SR**) **No. 365/2015 Coll.**, which establishes the **Waste Catalogue**, used to categorise and manage all types of conventional waste streams.

Together, these frameworks provide the legal basis for:

- classification of materials,
- determination of appropriate treatment, storage or disposal routes,
- application of correct packaging forms, labelling and documentation,
- environmental and radiological safety during all stages of handling.

By consistently adhering to these regulatory requirements, JAVYS ensures that material management is technically robust, fully traceable and compliant with both national and European Union standards.

### 2.1.3. Material classification and segregation at source

The following sections elucidate the general principles for the effective management of radioactive and conventional wastes from V1 NPP´s decommissioning. The RAW management process can be seen in Figure 2 below.

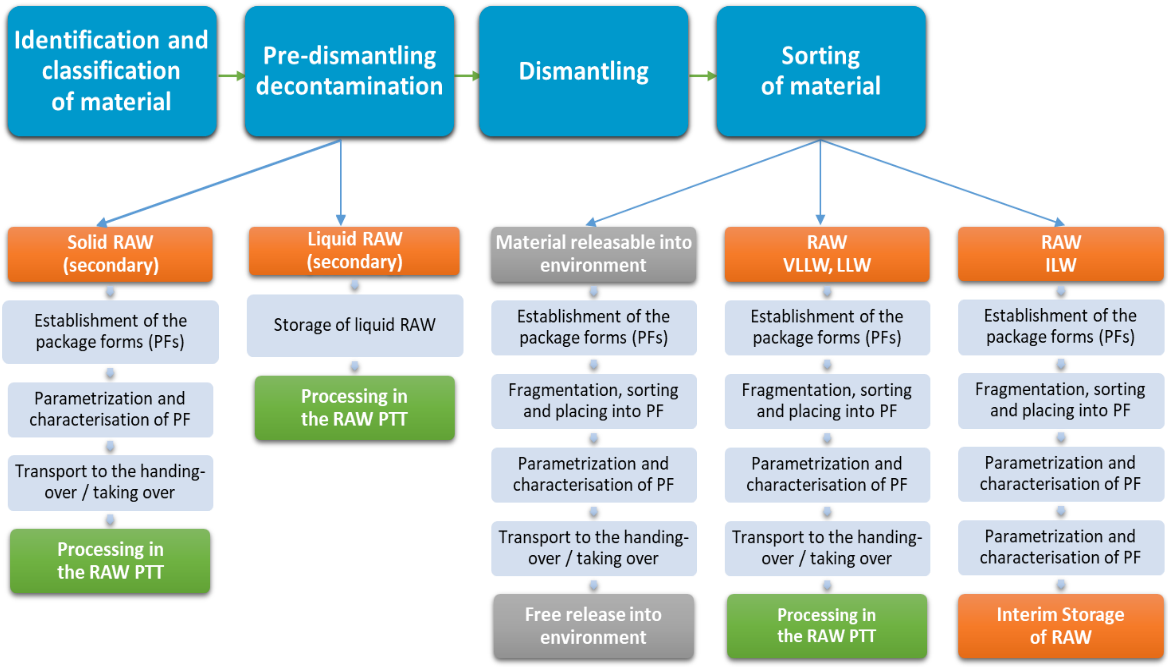


**Figure 2:** Schematic of RAW management process

#### 2.1.3.1. Radioactive waste

From the point of view of the generation of radioactive material from V1 NPP´s decommissioning, the following main activities can be defined:

- **Activities related to contaminated buildings** within the process of preparation for dismantling, such as decontamination prior to dismantling, partial dismantling related to re-storage and relocation of material, usually inside the original structures. Liquid and solid RAW from decontamination prior to dismantling, decommissioning material from partial dismantling, and decommissioning material from the modification of construction premises/area, which is treated as contaminated, are transferred from this phase to the decommissioning RAW management process. Decommissioning material defined as releasable to the environment is generated after it has been measured at the monitoring workplace for the purposes of release from under control of the regulatory authorities.
- **Dismantling of contaminated technologies of buildings**, where a significant part of radioactive material from decommissioning is generated. This includes the dismantling of technological equipment, dismantling of equipment that is also used to dismantle corresponding parts of buildings and dismantling of contaminated structural parts (e.g. contaminated parts of the reactor shaft near the reactor core). Decommissioning material defined as releasable to the environment is generated after it has been measured at the monitoring workplace for the purposes of release from under control of the regulatory authorities and the limits for the release of materials to the environment are not exceeded during the measurement of the material.
- **Decontamination of building surfaces** (walls and floors), i.e. removal of contamination from the surface of building structures and removal of contaminated parts of buildings. It is anticipated that practically all decommissioning materials generated during these activities will be classified as potentially contaminated after being measured at the monitoring workplace.
- **Dismantling of contaminated piping routes** between contaminated structures. A significant portion of the decommissioning material generated is likely to be classified as VLLW/LLW, particularly waste from the dismantling of the piping routes and decommissioning material from the structural parts of these routes.
- **Management of contaminated metallic materials** includes metallic fragments from the dismantling of decommissioned facilities or other solid materials are subjected to further fragmentation, decontamination and monitoring for release into the environment. Materials that subsequently fail to be released to the environment due to their level of radionuclide contamination are defined as RAW.
- **During final site restoration**, additional decommissioning material is generated minimally, if at all, and is always uncontaminated; such material is typically reused directly for site restoration. This phase also involves the introduction and utilisation of other uncontaminated materials, including grading material, soil, revegetation materials and the like.

#### 2.1.3.2. Conventional waste

Conventional waste generated during the decommissioning process is considered uncontaminated. This category includes:

- **Waste produced during decommissioning within the controlled area** of active nuclear facilities, which, after sorting, appropriate decontamination and radiation monitoring at specialised workplaces, has been classified as material releasable to the environment.
- **Waste produced during decommissioning outside the controlled area**. These materials have not come into contact with radioactive substances and are pre-qualified as uncontaminated. Nevertheless, these wastes undergo radiation monitoring/control before release to the environment.

Other waste and hazardous waste from decommissioning are managed using the standard methods, similar to those for non-nuclear industrial waste disposal, including recycling, thermal treatment, mechanical treatment, chemical treatment or landfilling.

**Focus:** Decision-making and sorting as materials are dismantled.

**Purpose:** Routing for treatment/disposal. To separate and route materials in real time, based on pre-defined criteria, into different waste or release streams.

- It happens during or immediately after dismantling.
- Classification is based on real-time measurements and earlier characterisation.
- Segregation avoids cross-contamination and ensures that materials follow the most efficient treatment/disposal path.

### 2.1.4. Minimisation of radioactive waste & ALARA principle

**ALARA** stands for ¨As Low As Reasonably Achievable¨; applying this principle ensures that radiation levels during the waste management process do not exceed permitted limits.

**The main aspects of the ALARA principle include:**

- **Minimise radiation exposure to workers and the public** (e.g. radiation monitoring, inspection of operating conditions by regular inspection of equipment and technology, as well as optimisation of operating processes to minimise unintentional radiation leaks).
- **Use of protective barriers**, **equipment and specialised technologies**, such as robots, automated systems and remote control to minimise the need for human presence in hazardous areas.
- **Control of exposure time** (optimisation of working hours in hazardous areas).

The objective of all decommissioning activities is, in accordance with the ALARA principle, to ensure that the generation of RAW is minimised. All activities in this area must be planned and implemented in accordance with this principle in such a way as to produce the least possible amount of radioactive materials, as well as to manage the radioactive materials produced in such a way as to produce the least possible amount of RAW (i.e. waste which cannot be released into the environment because of its radionuclide content). RAW management must lead to safe disposal at an appropriate type of repository.

**Practical implementation of the ALARA principle at JAVYS**

In line with the ALARA principle, JAVYS implements multi-stage decontamination, optimised cutting techniques and selective dismantling to reduce the generation and activity of RAW. Contaminated materials are reprocessed when feasible to allow for free release or transfer to decay storage, thereby reducing final RAW volumes and associated disposal costs. To reduce transport volumes and radiological exposure, JAVYS prioritises on-site treatment. Facilities for F&D are located within V1 NPP´s controlled area, which allows for direct processing of contaminated metallic material. Decontamination methods include: abrasive blasting, semi-dry electrochemical treatment (PODEZA) and alkaline degreasing. These measures significantly reduce the proportion of material classified as RAW and enhance operational efficiency.

### 2.1.5. Monitoring, traceability and documentation

Every material item is tracked throughout its management lifecycle. Records include, for instance, material ID, source project or component, classification result, radiological survey outcomes, packaging form, and final destination (release, disposal, storage, etc.). Digital and physical documentation is maintained in line with JAVYS´ procedures and regulatory requirements, ensuring full traceability and facilitating audits or post-project reviews.

JAVYS applies a rigorous system to track all materials generated during decommissioning, ensuring full traceability from the point of origin to final disposal, release or reuse. Each item or batch of material is uniquely identified and monitored throughout its life cycle. This includes records of:

- **Source**: where and how the material was generated (e.g. specific building, system, or dismantling activity).
- **Classification**: whether the material is considered radioactive (VLLW, LLW, etc.), or conventional waste, based on radiological characterisation and regulatory thresholds.
- **Treatment history**: information on any decontamination or fragmentation processes applied (e.g. mechanical cutting, electrochemical treatment, abrasive blasting).
- **Radiological monitoring**: measurement results from clearance monitoring workplaces, including surface contamination, dose rate and radionuclide content.

All data is recorded in a central documentation system in accordance with JAVYS' internal procedures and Slovak nuclear legislation. Measurement data is validated against clearance limits and release criteria before any material leaves regulatory control. Final documentation accompanies all material transferred for storage, disposal, or environmental release and is available for inspection by regulatory bodies.

This comprehensive documentation and traceability system ensures safety, regulatory compliance, and accountability throughout the decommissioning process.

## 2.2. Principles of effective management of radioactive waste from V1 NPP´s decommissioning

The effective management of RAW is a critical aspect of V1 NPP´s decommissioning process. It requires a structured approach that ensures safety, regulatory compliance, environmental protection and optimisation of disposal resources. A fundamental step in this process is the classification of RAW based on its radiological properties and potential hazards. Classification determines the appropriate handling, treatment, storage and disposal methods.

### 2.2.1. Classification of radioactive waste by level of activity

The classification scheme used at V1 NPP aligns with national and international standards and is summarised below:

- **Short-lived RAW,** the activity of which falls below the limit value for release into the environment during storage due to the very short half-life.
- **Very low-level RAW,** the activity of which is slightly higher than the limit value for its release into the environment, preferably containing short half-life radionuclides or, where appropriate, long half-life radionuclides in low concentrations, which require a lower degree of isolation from the environment by an engineered barrier system or do not require the use of engineered barriers for disposal, and the period of institutional control of the repository is shorter than in the case of a surface-type repository for RAW.
- **Low-level RAW** with an average mass activity of long-lived radionuclides, in particular alpha-emitting radionuclides, of less than 400 Bq/g, the maximum mass activity of long-lived radionuclides, in particular alpha-emitting radionuclides, are locally below 4,000 Bq/g, do not produce residual heat and, after treatment, meet the limits and conditions of safe operation for a surface-type RAW repository.
- **Intermediate-level RAW,** for which the average mass activity of long-lived radionuclides, in particular alpha-emitting radionuclides, is equal to or greater than 400 Bq/g, may generate residual heat and the arrangements for its removal are lower than for high-level RAW and, after treatment, do not meet the limits and conditions of safe operation for a surface-type RAW repository.
- **High-level RAW,** for which the average mass activity of radionuclides with short but also long half-life, in particular alpha-emitting radionuclides, exceeds the values established for low-level and intermediate-level RAW, shall only be disposed of in a deep geological repository, with residual heat removal measures being a significant factor in the design of such repositories.


**Figure 3:** Material management - LLW

# 3. RADIOACTIVE WASTE MANAGEMENT FROM DECOMMISSIONING OF NUCLEAR FACILITIES

Activities in the field of RAW management are governed by definitions contained within the legislation of the Slovak Republic. The scope of these activities, as carried out under conditions of JAVYS, is as follows:

**Monitoring and characterisation**

Activities related to the collection of RAW, where, on the basis of radiological measurements, the activities of limited radionuclides in RAW are declared.

Surface and internally contaminated technological equipment that has come into contact with contaminated media is released in a bulk storage chamber after fragmentation and decontamination. In the case of large components/equipment, this is preceded by pre-dismantling decontamination.

Volume-contaminated material such as construction debris, soil and others are released in the workplace with measuring equipment in bulk containers. The advantage of this equipment is the subtraction of the activity of natural radionuclides and automatic control of radionuclide vectors.

**RAW characterisation equipment**

Within Project D4.2, two new workplaces for the characterisation of RAW generated during V1 NPP´s decommissioning were established.

**Workplace in the reactor building**

The workplace was used for the characterisation of box pallets and big bags with LLW. After characterisation at the workplace, the RAW was transported for further processing.

**Workplace in the auxiliary operations building**

Gamma spectroscopic equipment was used for the characterisation of waste stored in 200 litre MEVA drums.

Only surface contaminated technological equipment and structural elements with very low contamination was dismantled, decontaminated and released (monitored for surface contamination by portable instruments, while maintaining the calibration geometry) at the bulk material workplace.

Once the technological equipment had been removed from the rooms, the surface contaminated building parts (walls, floors, ceilings) were decontaminated and the entire area is monitored for surface contamination and released as a whole within the building release workplace.

**Sorting**

An activity following collection and characterisation in which RAW is classified into prescribed categories of the same characteristics suitable for further management.

Sorting of RAW is carried out by the waste producer (contractor of V1 NPP´s decommissioning projects) at the site of generation. In connection with further treatment, each RAW producer is obliged to sort, package and register the RAW in accordance with the internal instruction regulation.

**Treatment**

Activities aimed at separating radionuclides from RAW, changing its composition and reducing its volume in order to improve the safety and economic efficiency of its management.

### RAW types by treatment and conditioning

- **Combustible solid RAW**

  Combustible RAW includes textiles, paper, plastics, activated carbon from filters, PPE etc.

- **Combustible liquid RAW**

  This includes contaminated oils, lubricants, solvents and other organic liquids.

- **Compressible RAW**

  This category includes mainly small ferritic metal and its alloys, small non-ferrous metals, cable insulation, thermal insulation, contaminated DN pipes smaller than 50 mm, small fittings, electric motors, electrical equipment the decontamination of which is not effective.

- **HVAC filters**

  This waste stream includes contaminated HVAC filters originating from mobile HVAC equipment used to control gaseous radionuclides produced during the dry dismantling of metallic and concrete components.

- **Contaminated metallic material**

  Material that is intended to be treated by fragmentation, decontamination and subsequent monitoring for release into the environment.

- **Metallic RAW for melting**

  Carbon steel material that cannot be released into the environment after decontamination. Contaminated aluminium, which is used as an additive in the re-melting process, is also registered in this category.

- **Metallic RAW for decay**

  Short-lived RAW with activity during storage, due to very short half-lives, falls below the limit value for release into the environment and is thus classified as RAW for decay. This is mainly RAW after decontamination at V1 NPP´s F&D facilities with an activity just above the limit for release to the environment.

- **RAW intended for cementation into the FCC**

  Large RAW components (metal and reinforced concrete) that do not meet the conditions for acceptance for treatment, or whose treatment is inefficient, are loaded directly into the FCC with subsequent cement grouting.

  The contaminated steel grit is a secondary product from the dry decontamination workplace. It is added to the FCC's cement grout. Drums with RAW treated in a suitable matrix are also loaded into the FCC.

- **Liquid RAW for cementation**

  Radioactive waters that are contained in the decontamination solutions from the wet decontamination workplace at the V1 NPP F&D facilities are treated by cementation at the facility for treatment and conditioning of RAW and form the FCC grout.

- **Activated RAW for long-term storage**

  RAW from V1 NPP´s decommissioning, which does not meet the limits and conditions of safe operation for the surface type of RAW repository, is stored in shielded containers in the interim storage unit for RAW.

- **Very low-level waste**

  Intended for storage in the disposal boxes at the National RAW Repository at Mochovce. It was packaged into big-bags or MEVA drums. VLLW generated during Project D4.2 consisted mainly of concrete rubble, reinforced concrete, dry sludge from concrete cutting and plastics.

**Storage**

Constitutes the placing of RAW in premises, buildings or facilities allowing its isolation, control and protection of the environment, with the intention of subsequent treatment and disposal.


**Figure 4:** Interim Storage of RAW

**Conditioning**

Includes activities leading to the creation of package form (by cementation into FCC) suitable for safe management during storage and disposal.

**Disposal**

The placement of RAW at a RAW repository. The national RAW repository consists of two repositories:

- LLW repository,
- VLLW repository.

The LLW repository is a surface-type repository designed for the disposal of solid and solidified low-level RAW, generated mainly during the operation of nuclear installations in the territory of the Slovak Republic; as well as in other institutions engaged in activities generating RAW. The repository site is located about 2 km north-west of the Mochovce NPP site.

The basic safety requirement for the repository is that there should be no release of radionuclides into the environment during its operation, during institutional control and after its termination, which would result in a radiation exposure higher than the values established by the applicable legal regulations.

**Fibre-concrete container**

Manufacturing of fibre-concrete containers is also an important part in the management of low-level RAW. Maximum safety must be ensured during the RAW management activities, which is why the fibre-concrete container has special properties that are continuously monitored during its manufacturing.

**Figure 5:** LLW Disposal at the National Radioactive Waste Repository

## 3.1. Principles of effective management of conventional waste from V1 NPP´s decommissioning

Effective management of conventional waste from the dismantling of technological equipment and from demolition of buildings requires a specific approach, as these are complex and material-intensive activities that generate different types of waste, often in significant quantities. Proper management of these wastes reduces environmental impacts, increases recycling rates and promotes sustainable construction and industry.

**The Waste Act** (**No. 79/2015 Coll.** defines waste as a movable object or substance which the holder disposes of, intends to dispose of or is obliged to dispose of in accordance with this Act or special regulations. Based on this Act, waste must first of all be correctly identified and the following steps are applied for this purpose:

- identification of material of which it is composed,
- an analysis of whether the waste can be released directly into the environment or requires pre-treatment activities,
- assigning the correct code to the waste for its registration,
- indicating as accurately as possible the physical characteristics of the waste (volume and weight),
- identification of the area for the need for intermediate storage,
- recording data to ensure that the waste is traceable in accordance with the legislation in force.

The waste is categorised according to the **Decree of the MoE SR No. 365/2015 Coll.**, which establishes the Waste Catalogue as amended. It is divided into categories and types according to the List of Wastes, which is set out in the Annex of the Waste Catalogue, using a specified procedure.

The different types of waste are subdivided into waste groups and subgroups. Waste is divided into the following categories:

- hazardous waste marked with a capital letter “N”,
- other waste, marked with a capital letter “O”.

If waste cannot be classified according to the Waste Catalogue, it shall be classified as the waste type or waste group closest to its characteristics or origin.

**Materials generated during decommissioning** of V1 NPP´s facilities **and structural parts can be divided into three main groups**:

- **Waste left in the ground** at its original location.
- **Waste for unrestricted use** sorted and recycled materials intended e.g. for backfilling of pits on site after demolition of buildings, for reinforcement of areas used during the decommissioning or for export to the environment as reusable raw materials.
- **Waste unsuitable for unrestricted use** disposed of in municipal waste landfills or specialised landfills for hazardous waste. Materials unsuitable for unrestricted use (municipal waste) include material that will be exported to a municipal waste landfill and is not suitable for recycling. Materials classified as hazardous waste will be exported to specialised landfills for hazardous waste.

In the case of waste generated during the execution of service, cleaning or maintenance works performed for JAVYS by a contractor, the waste originator is JAVYS, in line with the Waste Act. However, as stipulated by a contractual relationship, it is possible to delegate to the contractor the obligations of a waste holder pursuant to the Waste Act (i.e. in cases of works implemented by the contractor during which the waste is generated by the contractor's activities).

During the implementation of V1 NPP´s decommissioning projects, the contractors of the projects are responsible for waste management and must provide information on waste management to JAVYS. The waste generator is obliged to comply with the waste management hierarchy according to the Waste Act.

Based on information from the waste generator, a JAVYS employee classifies the waste according to the **Waste Catalogue** in accordance with the **Decree of the MoE SR No. 365/2015 Coll**.

In the case of hazardous waste, the waste producer (decommissioning project contractor) shall issue a hazardous waste identification sheet in accordance with the aforementioned decree.

Waste that will be releasable to the environment in accordance with the applicable legislative regulations regarding its very low radioactivity (**Government Decree No. 345/2006 Coll.** on basic safety requirements for the protection of the health of workers and the population against ionising radiation), will be managed in accordance with the applicable **Slovak waste management Acts**. This means that such waste will be identified according to the **Waste Catalogue** and will be treated or disposed of according to the possibilities of management of individual types of waste.

**Records of the types** and **quantities** of **waste generated** at JAVYS and **the methods of waste management** (recycling/disposal) **are continuously maintained** on all waste generated in the form of **a waste record sheet**, as well as in an electronic form. The **data recorded will be held on record by JAVYS´ environmental department for a period of 5 years**.

Dismantled equipment and demolition of V1 NPP´s structural parts will also generate a quantity of non-contaminated material, namely:

- Metallic material from dismantling after decontamination or material that meets the limits for release into the environment, i.e. for recycling and reuse (steel, non-ferrous metals, decontaminated cables processed at the cable recycling plant, etc.).
- Construction waste from demolished buildings.
- Parts of equipment after dismantling and sorting.

**Figure 6:** Metals separated from the reinforced concrete

## 3.2. Project D4.2 "Dismantling of Reactor Coolant System Large Components"

The D4.2 decommissioning project "*Dismantling of Reactor Coolant System Large Components*" was one of the key projects essential for the successful completion of the second stage of V1 NPP´s decommissioning. The **project's scope** included **pre-dismantling decontamination**, **dismantling**, **fragmentation**, **material sorting**, **packaging into appropriate containers**, and **transport of materials** and **containers for the large components that were part of the reactor primary circuit** and **other components located in the containment area and in the storage and refuelling pools** of both V1 NPP units, as well as all other related activities. During the project, a substantial amount of material was dismantled and fragmented within the controlled area of the reactor building. **To meet project objectives**, **an efficient and reliable material management system had to be designed and implemented**.

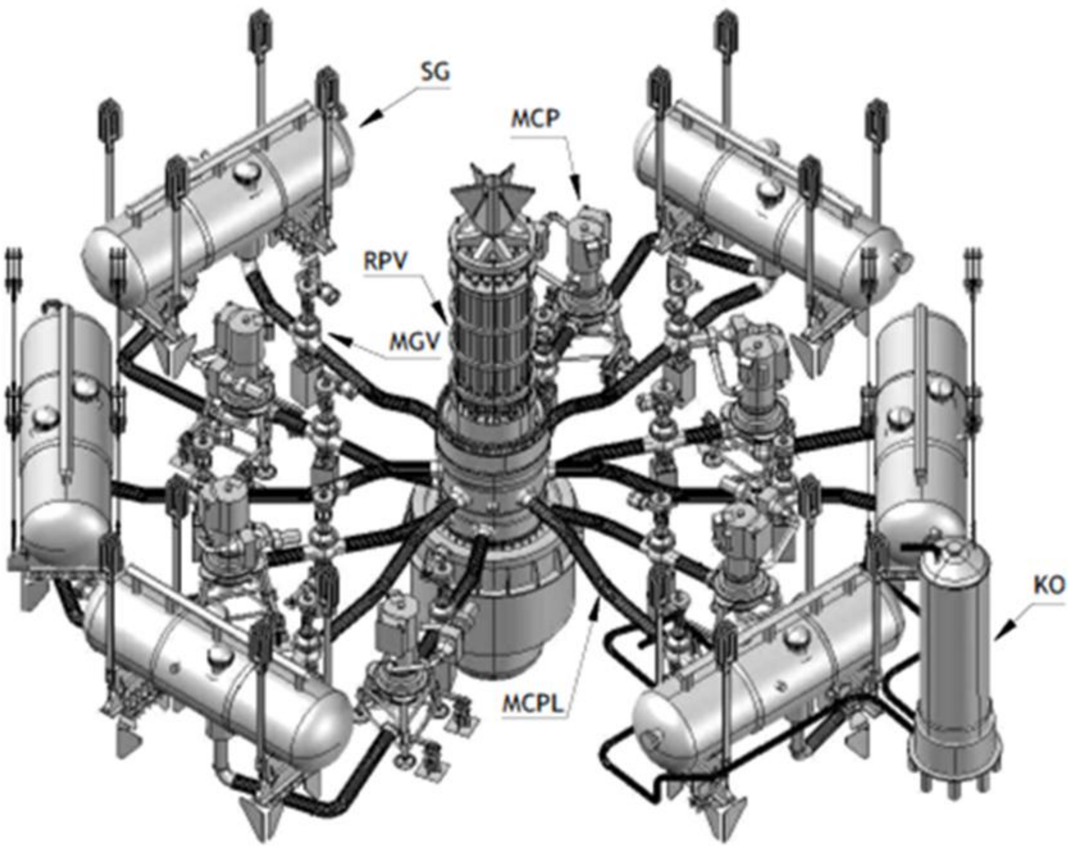


**Figure 7:** Reactor coolant system

The reactor coolant system is shown above in Figure 7, and the acronyms of the main components are listed in Table 1 below:

**Table 1:** Reactor coolant system main components acronyms

| Main component acronyms | |
|---|---|
| **RPV** - Reactor Pressure Vessel | **MGV** - Main Gate Valves (or MIV) |
| **SG** - Steam Generator | **KO** - Pressuriser (PRZ) |
| **MCP** - Main Circulation Pump | **MCPL** - Main Circulation Pipeline |

### 3.2.1. Challenges encountered and solutions developed

One of the critical areas was the logistics of the planned volume of over 13,837 tonnes of materials dismantled during the project's implementation. Management of materials for the purpose of the decommissioning project D4.2 "*Dismantling of Reactor Coolant System Large Components*" included the following activities:

- characterisation,
- sorting,
- packaging,
- transport,
- processing of contaminated metallic materials.

A key challenge was the processing of contaminated metallic materials directly at their production location within V1 NPP, without the need to transport them to a storage location and for subsequent processing outside the decommissioned nuclear facility.

To address this challenge, a key solution was the delegation of the operation of the on-site **F&D facilities** to Project D4.2´s contractor. By incorporating the F&D facilities into the contractor's scope, the project enabled direct and continuous processing of dismantled contaminated metallic materials within the controlled area. This solution proved both practical and efficient, as it optimised material flow, eliminated the need for off-site transport and allowed full control over logistics, processing timelines and performance.

The amount of contaminated metallic materials processed during the 65 months of operation of the F&D facilities and the volume of material released to the environment after decontamination served as a KPI in the overall material management strategy. The high decontamination efficiency, carried out in accordance with the ALARA principle, greatly reduced RAW generation and had a positive impact on the overall logistics of materials from the V1 NPP decommissioning.

### 3.2.2. Systems and equipment dismantled within the scope of Project D4.2

To give an overall picture of the amount of material being dismantled, a brief overview of the systems and equipment decommissioned in this project can be seen below. The dismantled parts or fragments of these systems and equipment were subject to subsequent material management under Project D4.2.

#### 3.2.2.1. Reactor components

V1 NPP consisted of two WWER-440/V-230 reactor units. It can be inferred from this that the two reactor shielding vessels were dismantled first. The two units shared a common reactor hall and each unit included the following components:

- reactor shaft protection lid,
- reactor vessel head upper block,
- reactor shaft protection lid,
- reactor pressure vessel,
- protective tubes,
- core basket,
- bearing shell and bottom of the bearing shell,
- annular water tank,
- reactor shielding assemblies.

#### 3.2.2.2. Activated and contaminated concrete of the reactor shaft

The reactor pressure vessel was located in the reactor´s concrete shaft. The concrete shaft served as structural support for the reactor as well as shielding in and around the reactor core area.

#### 3.2.2.3. Primary circuits components outside the reactor

The primary circuit components outside the reactor included:

- steam generators,
- pressuriser release tank (“bubble tank”),
- main circulation pumps,
- main isolation valves,
- main circulation pipeline.

#### 3.2.2.4. Auxiliary equipment

The auxiliary equipment included:

- refuelling equipment, including accessories,
- reserve main circulation pump,
- used drives of fuel assemblies, equipment and stands,
- nut wrenching device,
- concrete container,
- reactor internals container,
- liners,
- spent nuclear fuel racks,
- dampers and flanges, separating storage pools and refuelling pools in SFSPs,
- hangers and catchers for operation and manipulation of transport container C30.

#### 3.2.2.5. Other equipment

Other equipment included the RH-waste storage (“Mogilnik”).

It should be noted that, in the original V1 NPP design, an RH-waste storage place ¨Mogilnik¨, R115, was established in the room R301 for safe storage of RAW to allow easy and rapid storing of high activity solid wastes.

### 3.2.3. Characterisation and radiological surveys

The overall objective of the characterisation process in general is to obtain a set of radiological data necessary for decommissioning implementation. Results of radiological surveys, as well as results of the initial and additional characterisation are used by the contractor for the definition of the detailed sequence of works, strategy of RAW management, dismantling activities, pre-dismantling decontamination plan, shielding requirements, etc. Specifically, the results of these surveys support ALARA protective measures and management of radiation protection within the project.

The scope of **characterisation can be divided into two parts**:

- **Characterisation of activated components/systems**
    - pre-dismantling characterisation,
    - characterisation during/after dismantling.
- **Characterisation of contaminated components/systems**

**Characterisation and sampling plan**

The initial step in the radiological characterisation process involved reviewing available information. This included analysing relevant database records and the entire process of characterisation for activated components (an output of Project B6.4 “*Decommissioning Database*“). This analysis of existing data formed the foundation for developing the characterisation, sampling and analysis plan. The primary goal of this plan was to minimise the effort required to gather the necessary data while ensuring the adequacy, sufficiency and reliability (quality) of data obtained from planned in-situ measurements, sampling and analyses.

### 3.2.4. Types of material classification activities during Project D4.2

Waste from Project D4.2 was categorised based on its radionuclide or other hazardous substance content and its physical form, which influences the management process, into two main groups:

- **Radioactive waste**
    - solid RAW,
    - liquid RAW,
    - waste containing radioactive and hazardous waste.
- **Conventional waste**
    - hazardous waste,
    - other waste.

For the first group of waste, the legislative requirements of the **Atomic Act No. 541/2004 Coll**. and **Decree of the NRA SR No. 30/2012** for the management process were applied. For the second group, the legislative requirements of **Act No. 79/2015 Coll. on Waste** and **Decree No. 365/2015 Coll. of the MoE SR**, which establishes the **Waste Catalogue**, were applied.

However, **it was necessary to subdivide the above basic waste groups in more detail** according to other criteria that determine the requirements for further process management:

- level of radionuclides,
- material composition,
- content of hazardous substances,
- origin (primary, secondary).

The assimilation of the abovementioned criteria enabled the identification of different materials/waste flow branches that were used to manage the different types of materials/waste from dismantling activities to their final disposal location.

#### 3.2.4.1. Origin of material

Other types of material categories were defined based on the **origin of the material**, as follows:

- **Primary materials** originated from equipment and structures that are subject to decommissioning within the scope of the project.
- **Secondary waste** generated mainly during dismantling and decontamination activities, including:
    - **process fluids from cutting technology**, such as dry cutting coolants and water from wet cutting workplaces,
    - **waste from the treatment of waters** from wet cutting workplaces, filters and sorbents,
    - **used cutting tools** such as saw cutting wires and blades, grinding wheels, and manual dismantling equipment and spare parts,
    - **liquids from pre-dismantling decontamination**,
    - **air-conditioning filters**,
    - **combustible waste** such as rags, overalls and other personal protective equipment.

#### 3.2.4.2. Level of radionuclide content

The level of radionuclide content is a major characteristic in the sorting and further management of materials. According to the level of radionuclides present, the material was sorted into the following groups:

- **Radionuclide free material** from outside the controlled area where contamination with radionuclides is not expected or the content is negligible compared to the limits for release to the environment.
- **Potentially releasable material to the environment** only generated after measurements have been made at the designated workplace, it can subsequently be released from the administration of the regulatory authorities.
- **Material that is potentially releasable to the environment only after postdismantling decontamination has been carried out** which includes metallic contaminated material that met the criteria for underground decontamination and at the same time did not meet the limit values for direct release to the environment. These materials were sorted based on material type (carbon steel, stainless steel, non-ferrous metals) and method of further processing. This group also includes all carbon and stainless steel materials with surface contamination < 500 $Bq/cm^2$ that have been decontaminated by dry decontamination in V1 NPP (abrasive blasting in cabin) or transferred to the TSU RAO for treatment. Metallic materials that could not be released into the environment after decontamination were registered as RAW. Contaminated aluminium materials were handed over for processing by remelting.
- **RAW** which constitutes material originating in a controlled area containing radioactivity in the form of contamination or volume activity at levels exceeding the limits for release to the environment and which does not meet the conditions for decontamination. RAW is managed according to the level of radioactivity.
- **Nuclear material** which constitutes a separate type of RAW contained in the neutron flux measurement chambers.

### 3.2.5. Containers and package forms for materials from dismantling

All dismantled material was packaged into approved package forms according to JAVYS´ procedures. The package forms create a protective barrier, preventing external surface contamination while the material is within the controlled area. The package forms for different waste types were defined with respect to the material's type, radioactivity, future handling and final disposal/storage location. **Loading of the packages was optimised to achieve maximum package form usage effectiveness with respect to the following limits**:

- volume and weight limits,
- categorisation by waste type,
- applied radionuclide vector,
- radiological limit.

**Table 2:** Types of package forms for solid RAW

| Container types for solid RAW | Dimensions | Maximum loading capacity |
|---|---|---|
| Standard box pallets | 1.2 m x 0.8 m x 0.8 m | 1,000 kg |
| ISO 20’ | 6.06 m x 2.44 m x 2.59 m | 27,000 kg |
| MEVA Drum 200L | ø 595 mm x 820 mm | 450 kg |
| FCC | 1.7 m x 1.7 m x 1.7 m | 15,000 kg |
| FCC with 80 mm shielding | 2.03 m x 1.88 m x 1.88 m | 24,900 kg |
| FCC with 150 mm shielding | 2.17 m x 2.02 m x 2.02 m | 37,800 kg |
| FCC with 210 mm shielding | 2.29 m x 2.14 m x 2.14 m | 50,000 kg |
| MEVA drum 200 L shielded for fission chambers | ø 595 mm x 820 mm | 450 kg |
| Container UKTIIA-130 for neutron sources | ø 0.42 m x height 0.42 m | min. 53 kg |

#### 3.2.5.1. Standard box pallet for RAW

Standard box pallets are used for handling and storing RAW. These containers are not approved transport containers and can only be transported after being placed in an approved transport equipment (ISO container). The box pallet can also be used for potentially releasable materials, provided that equipment undergoes measurements for free release. Basic technical parameters of the box pallet are as follows in Table 3.

**Table 3:** Basic technical parameters for the box pallet

| | |
|---|---|
| **Dimensions** | 1.2 m x 0.8 m x 0.8 m |
| **Maximal loading capacity** | 1,000 kg |
| **Empty box pallet weight** | 56 kg |
| **Internal volume** | 380 L |

**Figure 8:** Standard box pallet

### 3.2.5.2. MEVA drum 200 L

200 L MEVA drums are used for transportation of solid or solidified RAW. It is also possible to use them for the transportation of oil and radioactive sludge in PKIII/drums. MEVA drums can by also used for potentially clearable materials, through being measured by equipment for free release. The basic technical parameters of the drums are as follows in Table 4.

**Table 4:** Basic technical parameters of the 200 L MEVA drums

| | |
|---|---|
| **Drum diameter** | Ø 595 mm |
| **Lid diameter** | Ø 610 mm |
| **Height** | 820 mm |
| **Empty drum weight** | 22 kg |
| **Maximum weight after filling** | 450 kg |

**Figure 9:** 200 L MEVA drum

### 3.2.5.3. Large-volume bag "Big-bag"

A large volume bag colloquially referred to as a "Big–bag" is intended to be used for transport of clearable concrete debris within the controlled area. The debris is measured directly in the ¨Big-bag¨ on the ROBOCOUNT or can be transported from the bag to the release container before measurement. The ¨Big-bag¨ was used for transport and disposal of VLLW concrete debris. The basic parameters of a "Big-bag" are as follows in Table 5.

**Table 5:** Basic parameters of a ¨Big-bag¨:

| | |
|---|---|
| **Dimension** | 950 x 950 x 1,300 mm |
| **Loading capacity** | max. 1,000 kg |
| **Vlume** | 1 $m^3$ |

**Figure 10:** Big bag

### 3.2.5.4. Fibre concrete container

The FCC was designed as a universal package form for storage/disposal of fragments from the dismantling of large activated components and components from the RH-waste storage (Mogilnik). It is currently used for the disposal of LLW at the National RAW Repository in Mochovce. The FCC was used for packaging RAW in an internal baskets structure, which was, along with the waste, placed inside the container. The basic technical parameters of the FCC are as follows in Table 6.

**Table 6:** Basic parameters of the FCC

| | |
|---|---|
| **Outer dimensions** | 1.7 x 1.7 x 1.7 m |
| **Inner dimensions** | 1.45 x 1.45 x 1.47 m |
| **Empty container weight** | 3,500 kg |
| **Lid weight** | 600 kg |
| **Slug weight** | 25 kg |
| **Maximum FCC weight after filling** | 12,500 kg |

**Figure 11:** FCC Container

### 3.2.5.5. Containers for large Components (LLW / ILW)

**To avoid exceeding the maximum dose rate of 10 mSv/h on the surface of the package form**, the following package forms and shielding solutions for the FCCs were used for large components:

- FCC container without shielding,
- FCC containers with 80 mm shielding,
- FCC containers with 150 mm shielding,
- FCC containers with 210 mm shielding.

The baskets were manufactured with respect to the technical parameters of the FCC listed above.

**The FCC shielding** consists of a welded steel structure that **has two separate parts**, a **shielding body** and a **shielding lid**, forming a functional unit. There are attachment points on the sides of the shielding body. Based on calculations, shielding containers with thicknesses of 80 mm, 150 mm and 210 mm were used. The complete package form, including the basket, FCC, and external shielding, is shown below. The main requirement for the shielding is to ensure that the maximum dose rate on the outer surface of the package form does not exceed 10 mSv/h. This applies to both transport and storage conditions within the IS RAW facility.

They served as a basic and supporting structure for inserting fragments for ILW containers in wet cutting workshops (WCWs) before subsequent placement into the respective FCC. Considering that baskets were to be used underwater in the WCW, they were designed to provide the possibility of draining the remaining water from the bottom part of the basket through the shielding bell bottom cover drainage system (once the shielding bell has been extracted from the water). The baskets were made of carbon steel coated with high resistance waterproof and non-flammable paint, epoxy resins or similar which will not produce any explosive gases (e.g. hydrogen).

Three types of baskets were designed based on expected use. A standard basket design was used for most materials. The standard design was modified for another two uses with additional internal insertions.

**The types of baskets used were as follows**:

- **basket for FCC** – standard structure,
- **basket for KNI** – standard structure of the basket for FCC with additional inner insertion of 2 mm thick steel plates – used in dry conditions for cutting of KNI,
- **basket for RSA** – standard structure of the basket for FCC with additional inner insertion of 20 mm thick steel plates – used for the fragments of reactor shielding assemblies.

**Figure 12:** Inner steel basket & external steel shielding

#### 3.2.5.6. Container for fission chambers and container for neutron source

For the storage of IBN-9 fast neutron sources, special UKTIIA-130 containers are currently in use. These sources will continue to be stored in the same containers.

**Figure 13:** Container UKTIIA-130

### 3.2.6. Radioactive Waste Transport Equipment

Transport of solid or solidified RAW within the European Union is performed by the approved means of transport. Transport containers must be approved according to **Act No. 541/2004 Coll**.

Conditions for the transport of radioactive materials are specified in the **Decree of the Nuclear Regulatory Authority of the Slovak Republic No. 57/2006**, laying down details of requirements for the transport of radioactive materials, as amended by **Decree No. 105/2006 Coll**. Slovakia is an intercontinental country and all facilities (V1 NPP, NRWR and IS RAW) are located far from large rivers. This fact means that there are two possible ways to transport RAW. The first option is transport by road using a transport container and truck. The other option is a combination of rail transport of RAW using a special wagon and subsequently transport by road. **For the transport of RAW**, **the following transport equipment was used**:

- **200L drums MEVA type 0488** for the transport of solid or solidified RAW,
- **standard 20' ISO container**,
- **transport container PK90,**
- **container PK/SK,**
- **container PK/SK 2,**
- **container PK III/drums,**
- **fibre-concrete container.**

All transport equipment had to comply with the limits and conditions for transport from the aforementioned legislation.

**Transport of radioactive waste**

For transport within Project D4.2, only road transport was considered due to its advantages over rail transport. If rail transport was used, the train composition would require three wagons, but only the last one would be utilised. This is because the locomotive is not permitted to enter the internal areas of the turbine hall due to the production of emissions, which the HVAC filters are not designed to handle. Consequently, due to the total length of the train, the locomotive and part of the train would have to be extended outside of V1 NPP´s designated area to allow for changeover points. The limitations of rail transport led to the rejection of this method for transporting RAW from the Reactor Hall (CB 800:V1) to the IS RAW.

**Two different types of transport equipment were used for ILW**:

- **standard 20‘ ISO container**,
- **new transport equipment for transport of FCCs** (PK90 transport container).

All transport equipment met the limits and conditions for transportation established in the abovementioned legislation.

There is an important limit from the dose rate point of view:

Under normal transportation conditions and also under exclusive use conditions, the dose rate on the surface of the transport equipment shall not exceed a value of 2 mSv/h at any point and, at a distance of 2 m away from the surface of the transportation equipment, a value of 0.1 mSv/h.

During the implementation of Project D4.2, all package forms met the above limits and conditions for transportation.

### 3.2.6.1. Standard ISO 20‘ container

**The ISO 20’ container** was used to transport material from dismantling or containers with VLLW that have a half-life of several years, after which it could be free-released (subject to storage and radiological control before free-release).

According to **NRA Decision No. 262/2016**, standard ISO 20’ containers are approved as the transport container for radioactive material. Two non-shielded FCCs can be put into one standard ISO 20’ container. This type of transportation equipment is commonly used in Slovakia. It was also used to transport non-shielded FCCs with LLW or ILW to the RWTC and IS RAW. The basic technical parameters of the container are as follows in Table 7.

**Table 7:** Basic technical parameters of the ISO 20’ container

| | |
|---|---|
| **Cladding weight** | 2,300 kg |
| **Outer length** | 6,058 mm |
| **Outer height** | 2,591 mm |
| **Inner length** | 5,898 mm |
| **Inner height** | 2,320 mm |
| **Door opening width** | 2,338 mm |
| **Door opening height** | 2,281 mm |
| **Maximal loading capacity** | 28 t (limited also by truck) |

**Figure 14:** ISO 20’ container for transport of RAW in Slovakia

### ISO 20’ container

It was necessary for the package form with RAW to meet transport conditions and to be secured against undesirable movement. The non-shielded FCC was placed into an auxiliary structure that prevented undesirable movement inside the transport container. The loading capacity of the ISO 20’ container limited its use as a transport container for shielded FCCs.

#### 3.2.6.2. New transport form for shielded FCC – PK90 transport container

**A new transport container the PK90 was used** for FCCs with external shielding or unshielded FCCs with higher dose rates. This was **due to the low load capacity of the original ISO 20' container and its insufficient shielding capability in the case of FCCs with higher dose rates**. The PK90 was licensed as a B(U) type shipment.

**The PK90 fulfilled all transport requirements** for RAW concerning the weight of the transported package form and the type of the radioactive material. The requirements are defined by **NRA SR Decree No. 57/2006**, laying down details of requirements for the transport of radioactive materials, as amended by **NRA SR Decree No. 105/2006**.

The PK90 was situated on a heavy-load trailer that was assigned to this purpose only. The transport package form can transport only one shielded or non-shielded FCC with RAW. The PK90 is designed for transportation only on a suitable transport platform semitrailer. The FCC container was loaded / unloaded to / from the overpack placed on the transport platform semitrailer. The transit was carried out within the V1 NPP site.

The PK90 consists of a body, a lid and its accessories include side railings and a ladder for operational staff. **The basic parameters of the transport package form are as follows in** Table 8.

**Table 8:** Basic parameters of the transport package form

| | |
|---|---|
| **Outer dimensions (L x W x H) with accessories** | 4,096 x 3,369 x 3,798 mm |
| **Inner dimensions (L x W x H)** | 2,390 x 2,390 x 2,150 mm |
| **Wall thickness of lid, wall body and bottom** | 90 mm |
| **Inner volume** | 12.28 $m^3$ |
| **Total weight of empty container** | 30.54 t |
| **Total weight of filled container - max** | 80.54 t (max. RAW + PK90) |
| **Type of RAW transport** | Solid RAW |
| **Maximum total activity of Co-60 RAW** | 4.22 E+15 Bq |

The PK90 is permanently placed and anchored with eight chains on a semitrailer with a load capacity of 80 t for the heaviest option (shielding container TK210 + FCC + basket with solid RAW fragments). PK90 individual parts together with the platform trailer are shown in Figure 15 below.

Inserting of shielded container into the transport container in Reactor Building | Transport into the IS RAW | Unloading of shielded container in RAW ISF

**Figure 15:** Transport into the IS RAW

### 3.2.7. Processing of Contaminated Metallic Materials - Fragmentation and Decontamination (F&D) facilities

The F&D facilities, owned by JAVYS, were designed to process surface-contaminated metals and construction materials from V1 NPP´s decommissioning. They were installed in 2015 as part of Project C7-A3 "*Erection of the new large capacity F&D facility NPP V1*". For Project D4.2, these facilities began operations in June 2019. The facilities themselves were located within the reactor building (CB 800:V1), where they spread across various locations and floors, and comprised five workplaces: two for fragmentation and three for decontamination.

**FP1 – Fragmentation workplace**
- Low-speed fragmentation
- Hydraulic fragmentation

**FP2 – Fragmentation workplace**
- Thermal fragmentation

**DKP1 – Decontamination facility**
- Electrochemical decontamination
- Ultrasonic decontamination
- High-pressure water spraying

**DKP2 - Workplace for abrasive blasting in a basket**
- Suspended blasting equipment

**DKP3 - Workplace for manual abrasive blasting**
- Manual blasting booth

**Figure 16:** Fragmentation and decontamination facilities

**To increase decontamination capacity and achieve lower contamination levels for certain complex equipment**, such as removable parts of main circulation pumps (MCPs) or other highly contaminated components exceeding 500 Bq/cm$^2$ (a value beyond the acceptance limit for material processing on the DKP1, DKP2, and DKP3 lines), **the former stationary decontamination facility was recommissioned**. This facility, primarily used during V1 NPP's operation period (outages) for metal decontamination, was named **DKP4** and was in operation from May 2020 to December 2022.

The **DKP4** facility was predominantly used to reduce material contamination, thereby simplifying its subsequent management. This included facilitating further dismantling or subsequent decontamination on the then operational facilites within V1 NPP. Moreover, DKP4 was used to support or facilitate the processes for other DKP facilities in operation at that time, e.g. by applying alkaline degreasing to contaminated metallic materials, which were subsequently decontaminated at DKP1, DKP2 or DKP3.

### Decontamination of contaminated metallic materials

As part of Project D4.2, the F&D workplaces enabled the processing of contaminated metallic materials generated by other decommissioning projects implemented in the V1 NPP controlled area. Additionally, a new and effective semi-dry electrochemical decontamination process for metals was implemented, which included the delivery of new equipment (PODEZA).

Beyond evaluating the decontamination performance of DKP1, DKP2, and DKP3 based on the quantity of metal free-released, and the overall material processed by all decontamination facilities, one objective was the processing of contaminated metals on the DKP4 facility. This is notable because the purpose of DKP4 was not to achieve direct free release of metals but rather to enable subsequent decontamination of dismantled parts of contaminated metallic material at DKP1, DKP2 or DKP3. All decontamination facilities (DKP1, DKP2, DKP3 and DKP4) were integral to and operated under Project D4.2.


**Figure 17:** V1 NPP Fragmentation & Decontamination Facilities

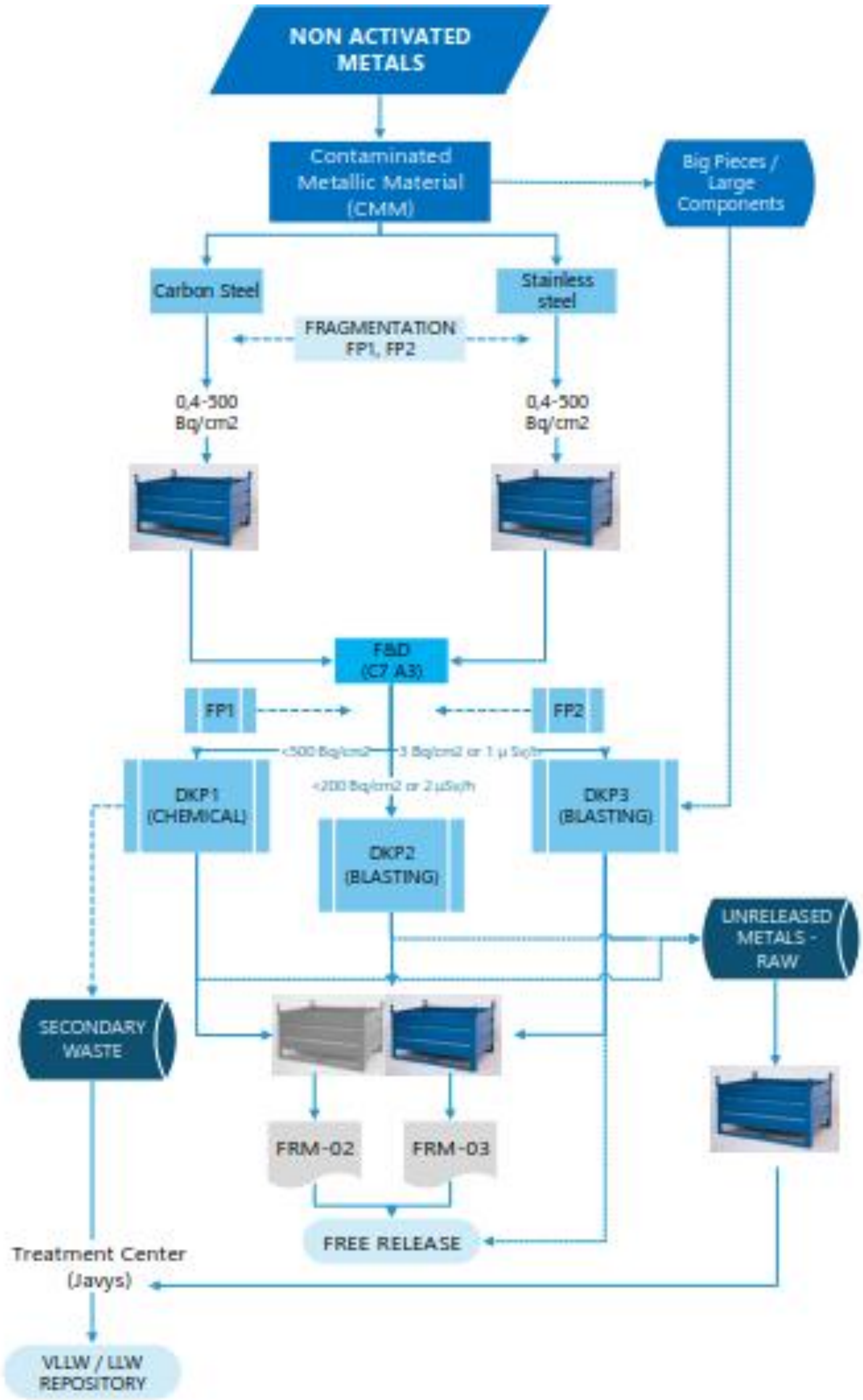


**Figure 18:** F&D Operation Workflow

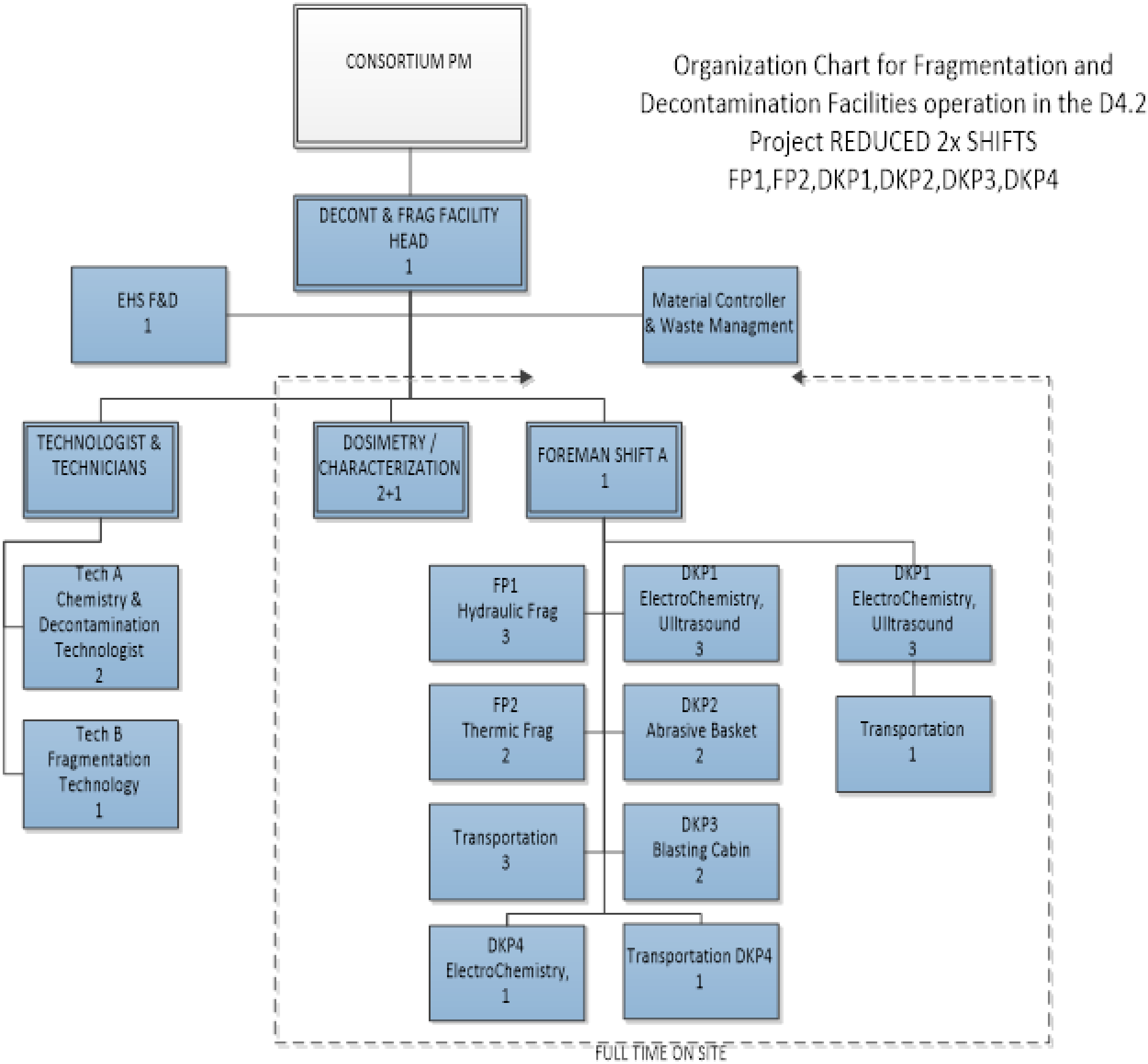


**Figure 19:** F&D organisational chart

### 3.2.8. F&D Performance Evaluation

This section presents a graphical overview of the F&D facilities' operational results. **The data covers the entire period**, from the **commissioning date** on the **1st of June 2019** through to the **31st of October 2024**, and illustrates overall and individual performance, as well as input and material released.

The **concept of performed input and output material are based on the following** criteria and considerations:

- **Input material** is the total amount of contaminated metal material delivered to the F&D facility. This material is then fragmented/decontaminated at each relevant facility or facilities, and subjected to the corresponding process or cycle at each facility, to achieve the decontamination level required for free release of the material.
- **Many times**, **more than one cycle was required**, for example during electrochemical decontamination, to achieve a suitable surface contamination activity for free release of the metals and many times a previous decontamination cycle was performed at DKP1 before going to DKP2 or DKP3.
- **Performed** (different to processed) **material** should be understood as the total amount of metallic material which has gone through any fragmentation or decontamination process or cycle (i.e. if a fragment with mass 100 kg is decontaminated in two cycles at DKP1 and one cycle at DKP3 before free release, then the input material is 100 kg but the performed material at DKP1 is 200 kg and the performed material at DKP3 is 100 kg).
- **Performed mass value** was always higher than input material mass value as well as output material mass value, i.e. the total mass of metals effectively decontaminated below the free release levels and released.
- **Decontamination facility DKP4** is considered only in terms of material performed, not as a contribution to the free-released material.
- **Fragmentation facilities FP1** and **FP2** served for fragmentation of metalic materials that were afterwards decontaminated at each DKP´s workplaces.
- The **decontamination effectiveness** should be considered as the ratio between the total output material released + material intended for decay and re-melting and total input material taken into V1 NPP´s F&D facility.

Each KPI presented below corresponds to a specific performance graph, allowing clear visual interpretation of results achieved through the operation of F&D facilities during Project D4.2.

#### 3.2.8.1. KPI #1 – Total material throughput

This KPI **monitors the total quantity ("performed mass") of metallic material processed by all F&D facilities** from the 1st of June 2019 to the 31st of October 2024. During 65 months of operation, the decontamination facilities (DKP1 + DKP2 + DKP3) processed a total of 6,482.1 tonnes of metals. Considering the value of 800 tonnes as an initially expected reference mass to be performed by these facilities in the first year of operation, the results have proven to exceed these expectations. The facilities achieved an excellent average annual operating capacity of 1,197 tonnes and a very high level of decontamination efficiency of more than 98%. It should be noted that DKP4´s performance corresponds to 30 months of operation, from its recommissioning in June 2020 to December 2022.

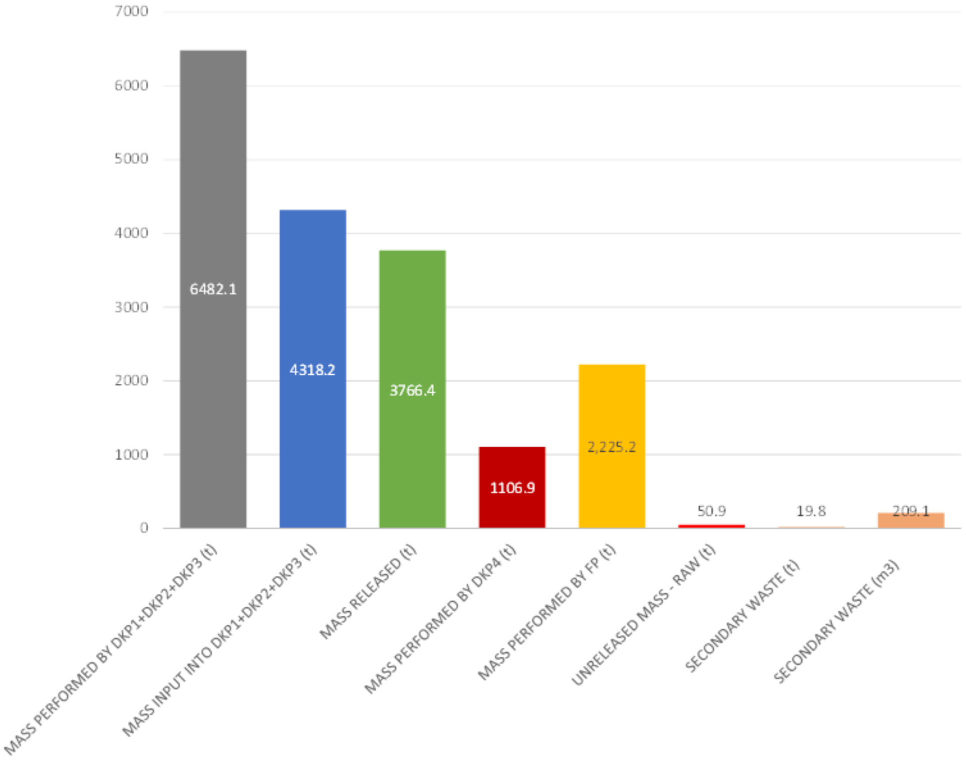


**Figure 20:** Overall performance of all F&D facilities in the period 1st of June 2019 to the 31st of October 2024

### 3.2.8.2. KPI #2 – RAW production rate

This KPI was **established to monitor the total amount of metals unreleased from the decontamination processes**, which remained classified as RAW. It represents approximately 1.2 % out of the total material input into the decontamination facilities (excluding DKP4). The significance of this KPI is that it highlights the minimal volume requiring disposal, thus supporting environmental and financial goals.

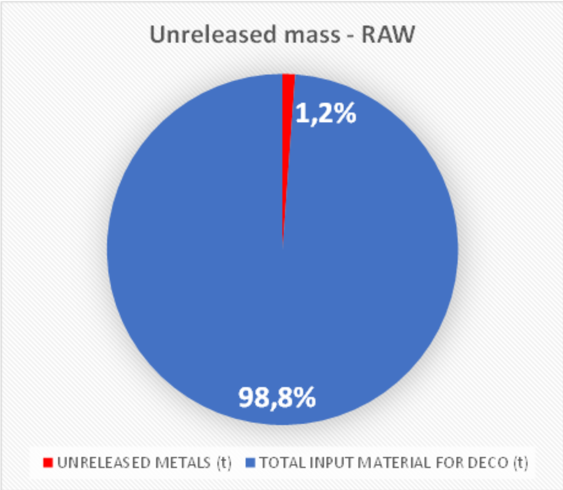


**Figure 21:** Unreleased mass – RAW

### 3.2.8.3. KPI #3 – Decontamination effectiveness and its evolution

**An outstanding decontamination effectiveness of 98.8% was achieved**. This figure is derived from the total mass free released compared to the total mass taken in for decontamination, as evidenced by the RAW production rate shown in Figure 21. The evolution of this KPI throughout the entire period of operation is further illustrated in Figure 22 below. This KPI's significance reflects excellent adherence to ALARA principles and a highly successful minimisation of RAW.

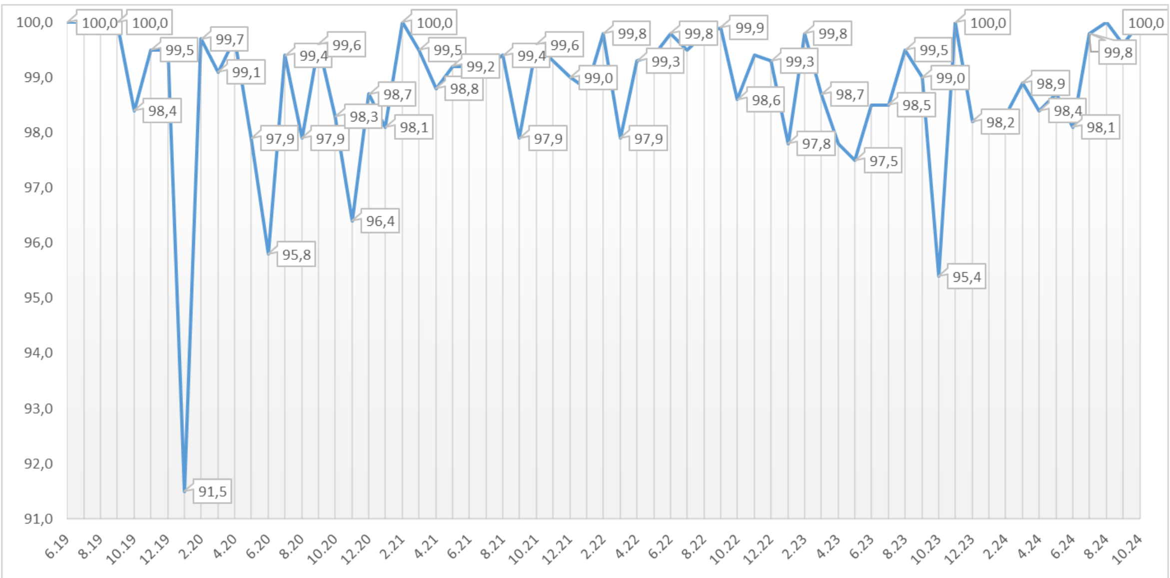


**Figure 22:** Decontamination effectiveness evolution

### 3.2.8.4. KPI #4 – Input-output-performed metallic mass evolution

**Another indicator for monitoring the performance of the decontamination lines** was the monthly evolution of the input, output / released and performed mass by the workplaces DKP1, DKP2 and DKP3, as shown in Figure 23 below (excluding DKP4). It provides a comprehensive view of the material flow and efficiency of the decontamination process, highlighting how much material was handled, successfully treated, and ultimately released, which is vital for assessing the overall performance and environmental impact. While not directly a line on the figure, the relationship between these lines inferred from the figure helps to understand decontamination cycle intensity. If a large amount of material enters the process (input mass) and a similarly large amount is successfully processed and released, this indicates efficient operations requiring fewer repeated treatments. Conversely, a large difference between performed and released implies more processing cycles.

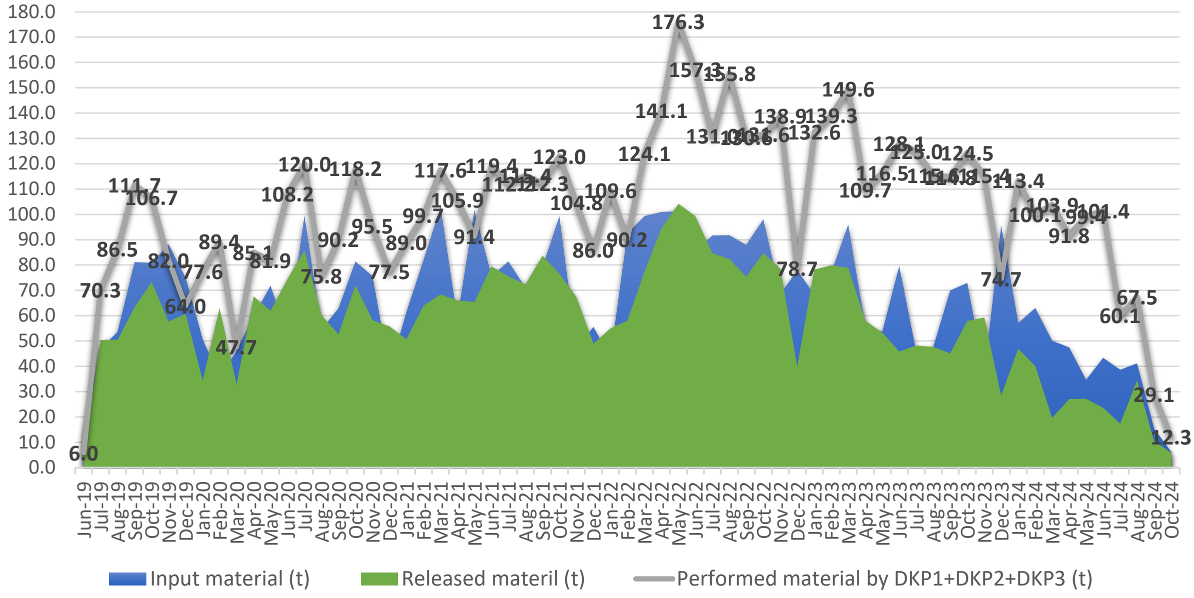


**Figure 23:** Input-output-performed metallic mass evolution

### 3.2.8.5. KPI #5 – Monthly performance evolution for all F&D facilities

Figure 24 below **illustrates the evolution of the total material performed** (**processed**) monthly by all decontamination facilities, including DKP4, and by the fragmentation facilities (FP1 and FP2). Over the entire period under consideration, the average monthly mass processed (performed) by all these facilities (including FP1 and FP2) was 154 tonnes (rounded value).

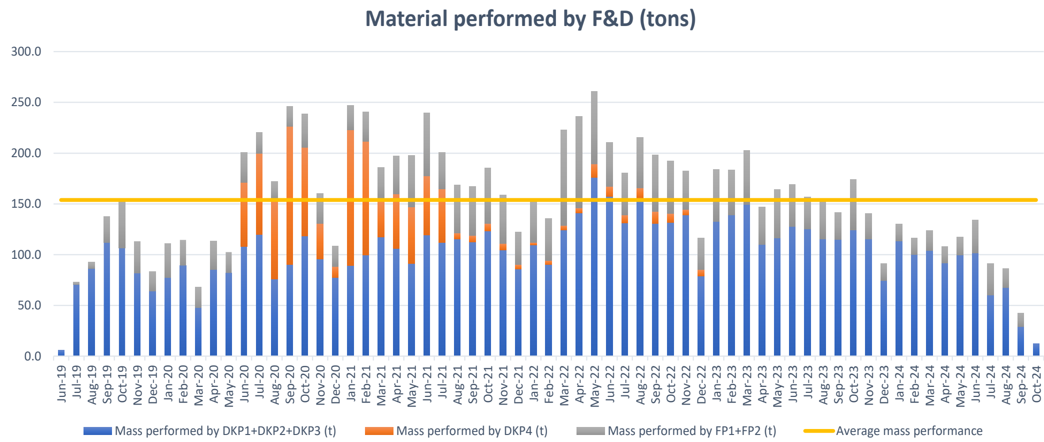


**Figure 24:** Monthly performance evolution for all F&D facilities

### 3.2.8.6. KPI #6 – Mass performed vs. mass released (DKP1, DKP2, DKP3)

This KPI **provides insight into the efficiency of decontamination processes across individual DKP workplaces**. The following figures (Figure 25 to Figure 27) show the individual performance of the DKP1, DKP2 and DKP3 facilities. The difference in the gap between average values, mass performed, and mass released can be observed in the ensuing figures, for the three different facilities.

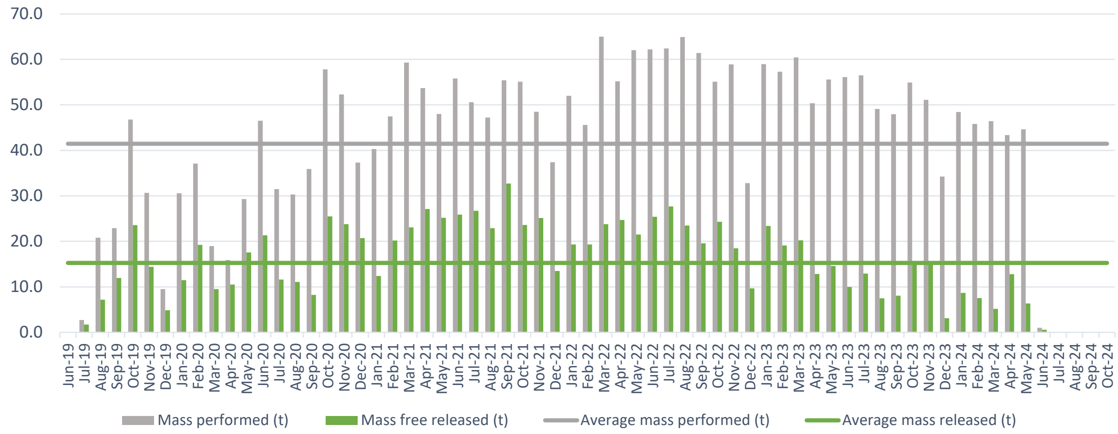


**Figure 25:** Material performed and released by DKP1

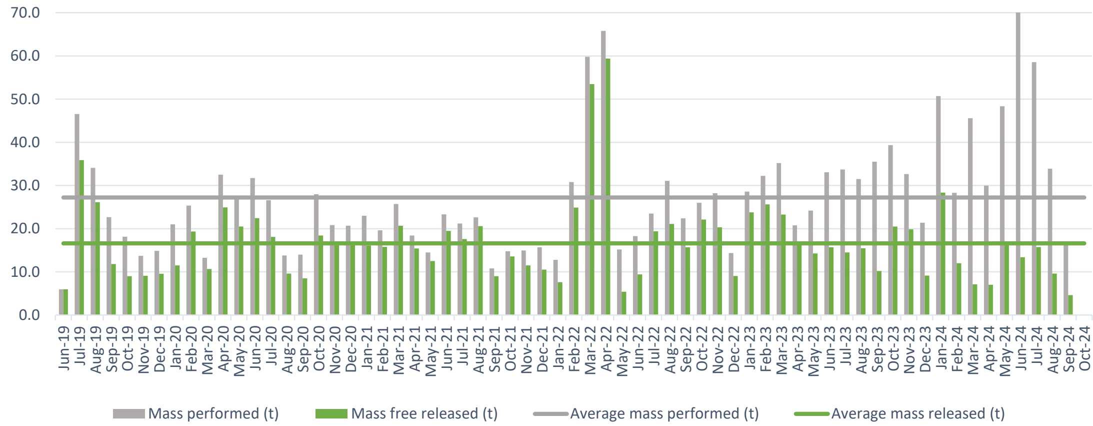


**Figure 26:** Material performed and released by DKP2

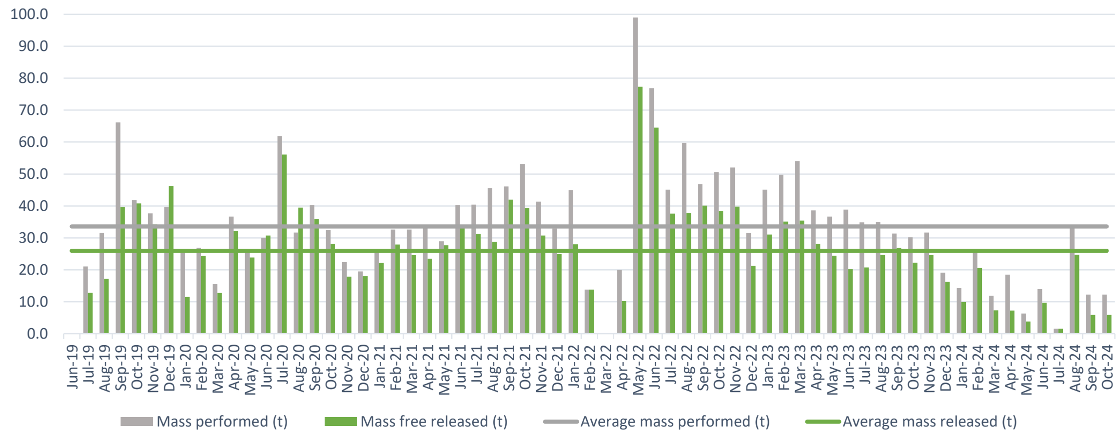


**Figure 27:** Material performed and released by DKP3

In the case of DKP1, the greatest difference can be explained by the different number of cycles that had to be carried out with the material entering the workplace in order to achieve the final material suitable for release into the environment, as DKP1 was the facility with the highest permissible operating value for the material in relation to the level of surface contamination. On the other hand DKP3 was the facility with the lowest admitted operational value for surface contamination of the metals incoming for decontamination, as it consisted of a manual blasting process, where only one process or cycle was performed, explaining the small difference between the mass performed and the mass released.

#### 3.2.8.7. KPI #7 – Monthly released mass by DKP

This KPI **illustrates the monthly performance trends of each DKP facility in terms of mass of material successfully decontaminated and released**.

As can be inferred from Figure 28 below, for the first three months of operation (June to August 2019) the greatest amount of decontaminated material was released by DKP2, almost double compared to the other two DKPs together. But from September 2019 onwards, the greatest amount of decontaminated material was free released by DKP3.

This indicates different performance and output capacities and rates depending on the type of decontaminated metallic materials that were available, dismantled and delivered to the F&D facilities. The high performance of DKP3 results from production of large metallic pieces complying with radiological operational criteria for their decontamination in DKP3 (e.g. pressuriser fragments, shielding parts from MCPs and MIVs).

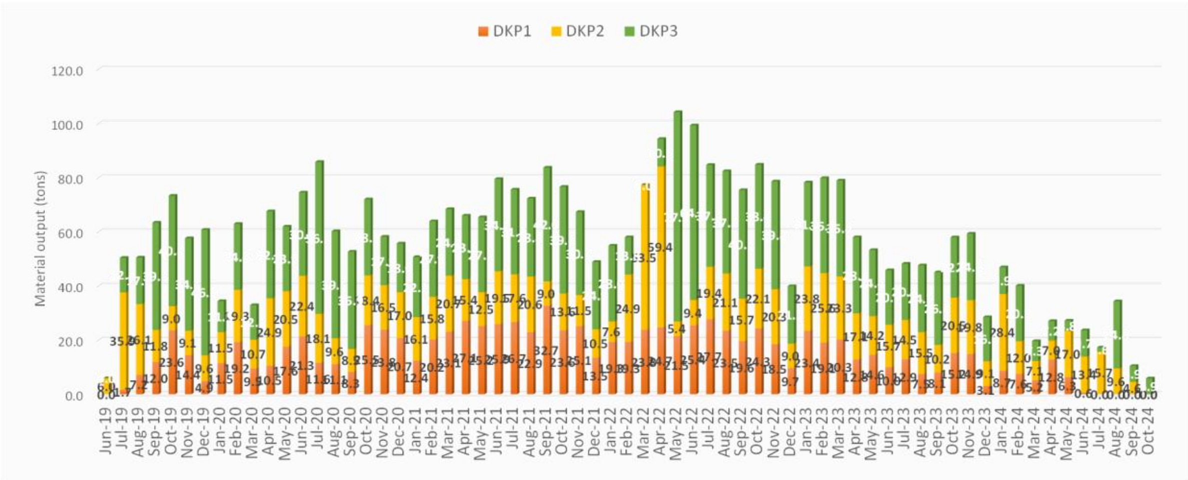


**Figure 28:** Released material by decontamination facility per month

### 3.2.8.8. KPI #8 – Distribution of output material released into the environment

If we consider the total amount of metal decontaminated and released by each decontamination facility, as shown in Figure 29, almost 45% of this amount was due to DKP3 and, together with DKP2, the abrasive blasting decontamination turned out to have performed almost 74% of the total output material released. It is important to note that DKP1 was the last facility to start operating and moreover, its operation was critical for processing of contaminated metallic materials with higher levels of surface contamination.

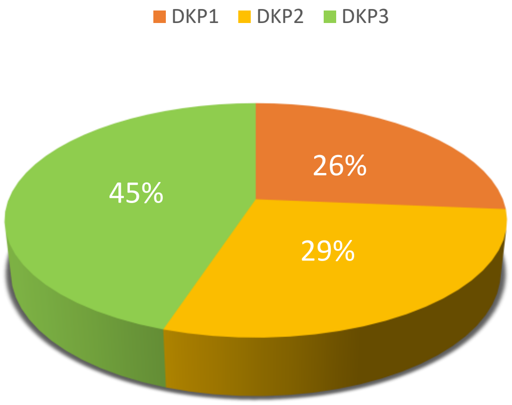


**Figure 29:** Distribution of output material released into the environment

### 3.2.8.9. KPI #9 - Performance distribution of each F&D facility

This KPI **quantifies the** share of total performed mass **processed by each DKP** (**DKP1-4**) **and fragmentation workshops** (**FP1, FP2**), in terms of individual performance, providing insight into how overall operational effort was distributed among the available F&D infrastructure. Out of the three decontamination facilities which directly released mass (DKP1, DKP2 and DKP3), DKP3 processed the largest amount of material, as expected, and, together with DKP2 both abrasive blasting facilities represent the majority of the total material performed.

With the aim of optimising the usability of the DKP2 workplace (due to the temporary lack of suitable CMM metal from the Project D4.2), only CMM materials from Project D4.4C were processed at the workplace within the period, from October 2022 to February 2023. Figure 30 also includes the mass of metals performed by the DKP 4 facility. It should be noted that within 30 months of operation, compared to 65 months for other F&D facilities, DKP 4 performed approximately 11% of the total mass. This highlights the significance and contribution of the DKP4 facility to the overall performance of metal processing and the excellent results achieved by decontamination processes within Project D4.2.

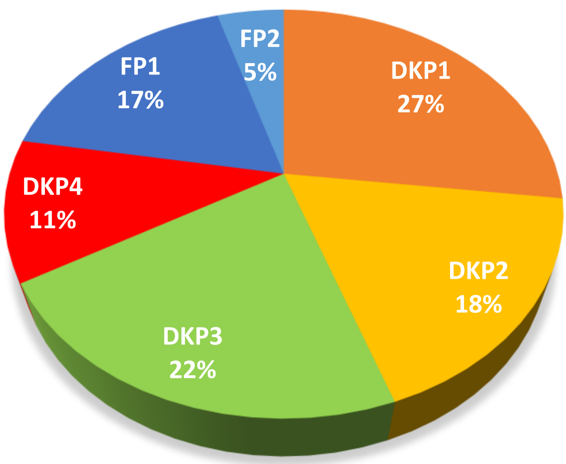


**Figure 30:** Performance distribution of each F&D facility

### 3.2.8.10. KPI #10 – Total decontamination performance status by contributing project as of the 31st October 2024

This KPI **presents the CMM processing final performance status at the decontamination facilities** as of the 31st of October 2024, marking the end of all F&D operations under Project D4.2. Figure 31 visualises the total processed mass across all DKPs, clearly segmented by contributing project (D4.2 and D4.4C) over the full 65-month operational period. This breakdown enables a better understanding of how decontamination capacity was allocated between concurrent projects.

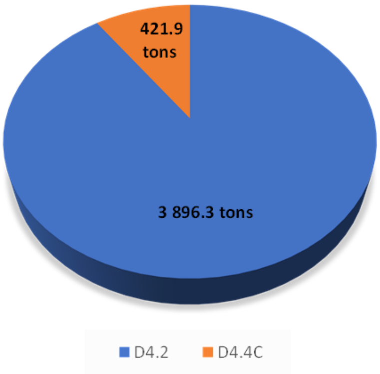


**Figure 31:** Decontamination performance status by contributing project as of the 31st of October 2024

## 3.3. Key performance indicators results

Based on the assessment presented in Section 3.2.8 of this document, the following conclusions can be drawn:

- It has been demonstrated that the operation, efficiency and performance of the individual NPP V1 F&D facilities can be considered satisfactory and represent a real and significant optimisation for the management of contaminated metals within Project D4.2.
- It has been demonstrated that all three decontamination facilities DKP1, DKP2 and DKP3 efficiently achieved the decontamination of the metals and their free release. The additional decontamination facility, DKP4, significantly contributed to improving the performance of the post-decontamination and free release of additional CMM from the other decontamination facilities, optimising and increasing the effectiveness of the Project D4.2 materials management process from the points of view of: time, ALARA and H&S.
- During the entire evaluated period of operation, the decontamination workplaces (DKP1 + DKP2 + DKP3) processed a total of 6,482.1 tonnes of metals. Given the value of 800 tonnes as the initially expected reference weight to be achieved by these plants in the first year of operation, the results proved to exceed these expectations, as the sites achieved an excellent average annual operating performance of 1,197 t and a very high level of decontamination efficiency of 98.8%.
- The total amount of metals released into the environment from V1 NPP´s F&D facilities was 3,766.4 tonnes + 501 tonnes destined for extinction or remelting, resulting in an excellent decontamination efficiency of 98.8%. The values of metallic RAW must also be deducted from the total value of the material delivered to the workplaces.
- The percentage of completion for the CMM received by the decontamination facilities on the 31st October 2024, after 65 months of operation, was at 100%.
- Technical solutions designed by the contractor and approved by the Employer were implemented to increase the efficiency of decommissioning processes, namely the implementation of new transport routes and the increased efficiency of heat production at the DKP1 workplace.
- Due to the performance optimisation of individual workplaces and the temporary unavailability of CMM material from Project D4.2 for the DKP2 workplace, only CMM from the Project D4.4C was processed at this workplace within the period, between October 2022 to February 2023.
- The new efficient process of semi-dry electrochemical decontamination of metals was put into operation (including delivery of new equipment PODEZA) in August 2022. During its operation as of the 31st of October 2024, the mobile device processed 100.5 tonnes of CMM, which did not end up as metallic RAW, rather the metals were released to the environment or were intended for decay storage.
- In the period between November to December 2024, 20.5 tonnes of CMM were processed from the demobilization of the contractor's equipment, of which 17.1 tonnes was released into the environment.

# 4. KEY TAKEAWAYS

The D4.2 decommissioning project *"Dismantling of Reactor Coolant System Large Components"* was one of the key projects for the successful completion of the second stage of V1 NPP´s decommissioning.

**One of the critical areas was the logistics of over 13,837 tonnes of materials dismantled during the implementation of the project**. A significant part of this amount was contaminated metallic material intended for post-dismantling decontamination. The process of managing this contaminated metallic material took place amidst substantial and highly technically complex activities related to the management of activated and intermediate-level RAW. However, a failure in the CMM management process would have impacted not only Project D4.2 but also the entire second stage of V1 NPP´s decommissioning.

The operation of equipment / systems for treatment of contaminated metallic materials at V1 NPP´s F&D facilities was not originally included in the scope of Project D4.2´s deliverables. This decision was based on an extensive analysis which included, inter alia, the following areas:

- an assessment of the capacity of TSU RAO treatment facilities that also treated RAW from other major producers,
- an assessment of JAVYS human resource capacity to ensure single-shift operation of the F&D facilities,
- an assessment of the storage capacities for RAW at V1 NPP.

The successful operation, efficiency and performance of each of V1 NPP´s individual F&D facilities influenced the following material management activities (emboldened below) undertaken during Project D4.2*.*

### Characterisation

The key input for acceptability of contaminated materials for treatment at V1 NPP´s F&D facilities was the characterisation of the dismantled material, based on which the optimum decontamination procedure was selected. The characterisation and activity measurement of each dismantled segment was carried out after each decontamination step.

> i The contractor's personnel responsible for the dosimetric measurement of the decontaminated fragments was present during each work shift.

The capacity of the facilities to release the material into the environment and then dispose of the material outside the controlled area was important for the continuous flow of metallic materials. The **decontaminated metallic material was registered as other waste for reprocessing according to the Waste Catalogue** after release into the environment.

### Package forms

**During the preparation phase** of Project D4.2 and preparation of the **Waste Management Plan**, an **anticipated throughput of 10,000 box pallets** were estimated. Due to the successful decontamination, the pallets were returned to circulation and **out of the 3,600 units** originally purchased, **approximately 3,200 were utilised**. Following decontamination of used box pallets, **over 1,200 units were free released** as conventional waste. **The remaining box pallets are either in circulation** for other decommissioning projects **or are being used to store materials designated for decay** in RAW storage locations.

Contaminated box pallets and pallets used in the controlled area had to be decontaminated and subsequently free released. Those that could not be released into the environment after decontamination were fragmented into drums and further managed as RAW. It is essential to include these activities in the project's scope and schedule.

### RAW storage and buffer storage

The successful decontamination process applied to contaminated metallic materials ensured a continuous flow of material throughout V1 NPP´s decommissioning. The material was processed within the decommissioned nuclear facility without the need for its transport or re-storage due to the capacity of the decontamination facilities located at the TSU RAO.

### Secondary RAW from the decontamination of contaminated metallic materials

**Liquid RAW:**

- Decontamination solutions
- Rinsing water

**Solid RAW:**

- Abrasives from the dry decontamination workplaces
- Protective equipment and instruments
- Cloths
- Tools

It is essential that decontamination media used during the decontamination process can be subsequently processed. At JAVYS, contaminated decontamination solutions and abrasives from the dry decontamination workshops were processed through cementation into an FCC with cement grout.

**The decision to include the operation of F&D facilities resulted in the following benefits conducive to V1 NPP´s successful decommissioning:**

- The ensured and continuous operation of the F&D facilities with the production of contaminated metallic materials. Two-shift operation during periods of high production and, in the case of the DKP1 workplace, round-the-clock operation was ensured.
- The costs planned for the establishment of a contaminated metallic materials storage facility outside V1 NPP were not drawn on and were used for other decommissioning projects. The original purpose of the storage was to serve as buffer storage. The contaminated materials were processed at V1 NPP without the need for re-storage.
- The number of RAW shipments outside of V1 NPP decreased significantly.
- Costs for the purchase of new box pallets for the contaminated metallic materials were saved. Package forms were put back into circulation after material decontamination for V1 NPP´s other decommissioning activities.
- High decontamination efficiencies significantly increased the amount of material released into the environment, as well as the subsequent hand overs for reprocessing and recycling. The profit from the sale of the scrap was used for other V1 NPP decommissioning activities.
- The costs of RAW treatment were reduced due to the high decontamination efficiency. Some unreleasable material after decontamination with activity just above the limit for release into the environment will be stored for about 10 years and then released.

## 4.1. Lessons Learnt

The implementation of material management strategies during Project D4.2 offered valuable lessons learnts (LLs) that will be beneficial for future nuclear decommissioning projects. These LLs span technical, operational and strategic aspects of the work and highlight the importance of integrated planning, regulatory awareness and on-site capability development. A couple of high-level LLs have been provided in the following paragraphs and a list of detailed LLs can be seen below.

Management of materials is an important part of the safe decommissioning of nuclear installations. The process involves a number of steps to ensure that RAW is properly managed, stored and disposed of so as not to endanger people or the environment. All materials management is governed by strict standards and legislation to minimise the risk of radioactive substances releases and to ensure the protection of human health and the environment. This process is key to maintaining the safety and sustainability of peaceful nuclear power generation.

Proper and responsible management of conventional waste reduces environmental impacts and ensures that waste materials are disposed of or recycled in a manner that complies with international and national standards. This is very important for long-term sustainability and safety.

### LESSONS LEARNT (LL) 1 / 2

**LL-1. Early and detailed radiological characterisation is critical**

Accurate and early characterisation of dismantled materials enables efficient planning of workflows and waste routing.

**LL-2. Material flow segregation improves efficiency**

Systematic segregation of materials by activity level, form and composition helps optimise processing routes and ensures compliance with regulatory requirements. This step is essential to maximising material that could be released to the environment or reused.

**LL-3. Multidisciplinary coordination enhances project resilience**

Coordination across engineering, radiological protection and logistics teams is essential for meeting project objectives..

**LL-4. The high performance of F&D facilities reduced the costs of package forms**

The high performance of F&D facilities increased the turnover of package forms and thereby reduced the costs associated with purchasing new ones.

**LL-5. Optimised material flow and recycling**

Sufficient capacity for material characterisation and free-release workplaces is crucial, as it enables a continuous flow of material and eliminates the need for temporary storage. At JAVYS the high success rate of decontamination allowed the free-released material to be recycled, which not only contributed to environmental protection but also ensured full compliance with legislative requirements and human safety principles.

## LESSONS LEARNT (LL) 2 / 2

### LL-6. On-site processing infrastructure offers significant benefits

Operating the existing F&D facilities in V1 NPP´s controlled area simplified logistical complexity, cut down expenses for RAW transport and off-site storage, and optimised waste processing, all while promoting adherence to the ALARA principle.

Treatment of contaminated metallic materials at V1 NPP´s F&D facilities was only one, yet significant, part of a more complex process of RAW management employed during V1 NPP´s decommissioning. The significant amount of treated material with high decontamination efficiency had a positive impact on the safety process and efficiency in the subsequent phases of RAW management, which includes conditioning, storage and disposal.

### LL-7. Strong documentation and traceability are fundamental

Maintaining detailed records of characterisation, handling and clearance decisions ensures full traceability of each material stream, supports regulatory audits and contributes to knowledge transfer objectives under the NDAP framework.

### LL-8. Integrated waste management planning supports long-term goals

A lifecycle perspective on material handling, from dismantling to final disposal, is essential to minimising RAW volumes and ensuring alignment with national disposal infrastructure capacities. At JAVYS, effective decision-making, with a focus on future activities, resulted in the efficient utilisation of generated waste. A prime example is the use of the F&D facilities processing contaminated metallic material from V1 NPP´s decommissioning projects. The high efficiencies achieved allowed for the release of much more material into the environment than originally anticipated, which reduced disposal capacity and saved financial resources.

## 4.2. Recommendations

Based on the implementation experience and outcomes of Project D4.2, the following recommendations (Rs) have been proposed for future nuclear decommissioning activities involving complex material management. These aim to enhance efficiency, reduce risk and align with best practices across the EU decommissioning sector.

### RECOMMENDATIONS 1 / 2

#### R-1. Prioritise early investment in on site processing facilities

Future projects should invest in on-site fragmentation and decontamination capabilities wherever feasible. This minimises transport requirements, improves safety and reduces cost while maintaining greater control over material handling.

#### R-2. Placement of processing facilities on site

When planning the placement of processing facilities, design the connection of auxiliary systems in such a way that the operation of such systems does not impact future projects.

#### R-3. Secondary waste from processing facilities

Processing of metallic contaminated materials generates both solid and liquid secondary waste. Used decontamination solutions and spent abrasive media must be processable in other facilities available on site.

#### R-4. Standardise and automate radiological characterisation

The adoption of automated and standardised radiological measurement tools, such as spectrometric scanning systems and mobile counting stations, can improve data quality and accelerate material classification, particularly for high-volume projects.

#### R-5. Develop and maintain integrated material flow models

An integrated digital model mapping all material flows from origin to endpoint (characterisation, processing, release, recycling or disposal) should be developed at the planning phase. This enables proactive scenario management and regulatory compliance tracking throughout the project lifecycle.

#### R-6. Strengthen KPI-based performance monitoring

Future decommissioning projects should establish a consistent set of KPIs from the outset, linked to safety, efficiency and cost. These indicators should be reviewed at regular intervals to enable adaptive management and reporting.

## RECOMMENDATIONS (Rs) 2 / 2

### R-7. Expand workforce cross-training in material management

Staff involved in material handling, logistics and characterisation should receive cross-training in radiological protection, documentation standards and regulatory frameworks to improve responsiveness and reduce errors.

### R-8. Incorporate circular economy principles

Material management strategies should incorporate reuse and recycling goals aligned with the circular economy. Whenever technically and legally feasible, materials should be processed for secondary use rather than being designated as waste.

# REFERENCES


/1/ Act No. 541/2004 Coll. on the Peaceful Use of Nuclear Energy (Atomic Act) and on Amendments and Supplements to Certain Acts, as amended.

/2/ Decree of the Nuclear Regulatory Authority of the Slovak Republic No. 58/2006 Coll., laying down details on the scope, content and method of preparation of documentation of nuclear installations necessary for individual decisions, as amended.

/3/ Act No. 124/2006 Coll. on Occupational Health and Safety and on Amendments and Supplements to Certain Acts, as amended.

/4/ B6.5-D13.1 Treatment and Transportation Plan of Radioactive Waste from Decommissioning 2nd Stage

/5/ B6.5-D13.2 Conventional and Hazardous Waste Management and Shipment Plan from the 2nd Stage of Decommissioning