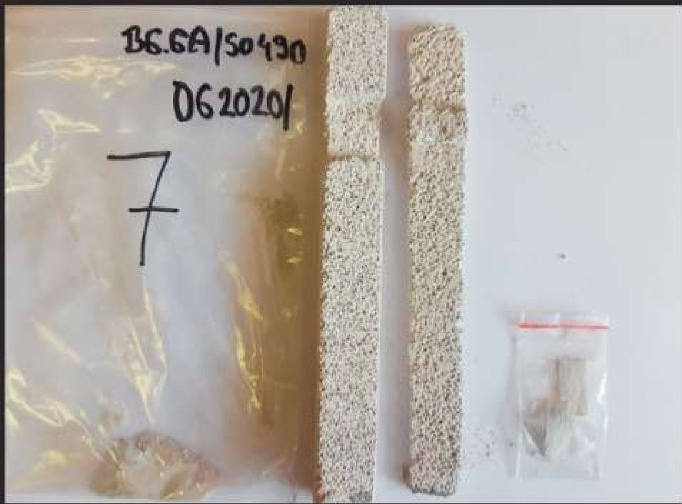

Establishment and Update of a Decommissioning Database in V1 NPP Decommissioning Process

GUIDELINES

KP-JAVYS-004

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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 (RAW). 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 abovementioned 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 under implementation in the JRC Nuclear Decommissioning and Waste Management Directorate (NDWMD), which becomes a knowledge generator extracting the knowledge from the ongoing decommissioning activities at the different sites (Geel, Ispra, Karlsruhe, and Petten).

The JRC NDWMD aims to become a Centre of Excellence in nuclear decommissioning knowledge management and develop a decommissioning knowledge platform which allows exchanging information and building on the best practices in the EU inside the multi-annual financial framework (2021 – 2027) strategy. The operational phase of the project is expected to start in 2024 to develop ties and exchanges among EU stakeholders and 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, to develop potential EU synergies.

This is a Knowledge Product prepared by JAVYS a.s., Slovakia for the JRC NDWMD.

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[1] Council Regulation (Euratom) 2021/100 of 25 January 2021 establishing a dedicated financial programme 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 nuclear power plant in Lithuania and repealing Regulation (EU) No 1369/2013

PRODUCT DESCRIPTION

The guideline "*Establishment and Update of a Decommissioning Database in V1 NPP Decommissioning Process*" was prepared by a team of experts from JAVYS at V1 Jaslovské Bohunice Nuclear Power Plant in Slovakia. The guidance and recommendations of this product are collected from the experience gained during the execution of the BIDSF Project B6.4 "*Decommissioning Database*" and BIDSF Project B6.6A "*Decommissioning Support Surveys*", sponsored by the European Commission via the Nuclear Decommissioning Assistance Programme (NDAP) between years 2008 to 2023.

The guideline presented in this report aims to assist EU decommissioning operators in charge of facility decontamination, contractors, research facilities personnel set out a framework for establishing an effective database for inventory characterisation, both physical and radiological, while considering certain specific aspects involved in this process.

This product was developed as part of an effort to disseminate and share with all EU State Members the knowledge acquired during the decommissioning and radioactive waste management activities performed with NDAP funding.

ABSTRACT

The guideline "*Establishment and Update of a Decommissioning Database in V1 NPP Decommissioning Process*" aims to highlight the importance of physical and radiological characterisation in individual phases of decommissioning of a nuclear facility since it lays a solid foundation for the identification of contamination, assessment of potential risks, cost estimation, planning and implementation of decommissioning. If sufficient attention is paid to it in the initial planning stages, time, effort and costs may be significantly reduced. Therefore, it is considered a precursor to decommissioning. This guideline provides decommissioning and waste management organisations with technical guidance to successfully compile a decommissioning database, which will record all physical and radiological inventory data required for decommissioning.

OBJECTIVE

To provide a process to implement a comprehensive physical and radiological decommissioning inventory database, capable to store and manage all the physical and radiological information on buildings, structures, equipment and media, required for planning and implementing a decommissioning process of a nuclear facility. A special regard must be taken in respect of the need for its continuous update and data collection, which goes hand in hand with the progress of decommissioning activities.

APPROACH

This guideline was developed by JAVYS on the basis of a teamwork of our experts in cooperation with the contractor during the then-ongoing process of compiling a decommissioning database suitable for the needs of planning and implementation of V1 NPP decommissioning and during a material characterisation process, by incorporating experience gained and lessons learnt into developing this guideline.

RESULTS, FINDINGS, AND INSIGHTS

This document provides guidance to establish an inventory database suitable for the needs of decommissioning of a nuclear facility, including useful tips from its initial creation to continuous updating. Considerations that should be included in the decision-making process are:

1. Decision on whether it is necessary to create a completely new system application or only to expand the existing inventory database from the operation period with a suitable module that would allow collecting data relevant for decommissioning purposes.

2. Early decision on property rights in order to prevent any limitations between the developer of the database system and the end user

3. Decision on how to manage the physical and radiological inventory process to ensure it would be an uninterrupted process starting from the pre-decommissioning phase up to the site release without large time gaps and possible loss of knowledge.

4. Decision of how new and updated data will be incorporated into the decommissioning database with the progress of dismantling works to reflect the most current on-site conditions of a nuclear facility, serving as input data for planning of further decommissioning activities.

Based on information provided in this document, the user can create a site-specific inventory database suitable for the decommissioning purposes of a nuclear facility, during its planning and implementation phases. The desired output of this document is understanding the importance of having the most detailed and updated database since it provides crucial information to support facility dismantling; the management of material and waste production; the protection of workers, the public and the environment; and associated cost estimations.

TARGET USERS

Every operator of a nuclear facility responsible for decommissioning, including their internal and external staff taking part in planning, preparation, managing and supervision of safe, effective nuclear decommissioning processes and waste management. They will benefit from JAVYS experience gained during the process of compiling and updating the decommissioning database.

For experts having enough background information on the matter. It might be useful for them to get to know the process applied in another nuclear facility and the challenges that had to be dealt with, including lessons learnt.

APPLICATION, VALUE AND USE

This guideline aims to provide a systematic way of creating a decommissioning database, taking into account lessons learnt and limitations based on experience of JAVYS experts involved in the respective projects.

Another organization can use this guideline directly; however, the local context and plant conditions have to be considered. Customization may be required, since a platform selected to host a decommissioning database may require changes to reflect the users' specific needs by configuring layout, content or functionality. This will let users make their own selections about what data they want to include in the decommissioning database, or set preferences for how information is organized, displayed and further updated.

Moreover, a detailed and updated decommissioning database with physical and radiological inventory is a useful source of information for communication with regulatory authorities in addition to the above-mentioned benefits in planning, managing the decommissioning of a nuclear facility and maintaining the highest possible level of safety.

The final results are used for preparation of different issues, such as determining decontamination processes, dismantling procedures and tools, radiological protection, materials management (radioactive, non-radioactive and hazardous) and costs planning, allowing the optimisation of the decommissioning planning.

KEYWORDS

Decommissioning, Nuclear power plant, Nuclear facility, Decommissioning database, Inventory database, Radiological characterisation, Survey, Characterization, Facility Characterisation, Programme Management.

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LIST OF ACRONYMS AND DEFINITIONS

ARSOZ	Information system for support of equipment maintenance, operation and administration
BIDSF	Bohunice International Decommissioning Support Fund established and administered by EBRD in compliance with the fund rules
Characterisation	A systematic identification of the types, quantities, forms, and locations of contamination within a facility.
Characterisation survey	A type of survey that includes facility or site sampling, monitoring, and analysis activities to determine the extent and nature of contamination. Characterisation surveys provide the basis for acquiring necessary technical information to develop, analyse, and select appropriate clean-up techniques.
DDB	Decommissioning Database
D&WM	Decommissioning and Waste Management
EBRD	European Bank for Reconstruction and Development
Hazardous materials	Hazardous materials for the purposes of this report are materials and chemical substances that potentially, in the scope of decommissioning, may become hazardous waste.
HAS	Historical Site Assessment
IAEA	International Atomic Energy Agency
JAVYS	Jadrová a vyraďovacia spoločnosť, a.s. (Nuclear and Decommissioning Company), a state-owned joint stock company responsible for V1 NPP decommissioning
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
NDAP	Nuclear Decommissioning Assistance Programme
NPP	Nuclear Power Plant
Radiological characterisation	Determination of the nature, location and concentration of radionuclides at a nuclear installation
RAW	Radioactive waste
RNV	Radionuclide vector (determines specific presence of radionuclides in substance in certain time)
Survey	A systematic evaluation and documentation of radiological measurements with a correctly calibrated instrument or instruments that meet the sensitivity required by the objective of the evaluation.
V1 NPP	V1 Nuclear Power Plant Bohunice

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1. BACKGROUND

In the context of the negotiations for accession to the European Union, the Slovak Republic took the commitment to close and subsequently decommission Unit 1 and Unit 2 of Jaslovské Bohunice V1 NPP by 2006 and 2008, respectively.

When a nuclear facility is about to be shutdown permanently, the process of a radiological characterisation should follow as soon as possible. This is because it is crucial for decision-making and planning, especially during the transition phase when operation has ceased, and during the implementation of decommissioning. It helps to determine the type, isotopic composition, and extent of contamination in structures and systems, as well as to define the extent of remedial activities and decontamination, and thereby helps to estimate the total costs of decommissioning.

During V1 NPP operation, from 2003 to 2005, an information system ARSOZ for management and maintenance of technological equipment was developed and updated. This system provided comprehensive information on the location and state of equipment; it enabled reporting of faults, creation of various tasks and work orders for corrective and planned maintenance. However, this database did not include the complete physical inventory of V1 NPP and for the purposes of decommissioning, it was practically empty since at that time, it did not include any radiological data.

Considering the planned termination of operation of both units of V1 NPP and related planning of decommissioning activities, the need to characterise the plant from a radiological point of view came to the fore. The radiological inventory of a facility shall be developed based on a facility characterisation, which involves a set of activities, such as investigations, measurements, and calculations that start from the knowledge of the facility and its operational history. This was done within the scope of the project B6.4 “*Decommissioning Database*” launched in 2008. It aimed to generate an integrated decommissioning database, including a database of equipment, buildings, and rooms of V1 NPP, as well as physical and radiological inventory and other characteristics required for planning and performing decommissioning activities. The project was completed in 2011, in the same year when all pre-decommissioning activities were completed, and the first stage of V1 NPP decommissioning started.

In this first stage of V1 NPP decommissioning, the dismantling of inactive systems and equipment and demolitions of auxiliary civil buildings were performed. The processing of radioactive wastes produced from the operation was completed. The first stage activities included the following:

- Removal of inactive systems and demolition of buildings, which were no longer needed for the support of dismantling activities later in the second stage of decommissioning. These included the removal of systems in the turbine hall (turbine and the entire technology of the so-called secondary circuit – Balance of Plant), demolition of power transformers and switchboard structures, civil buildings related to cooling, removal of back-up systems for operation and demolition of the diesel generator station, dismantling of some external tanks and preparation of temporary and buffer storage facilities to store waste on-site.
- Modifications of civil buildings for their future use.
- Development of technical and procurement documentation for activities planned to be implemented in the second stage of V1 NPP decommissioning.

The first stage of V1 NPP decommissioning was completed on 31 December 2014.

The aim of the second stage of V1 NPP decommissioning (2015-2027) is the decommissioning of structures and buildings in the power plant nuclear island, i.e., the reactor, steam generators, main reactor building, auxiliary operations building and remaining auxiliary buildings, which had not been decommissioned in the first stage of decommissioning. The main activities in the second stage of V1 NPP decommissioning are the following:

- Dismantling of Units 1 and 2 reactors and the primary circuit equipment.
- Dismantling of other equipment in the controlled area.
- Removal of contamination from technologies and from buildings and subsequent radiation monitoring of the cleanliness of systems and buildings.
- Demolition of original buildings down to their foundation slab.
- Site restoration and its release under the administration of the Atomic Act with subsequent release into the environment for unrestricted industrial use.

At the time when the project B6.4 "*Decommissioning Database*" was implemented (2008-2011), full access to several areas of the plant, equipment and systems (e.g., spent fuel pools, ventilation ducts, etc.) was not granted due to the radiation safety reasons. Another limitation was, that after completion of the project, the database comprised information on accessible systems and civil structures only. Those inaccessible areas, system components and equipment were not surveyed with sufficient detail regarding their radiological conditions, or their characteristics data were obtained by empirical calculations. This necessitated a launch of the project B6.6A "*Decommissioning Support Surveys*", which has been ongoing since 2017 and will be completed by the end of 2023. Its aims to execute radiological and hazardous materials sampling as well as laboratory analyses for the supporting characterisation within V1 NPP decommissioning.

1.1. Current Practice in V1 NPP

The company JAVYS uses a system ARSOZ for several tasks at V1 NPP. ARSOZ is a database integrated modular information system designed for complex management and maintenance of technological equipment. It is divided into applications, which are divided into modules. It is primarily intended for energy companies that use complex technological equipment requiring regular maintenance and its management (nuclear, thermal and hydropower plants). ARSOZ allows the user to add, delete, change, search, print and export records, or display the required information.

Since its establishment in 2003, this information system underwent necessary adaptations and extensions to store all V1 NPP physical and radiological inventory data for decommissioning maintenance and management purposes. It was not necessary to create a new database system but to design a new module within the existing ARSOZ system. This database had the flexibility to add new fields and tables with new characteristics – data necessary for decommissioning management – e.g., radiological data such as information on equipment/room categorisation from the decommissioning point of view, surface contamination (inside and outside), volumetric activity and dose rate. The existing table structure was modified and extended to handle and manage the necessary inventory information. This new application module was named DDB – **Decommissioning Database** and it records data collected during the implementation of the projects from both the first and second stage of V1 NPP decommissioning into the ARSOZ system.

The **initial characterisation** of the V1 NPP was completed before the start of the first stage of decommissioning in 2011. Stage I of decommissioning (2011-2014) used the outputs from the Decommissioning Database (B6.4) in full range for planning and procurement documentation preparation purposes. Technological components and building structures of the nuclear power plant, which were subject to decommissioning, were additionally physically inventoried and radiologically characterised. Characterisation for the presence of dangerous substances was performed.

The original ARSOZ database from the V1 NPP operation period included the following data related to physical inventory:

- There were about 45,000 items of technological equipment, and about 70% of them had a record in the ARSOZ database. However, none had radiological, material, and physical characterisation information.
- There were about 1,000 items of buildings and rooms, and about 90% of them had a record in ARSOZ database, including only basic information. From a decommissioning point of view, this database was empty.

Currently, **the updated ARSOZ database**, after initial characterisation and additional characterisations, includes:

- There are about 77,000 items of technological equipment, all with radiological, material, and physical characterisation information.
- There are about 2,200 items of buildings and rooms, all of which have a record in the ARSOZ database.

1.2. New Practices Contained in this Guideline

Once the physical inventory of V1 NPP was developed, the second step was the radiological characterisation of all the items identified in the physical inventory because each item must have associated a radiological classification. This data was collected as part of the project B6.4 "*Decommissioning Database*". However, V1 NPP decommissioning has been in its Stage II since 2015, dealing with decommissioning of structures and buildings in the power plant nuclear island, i.e., the reactor, steam generators, main reactor building, auxiliary operations building and remaining auxiliary buildings. During the performance of these activities, where a lot of dismantling projects were in progress, a need for more detailed characterisation, categorization and re-characterisation occurred. This is mainly to detect and avoid situations when application of decontamination and dismantling techniques could cause complications or for a simpler reason, to supplement radiological data from areas that had been previously inaccessible. After implementation of certain decontamination activities, it became obvious that a new radiological characterisation was required as one of the key factors for the continuation of successful decommissioning, with the main goal to update the radiological inventory and the waste management plans. The need for a new level of information necessitated the launch of the project B6.6A "***Decommissioning Support Surveys***" in 2017.

At the beginning of the project, it was estimated that the entire V1 NPP decommissioning process would be completed by the end of 2025; however, this final deadline was reassessed and is currently set at the end of 2027. The project B6.6A, "Decommissioning Support Surveys", will only ensure additional characterisation until the end of 2023. The main project activities include the provision of updated estimates of site-specific parameters (radiological & hazardous) used for detailed planning and control of decontamination activities. This additional characterisation supports decommissioning activities, determining whether the decontamination process has achieved the corresponding targets and when a survey unit or group is ready for the final survey (through confirmatory surveys). Specifically, it aims to **implement a sufficient and metrologically correct monitoring capability to check the consistency of initial and final conditions of the decontamination projects and the achievement of the established acceptance criteria**.

This project does not cover the final survey and activities related to site release; however, it will provide essential data for elaborating Optimization studies in the future to support V1 NPP delicensing.

Figure 1: V1 NPP Timeline

1.3. Relevance of New Guidance

This guideline is focused on creating an effective decommissioning database. It aims to highlight the significance and crucial importance of radiological characterisation during a nuclear facility's pre-decommissioning and decommissioning phases. The importance of radiological characterisation should not be underestimated since it lays a solid foundation for identifying contamination, assessing potential risks, cost estimation, planning and implementation of decommissioning. If sufficient attention is paid to it in the initial planning stages, a significant reduction of time, effort and costs may be achieved; therefore, it is considered a precursor to decommissioning.

Before starting the decommissioning process, knowing the exact material and radiological composition of systems, and building structures, including activated materials and hazardous materials is indispensable.

This information will assist the planners in determining factors such as the need for decontamination, shielding or remotely operated equipment, waste management and disposal, and potential radiation exposures to the workforce. Otherwise, inaccuracies would be reflected in the assignment of decommissioning projects. This would result in incorrect allocation of personnel and technical resources, disproportionate price increases and, finally, non-compliance with set deadlines. As already indicated and having in mind creating a safety-first decommissioning culture, adequate characterisation provides crucial information to support the protection of workers.

Radiological characterisation provides a lot of input data. It thereby helps to estimate parameters such as the required amount of decontamination, how much waste will be produced, quantities of material eligible for free release, and the decision on the application of manual dismantling techniques or remote control that would otherwise be associated with a significant uncertainty of costs.

Following, continuous sampling is appropriate during decommissioning activities. The most significant advantages of continuous sampling are:

- To summarise the **complete itinerary of the plant and remove uncertainties of areas where** fixed systems and equipment are removed.
- Achieve the information on **actual radiological conditions of spaces** after the decontamination activities performed.
- Possibility to perform a **direct local characterisation of hot spots on demand** in case of unexpected changes during the implementation of projects.

2. SCOPE OF THE GUIDELINES

The guideline covers essential aspects relating to the practical implementation of establishing a decommissioning database and following the initial and supporting characterisation process when undertaking the decommissioning of a nuclear facility. It details the characterisation conditions in V1 NPP Jaslovské Bohunice during various phases of the life cycle of this nuclear facility, mainly characterisation during the transition phase (after final shutdown before initiation of dismantling) and characterisation during dismantling (including remediation and decontamination). It does not cover characterisation to support the final status survey for site release from regulatory controls since this activity is only planned as part of the very last V1 NPP decommissioning project, "*Decontamination and Demolition of V1 NPP Buildings and Site Restoration*", which is currently in the procurement phase (2023).

An essential part of the project scope will be the final radiological survey and elaboration of the Optimisation study for the successful site release. The Slovak Nuclear Regulatory Authority and Public Health Authority must approve the Optimisation study. Only then the V1 NPP site can be released from the scope of the Atomic Act for unrestricted use in line with the relevant Slovak and EU legislation.

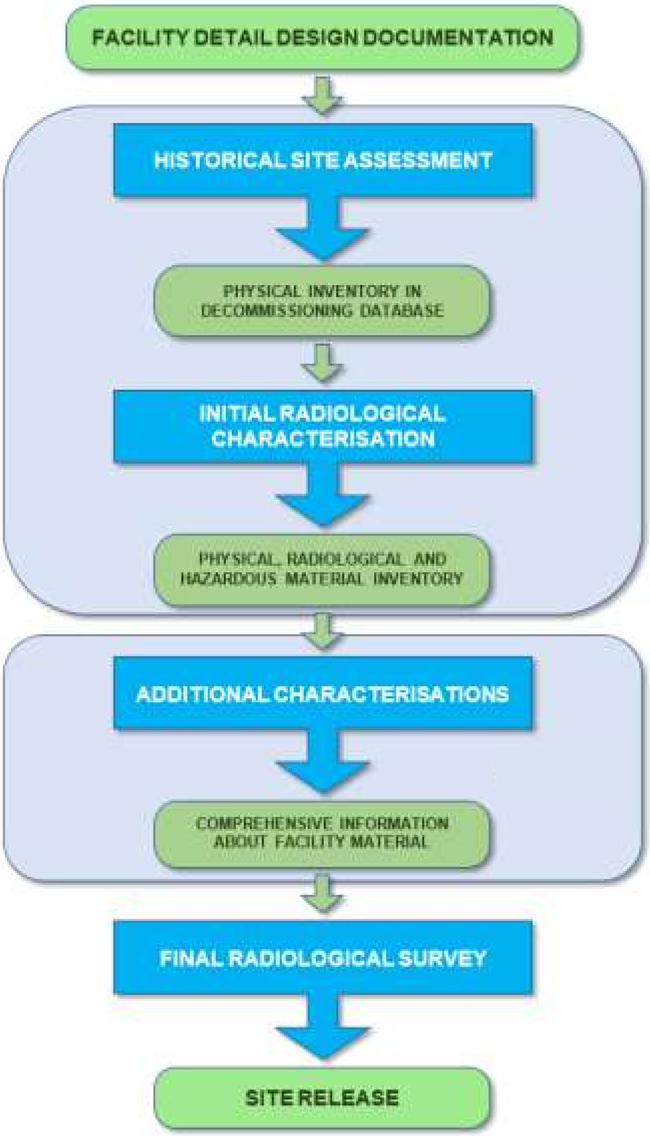

Figure 2: Characterisation steps for V1 NPP decommissioning.

3. A DECOMMISSIONING DATABASE AND ITS CONTINUOUS UPDATE

3.1. Part 1: Initial Characterisation

Initial characterisation is the first step in the decommissioning process. It helps to gather enough data to evaluate the facility's radiological status and identify as many problem areas as possible to select a suitable decommissioning strategy and plan a decommissioning programme. Therefore, a pre-requisite is a reliable database containing information on the quantity and type of radionuclides, their distribution, and physical and chemical states.

3.1.1. Create a decommissioning database

To have an inventory database that would be suitable for decommissioning purposes, it is necessary to assess whether there already exists an inventory database from the plant operation period that could be modified to serve as a decommissioning database as well or a completely new database will have to be established.

If there is an existing database, the user should analyse it in order to prepare the detailed design for modification of the DDB. The DDB will be a tool merging all the data concerning the physical and radiological inventory of the plant.

This database will help the user to divide the decommissioning materials (radioactive, non-radioactive and hazardous) into different streams according to the end destination that will be defined.

In the V1 NPP, it was not necessary to create a new database system, but to design a new module within the existing ARSOZ system that would allow modification of the DDB structure and extend the stored data. To ensure the data structure integrity and consistency in the usage of the ARSOZ applications, standard code lists for all ARSOZ applications had to be defined.

The DDB software modification should ensure the following capabilities to allow the users multi-criteria searching and sorting out of all the data recorded in the DDB, but not limited to:

- Allowing the user to create new records, select, display, modify and print all information concerning specific equipment/civil structures or for a group of equipment/civil structures.
- Allowing the user to obtain all information recorded in the DDB concerning either selected individual equipment/civil structure or group of equipment/civil structures grouped according to the technological system, buildings, or room structure.

Resolving all the property rights and copyright issues before implementing any software modifications is advisable.
In the V1 NPP, due to limitations of the property rights established between the developer of the ARSOZ database system and the end user (JAVYS), the Consultant's experts could not have been provided access to the system to the necessary extent. To implement these partial tasks, the developer of the ARSOZ system had to be subcontracted as they were the owners of the licenses to implement the required software changes to the existing system.

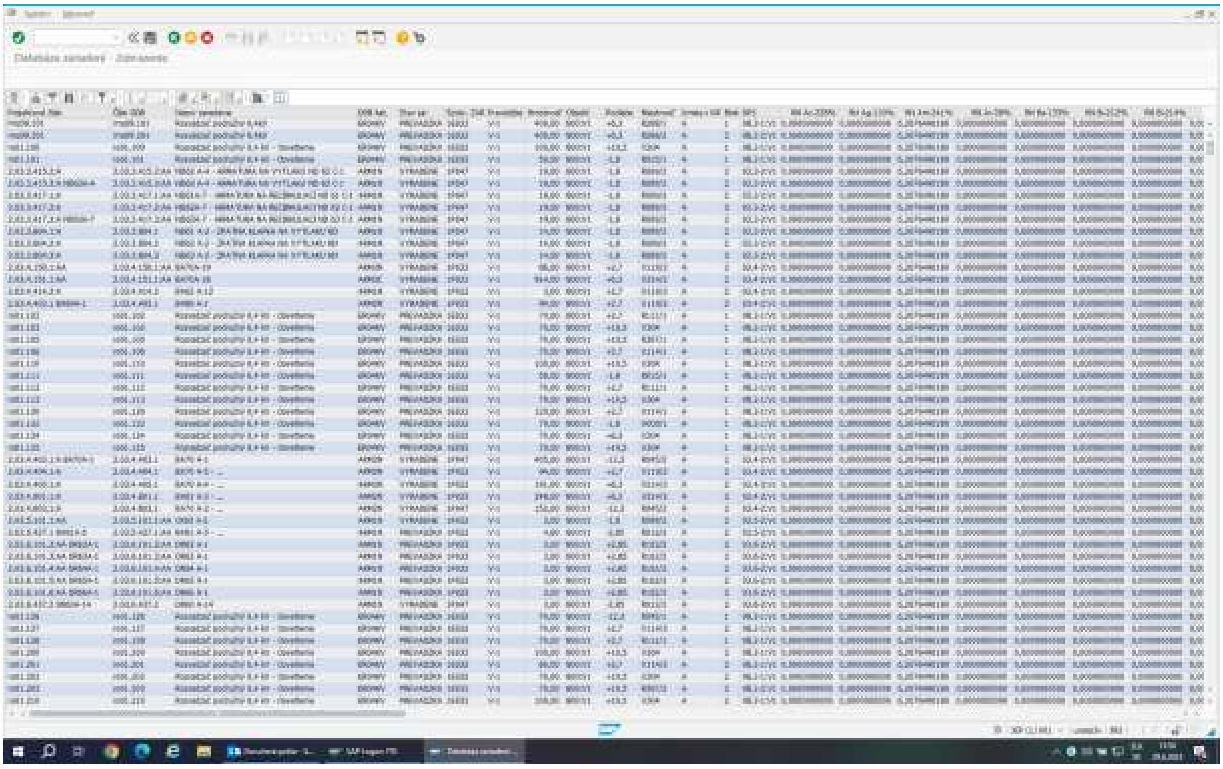

Figure 3: Visualization of DDB in V1 NPP including physical and radiological data.

3.1.2. Assess existing data and information

The next step is to provide the input data necessary for preparation and development of the physical and radiological inventory. This is to be done by means of **Historical Site Assessment (HSA)**, which shall summarize all existing historical data concerning the physical and radiological characterisation, environmental conditions, and operational history of the plant. Discussions with operational staff, incident reports, and occurrences provided all known historical physical and radiological data. These data represented hints for hot spots and showed areas that should be focused on.

The spots were then highlighted during development following characterisation plans. More detailed and specific sampling was chosen around the spots. The analyses results were recorded in the DDB. The primary purpose of HSA was to collect existing information concerning the site and its surroundings. The HSA was then finished, and characterisation activities started. HSA should consist of the following tasks:

- Review of the plant technical documentation.
- Visual inspections in those areas where the materials of interest are located.
- Meetings with the personnel that have operated the plant.
- Development of HSA Report.

HSA Report shall identify, collect, organize, summarize, and evaluate information on the relevant NPP that could be used as a basis for planning and realising the plant's physical and radiological characterisation, including assessing present hazardous substances and future remediation activities on the site. More specifically, this report shall:

- Provide summarised information on the physical configuration of the NPP.
- Provide preliminary information on the presence and distribution of hazardous substances and radioactive materials on the site.
- Identify media, equipment, civil objects, and outer areas that are contaminated (impacted) or potentially contaminated by hazardous substances and/or radioactive nuclides and provide its initial preliminary radioactive contamination classification by the level of contamination that will be used to guide future characterisation and remediation efforts.

- Identify the main radioactive nuclides and hazardous substances/contaminants of NPP that shall be included in the scope of the characterisation phase.
- Describe information sources and the methods used to collect the information.
- Provide an assessment and evaluation of the collected information to indicate weaknesses and/or reliability of the provided information and gaps in the information.
- Indicate areas of further investigation required/recommended to substantiate unreliable information and/or to fill gaps in the available information.

3.1.3. Carry-out a comprehensive physical inventory of the plant

The physical inventory means physically counting the items (buildings, rooms, systems, equipment, components, materials, and media) in the plant at a particular date and time. The authorisation holder will maintain the itemised records during the decommissioning process using the DDB.

The physical inventory should consist of specific data related to mechanical and electrical equipment, civil structure (floor, ceiling, walls, etc.), and operational and environmental media (soil, subsurface soil (vadose or non-saturated zone, saturated zone, surface, and underground water).

Each entity shall be characterised from the material properties point of view. It is advisable to take a picture of each equipment and room/civil structure and record it into the DDB. Each picture shall be assigned to the relevant equipment or room/civil structure.

In the V1 NPP, the first step of the physical inventory development was existing data export from the ARSOZ database in the agreed format. The physical inventory was developed so that every piece of equipment, civil structure, and operational and environmental media related to the decommissioning had unique identification in the DDB, compatible with the database system structure ARSOZ.

3.1.4. Estimate radiological inventory of the plant

It is recommended to achieve this activity by the following steps:

1. **Collect and merge** all radiological data currently available on-site, including inserting these data into the database.
2. **Design, planning and performing** of the initial radiological characterisation campaign.
3. **Estimation** of the radiological inventory of the plant based on the results of the radiological characterisation campaign.

To perform the radiological and hazardous material investigation of a relevant NPP, the Sampling and Analysis Plan shall be developed to describe the basic approach, schedule, detailed methodology and quality assurance measures. It is advisable to consider **MARSSIM** (Multi-Agency Radiation Survey and Site Investigation Manual [13]), which will define a procedure for obtaining sufficient quality and quantity data. This Sampling and Analysis Plan shall determine:

- Quality Assurance Plan specific to this task describes the policy, organisation, and functional activities.
- The location and number of the planned measurements and samples and selection of the measurement methods measurements needed to perform radiological characterisation.
- The location and number of the planned samples and selection of the measurement methods needed for soil contamination and civil structures detection for hazardous material – oil products and chemicals.
- Initial radiological characterisation criteria.
- Methodology for data analysis.
- The characterisation programmes.
- Setting up the rules for data handling – procedure for data import to the existing DDB.

In the V1 NPP, the following types of taking samples were performed during the initial sampling process:

- Dose rate measurement.
- Direct-reading surface contamination measurement.
- On-site gamma spectrometry measurement.
- Wipe test to measure the non-fixed surface contamination.
- Electrochemical sampling of the corrosion and surface layers of metal materials.
- Sampling by scraping from carbon steels.
- Liquid and sludge sampling.
- Concrete sampling from the civil structures.
- Soil sampling.
- Determination of hazardous materials - polychlorinated biphenyls, asbestos, oils and gasoline products, detergents.

Activated Material Inventory

The next step is estimation of **activated material inventory**. The Activated Material Inventory Report will provide relevant information on the activation of materials belonging to the relevant NPP reactor units and their surroundings (e.g., reactor pressure vessel, reactor internals, core components and biological shield) that were activated during the plant's operation, caused by interaction of these materials with neutrons resulting from the nuclear fission process in the reactor cores as the initiating event and subsequent decay processes. The results shall include, at least, the following information:

- Activation process.
- Radionuclides selection.
- Calculation methodology.
- Reactor internals, reactor vessel and concrete structures description.
- Calculation.
- Statistical data processing to radiological contamination and radionuclide vectors.
- The three-dimensional distribution of the neutron source in the reactor core and the resulting neutron fluxes.
- Activation of the individual reactor components or their defined parts.

Hazardous Material inventory

The user should identify hazardous material contaminating a nuclear facility's civil structures, soils, and water. The report shall estimate the amount of the hazardous material and the amount of each material contaminated. Results should be incorporated in the "Hazardous Material Inventory Report" including input data, methodology and calculations results, e.g.:

- Amounts of hazardous substances present as potentially hazardous wastes: parts of civil structures, insulation materials and equipment - such as asbestos, lead parts, batteries, lighting, etc.
- Amounts of media containing hazardous substances are residues, deposits at tanks, systems, and equipment, e.g., oil, petroleum, chemicals, etc.
- Number of materials in the technological systems, floor and wall paintings, water and soils, and the construction parts of the civil objects contaminated by hazardous substances to such level that will form potentially hazardous wastes.

During the sampling and analysis process in V1 NPP, a delay in the submission of documentation occurred, which was caused by the temporary inaccessibility of the primary circuit premises of V1 NPP Unit 2 for sampling. This could have been avoided by careful coordination and planning of decommissioning activities. Therefore, it is recommended to analyse all project interfaces carefully.

3.1.5. Perform decommissioning database backup and training

The complete inventory data set shall be backed up to preserve all the collected data. If an external consultant creates a database, a **detailed user manual** for DDB shall be developed, and the concerned plant's employees shall undergo **training** to use the database effectively.

3.1.6. Recommendations on initial characterisation

- ✓ Develop **modification of the existing material database** that can be used to store all necessary physical and radiological inventory data for decommissioning purposes (to design a new application module within the system and the modification/extension of the existing table structure to handle and manage the necessary inventory information).
- ✓ **Update and amend the existing inventory information relevant for decommissioning** to gather missing inventory data on buildings, equipment and media not yet recorded in the existing database and record all physical and radiological inventory data required for decommissioning into the database.
- ✓ During the physical inventory, **it is recommended to relocate the plant's experienced staff** from the operational department for decommissioning tasks full-time to facilitate the faster gathering of required information.
- ✓ It is recommended to **keep records of *uncertainties* while performing the characterisation**, i.e., areas that, based on results of the initial characterisation, may appear problematic in the future and will require special attention (due to sampling inaccuracies, inaccessibility, bad results, etc.) to preserve this kind of information for future use. In the ideal case, use appropriate management tools for project management so that the inventory characterisation forms an uninterrupted process.
- ✓ A decommissioning database may include the proposed optional parameters for equipment and building structures: Equipment dimensions (length, width, height, diameter), pipeline No., equipment classification, surface material, etc.
- ✓ A decommissioning database may include the following proposed mandatory parameters for equipment and building structures:

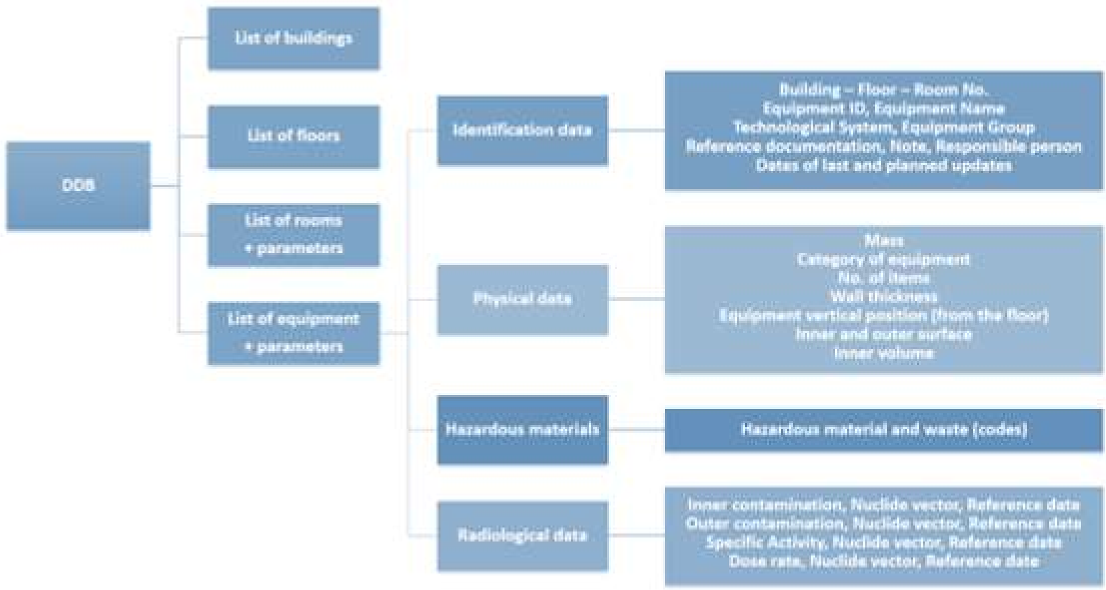

Figure 4: Proposed hierarchical structure of DDB.

- ✓ **Activities within the radiological survey of the facility are divided into two groups: activities in buildings outside and inside the controlled area.** Carry out in both groups of buildings the following activities: direct measurements of dose rates and surface contamination, gamma spectrometry in-situ, smear samples taken from external surfaces of equipment, walls and floors of individual rooms and drilled concrete samples.

3.2. Part 2: Additional Characterisation

At the time of initial characterisation, some technological components and building structures are still in operation or are not physically accessible, so it is not possible to carry out their initial characterisation. This fact represents uncertainty that has an impact on decommissioning processes (inaccurate cost estimation, impossibility of fully integrated planning of certain decommissioning processes, etc.). **Due to the iterative nature of characterisation, additional characterisations are required** to have a better knowledge of the radiological status of components, systems and buildings that allow developing the corresponding technical specifications with enough confidence for contracting the future activities in the controlled area minimizing risks (extra-costs, delays, higher radiation exposures and unexpected contamination to the workers, etc.).

Another substantial advantage of additional characterisation is the possibility of **on-time sampling of hot spots on demand**. The results of local characterisation also provide regulatory authorities with information about the radiological situation, based on which they approve selected procedures and processes from the public safety perspective.

3.2.1. Update of the radiological inventory

An initial radiological survey in DDB identifies parts of the site that were contaminated and affected by on-site activities. The survey also indicates parts unaffected by the operation and can be classified as "unaffected. **"All equipment and building structures in the DDB database should be divided into groups related to the individual radionuclide vector (RNV).** Based on the analysis of the results of all measurements, the target user should define the number of vectors. The automatic database functions calculate the total specific activity and surface activity index. Radiological data of each item in DDB are used to determine the total radiological inventory of the plant.

However, with the progress of decommissioning activities in the nuclear facility, all radiological values mentioned in the sampling and analysis report of DDB shall be recalculated. **DDB shall enable continuous conversion of activities of the individual radionuclides following the appropriate decay curves and the time update of RNV**. A project dealing with additional and continuous characterisation shall ensure a continuous and systematic review of the already identified RNV, focusing mainly on the decontamination processes. If there is a reasonable suspicion for a change of RNV of appropriate material, a new RNV will be determined. Moreover, **the RNV control will provide information about the correct implementation of the contractors' decontamination activities**, indicating if the expected end use of a specific material could be achieved or if it must pass through the decontamination process once more.

Additional sampling provides exact data on a nuclear facility's material and radiological composition. Continuous sampling is performed during dismantling and demolition works when fixed systems and equipment are removed, thus making available parts of the nuclear facility that were not accessible until then. This allows the operator to summarise the **complete itinerary of the plant and remove uncertainties of initial characterisation**. Another benefit of continuous sampling is the possibility to perform a **direct local characterisation of hot spots on demand** in case of unexpected changes during the implementation of projects.

> A technical problem occurred while cleaning the bottom of the wet-cutting workshop pool in the V1 NPP reactor hall. The original sequence of activities and the use of technology were suspended, and the search for a feasible technical solution began immediately. Based on the results of sampling performed within the scope of project B6.6A, "*Decommissioning Support Surveys*", a new technical procedure was established and followed in a relatively short time.

In the V1 NPP, the project "*Decommissioning Support Surveys"*:

- Helps execute radiological and hazardous materials sampling and laboratory analyses for the supporting characterisation within the V1 NPP decommissioning process.

- Provides updated estimates of site-specific parameters (radiological & hazardous) for detailed planning and execution of the V1 NPP decommissioning projects.

- Supports decommissioning activities by determining whether the decontamination process has achieved the corresponding targets and whether a survey unit or group is ready for the final radiological survey (via confirmatory surveys).

More specifically, materials characterisation is implemented via:

- Execution of radiological surveys during decontamination activities (checking radionuclide vector, new radionuclide vector definition, radiochemical analysis of hard-to-measure radionuclides).

- Execution of radiological and hazardous materials sampling and laboratory analysis of systems and materials which were not subject to characterisation in the frame of the completed project B6.4 "Decommissioning Database".

All data collected are incorporated into the decommissioning database in the ARSOZ system, making a valuable contribution to decision-making on planning the following activities of V1 NPP decommissioning. Data are accessible for facility personnel at any time for planning, organisation, and implementation activities. They will also be helpful and necessary at the end of decommissioning during site release and delicencing.

In the V1 NPP, during the additional characterisation process, the following types of taking samples were performed:

- Electrochemical sampling of the corrosion and surface layers of metal materials
- Concrete core drilling.
- Scraping (grinding) of surface materials (up to the primary structure material)
- Drilling into soil loose material.
- Sample-taking of metal - drilling, cutting, milling in whole or sawdust
- Sample-taking of loose material.
- Determining hazardous materials - polychlorinated biphenyls, asbestos, oils and gasoline products, and detergents.

3.2.2. Recommendations on additional characterisation

- ✓ Obtain the necessary information of nuclear facility so that various decommissioning activities can be planned more effectively, e.g.:
    - protection of employees against risks (hazardous waste, radiological risks and other dangers)
    - supporting data to prepare technical specifications for the individual decommissioning projects,
    - scope of need of sorting and fragmentation of the individual components,
    - scope of need of decontamination of the individual components,
    - scope of need of RAW processing and processing of other kind of waste during the implementation of the individual components
    - scope of need of additional cost estimations, etc.

- ✓ **Create capacities (personnel, equipment, etc.), to be able to respond continuously to operational requirements, further characterisation of these systems and buildings, and their decommissioning processes**, in order to gradually further characterise the technological systems and building structures in question. In case of unexpected changes, based on the results, make key decisions in the current processes of planning and implementing activities.

- ✓ **The material inventory together with the radiological information needs to be available to the user in one place at any time during decommissioning**. It is not possible to collect and summarize this information on the fly additionally under time stress, therefore continuous update of the database based on latest data available is essential.
- ✓ **Characterisation shall be planned as an uninterrupted process** starting from the pre-decommissioning phase up to the site release without large time gaps. With the progress of decommissioning works, new characterisation will be required aiming to update the radiological inventory and the waste management plans; estimate the decontamination factor and the efficiency of the decontamination; and obtain the final survey parameters.

> In the V1 NPP, inventory characterisation was not achieved as a follow-up process. The chapter *1.1 Current Practice in V1 NPP* has described the temporal connections between the first and second phase of V1 NPP decommissioning.
>
> The first phase took place between 2011 and 2014, and the second phase has been ongoing since 2015. In the period after the end of the project B6.4 "*Decommissioning Database*" in 2011 until the start of the implementation phase of the project B6.6A "*Decommissioning Support Surveys*" in 2017, there was a time gap when characterisation activities were not carried out at V1 NPP. This relates to the license for the second decommissioning phase, issued in 2015. It was only in this second phase of decommissioning that dismantling and demolition of the contaminated and activated parts of the power plant started, which made room for ongoing characterisation. For this reason, planning an ongoing characterisation project (sampling) earlier than in 2015 was not justified.
>
> In the ideal case, it would be appropriate for the B6.6A project to last until the end of decommissioning since characterisation of the materials will also be necessary in the final stage of decommissioning during demolition and especially during the site release.

4. SUMMARY OF ACTION ITEMS

The complete inventory characterisation of the nuclear facility is accomplished according to steps as follows:

1. Assess whether the existing software/application suits the Decommissioning Database (DDB). If no such database is available, procure a consultant to create a new one.
2. Get the software/application that will be used to access the DDB.
3. Assess the operational events/changes that occurred during the entire period of operation of the facility. Insert all relevant data into the DDB.
4. Determine the scope, type, and quantities of samplings for radiological and hazardous materials characterisation and develop a Sampling Plan following the MARSSIM's methodology [13].
5. Carry out sampling in pre-specified locations of the facility.
6. Perform analyses on the collected samples.
7. Perform calculations to determine the number and values of the radionuclide vector.
8. Plan further additional sampling and sample analyses according to the specific requirements of the implemented decommissioning projects.
9. Based on additional samplings and measurements, regularly update the decommissioning database to keep it updated as much as possible.
10. Ensure the final radiological characterisation to define the parameters relevant for the final survey and the successful free release of the site.

5. CONCLUSIONS

The success and effectiveness of decommissioning nuclear facilities require obtaining as much specific and detailed information as possible about the state of the equipment and systems under decommissioning. Site characterisation is an iterative process based on a cost-benefit approach for decision-making during decommissioning. Supporting characterisation of the facility provides additional information about the status of the facility.

The project "*Decommissioning Database*" carried out the necessary physical and radiological characterisation of V1 NPP and established a comprehensive physical and radiological decommissioning inventory database capable of storing and managing all the physical and radiological information on buildings, structures, equipment, and media required for planning and implementing the V1 NPP decommissioning process. Because during the implementation of the project B6.4, some spaces, system elements and equipment could not have been characterised in sufficient detail and data were obtained only by empirical calculation, the project B6.6A "*Decommissioning Support Surveys*" was created to perform additional radiological and hazardous materials characterisation. This project has helped characterise materials and components' radiological and hazardous properties by using suitable field activities and laboratory measurement techniques to have complete characterisation data and expand the decommissioning database with essential data necessary for further decision-making processes.

This guideline presents valuable information and know-how from implementing the above-mentioned projects under the conditions of the V1 NPP in Jaslovské Bohunice. It provides the target users with steps to create an effective decommissioning database. It underlines the significance of the inventory characterisation of the technological equipment, civil structures, and surface and underground waters, as it was proven to be an efficient tool for planning various processes associated with decommissioning. The inventory characterisation will provide the amounts of radioactive, hazardous, and releasable waste and hazardous substances that are present at the nuclear facility site, which is critical information to support facility dismantling, the management of material and waste, the protection of workers, the public and the environment, and relevant cost estimations.

It is **highly recommended for other entities** in a phase of planning, preparation and managing the decommissioning process to establish and continuously update a comprehensive physical and radiological inventory database (DDB of the plant) capable of collecting and managing all the information needed to describe the conditions of the nuclear facility, to allow the user to plan and implement all decommissioning activities (e.g. decide on decommissioning methods, dismantling works planning, manpower, decontamination efforts, waste stream determination, waste management, dose assessment, free release of materials, cost estimation, and other).

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