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## ***CRAFT***

***The International Project on  
Complementary Safety Reports: Development and Application to  
Waste Management Facilities  
2011-2014***

## FOREWORD

The development of the safety standards is aided by having a degree of international consensus on the “what” and “how” of waste safety - something that projects such as IAEA International Project on Complementary Safety Reports: Development and Application to Waste Management Facilities (CRAFT) work towards. The results from the CRAFT project will inform the application of the IAEA safety standards by providing foundation material to clarify requirements related to the safety case (SC) and safety assessment (SA) for predisposal management of radioactive waste (RW) and to support expert missions, training events and peer reviews carried out under the IAEA’s Technical Cooperation Fund. Exchange of information among the Member States was also fostered by participating in the various CRAFT project meetings and through dissemination of the material developed during the project.

This publication includes the results of the CRAFT Project. The document provides input that can be useful to supplement current IAEA safety standards for addressing the demonstration of safety for facilities and activities associated with the predisposal management of RW.

The IAEA gives thanks to the primary contributors to the Slovenian illustrative case Mr. Sandi Virsek of the Slovenian Agency for Radwaste Management and to the primary contributors to the RADON-Type Facility illustrative SC and SA, Mr. Alexander Smetnik and Mr. Denis Murlis of the Federal State Unitary Enterprise VO “Safety”, Russian Federation. The IAEA also wishes to thank Mr Frederic Ledroit of the Institut de Radioprotection et de Sûreté Nucléaire in France and Mr Christian Drobnewski of the Bundesamt für Strahlenschutz in Germany for their contribution to the Project Report and the illustrative SCs and SAs. The IAEA Technical Officer of the CRAFT Project was Ms. Monika Kinker. The IAEA also wishes to give special thanks to Ms. Malgorzata Sneve of the Norwegian Radiation Protection Agency for her contributions towards the development of the RADON-Type Facility illustrative SC and SA, and to

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## EXECUTIVE SUMMARY

The SC is the collection of scientific, technical, administrative and managerial arguments and evidence in support of the safety of a facility or activity, covering the suitability of the site and location and the design, construction and operation of the facility, the assessment of radiation risks and assurance of the adequacy and quality of all of the safety related work. The SC and supporting SA provide the basis for demonstration of safety and for licensing; they evolve with the development of the facility or activity, and assist and guide decisions on siting, location, design and operations. The SC will also be the main basis on which dialogue with interested parties will be conducted and on which confidence in the safety of the facility or activity will be developed.

The International Atomic Energy Agency (IAEA) has set out a framework of internationally agreed standards for demonstration of safety of the predisposal management of RW:

- General Safety Requirement (GSR) Part 5 [1] establishes requirements that must be satisfied in the predisposal management of RW, including the preparation, scope and documentation of the SC and supporting SA.
- GSR Part 4 [2] establishes the generally applicable requirements to be fulfilled in SA for facilities and activities, with special attention paid to defence in depth, quantitative analyses and the application of a graded approach to the ranges of facilities and of activities that are addressed.
- General Safety Guide No. 3 (GSG-3) [3] provide recommendations for development and review of the SC and supporting SA for facilities and activities dealing with the predisposal management of RW and spent fuel storage facilities.

Predisposal RW management facilities and activities are varied in nature, size and complexity, and have different hazards associated with them. Furthermore, a RW management facility or activity could be one of several facilities or activities on a site and may be independent of the other facilities, may be connected to other facilities or may be an integral part of a larger facility. The International Project on Complimentary Safety Reports, Development and Application to Waste Management Facilities (CRAFT) was developed to assist in illustrating the application of the graded approach to SC.

The objectives of the CRAFT project were to:

- Apply the GSG-3 methodology to representative predisposal RW management facilities and activities;
- Oversee the development of complementary reports illustrating the application of GSG-3;
- Provide a forum for supporting the use and application of the GSG-3 methodology for the SC and SA; and
- Share experiences and identify lessons learned.

This publication presents the outcomes of the CRAFT project.

## **1. INTRODUCTION**

### **1.1. PROJECT DESCRIPTION**

#### **1.1.1. Project background**

Work within the IAEA has been underway for a number of years to develop safety standards addressing the demonstration of safety for facilities and activities associated with the predisposal management of RW. Recognizing that the approach to such SC and SA is very similar in nature, the IAEA developed General Safety Guide No. 3 (GSG-3) [3] to cover all these facilities. Whilst there are many similarities, there are also significant differences and the guide emphasizes the importance of ensuring that the extent and complexity of the assessment is commensurate with the nature of the activity or facility and its attendant risk.

When the IAEA presented the draft GSG-3 to the 29th Meeting of the Waste Safety Standards Committee (WASSC) for approval in 2010, during discussions it was proposed that the use of the graded approach be illustrated through the development of supporting Safety Reports. Soon afterwards, the IAEA organized the final plenary meeting of the International Project on Safety Assessment Driving RW Management Solutions (SADRWMS), which had been organized in 2004 to examine international approaches to SA for predisposal management of RW. The outcomes of the SADRWMS Project were:

- Input to a harmonized version of GSG-3 [3] that includes the SADRWMS framework and flowcharts;
- A TECDOC [4] that describes the methodology for SA of predisposal RW management activities developed under the SADRWMS project;
- The SAFRAN software tool [5] for applying the SADRWMS methodology to SA of predisposal management of RW.

During the final SADRWMS Plenary Meeting, it was agreed that the completion of complimentary reports illustrating the use and application of the GSG-3 [3] methodology and the SAFRAN tool [5] would be a significant part of the follow-up project. To oversee the development of these complimentary reports it was agreed to establish the International Project on Complimentary Safety Reports, Development and Application to Waste Management Facilities (CRAFT).

#### **1.1.2. Project objectives**

The objectives of the CRAFT project are to:

- Apply the GSG-3 methodology and SAFRAN tool to representative RW management facilities and activities;
- Oversee the development of complementary safety reports illustrating the application of GSG-3 methodology and SAFRAN tool;
- Provide a forum for supporting the use and application of the GSG-3 methodology and SAFRAN tool for the SC and SA;
- Share experiences and identify lessons learnt.

The expected deliverables of the CRAFT Project were:

- IAEA Illustrative Reports to complement GSG-3 as requested in 2010 by the WASSC;
- Guidance on the use and application of the methodology and SAFRAN tool developed under the SADRWMS Project for predisposal RW management facilities; and
- Expanded network of expertise on the development of the SC and application of SA methodology to predisposal RW management.

### **1.1.3. Project scope**

In line with the scope of GSG-3, the CRAFT project encompassed all types of RW, including disused sources, small volumes, operational waste and spent fuel, legacy and decommissioning waste, and large volume naturally occurring radioactive material residues.

### **1.1.4. Project organization**

The first meeting of the CRAFT project was held in May 2011 and was attended by 30 specialists from 23 countries. The main objectives of the 2011 plenary meeting were to:

- Review the outcomes of the SADRWMS project (Methodology Report [4] and SAFRAN software tool [5]) and the results of the SADRWMS test cases (TINT and Studsvik Facilities);
- Discuss the use of existing national facilities as application cases in support of CRAFT project activities; and
- Develop the Terms of Reference for the CRAFT Project.

At the 2011 Technical Meeting, the following Working Groups were formed:

- Storage Facility Application Case;
- RADON-Type1 Facility Application Case; and
- Regulatory Working Group.

The working groups collaborated on the development of the application cases and identified a number of general points relevant to both applications. The working groups continued to consider their areas using the forum for correspondence. The IAEA worked with those countries that had shown an interest in hosting an application case.

The working groups prepared the material needed for the presentation, discussion, and documentation of the technical issues which addressed by the project; helped to organize the technical sessions of Technical and Working Group meetings; and supported the Steering Group as required in production and reviewing the CRAFT documentation. Each working group consisted of a working group leader and a number of participants who actively contributed to the work undertaken by the working group.

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<sup>1</sup> The RADON-type facilities took their name from the RADON system that was established in the former Soviet Union for collecting, transportation, processing and near surface disposal of low and intermediate level institutional RW including disused sealed radioactive sources (DSRS).

### **1.1.5. Project participation**

The CRAFT project was open to professionals from Member States who undertook technical activities related to SA or predisposal management of RW. Participants can be from regulatory bodies, facility operators, technical support organizations and research organizations. They were expected to contribute actively to the project by participating in technical discussions, applying methodologies to real problems and taking part in the development of the complementary safety reports. Participants were able to participate in CRAFT working groups. In addition, during the topical sessions of coordinating meetings they had the opportunity to give oral or poster presentations describing the SA related work they have undertaken within their own national programs or related projects.

### **1.2. OBJECTIVE**

The objective of this publication is to illustrate the demonstration of safety in the predisposal management of RW using the methodology outlined in GSG-3 and using the SAFRAN tool. The secondary objectives are, for certain predisposal RW management facilities and activities, to highlight the key components of the SC and supporting SA within the context of predisposal waste management, to describe what is needed in the way of safety justification for establishing the context and contents of the SC and SA, and to explain the implementation of the GSG-3 methodology and the use of the SAFRAN Tool.

### **1.3. SCOPE**

This scope of this document covers the application of the GSG-3 methodology and the use of the SAFRAN Tool for the development of illustrative SCs for predisposal management of RW. Specifically, it addresses the development of illustrative SCs for the storage of low and intermediate level RW at a dedicated/centralized storage facility, as well as for the retrieval of low and intermediate level RW from RADON-type facilities.

It is not the intention of this publication to produce detailed guidance for the SC for any type of predisposal waste management facility or activity. Instead this document identifies possible ways of addressing the methodology presented in GSG-3 and highlights where differences might occur between facilities or activities.

### **1.4. STRUCTURE**

Chapter 1 of this document provides an introduction to the CRAFT Project, as well as the objective and scope of this publication. Chapter 2 provides an overview of the relevant IAEA Safety Standards (GSR Part 5 [1] and GSG-3 [3]) related to the demonstration of safety for predisposal management of RW, specifically the SC and SA. Chapter 3 describes the work carried out by the application working groups within the CRAFT Project. Chapter 4 presents the main outcomes of the application working groups. Chapter 5 summarizes lessons learnt.

The publication includes 1 appendix and 2 annexes. Appendix 1 deals with the use of the graded approach during the evolution of the SC. The illustrative SCs developed within the working groups are provided as Annexes to this publication. Annex I provides the illustrative SC for the Centralized Storage Facility of low and intermediate level RW in Slovenia. Annex II provides the illustrative SC for the retrieval of RW from legacy RADON-type facilities



typically encountered in countries that were formerly part of the Soviet Union. The SAFRAN files related to the 2 annexes are given in the CD-ROM which accompanies this publication.

## 2. RELEVANT IAEA SAFETY STANDARDS

The SC is defined as the collection of scientific, technical, administrative and managerial arguments and evidence in support of the safety of a predisposal waste management facility or activity. The SC and supporting SA provide the basis for demonstration of safety and for licensing. GSR Part 5 [1] requires that a SC, together with the necessary supporting SA, be developed and undertaken for each predisposal waste management facility or activity.

GSG-3 [3] provides recommendations on the components, development, and other aspects to be considered in the SC during the lifecycle stages of a predisposal waste management facility or activity. These components of the SC, indicated in Fig. 1, include the context; safety strategy; facility description; SA; limits, controls and conditions; iteration and design optimization; uncertainty management; and integration of safety arguments. Guidance on these components of the SC is addressed in Chapter 4 and also in Chapter 7 of GSG-3.

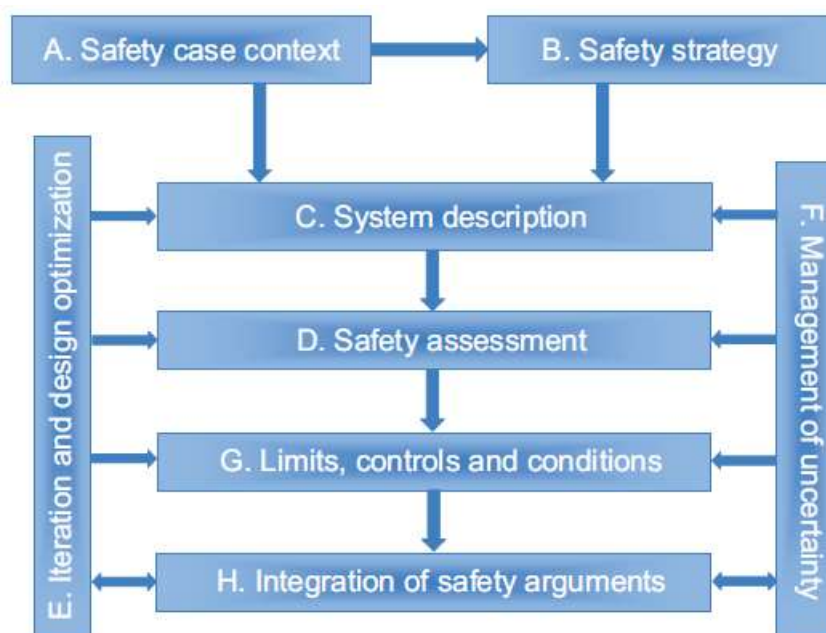


FIG. 1. Components of the safety case (GSG-3).

SA is the main component of the SC and involves assessment of a number of aspects as illustrated in Figure 2. The fundamental element of the SA is the assessment of the radiological impact on humans and the environment in terms of both radiation dose and radiation risks. The other important aspects are site and engineering aspects, operational safety, non-radiological impacts and the management system.

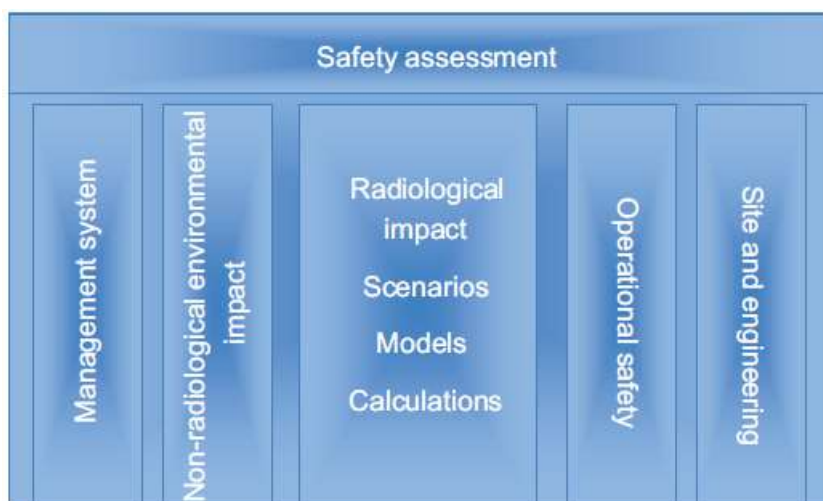


FIG. 2. Aspects included in the safety assessment (GSG-3).

### 3. SAFETY CASE APPLICATION STUDIES IN THE CRAFT PROJECT

GSG-3 [3] acknowledges that the extent and complexity of the SC and supporting SA will differ according to the facility or activity, and will also evolve through its lifetime (e.g. construction, commissioning, operation, etc.). In view of these considerations, a graded approach is required to be applied to the development and review of the SC and supporting SA.

In order to address the general guidance for SCs provided in GSG-3 and taking into consideration issues that are facility and/or activity specific, the CRAFT application working groups applied GSG-3 and the SADRWMS methodology [4] to the development of SCs for a selection of existing facilities. Below a short description of the work carried out by the application working groups is presented.

#### 3.1. STORAGE FACILITY WORKING GROUP

##### 3.1.1. Context

In many countries the storage of RW is performed in a dedicated facility which is designed to store RW (including DSRS) generated within the country. Such RW may be processed or unprocessed, and may also be packaged and unpackaged, with storage periods lasting up to tens of years. The objectives for storing RW and DSRS at these facilities can include inter alia (WS-G-6.1) [6]:

- To allow for the decay of short lived radionuclides to a level at which the RW can be released from regulatory control (clearance) or authorized for discharge, or recycling and reuse;
- To collect and accumulate a sufficient amount of RW prior to its transfer to another facility for treatment and conditioning;
- To collect and accumulate a sufficient amount of RW prior to its disposal.

To ensure the safety of storage of RW and DSRS, the RW to be stored must be properly characterized, treated and conditioned for the type of storage envisioned and taking into consideration the characteristics of the storage facility. Requirements for the types and characteristics of RW that can be accepted for storage are typically included in the waste acceptance criteria for the storage facility, which is derived from the SC that has been developed for the facility.

### **3.1.2. Objectives and approach of the Working Group**

The objective of the CRAFT Storage Facilities Working Group was to apply the GSG-3 methodology and the SAFRAN tool to existing facilities for the storage of RW.

The facility considered in the development of the illustrative SC was the Central Storage Facility in Slovenia, which is currently in operation for the storage of institutional RW generated during research activities, medicine and industrial uses.

The Storage Working Group structured the illustrative SC following the template provided in Section 4.1. In order to develop the illustrative SC, the working group undertook the following tasks:

Task 1 – Assemble and collate input data (site, facility, activities, waste streams, etc)

Task 2 – Develop SA:

- a. Input facility structure information in SAFRAN utilizing facility data;
- b. Define normal operations;
- c. Define and agree on the Postulated Initiating Events (PIEs) that could lead to accident scenarios;
- d. Identify the accident scenarios (derived from the PIEs) for quantitative analysis;
- e. Complete data entry into SAFRAN utilizing information from above Tasks;
- f. Perform analysis of normal and accident scenarios (SAFRAN);
- g. Review the SA (facility-specific SAFRAN file) to verify consistency with the methodology in GSG-3;
- h. Review the SA (facility-specific SAFRAN file) and modify as required, e.g. based on findings from review;

Task 3 – Incorporate pertinent information from the SA into the SC for the Facility

Task 4 – Review the SC and modify as required, e.g. based on findings from reviews

## **3.2. RADON-TYPE FACILITIES WORKING GROUP**

### **3.2.1. Context**

#### ***Historical RW***

In the context of this working group, “Historical RW” is considered to be RW that was disposed of in accordance with national regulations that were in place at that time, but which do not meet current requirements for characterization programs or quality management systems. Key characteristics of historical RW are:

- Incomplete or improper characterization/treatment (waste streams may be mixed, and may be conditioned, partially treated, or raw);
- Poor or no information/traceability (cannot conclusively identify characteristics or originating process or location);
- Quality system did not cover the whole life cycle at the time of generation and does not meet current requirements for addressing the whole life cycle.

Many countries (e.g. the USA, Russian Federation, United Kingdom, the former USSR republics, Eastern European States, China) currently have historical RW disposal facilities which were designed and constructed before requirements for quality management systems and acceptance criteria were developed. These facilities no longer meet current requirements for safe disposal of RW and many countries are in the process of retrieving these wastes.

### ***Legacy facilities and sites***

Due to historic activities typically related to radium industry, uranium mining, and military programs, there are numerous sites that contain or are contaminated with radioactive materials. Historical RW disposal facilities can also be considered as legacy facilities.

Some legacy disposal facilities have never been licensed for disposal; some of those that had been originally licensed no longer meet international safety standards and even national requirements. Due to such non-compliance some of these disposal facilities are now considered “storage facilities” and operators of these facilities currently face serious problems in the practical recovery of the RW and remediation of the site. In some cases unfavorable conditions inside some facilities have caused corrosion and degradation of the waste packages and the engineered barriers. In many cases, inadequate conditions have resulted in disappearance of original markings, labels, and signs that could help identify the origin and characteristics of the waste; this is further compounded by the lack of adequate records or records keeping. Accumulation of water within the vaults is often identified and according to radionuclide content and specific activity this water can often be classified as liquid RW. In some cases radionuclides migrate into the vicinity of the sites.

### ***Decision making for retrieval***

This topic is addressed in IAEA Technical Report Series 456 [7]; relevant paragraphs are below:

*Safety assessments and environmental measurements have demonstrated that some of these historical facilities may represent an unacceptable risk or hazard to the environment, workers and the public, therefore requiring remediation actions.*

*Similarly, some legacy interim storage facilities contain waste items and waste containers that have deteriorated, or the general storage conditions no longer meet the requirements for safety. Again, this indicates a need for remediation of the facilities.*

*In some cases, inadequate waste storage practices continue to be applied, due to:*

- a. A lack of appropriate knowledge and practical experience in safe radioactive waste management in general;*
- b. A lack of appropriate technologies for waste processing (treatment and conditioning) in the places where this practice is taking place;*
- c. A lack of well-defined requirements for waste quality and acceptance criteria for long term storage or disposal derived from a proper safety assessment and safety case;*
- d. Inadequate storage or disposal conditions, and unacceptable impact of external conditions on waste and waste packages;*
- e. Poor quality of waste forms, waste containers or other engineered barriers;*
- f. Storage or disposal of waste in its original form and without appropriate conditioning and packaging.*

*A decision to retrieve radioactive waste from some legacy storage or disposal facilities could be made if the present status of safety and security does not correspond to current standards or requirements, or if the existing social, political or economic situation requires such remediation actions. The cost of waste retrieval and facility or site remediation — both in terms of radiation exposure and financial expenditures resulting from the remediation — is normally justified by the improved safety and security of the facility or site after remediation, the availability of the facility or site for other purposes, etc. In all steps of waste retrieval and site remediation, safety of the staff, protection of the environment and waste security should be given the highest priorities.*

### **3.2.2. Objectives and approach of the Working Group**

The main objective of RADON Group was to apply the GSG-3 methodology and the SAFRAN tool to retrieval of wastes from a typical near surface RADON-type facility. The secondary objective is to support decision making for planned operational waste retrieval operations and predisposal RW management activities at a near surface historical disposal facility for solid institutional RW.

In developing their illustrative SC, the RADON Working Group followed a similar approach as the Storage Working Group; their illustrative SC was structured following the template provided in Section 4.1.

The application case demonstrates the application of the GSG-3 methodology and SAFRAN tool to assess activities and technologies for waste retrieval procedures as well as other decision making related to the operation of the RADON-type facility.

### **3.3. REGULATORY WORKING GROUP**

The regulatory review WG provided guidance and support to the other WGs during the drafting process of their reports. The group also worked on the identification of what is necessary to address in the SC while applying the “graded approach” as presented in GSG-3

considering the different steps of lifecycle of facilities (from site selection to decommissioning). The results of the discussions are summarized in Appendix 1.

## **4. MAIN OUTCOMES OF THE CRAFT PROJECT**

The main outcomes of the CRAFT Project are the illustrative SCs and supporting SAs developed by the working groups. These illustrative reports followed the structure outlined in Section 4.1, which was agreed and refined during Technical Meetings of the CRAFT Project.

### **4.1. STRUCTURE OF THE ILLUSTRATIVE SAFETY CASE REPORTS**

For preparation of the illustrative SC reports a template was developed and was later used by the working groups. The template considers the guidance given in GSG-3 [3] as well as the specific elements that would need to be addressed during the preparation of a SC for the centralized storage of RW as well as for the retrieval of RW from legacy facilities.

#### **A. Safety case context:**

- Purpose of the SC;
- SC scope;
- Demonstration of safety;
- Graded approach.

#### **B. Safety strategy**

#### **C. Description of facility or activity and waste:**

- Site conditions;
- Facilities and activities;
- Inventory of RW.

#### **D. Safety assessment:**

- Radiological impact assessment;
- Site and engineering aspects:
  - Engineering analysis;
  - Passive safety;
  - Defense in depth;
  - Scientific and technical / engineering principles;
  - Quality of the site characterization.
- Operational safety aspects;
- Non-radiological environmental impact;
- Management systems.

#### **E. Management of uncertainties**

- F. Iteration & design optimization
- G. Identification of safety measures
- H. Limits, controls and conditions
- I. Integration of safety arguments:
  - Comparison against safety criteria;
  - Plans for addressing unresolved issues.
- J. Interacting processes

#### 4.2. STORAGE FACILITY SAFETY CASE

The SC report developed for the storage facility application case is provided in Annex 1. The SAFRAN file which captures the SA for the storage facility SC is provided in a CD-ROM which accompanies this publication.

#### 4.3. RADON-TYPE FACILITY SAFETY CASE

The RADON-Type Working Group developed two documents: the illustrative SC for retrieval activities, and a set of recommendations or guidance that can be considered in future development of such SCs. This set of recommendations is included in Section 5.2 as it can also be considered lessons that were learned during the development of their SC and SA.

The SC report developed for the Radon type facility application case is provided in Annex 2. The SAFRAN file which captures the SA for the storage facility SC is provided in a CD-ROM which accompanies this publication.

### 5. LESSONS LEARNED

#### 5.1. STORAGE FACILITY WORKING GROUP

While preparing the SC for the Slovenian Central Storage Facility and adopting the GSG-3 [3] methodology for the SC, some lessons learned were identified and are addressed in the sections below.

##### 5.1.1. Graded approach

Under Slovenian law, the Central Storage Facility meets the criteria to be classified as a nuclear facility (Slovenia also operates a nuclear power plant). Licensing requirements in Slovenia for nuclear facilities refer to the use of the graded approach, but do not give specific guidance on practical application of the graded approach. Prior to the development of the SC for the Central Storage Facility, ARAO communicated with the regulator their application of the graded approach for the development of the SC (following the guidance in GSG-3 and participating in the international CRAFT Project).

It is necessary to understand the site, the facility and the waste and their interdependencies at a detailed level in order to ensure that the SA is aligned with the lifecycle stage of the facility and the purpose of the SC.

### **5.1.2. Strategy for safety**

At the time that the SC was being developed for the Central Storage Facility, the strategy for safety was discussed with the regulator and was identified as a useful tool for communicating with the regulator.

The safety functions of the various systems, structures and components (SSCs) need to be defined and addressed in order to demonstrate that defence in depth is adequate for the facility.

### **5.1.3. Description of the facility or activity and the waste**

Building design and construction records and information form an important part of the records for the facility. The Central Storage Facility is an existing facility that met general building construction standards at the time that it was constructed (it was built in 1986). However, some building standards were either not in place or were not descriptive (e.g. seismic building codes at that time only required that structures be “seismically safe”). Other original facility design information was missing. During the preparation of the SC for the Central Storage Facility, additional investigation activities were necessary in order to enable ARAO to understand the characteristics of the facility. Records that could have helped ARAO to understand decisions that were made in the past about the building design were also missing.

The inventory of RW and DSRS needs to be verified and characterization of the waste (waste streams) need to be focused on reducing uncertainties in the results of the assessment. While ARAO already had records and information regarding the RW and DSRS in storage at the Central Storage Facility, further characterization and verification activities were needed in order to enable ARAO to prepare the SC.

If possible, the waste acceptance criteria for the storage facility should be aligned with the anticipated future disposal of the waste in storage. If no disposal facility exists, then acceptance requirements can only be anticipated.

### **5.1.4. Safety assessment**

Two methods were used to identify scenarios for anticipated (normal) operations as well as accident scenarios:

- Hazard and operability study (HAZOP) method; and
- Screening of potential initiating events (PIEs) listed in GSG-3 and the SAFRAN Tool.

The results from using the HAZOP method and the screening of PIEs were compared and it was found that both methods resulted in a comprehensive identification of scenarios covering anticipated (normal) operations as well as accident scenarios. Both methods require a team of experts from different backgrounds who understand the scope and the objectives of the SC.

A few scenarios were identified (e.g. terrorist attack, stealing of a package) that are not specifically within the scope of SA; these will need to be assessed through a security assessment. It will need to be decided if and how these scenarios are to be assessed.

SA is more than “just” calculating potential doses to the workers and the public; it requires



the developer to understand the methodology used to calculate the doses and to correctly interpret the results.

The focus of the SC development is typically on the radiological impact assessment; other aspects (e.g. site and engineering aspect, engineering analysis, non-radiological environmental impact, etc.) need to be included.

#### **5.1.5. Management of uncertainties**

The goal of managing uncertainties is to increase the confidence in the safety of the facility and activities, as well as enabling the developer to show compliance with regulatory requirements. It is important to develop an approach for managing uncertainties in the SC that ensures that they are identified, assessed, and reduced where possible. This has to be taken into consideration during the development of the SC and subsequent (independent and regulatory) reviews.

#### **5.1.6. Iteration and design optimization**

Typically, periodic safety reviews are performed every 10 years. In the case of the Central Storage Facility, it was determined that iterations of the SC need to be performed more frequently, in order to prevent the loss of data and knowledge caused by staff changeover, as well as changes in knowledge, methods and computer tools.

It is important to optimize and upgrade the facility during the operational lifecycle stage. In the case of the Central Storage Facility, the safety of the facility was improved (specifically, the risk of a fire inside the facility was reduced) by replacing the wooden pallets used to stack waste containers with metal pallets (and other upgrades).

### **5.2. RADON-TYPE FACILITY WORKING GROUP**

#### **5.2.1. Framework for specific guidance**

While developing the RADON-Type facility illustrative SC using the GSG-3 methodology and SAFRAN Tool (which utilized the SADRWMS Methodology), it was recognized that there is a need for specific guidance regarding waste retrieval operations from historical/legacy facilities. A framework for such specific guidance is presented below.

##### *5.2.1.1. Context of the SC*

In the case of historical waste facilities, the SC may not have been developed at earlier stages and may only be performed for the first time to support decision making (e.g. whether to retrieve the waste from the facility or to improve the safety of facility). The SC for decision making can differ from the SC that is developed for licensing of the facility. In general, the safety of waste retrieval operations should be assessed and demonstrated either within the operational licensing or within specific licensing depending on the National regulations. Management systems for ensuring the quality of all safety related work need to be applied throughout. Arrangements to facilitate the involvement of interested parties in the development and use of the SC should be in place.

In the case where there a safety report is in place for the facility, there may still be uncertainties due to the lack of information (due to data being lost or unrecorded) if it was not

required according to the former safety regulations. In this case, a complete review would need to be performed against the latest national regulations and international recommendations.

#### *5.2.1.2. Purpose of the SC*

As retrieval activities from historical waste facilities may be a part of the preparation for facility decommissioning or part of another activity aimed to improve safety, the purpose of the SC should be clearly established.

For each situation of the SC, the operator should provide a clear description of its purpose, which could include:

- Testing of initial ideas for safety concepts;
- Demonstration of the safety of the facility or activity;
- Optimization of the activity arrangements;
- Evaluation of clearance and discharge activities;
- Assessment of the maximum inventory of waste that can be managed or secondary waste generated as a result of the waste retrieval;
- Definition or revision of limits, controls and conditions.

#### *5.2.1.3. Scope of the SC*

The scope of the SC may be limited to retrieval of waste from the facility, or it may include other activities such as preparatory investigations (e.g. of the engineered barriers and/or of the waste inventory) and post-retrieval processing and conditioning. At a minimum, the scope of the SC for retrieval of waste from RADON type facilities should include the following:

- Retrieval of the waste or waste packages from historical storage or disposal units;
- Waste characterization;
- Packaging, repackaging or overpacking of retrieved waste and interim storage at the site (e.g. temporary holding of the waste pending the next steps).

#### *5.2.1.4. Use of graded approach*

Historical waste storage facilities are varied in nature, size and complexity, and have different hazards associated with them, both from normal operation and from potential accidents. The magnitude and content of the radioactive inventory is also varied. For example, a historical waste facility may have been designed for disposal and storage of RW and may represent several different types of construction methods, designs and facility age. Further, they may be independent of or dependent on other facilities, or may be an integral part of a larger facility that also includes waste treatment and other facilities. Commensurately, the extent and complexity of the SC and supporting SA will differ according to the facility or activity, and will also evolve through its lifetime (e.g. construction, commissioning, operation and decommissioning or closure). In view of these considerations, a graded approach is required to be applied to the development and review of the SC and supporting SA.

#### *5.2.1.5. Evolution of the SC*

The SC should be developed while the retrieval activities and the overall waste management

project (including final disposal of the retrieved waste) progresses and should be used as a basis for decision making (for example, optimization of waste retrieval procedures or for regulatory decision making).

#### *5.2.1.6. Strategy for safety*

The strategy for safety of the waste retrieval operations should address a number of key elements, namely the practical realization of multiple safety functions, engineered barriers, defense in depth, shielding and confinement, and the selection of appropriate approaches to waste retrieval and processing. It should also address how secondary waste will be minimized, how waste management will be optimized with regard to reuse, recycling and clearance of materials and, if relevant, discharge of effluents, and how interdependencies with other steps in the predisposal management and with the disposal of the waste will be taken into account.

#### *5.2.1.7. Description of the facility, activity and of the waste*

It has to be taken into account that historical waste can vary considerably in terms of inventory, activity, size, waste form, condition of the containers. Possible failure of the containers during retrieval operations has to be considered.

It also has to be considered that certain components of the engineered barrier systems may be in a condition that does not protect humans or the environment. In the case of RADON type facilities, the underground vaults and the waste may have been deteriorated by groundwater, precipitation and/or other external impacts. This can bring additional hazards during the waste retrieval activity that should be covered by the SC and supporting SAs.

#### *5.2.1.8. Safety assessment*

##### ***Identification of hazards and initiating events***

The historical waste may have been placed in bulk and that the waste packages may have deteriorated (e.g. due to corrosion), with a potential for dispersion or leakage of radionuclides or other types of hazardous material from the original packages. This may need to be considered during the identification of hazards and initiating events.

##### ***Management of uncertainties***

There are large uncertainties in estimating the time frames associated with the specific waste retrieval operations at these types of facilities. To manage these uncertainties, there are essentially two options:

1. Simulating actual retrieval activities (without radioactive material) to get a better estimate of the time needed for specific operations;
2. Making conservative assumptions of the time needed to conduct each activity.

Option 1 may be limited by a lack of specific knowledge of the actual conditions of the facility and the waste.

## ***Assessment models***

The models need to give special attention to background radiation originating from adjacent areas during retrieval operations (e.g. including vaults in the case of RADON type facilities). Consideration of potential worker doses under varying retrieval scenarios can be used to determine and refine retrieval strategies; specifically, this can be useful in informing decisions on defining the sequence of operations in order to optimize doses to the workers and the public.

### ***5.2.1.9. Specific issues***

#### ***Reliability***

In the SA, consideration should also be given to the reliability of components over the lifetime of the RADON type facility. For legacy waste facilities, independent of the decision to be taken in given timeframe, it is important to consider also the age of the facility at the time of retrieval (condition of waste packages and potential for degradation).

#### ***Interdependencies***

There may be other facilities on the same site which may have been constructed and used to store or dispose of other types of waste. Possible interdependencies may exist between other activities and other facilities located on the site and these will also need to be considered.

### **5.2.2. Application of the SAFRAN Tool**

The SA performed for the RADON type facility retrieval activities has demonstrated the potential application of SAFRAN tool for this purpose. The general sequence of work performed consisted of the following steps:

- Description of the facilities;
- Creation of the area structure, where work is to be performed, and parameters of exposure (e.g. external dose rate) in work areas;
- Description of operations performed in the course of the activity;
- Establishment of the dose constraints according to the national regulations;
- Description of the regulatory framework for normal and accidental situations;
- Input of personnel job positions who are assigned to perform aforesaid operations;
- Identification and assessment of potential impacts (potential doses to the worker and to the public) during normal operations and under abnormal conditions, and estimation of time parameters for each operation;
- Analysis of the results for normal operations and under abnormal conditions;
- Identification and assessment of postulated accident scenarios and calculation of the relevant exposure doses to the worker and the public by means of applying the SARAN's safcalc tool;
- If necessary, revision of the area structure and working zones resulting from the operations and personal involved (optimization) and iteration of the SA.

Application of SAFRAN tool allows processing of the input data, creation of the SA structure and analysis of the alternative options for personnel response actions under normal operations, abnormal conditions and postulated accidents.

Certain actions could not be easily performed using the SAFRAN tool, e.g. changing multiple parameters in order to determine the potential impact on worker doses. In order to perform analysis of different abnormal operation scenarios required the creation of separate files or “alternative configurations” inside the file, which led to considerable expansion of the calculation models.

## **APPENDIX I.**

### **GRADED APPROACH AND THE EVOLUTION OF THE SAFETY CASE**

There are generally five stages in the lifecycle of a nuclear facility. These stages are:

- Siting;
- Design & construction;
- Commissioning;
- Operations; and
- Shutdown and decommissioning.

At each stage, the operator should ensure a SC is developed, including a SA, to ensure overall worker and public safety. Within each stage of the SC, different factors need to be considered depending on the type of predisposal RW facility (e.g. storage, conditioning, and/or treatment). A graded approach is needed in the development of predisposal RW storage and processing facilities. As shown below, the factors of a SC for a large processing facility are more numerous and complex than for a simple storage facility. GSR Part 4 [2] identifies the following criteria to be taken into consideration in the application of a graded approach:

- The safety significance (most important);
- Complexity; and
- Maturity of the facility or activity.

Using the graded approach provides flexibility for both the regulator and the operator in ensuring the safety of the public and worker.

#### **I.1. SITING:**

The SC for the siting stage should simply present the strategy for safety and how safety will be met. It is generally not possible to provide a detailed description and assessment of the facility (or activity). In the absence of any quantitative demonstration, qualitative justifications for the strategy for safety adopted will have to be provided. Initial approaches for radiological impact assessment, the management system and management of uncertainties should be documented. The output of the SC at this stage of development is justification that the site is viable for the proposed facility (or activity) (para. 6.13 of [3]).

Factors include:

- Proposed activities at the facility (e.g. storage, long term storage, conditioning, thermal treatment,);
- Other activities at the site and their impact on the proposed facility or activity;
- Isotopic activity levels and form: solid, liquid, and/or gas;
- Site features:
  - Surface water (e.g. flooding, tsunami);
  - Seismology;
  - Depth to groundwater;
  - Geology;
  - Topography (e.g. for surface water run-on);
  - Weather impacts (e.g. snow, rain, wind).
- Building structure (e.g. in the desert with occasional fires >> metal);

- Nearest neighbours and surrounding industries (e.g. zoning, representative persons);
- Demographics;
- Access to facility;
- Transportation routes (e.g. aircraft flight paths, major highways);
- Additional land for expansion of the site;
- Anticipated waste acceptance criteria.

Concurrently, additional data will be gathered including:

- Environmental impact assessment;
- Stakeholder involvement.

## I.2. DESIGN & CONSTRUCTION:

In the design and construction, the SC will provide justification that the (as designed) facility (or activity):

- Is needed;
- Will meet all safety requirements; and
- Can be safely constructed and operated.

The SC should demonstrate that:

- The likelihood of safety-related structures, systems or component failing is low.
- In the event of degradation, the loss of a safety function of one component does not jeopardize the safety of the whole system (defense in depth).
- It is a mature assessment of the engineering and the impact of the facility or activity.

Factors include:

- Doses for workers and public are safely below regulatory limits:
  - Individual and collective dose optimized.
- Site security (this is typically addressed in the security plan for the facility):
  - Physical barriers and other passive or active access controls;
  - Monitoring and response (e.g. camera to an offsite guard).
- Building layout:
  - Access (personnel and vehicle doors, location of access points);
  - Sufficient and separate areas to segregate waste by dose rate;
  - Internal layout optimized for processes (e.g. receiving, storage, processing);
  - Lighting (natural and provided);
  - Optimized layout for package handling;
  - Shielding (e.g. engineered overpacks, hot cell);
  - Labyrinth passageways and cableways to prevent streaming;
  - Floor and walls sealed for ease of decontamination.
- Air circulation and temperature control:
  - Natural circulation or forced ventilation with controls such as HEPA filters;
  - Lowest ambient pressure at highest contamination levels;
  - Moisture control.
- Radiation Protection Program:
  - Over-arching policy statement;

- Optimization program;
- Procedures;
- Zoning (for dose rates, waste type, and processing priority);
- Personnel monitoring;
  - External and internal monitoring.
- Processing and storage of large volumes of liquid waste and effluents:
  - Compatible storage containers (e.g. proper for non-radiological hazards);
  - RW collection reservoir (e.g. low point sump) with sampling capability;
  - Containment with thick liner below concrete floor;
  - Volume and time limits placed on storage.
- Pre-operational environmental monitoring:
  - TLD's for ambient radiation levels;
  - Media sampling to establish baselines;
  - Continuous stack monitoring.
- Effluents and permitted discharges to the environment:
  - Air emissions limited: radiological, sulphur oxides (SO<sub>x</sub>) and nitrogen oxides (NO<sub>x</sub>);
  - Conditions suitable for liquid releases (e.g. consideration of water table).
- Management System (consistent with the activities inside the facility):
  - Quality Assurance program (e.g. records management, ensuring performance of components);
  - Independent review of the SC and SA;
  - Action in place to identify and report reversible and irreversible non-conformances.
- Non-radiological hazards (e.g. chemicals and/or combined chemical/radiological)
- Processing of retrieved and secondary RW: decontamination or packaging for storage?
- Consideration that the design facilitates decommissioning
- Other government agencies involved?
  - Building codes, fire codes, electrical codes;
  - Behaviour of building during off-normal events (e.g. fire, seismic).
- SA
  - Potential Initiating Events (PIEs):
    - External natural (e.g. lightning, extreme temperatures, offsite fires);
    - External human induced (e.g. fire, aircraft crash); and
    - Internal (e.g. inappropriate processing, arcs & sparks, explosions, gross incompatibilities, failure of component or systems).
  - Use of computer codes
  - Normal scenarios and abnormal conditions
  - Accident scenarios (including design basis accidents [DBAs] and beyond DBAs)

### I.3. COMMISSIONING OF THE FACILITY

In commissioning, specific attention should be paid to the performance of structures, systems, and components important to safety. The aim of the SC for cold commissioning is to justify the decision that the as-built facility is safe to operate (taking into account any design changes during construction) and also to identify potential areas for optimization. For hot commissioning, the aim is to justify the decision that the facility can accept radioactive



material safely. Additionally, the SC should provide updated information on the management system (para. 6.21 of [3]).

Factors include:

- Develop and proof-test procedures in all safety areas (e.g. health physics, management systems);
- As-built facility meets the final design criteria for safety:
  - Walls have required density for shielding to achieve dose standards;
  - Floor strength verified and sealant coating tested.
- System line-ups (e.g. valves and breakers as needed) verified;
- Cold commissioning of equipment prior to hot commissioning;
- Graded approach used for activity levels at start-up: kBq to MBq to GBq;
- Finalize waste acceptance criteria (e.g. DSRS, liquids, dry solid waste);
- Operating procedures necessary to operate facility:
  - Critical procedures embedded “in license”;
  - Non-critical procedures can be attached to license.
- Record keeping from notification of incoming RW until transfer to another facility:
  - Quality Assurance (e.g. Nuclear Quality Assurance [NQA] -1 program).
- Update plan for the decommissioning of the facility;
- Emergency Plan and procedures in place;
- Update of the SA:
  - Potential Initiating Events (PIE);
  - Normal (non-accident) scenarios and abnormal conditions;
  - Accident scenarios (including DBAs and beyond DBAs).

#### I.4. OPERATIONS

The initial SC for operations should provide evidence that the facility has been constructed in accordance with the design and that commissioning demonstrated the facility can be operated safely. Any significant differences between the actual performance and predicted performance of the facility (or activity) should be identified and the reasons for the differences investigated. All discrepancies should be justified.

The aim of the SC for operation is to justify the decision that the facility can be operated safely for a specific period and can then be safely decommissioned (para. 6.26 of [3]). It should be noted that the SC should also be updated if there are significant changes to the facility that could affect safety.

Factors include:

- Update plan for the decommissioning of the facility;
- Documentation of facility changes/updates vs. periodic safety review (PSR) update:
  - Changes may be extensive (e.g. adding conditioning or treatment) that require additional design, construction and commission stage evaluations.
- Changes in national statutes and rules;
- Change in knowledge;
- Management system (e.g. record keeping).

## I.5. DECOMMISSIONING

Every waste management facility will eventually be decommissioned. From the very earliest stage of the development of the SC, decommissioning must be addressed to justify decisions on its safety. The justification should be based upon techniques that are currently available and should take into account the level of resources that are likely to be available at the time of closure (para. 6.27 of [3]). The level of effort and expense during decommissioning is directly tied to the management system during operations. Aggressive contamination control techniques used during operations will make remediation efforts easier, faster, and less expensive.

(The decommissioning plan is not addressed here.)

DRAFT

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## **ANNEX I.**

### **ILLUSTRATIVE SAFETY CASE FOR THE SLOVENIAN NATIONAL STORAGE FACILITY FOR INSTITUTIONAL RADIOACTIVE WASTE**

#### **EXECUTIVE SUMMARY**

Slovenia joined the CRAFT project in 2012 with the view to implement the recently published International Atomic Energy Agency (IAEA) General Safety Guide GSG-3, The Safety Case and Safety Assessment for the Predisposal Management of Radioactive Waste (RW) [I-1] in the preparation of the safety case for the Central Storage Facility in Slovenia (CSF).

The Slovenian Agency for RW Management (ARAO), referred to herein as the Operator, received a 10 year operating license for the CSF in 2008. Since the issuing of the license in 2008, a number of new documents were prepared for the facility, prompting ARAO to make the decision to update the Safety Case. The updated Safety Case will also address changes and optimization of the facility. Work began on the Safety Case in 2013 and is expected be completed in 2017. The purpose of the safety case is to support the continued operation of the facility following requirements for the Periodic Safety Review as prescribed under Slovenian legislation.

During the revision of the safety case, the philosophies of the graded approach and the step by step approach were used. In order to reduce uncertainties, all data used in the safety case was updated. In order to increase the confidence of the competent regulatory authority [the Slovenian Nuclear Safety Administration (SNSA)] in the assessment, ARAO followed a combination of methods and tools to prepare safety assessment in parallel: “traditional” tools (performing standard dose calculations using MS Excel and other commercially available modeling tools); and following the Safety Assessment Driving RW Management Solutions methodology [I-2] and using the Safety Assessment Framework (SAFRAN) tool [I-3], both of which were developed under the predecessor to the CRAFT project.

This report presents the work performed from the period 2013 through 2015 during the preparation of the safety case for the CSF in Slovenia. The task is not yet complete and the final Safety Case is expected to be finalized in 2017. This report documents the work done and the results achieved in the updating of the Safety Case. The Safety Case includes a comprehensive safety analysis of the CSF facilities and activities, considering the current and anticipated future inventory. The scope of the Safety Case also includes the storage of institutional RW collected in Slovenia from various “small” producers. The Safety Case addresses issues of importance such as the management system, site aspects, facility design, RW inventory, storage capacity and operational (storage) activities.

The methodology for the safety assessment includes:

- Engineering analysis of the facility (description of SSCs and identification of their safety functions),
- Development of scenarios (normal and accidental) using the Hazard and Operability Study (HAZOP) method and subsequent identification and screening of postulated initiating events,
- Assessments of the exposures of the workers and public during normal operational conditions, anticipated occurrences, as well as accident conditions.

The results of the assessment indicate that the facility and activities described and performed in accordance with the provisions set out in this Safety Case comply with national and

international regulations and standards and meet the relevant dose criteria for workers and the public.

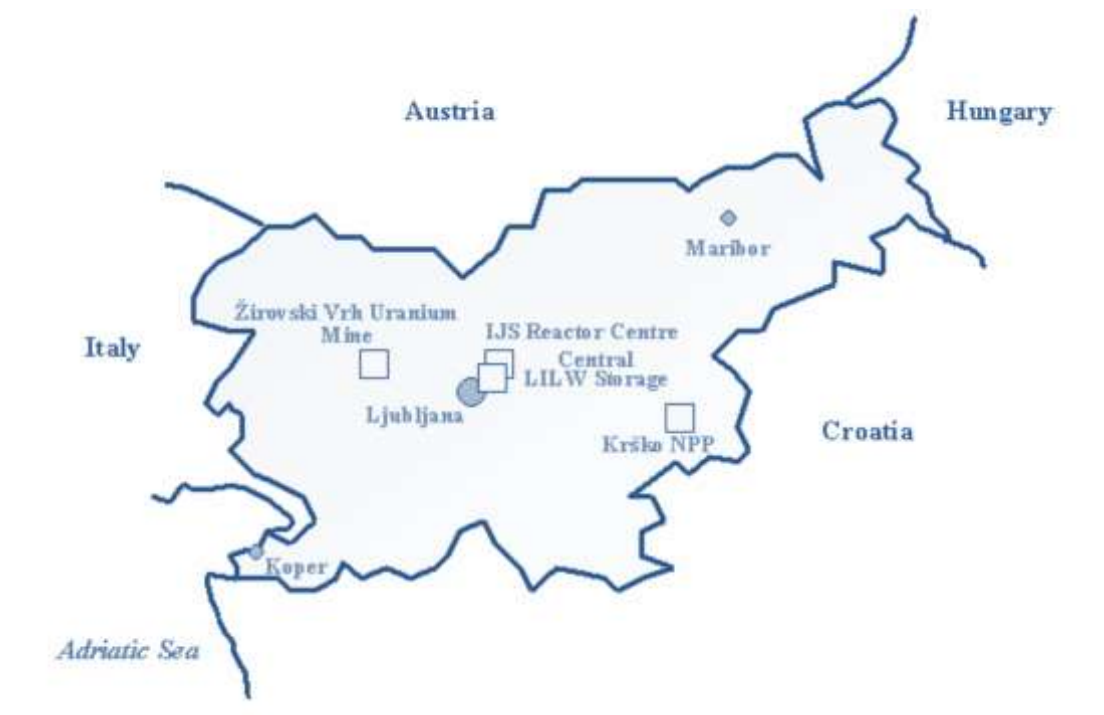
## I-1 INTRODUCTION

The Republic of Slovenia is a nation state in southern Central Europe located at the crossroads of main European cultural and trade routes. It is bordered by Italy to the west, Austria to the north, Hungary to the northeast, Croatia to the south and southeast, and the Adriatic Sea to the southwest. It covers 20,273 square kilometres (7,827 sq mi) and has a population of 2.06 million. It is a parliamentary republic and a member of the United Nations, European Union, and NATO. The capital and largest city is Ljubljana [I-4].



*FIG. 1. Location of Slovenia (dark green) in Europe and in the European Union (green) [I-4].*

Slovenia is a small country with a very small nuclear program (FIG. 1). It has one operating nuclear power plant, one research reactor and one central storage facility for radioactive waste (RW) generated by small producers. In addition there are also a uranium mine and a mill under decommissioning at Žirovski vrh. The Krško nuclear power plant (Krško NPP) is owned by state-owned Slovenian and Croatian electrical power companies, GEN energija d.o.o. and Hrvatska Elektroprivreda d.d., respectively.



*FIG. 2. Nuclear sites in Slovenia.*

There are two storage facilities in Slovenia that store RW awaiting disposal. One facility is operated at the site of the Krško NPP, storing RW arising from NPP operations. The second storage facility is the Central storage facility (CSF) which is located in Brinje near the Slovenian capital Ljubljana. It is intended for the storage of low and intermediate level RW (LILW) arising from medical, industrial and research applications. The CSF is operated by the Agency for RW Management (ARAO). ARAO is a non-profit organization of the Slovenian Government, providing a state-owned public service for RW management. The construction of the CSF started in 1984 and the facility was put into operation in 1986. In 1999, the responsibility for management and operation of the facility was transferred from the Josef Stefan Institut to the ARAO. Following refurbishment and two and a half years of trial operation, a new operating license was issued in early 2008, which is valid until 2018.

ARAO carries out the following activities:

- Collection of RW at waste producers' premises;
- Collection of RW on-site in the event of accidents;
- Collection of RW in the case where the waste producer is unknown;
- Storage of the collected RW in the CSF;
- Dismantling of sealed sources at producers' premises (less complex sources);
- The use of radioactive sources for calibration and testing of measuring devices;
- The treatment and conditioning of RW and disused sources in a processing facility – hot cell facility (rented) for the purpose of storage;
- The transport of radioactive materials, and transportation of nuclear materials as a part of public service.

ARAO operates within the framework of the RW Management Programme [I-5], which is an operational document for RW management in Slovenia that covers the organization and methods of carrying out activities, recording and reporting, definition of responsible services

and persons, information on documents forming the basis for carrying out activities, information on packaging, information on RW, management procedures and methods, measures to minimize RW generation, clearance, capacities in place, consideration of interdependencies between all stages of management, alignment of the management procedures with operative programmes under the national program of RW management.

The waste inventory in storage in the CSF has been characterized, treated and conditioned. ARAO has been performing treatment and conditioning of RW on a regular activity at the nearby processing facility (hot cell facility) since 2012. The ARAO staff carries out waste sorting, characterization, compaction, dismantling of disused ionizing smoke detectors and solidification of liquid RW. It is planned to implement dismantling of other sealed sources in the future.

During the development of the waste acceptance criteria (WAC) [I-6] for storing the institutional RW in the Central Storage Facility, ARAO considered the generic WAC for the planned LILW disposal [I-7], International Atomic Energy Agency (IAEA) TECDOC-864 [I-8], Slovenian legislation and operators' practices. The WAC for the storage facility will be revised when the WAC for disposal is approved.

## I-2 LEGAL AND REGULATORY FRAMEWORK

The main Act of the Republic of Slovenia in this area is the Ionizing Radiation Protection and Nuclear Safety Act, which regulates also RW and spent fuel management. The Act was amended in 2003, 2004 and 2011. The current regulations apply to the import, export, acquisition, production, transformation, detention, use, sale, transit, transport, recycling and re-use of equipment or substances capable of emitting ionizing radiation. They also apply to the treatment, handling, conditioning, storage, clearance and disposal of radioactive substances or RW and to any other activity involving a risk arising from ionizing radiation.

A system of licensing of spent fuel and RW management is provided in the 2002 Act, while the Rules on Radiation and Nuclear Safety Factors lay down details on documentation that must be submitted in a particular phase of licensing. The prescribed licensing process is of general nature, thus it is applicable to whole spectra of nuclear and radiation facilities.

The basic classification of facilities is provided by the Act itself, where in definition No. 22 of Article 3 it stipulates that a nuclear facility is "*a facility for the processing or enrichment of nuclear materials or the production of nuclear fuels, a nuclear reactor in critical or sub-critical assembly, a research reactor, a nuclear power plant and heating plant, a facility for storing, processing and disposal of nuclear fuel or high radioactive waste, a facility for storing, processing or disposal of low and intermediate radioactive waste*". Therefore the entire spectrum of licensing requirements (for siting, construction, trial operation, operation, decommissioning, and/or closure of the disposal) has to be taken by the applicant (investor or operator of the facility) in accordance with provisions of the 2002 Act and of the Rules on Radiation and Nuclear Safety Factors.

At every step of the licensing process the investor/operator is required to attach to the license application, in addition to the design documentation, a Safety Analysis Report and the opinion of an authorised radiation and nuclear safety expert authorised by the competent regulatory authority body (the Slovenian Nuclear Safety Administration [SNSA]) and other prescribed documentation required by the Rules on Radiation and Nuclear Safety Factors [I-9].

During subsequent licensing processes (e.g., approval of trial operation, operation, decommissioning or closure of the facility) the licensee is required to submit the above-described application containing an appropriately amended set of documents and opinions. Operating experience, feedback, and modifications of the facility are required to be clearly documented and described.

The SNSA is an organizational unit / body within the Ministry of Agriculture and the Environment. All operators of nuclear facilities in Slovenia are under other ministries and with this, the needed level of independence and autonomy is established. Decisions adopted by the SNSA within its scope of competence are taken solely and exclusively by the SNSA and cannot be dictated or imposed on the SNSA from the Ministry of Agriculture and the Environment, the Minister or any other body within the Ministry.

The SNSA performs specialized technical and developmental administrative tasks and inspections in the area of radiation and nuclear safety, radiation practices and use of radiation sources (except in health and veterinary care), protection of the environment against ionizing radiation, physical protection of nuclear materials and nuclear facilities, non-proliferation of nuclear weapons and safeguards of nuclear goods; the SNSA furthermore monitors radioactivity in the environment, third party liability, and transport, import and export of radioactive materials.

In the case of the CSF the SNSA is responsible for:

- Licensing;
- Inspection;
- Enforcement of nuclear and radiation safety.

On 6 March 2006 the Minister of the Environment and Spatial Planning adopted the Rules on RW and Spent Fuel Management [I-9].

On 1 February 2006 the Parliament of the Republic of Slovenia passed the Resolution on the 2006-2015 National Programme for Managing RW and Spent Nuclear Fuel [I-10]. This Programme is a part of the National Environment Protection Programme and sets goals and tasks in the field of RW and spent nuclear fuel management.

The resolution foresees general timelines and financing for activities related to RW and spent nuclear fuel management for all radiation and nuclear facilities.

On 2 July 2013 the Parliament of the Republic of Slovenia passed the Resolution on the 2013-2023 Nuclear and Radiation Safety in Slovenia (Official Gazette RS, No. 56/2013). The Resolution, as a high level national policy paper, covers the following chapters: The fundamental safety principles, description of nuclear and radiological activities in Slovenia, description of the international cooperation in the field of nuclear and radiation safety, description of the existing legislation (including binding international legal instruments, such as conventions and other relevant international instruments), description of the institutional framework, competence of professional support (research, education, training), objectives and measures to achieve them during the period up to 2023.



## I-3 CONTEXT OF THE SAFETY CASE

### I-3.1. Purpose of the safety case

In accordance with the requirements associated with the licensing process in Slovenia, the investor/operator attaches to the license application design documentation, a Safety Report, the opinion of an authorized radiation and nuclear safety expert (authorized by the SNSA) and other prescribed documentation set by the Rules on Radiation and Nuclear Safety Factors.

Revision 0 of the Safety Report for the CSF was prepared in 2007. Subsequently, the term Safety Case was defined in relation to the management of RW [I-1]. Following good international practices and requirements, a definition of the Safety Case is now included within the safety strategy for CSF [I-11] as a collection of scientific, technical, administrative and managerial arguments and evidence in support of the safety of a CSF, following the definition in GSG-3 [I-1]. Therefore, the Safety Case for the CSF includes a number of documents and reports that will be summarized in the main Safety Case report document.

As a result, a series of new documents related to the CSF and revisions of existing documents have been prepared: training program for staff relevant to nuclear and radiation safety [I-12], facility decommissioning plan, RW management program, physical protection plan, ageing management program [I-13], working procedures and manuals etc. The significant changes in the legislation in the field of physical protection of nuclear facilities came into force in 2013. The upgrades regarded the physical protection in the CSF were implemented in 2014 and 2015. In 2013, ARAO began work on the revision of the safety case for the CSF. The new revision takes into account all the above mentioned changes (changes in documentation and upgrades in the CSF) and also the commitment by ARAO to implement IAEA GSG-3 [I-1] and SADRWMS [I-4] methodologies and the SAFRAN [I-3] tool

The main purposes of the new revision of the safety case are:

- To perform a periodic reassessment of the safety of the facility; and
- To apply certain changes related to optimization of the facility design.

The Safety Case for CSF is a living document, with supporting references, which is developed and updated throughout the lifecycle of the facility - operation and decommissioning. This Safety Case forms the basis for phased regulatory decisions as well as operational decisions.

The CSF is currently in the operational stage. The principal purposes of this revision of the Safety Case are:

- To demonstrate the safety of the facility in its current stage;
- To support licensing (license prolongation) of the facility with the Regulatory body;
- To justify continued operations and identify areas for improvement in the facility.

As a result of the iterative development of the Safety Case through the facility lifecycle, the following results are achieved:

- The systematic collection, analysis and interpretation of the necessary scientific and technical data;
- The development of plans for operation;
- Optimization of protection and safety;

- Iterative studies for design optimization, operation and safety assessment with progressively improving data and comments from technical and regulatory reviews.

The following specific aspects will be addressed in this Safety Case:

- Demonstration of the safety of the CSF.
- Demonstration of the safety of various RW management activities performed by the Operator. These activities include: acceptance and characterization of the RW.
- Optimization of the respective waste management activities described above.
- Management systems implemented to ensure the safety of the respective waste management activities described above.
- Definition of limits, controls and conditions that will be applicable to the facilities and the respective activities described above.
- Input to the improvement of existing radiation protection programs and activity procedures.

This Safety Case takes into consideration the IAEA General Safety Requirements (GSR) Part 5 on the Predisposal Management of RW [I-14], the IAEA Safety Guide GSG-3 on the Safety Case and Safety Assessment for the Predisposal Management of RW [I-1] and General Safety Requirements (GSR) Part 4 on Safety Assessment for Facilities and Activities [I-15]. Safety criteria are taken from the Slovenian regulatory framework and GSR Part 3 on Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards [I-16].

### **I-3.2. Scope of the safety case**

The scope of the Safety Case includes the following activities:

- Acceptance, identification, removal of waste from the transport container and placement into the storage container (further considered as packaging in the document) and handling of RW at the CSF;
- Storage of the RW at the CSF;
- Maintenance and inspection of the RW packages and their contents during their storage in the CSF.

A detailed description of the above activities is given in Section I-5.3.

This version of the Safety Case specifically excludes the following activities:

- Collection and transport of RW to the CSF;
- Waste retrieval;
- Buffer storage of untreated liquid waste;
- Decommissioning of the facility;
- Non radiological hazards.

### **I-3.3. Demonstration of safety**

This section describes the approach to demonstration of safety, specifically the safety objectives and safety principles that are applied and the regulatory requirements that must be met. Taking cognizance of the scope of the Safety Case and the application of the graded approach as described in Section I-3.4, the safety of the waste management and storage facilities will be evaluated and demonstrated as described hereafter.

#### *I-3.3.1. Approach to Basic Engineering Analysis*

A qualitative assessment will form the basis of the basic engineering analysis, which will mainly cover the following:

- Basic site characteristics and credible external events considered in the design of the CSF to ensure structural stability;
- Quality assurance considered in the design, construction, maintenance and modification of the CSF;
- Application of national construction codes and standards;
- Inspection and maintenance plans;
- Formal processes for the evaluation, approval and implementation of modifications;
- Safety and security aspects.

Quantitative and qualitative assessments will be performed to assess the impact of the waste management activities and results will be assessed in terms of the safety criteria (Section I-6.1.2).

The following specific assessments will be performed:

- For normal operations, quantitative deterministic assessments of worker dose resulting from the range of activities by workers, including determination of the allowed working hours in CSF areas;
- For anticipated operational occurrences, quantitative deterministic assessments of worker and public doses as applicable;
- For all other credible accident scenarios, a quantitative and qualitative assessment of the impact of other occurrences with identification of specific preventative and mitigating measures.

#### *I-3.3.2. Approach to Safety Assessment*

The radiological assessment follows a realistic and conservative approach taking measured data into consideration where possible. Where such data are not available, the data embedded in the SAFRAN tool calculation modules and other models are applied to model exposures based on reasonable assumptions.

Uncertainties inherent to the assumptions made in the quantitative assessments or any other uncertainties identified during the safety assessment are evaluated to determine their impact on safety. The main sources of uncertainties that may have a significant impact on safety are presented along with recommendations for their management (See Section I-6.11, Table 57).

All of the above safety assessments are provided in Section I-6 of this document. Section I-10 presents the results from the quantitative and qualitative assessments for comparison against the proposed target and objectives set for the optimization of protection.

A qualitative assessment is performed of the availability and level of implementation of an integrated management system in order to ensure a sustained level of safety. This assessment focuses on radiation protection, work procedures, quality assurance, and processes for the management of operating limits and conditions.

#### *I-3.3.3. Overall Approach to Safety of the Facility*

A simple robust design was adopted for the construction of the CSF to make operations within the facility simple and easy to undertake. The facility design and construction provides defense in depth and is designed to rely predominantly on passive safety features. The overall safety of the facility does not rely on a single design feature.

#### **I-3.4. Graded approach**

A graded approach is applied to define the extent and depth of this Safety Case by the use of qualitative assessment of hazards and deterministic analysis of doses to potential representatives (e.g., workers and public). This takes into consideration the relative safety significance, low complexity of operations and the maturity of the facility and storage activities.

The main factors to justify a relatively simple approach to the safety assessment for the CSF are:

- The limited scope and function of CSF structures, systems and components (SSCs) (storage of RW packages awaiting disposal).
- The simplicity of the activities involving storage of RW and supporting activities (e.g. internal transport, monitoring, inspection, etc.). The facility is under permanent supervision (through monitoring and physical and technical protection).
- The radiological hazard when undertaking the various management activities involving stored containerized RW can be regarded as low.
- The maturity of the facility:
  - ARAO started operations at the CSF in 1999.
  - Reconstruction work was finished in 2004.
  - In 2005 the trial operation license was issued.
  - In 2008 the 10 years operational license was approved.
  - For the past 7 years, the CSF has, without any unexpected events, regularly accepted RW packages, performed continuous monitoring of the radioactivity, and has ensured that all installed SSC are well maintained and inspected and that workers are all trained.
  - Storage activities at the CSF follow good practice and internationally accepted concepts.
- Inherent high level of passive safety associated with the management of disused sealed radioactive sources (DSRS) and limited reliance on active protection systems.

#### **I-4 STRATEGY FOR SAFETY**

This section describes the strategy for safety, including the approach taken during facility design and all respective RW management activities to comply with regulatory requirements and to ensure that good engineering practice has been adopted and that safety and protection are optimized.

In view of the scope of the Safety Case as defined in Section I-3.2 and the document that described the safety strategy for the CSF prepared by ARAO [I-11], the following strategies for demonstrating safety of the management of RW are adopted:

- Safety principles – all the safety principles defined by IAEA requirements [I-17] and resumed in Resolution on Nuclear and Radiation Safety in the Republic of Slovenia [I-18] are met.
- Step by step approach is used with principle that the facility and the activities performed in the facility can adopt new findings and practice.
- Defense in depth – Care is taken to ensure that multiple safety layers and safety functions are established. This principle is considered to ensure that no important safety argument is based on a single level of protection.
- Passive safety – The use of passive safety systems wherever possible.
- Shielding – Ensuring that doses to workers and the public are as low as possible. This also includes the optimization of shielding usage during all waste management activities including transportation and storage is considered.
- Selection of implemented waste management practice – Approach to waste management with regards to the following is regarded as contributing to safety.

A qualitative assessment is performed on the implemented waste management practices. In the approach to waste management the following will be regarded as contributing to safety:

- Clearly defined responsibilities for waste management;
- Implementation of the principles of waste minimization and avoidance, namely, re-use or re-processing of waste, return to supplier, safe and secure storage and conditioning and final disposal of waste.
- Hazards of the generation of secondary waste associated with all waste management operations (routine and ad hoc) are known, monitored, projected and managed by due management processes.
- Interdependencies between the various steps of waste management are known and managed.
- Waste acceptance criteria are defined and waste management activities (and the outputs of such activities) are aligned with the set waste acceptance criteria.
- Interim storage of RW will only take place inside proper containment such as the original working shields or another type of suitable containment.
- Conditioned RW will be stored in a dedicated storage area with passive safety features and adequate access control.

Engineering aspects that ensure safety are:

- The engineering characteristics of the building. Information expressed in the building design document show the engineering features. Its design ensures structural stability under extreme environmental conditions (earthquake, storm, etc.).
- The characteristics of the walls ensure a dose rate that complies with the restriction for public exposure (0.1 mSv/a) for the representative person.
- The lighting system will be adequate and permits the performance of operations in a safe manner.
- Electric power is limited to the radiological control and management operations areas.
- Each delineated area has sufficient physical space to ensure a minimal probability of accident occurrence during package management.
- Storage building areas were designed under the principle of labyrinth, which contributes to optimize and minimize the exposure of workers.

- Drums with radioactive sources are stored in such a manner that packages do not contact the interior surface of the building walls. This enables adequate control operations and ensures that the potential corrosion of packaging/containers is limited.
- Unconditioned radioactive sources are stored in stacking systems ensuring normal operation and minimizing probability of accidents.
- There is a vault with special shielding structure that minimizes worker exposure for the storage of radioactive sources of high activity that cannot be conditioned.

For situations of operational occurrences and accidents due to internal operational factors, the engineering systems ensuring safety are:

- Floor and wall finish that allow easy decontamination.
- The segregation of the different areas limits the potential dispersion of any contamination.
- In case of a potential surface decontamination using liquids, there is a collection system inside the facility that prevents its release to the environment. The system has a retention tank that permits environmental monitoring before releasing to the environment.
- The facility has its own fire response equipment.

## I-5 DESCRIPTION OF THE FACILITIES, ACTIVITIES AND THE WASTE

### I-5.1. Short description of the CSF

Facility name: Central Storage Facility (CSF) for institutional RW

Country: Slovenia

Status: in operation

Waste types: solid RW from medicine, industry, research and education activities

Waste streams:

- T1 (solid, compressible, combustible);
- T2 (solid, compressible, non-combustible);
- T3 (solid, non-compressible, combustible);
- T4 (solid, non-compressible, non-combustible);
- SRS (sealed radioactive sources);
- M (mixed waste).

External packing: 210 l drums, 210 l drums with inner concrete shielding, 320 l drums, original containers of SRS, PE bags, PE or metal containers.

Typical radionuclides: Co-60, Cs-137, Eu-152, Am-241, Ir-192, Kr-85, Sr-90, Am-241/Be, Eu-152/154, Ra-226, Pu-239, C-14, H-3, Se-75, U-238, Th-232.

Facility Operations: accepting the waste packages, storing the waste packages, manipulation of the waste packages, monitoring, export (for T&C or release).

Layout of Facility: Controlled area with: 10 storage sections, separated with concrete walls.

Observation area: rooms for personnel, machinery room for ventilation system.



Capacity: 115 m<sup>3</sup> with the possibility to extend.

Systems: ventilation system with HEPA filters, fire protection system, drainage system, for potential liquid release collection, physical protection system.

Typical staffing: 6 persons.

### I-5.2. Site conditions

The CSF is located inside the premises of the Research Reactor Center of Josef Stefan Institute, north – west direction from Ljubljana (See FIG. 3). The Research Reactor is located adjacent (less than 50 meters) to the CSF. The Sava River flows approximately 1 km South from the site and the Pšata River flows 0.5 km to the north-east.

The perimeter of the site is enclosed by a simple fence. This fence is erected on the owner's property line and also encloses the Josef Stefan Institute buildings with the Research Reactor.



FIG. 3. CSF site.



### I-5.2.1. Demography

Table 1 presents the number of inhabitants (as of 1 January .2013) at distances presented in FIG. 4 in the surrounding areas adjacent to the CSF.

TABLE 1. NUMBER OF INHABITANTS AT RADIAL DISTANCE FROM THE CSF

Radius [km]	Number of inhabitants
0.5	62
1	776
2	3633
3	7122
4	19379
5	42579
6	85227
7	140078
8	177450
9	221005
10	271780

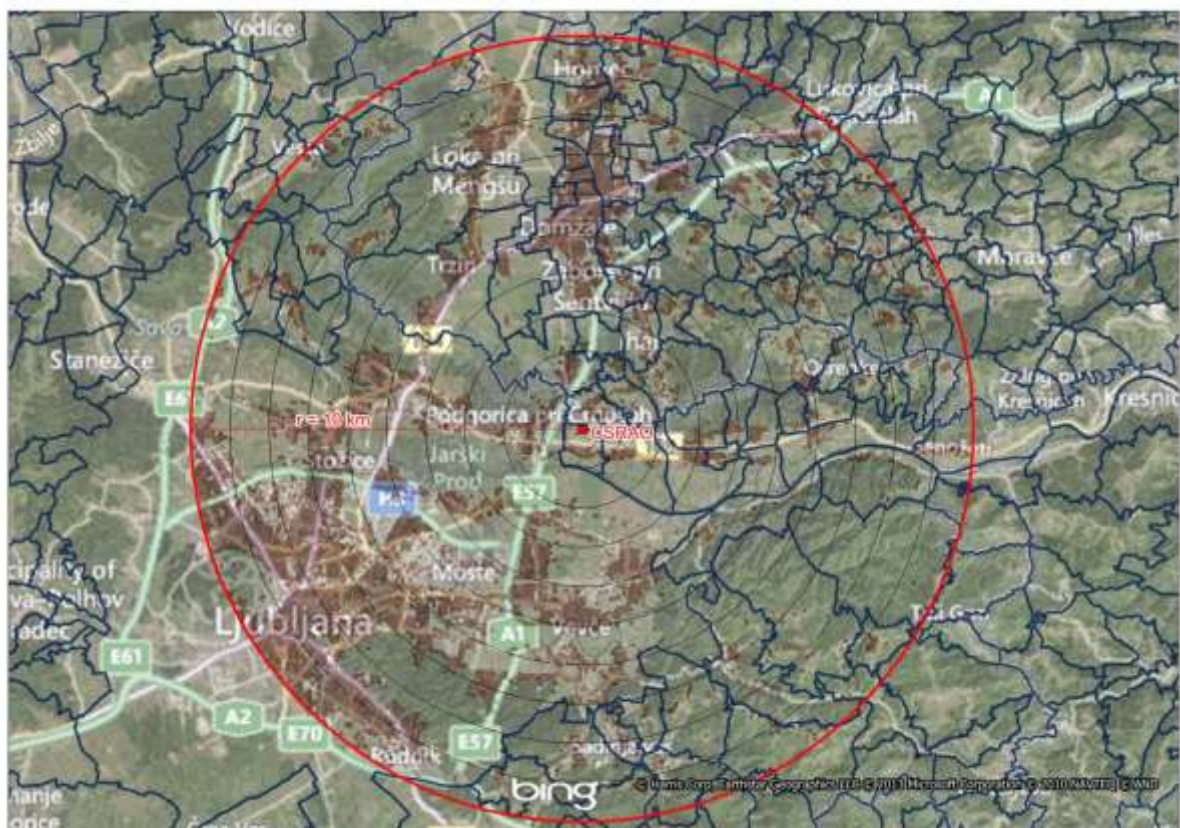


FIG. 4. Map of surrounding communities showing radial distances from the CSF.



Within a 0.5 km radius of the CSF there are only 62 inhabitants who use the land around the facility mainly for farming. Nobody lives permanently inside the Josef Stefan Institute premises, although around 150 people work there on a daily basis.

Most of the inhabitants of the urban areas are within a 6-7 km radius, as shown on the FIG. 5.

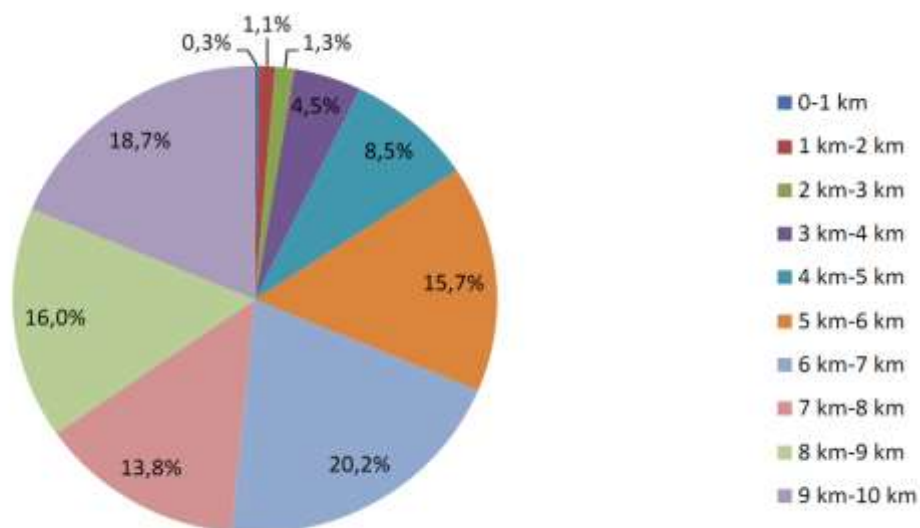


FIG. 5. Percentage of inhabitants at radial distance from the CSF.

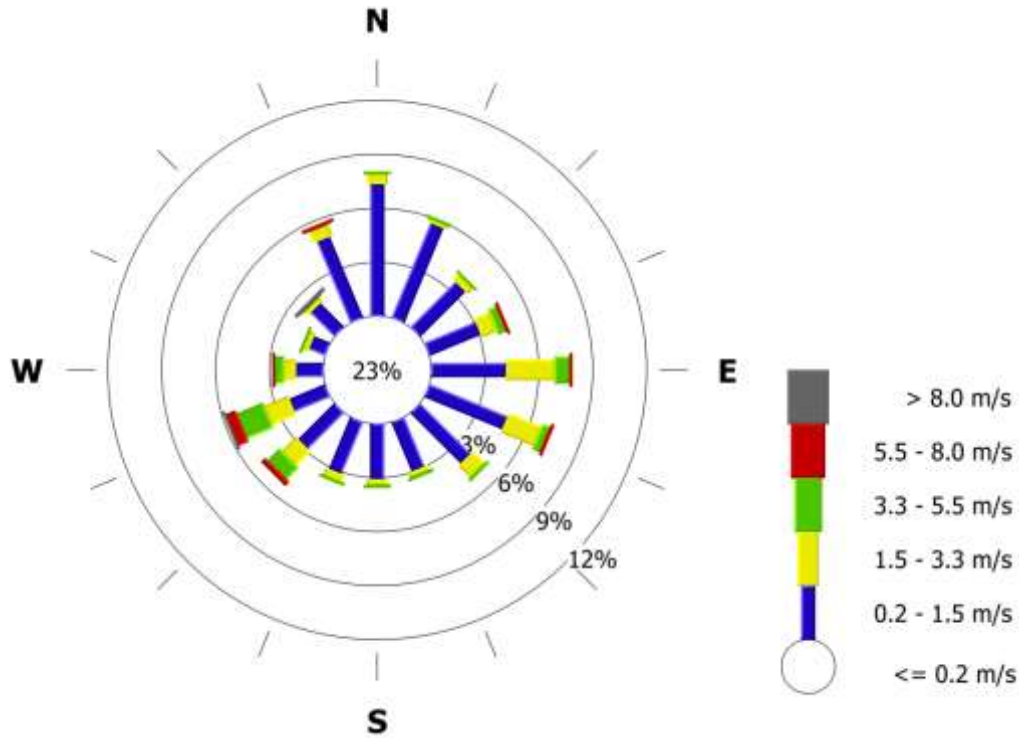
#### I-5.2.2. Meteorology

ARAO measures site meteorological conditions and collects data using the meteorological station (See FIG. 6) located 250 m west from the CSF. The site lies in an area with moderate continental climate, with low winter temperatures, frequent temperature inversion, relatively high summer temperatures, relatively high levels of precipitation and frequent fog.



*FIG. 6. Meteorological station near the CSF.*

Wind data has been collected since 2010 from the weather station adjacent to the site. As illustrated on the wind rose (FIG. 7), an evaluation of the characteristics of the wind shows that the most dominant winds are N and NW direction and E and SW direction with generally low wind speeds. The annual average wind speed is 1.3 m/s or approximately 4.7 km/h.



*FIG. 7. Wind rose for the CSF site (from 1.1.2010 to 31.12.2012) on the height of 10 m.*

Table 2 presents the number of days with the strong wind (wind speed greater than 11 m/s) and number of days with very strong wind (wind speed greater than 17 m/s).

TABLE 2. THE NUMBER OF DAYS WITH STRONG AND VERY STRONG WIND IN THE CSF AREA

	Number of days with the strong wind speed > 11 m/s	Number of days with the very strong wind speed > 17 m/s
1981	13	0
1982	22	0
1983	41	1
1984	29	4
1985	34	0
1986	12	2
1987	19	1
1988	36	0
1989	36	3
1990	47	1
1991	57	1
1992	60	1
1993	64	1
1994	52	2
1995	46	3
1996	41	2
1997	45	1
1998	44	1
1999	49	0
2000	50	1
2001	59	2
2002	48	2
2003	57	4
2004	37	1
2005	44	1
2006	50	2
2007	55	2
2008	56	2
2009	49	0
2010	43	1

Temperature data indicates that the annual average temperature is 10.5°C. Table 3 shows the average air temperatures, precipitations and average relative humidity in the CSF area.

TABLE 3. AVERAGE AIR TEMPERATURES, PRECIPITATIONS AND AVERAGE RELATIVE HUMIDITY IN THE CSF AREA

	Jan	Feb	Mar	Apr	Maj	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average air temperature [°C]	-0.4	-0.3	6.7	11.1	14.9	19.3	21	20.7	16	9.6	6.8	0.4	10.5
Precipitation [mm]	37.7	42.2	40.8	60.1	90.3	89.3	108	94.5	202	153	92.9	101	1111
Average relative humidity [%]	86	81	75	72	75	78	76	72	76	87	91	92	80

#### I-5.2.3. Site Geology and Hydrology

The land where the CSF is constructed is located on flat terrain with a slope of about 1 % (thus preventing the drainage of rainwater) in the direction to the Sava River, with average elevation of 280 meters above sea level.

From the map on the FIG. 8, it can be seen that the site of the CSF lies in an area that is not defined as an area that can be flooded.

The CSF lies on the Sava River terrace at around 9 m above the Sava River, which flows 1 km away from the facility site. The area consists from Quaternary conglomerate gravels and gravels with some layers of silt, clay gravels and clay.

In the area of CSF the thickness of unsaturated zone is from 7.5 to 10.5 m. The average hydraulic conductivity of the upper 20 m layers is  $5.6 \cdot 10^{-4}$  m/s.

The average temperature of ground water is around 11 °C.



FIG. 8. Map of the floods probability for CSF [I-19] where Very rear flood means floods with the return period more than 50 years, Rear flood means floods with the return period from 10 to 20 years and Frequent flood with the return period from 2 to 5 years.

#### I-5.2.4. Site Seismology

The area where CSF lies originate from older Pleistocene and it is one of earthquake-prone areas in Slovenia. In the last 20 years two more significant earthquakes occurs:

- Bovec, April 1998, 80 NW km from Ljubljana, magnitude 5.8 with intensity 7-8 (EMS);
- Trebnje, August 1998, 30 SE km from Ljubljana, magnitude 4.3, with intensity 5 – 6 (EMS).

These earthquakes did not cause any damage to the CSF. The CSF design documentation shows that it was constructed as earthquake resistant (seismically safe).

#### I-5.3. Description of the facilities and activities

The CSF was constructed in 1986. It lies inside the area of the Research Reactor Center of Josef Stefan Institute in Brinje.



*FIG. 9. View to the entrance of the CSF.*

The CSF was constructed for the purpose of storing LILW arising from the use of radioactive materials in medicine, industry and research activities in Slovenia. The CSF is a near-surface concrete building (seismic resistant) with the roof covered with a soil layer. The storage concept of the facility makes use of multiple barriers (reinforced concrete walls, cover, doors, additional shielding) to perform additional protection against radiation.

The building is subdivided by concrete walls into nine storage sections and an entrance area (see FIG. 9 and FIG. 10). The ground plan of the facility is 10.6 m x 25.7 m with a height of 3.6 m. A small area is intended for a checkpoint between radiological controlled and supervised area and has a space for loading and unloading the waste and for internal transport. The storage section at the back end of the building is relatively deeper compared to the level of the other sections.

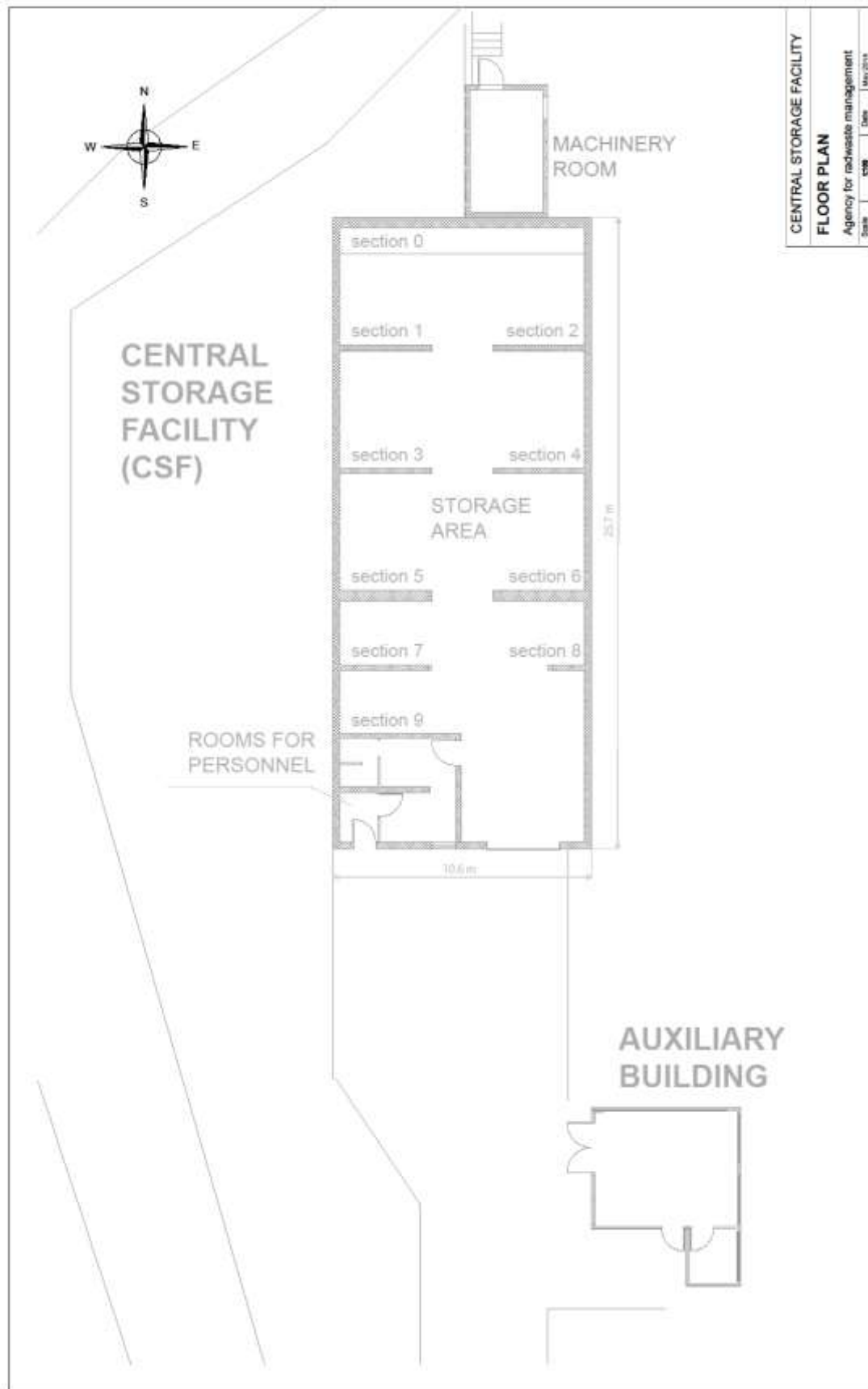


FIG. 10. The CSF floor plan.

The facility is equipped with a ventilation system for reducing radon concentration and air contamination in the storage facility. To maintain relatively low and constant humidity, the CSF is equipped with an air-drying system. The water and sewage collecting system is designed as a closed system that retains all liquids from the storage facility in the sump. Liquids are only discharged after measurements of radioactive contamination are demonstrated to be below the prescribed regulatory limits. Collected liquids exceeding the limit are treated. The electricity supply system is used for lighting the storage facility and for powering the ventilation. The storage facility is physically and technically protected against fire, acts of violence, burglary, sabotage and similar events.

#### *I-5.3.1. Facility Operation*

Operational activities within the CSF involve:

- Unloading from transport container;
- Control measurement;
- Packaging (take the package from transport overpack and put it in the storage drum);
- Storage.

The facility design is such that it makes these operational activities simple and easy to undertake in minimal time. Written operational procedures are prepared to ensure that the activities are carried out safely and in minimal time reasonably possible and to optimize safety and protection by ensuring that no individual dose constraints or limits are exceeded.

Operational radiation protection, maintenance and inspection procedures are formally documented and approved, an incident reporting system and emergency plans are prepared and approved. These procedures will be updated based on and justified by this Safety Case.

A record keeping system is in place for all operational activities, waste packages, DSRS and equipment. Stored waste in the CSF is clearly marked and labelled,

#### *I-5.3.2. Operational Radiation Protection*

The CSF is designated as a radiologically controlled area and people working in the facility are designated as occupationally exposed workers with the necessary training, dosimetry and medical control.

A radiation monitoring programme is implemented and covers routine monitoring of the facility and its environment, working environment, monitoring of specific operations such as treatment of waste, conditioning of DSRS and emplacement activities and some special monitoring that may be required from time to time. The programme makes provision to monitor external radiation levels and surface contamination [I-20].

### **I-5.4. Inventory of RW AND WAC for the CSF**

Relevant data associated with the waste inventory stored in CSF is kept in a database that is managed by ARAO.

At the end of 2013, 92.4 m<sup>3</sup> of RW was kept in the storage facility with total mass of 50 tons. The total activity of the waste was 3,2 TBq.



The storage facility currently contains 629 packages, which represents about 80 % of its capacity (storage space), and consequently the operator takes actions for volume reduction. The total volume was reduced in the past few years due to several campaigns of DSRS repacking and exemption of emptied and cleared containers. Annually there are approximately 50 receipts of waste from small producers ( $\sim 2 \text{ m}^3$ ). Figure 11 indicates the radionuclides and total activities of the different waste types in storage at the CSF.

Type of RAO	Radionuclides	Activity (Bq)
T1 (solid, compressible, burnable waste)	Ra-266, Co-60, Am-241, Cd-109, Ag-108, U-238, Co-57, Th-232, H-3	9,5E+08
T2 (solid, compressible, unburnable waste)	Ra-266, Co-60, Am-241, Cd-109, Ag-108, U-238, H-3, U-238, C-14	1,7E+10
T3 (solid, uncompressible, burnable waste)	Ra-266, Co-60, Th-232	1,2E+08
T4 (solid, uncompressible, unburnable)	Ra-266, Co-60, Cd-109, Cs-137, Ag-108, U-238, C-14, Th-232, Ba-133	1,6E+11
ZV0 (smoke detectors)	Am-241, Ra-266	5,7E+09
ZV1 (spent sealed sources: $A \leq 3,7 \text{ [GBq]}$ )	Ra-266, Co-60, Am-241/Be, U-238, Th-232, Ni-63, Fe-55, Sr-90, Ru-106, H-3	4,4E+11
ZV2 (spent sealed sources: $3,7 \text{ [GBq]} < A \leq 37 \text{ [GBq]}$ )	Ra-266, Eu-152, Co-60, Cs-137, Kr-85, Am-241/Be, Ba-133	1,4E+11
ZV3 (spent sealed sources: $37 \text{ [GBq]} < A \leq 370 \text{ [GBq]}$ )	Eu-152, Am-241, Co-60, Ba-133, Am-241/be	1,7E+12
ZV4 (spent sealed sources: $A > 370 \text{ [GBq]}$ )	Co-60	6,3E+11
Total activity on 31. december 2010		3,1E+12

FIG. 11. Waste forms stored in CSF.

RW stored in the CSF include waste packed in drums, DSRS in original containers, plastic or metal boxes and plastic bags.

The drums contain mostly contaminated material such as paper, glass and plastic material with induced radioactivity caused by neutron exposure in the research reactor. DSRS are stored in the original shielding containers or are repacked in containers that are then placed in the drums.

Since 2012 ARAO has carried out dismantling of ionizing smoke detectors as a regular activity. The volume reduction factor of this treatment is so significant that, despite the continuous receipt of new waste from waste producers at the facility, the volume of RW in the storage facility has actually been only very slightly increasing.

From 2012 to 2015 ARAO collected 600 liters of liquid waste from research activities in medicine. Prior to their acceptance to the storage facility these liquid waste were solidified. The annual increase is estimated to  $3\text{--}6 \text{ m}^3$ .

All waste accepted at the CSF must meet the CSF WAC [I-6]. The WAC defines the parameters that need to be met for acceptance at the CSF. These parameters are:

- Package record;
- Inner and outer packaging;
- Waste form (from FIG. 11);

- Labeling;
- Dose rate;
- Contamination;
- State of matter;
- Corrosion resistance;
- Strength;
- Flammability;
- Explosiveness;
- Organic matter;
- Leachability;
- Chemical stability
- Degradation effects due to radiation;
- Gas generation;
- Toxic substances;
- Poisonous substances;
- Free liquids;
- Chelating agents;
- Heat generation.

In 2010, the material composition of the inventory in storage in the CSF was assessed [I-21] and is presented in Table 4. The total volume in Table 4 is approximately 60 m<sup>3</sup>. The remaining volume is designated as unknown (mainly sealed sources). The package type identified as D1 represents standard 208 l drum.

TABLE 4. MATERIAL COMPOSITION ESTIMATE OF CSF WASTE IN 2010

	Aluminium	Stainless steel	Steel	Undefined metals	Iron and cast iron	Depleted uranium	Cellulose	Sum
Mass (kg)	3100	1000	5000	3600	3900	50	1900	18550
Package type	D1	D1	D1	D1	D1	Shielded container	Mainly D1	
Packaged volume (m <sup>3</sup> )	15	2.3	10	8	7.2	0.01	17.5	60

### **I-5.5. Interacting processes**

The following processes interact with the development of the Safety Case:

- Interested parties;
- Independent review; and
- The management system utilised to develop the Safety Case.

#### *I-5.5.1. Involvement of interested parties*

Relevant interested parties are engaged in the early stages of the development of the Safety Case to allow an understanding of the arguments included in the Safety Case. This includes the regulatory body responsible for nuclear safety, the environmental regulator and national governmental officials. Where relevant, public consultation is also undertaken.

#### ***Ensuring transparency***

While managing RW in a professional and responsible way, ARAO constantly faces challenges related to social acceptance. Therefore, to accomplish its mission it is of utmost

importance to keep in mind communication, education and cooperation with interested stakeholders, such as:

- Interested citizens;
- Residents of local communities where our activities are being performed or where the construction of facilities is planned;
- School-aged children and young people;
- Non-governmental organizations; and
- The media.

ARAOs work in this area includes informing, raising awareness, monitoring public responses and opinions, and establishing a dialogue with key groups. These activities are carried out so as to increase knowledge about radiation and to raise awareness about the fact that professional and responsible RW management, as implemented by ARAO, contributes significantly to the quality of the environment and to sustainable development.

ARAO ensures transparent operation with the following activities:

- Informing and awareness-raising via the ARAO website [www.arao.si](http://www.arao.si);
- Publishing in the media;
- Organizing events and presentations for various stakeholder groups;
- Participating in conferences, roundtables and other public events;
- Providing access to public and environmental information.

#### ***Relations with local communities***

ARAO recognized the importance of communication in local and regional environments where its activities are carried out, i.e. in the Municipality of Dol pri Ljubljani and the Posavje Region. ARAO mostly communicates with communities through:

- The local media;
- Presentations and reports at meetings of municipal councils, and through mayors.

#### ***Doors Open Day***

Every year, ARAO holds annual Doors Open Day. At a press conference, which takes place before the event itself, we present the ARAOs work. Visitors are able to attend a lecture on the impact of ionizing radiation on living organisms. Using experiments, ARAO demonstrates that radioactivity is an omnipresent natural phenomenon. There is also a guided tour of the Central Storage Facility.

#### ***Media relations***

ARAO communicate with the media proactively and on a regular basis, providing prompt answers to any questions. In the past few years, the topics that the public and the media were most interested in were:

- Planning of the LILW Repository;
- SNF management;
- Compensation for limited use of space due to nuclear facilities; and
- Carrying out the public service of RW management.

#### ***Monitoring stakeholder responses and measuring public opinion***

ARAO followed stakeholder responses in the media and questions sent via the ARAO website. ARAO has not conducted a public opinion poll on RW management. However, ARAO has gathered some data relevant for RW management from other opinion polls.

#### *I-5.5.2. Independent review*

ARAO ensures that Safety Cases are subjected to independent Review, as it is also obliged by national legislation. The independent reviewer (nominated by regulator SNSA) should verify the assumptions, models and assessment results. The positive opinion of the independent reviewer must be the part of the license documentation delivered to the regulator.

#### *I-5.5.3. Management system*

The ARAO has an integrated management system in place that gives the required priority to nuclear safety. The ARAO integrated management system is based on IAEA GS-R-3 [I-22], ISO 9001:2008 and ISO 14001:2004 requirements. Every year internal audits and management reviews are conducted to ensure the suitability, adequacy and effectiveness of the implemented management system. External management system assessment and certification is conducted according to ISO 9001:2008 and ISO 14001:2004 every year.

Through a process approach, the ARAO continuously improves the effectiveness of its integrated management system to achieve company's goals and enhance nuclear safety. Based on ARAO's mission, vision and company policy, the main objectives are defined at ARAO official website (<http://www.arao.si/agencija-arao/strateski-cilji>).

The management system [I-23] is compliant with international safety standards to assure that all safety related work is carried out at a high level of quality and only trained, qualified and competent persons will undertake work that is safety related, including the production of the Safety Assessment and Safety Case.

Safety is and will be assessed against international standards, uncertainties will be identified, characterized and formally managed. Decisions to move from one step of the project to the next (operation, optimization, decommissioning etc.) will only be made when compliance with international standards has been demonstrated.

Regulatory control over the facility design, construction and operation will be undertaken by the regulatory body independently from facility development and operational activities. Assurance of the independence will be demonstrated by the management system.

Elements of the management system that will interact with the Safety Case throughout its lifecycle also include:

- Management system reviews;
- Internal auditing;
- External auditing as applicable.

### **I-6 SAFETY ASSESSMENT**

#### **I-6.1. Assessment context**

The assessment is carried out to demonstrate safety of operations at the CSF. It provides assessments of radiation doses to workers and members of the public during normal operation

of the facility and during accidents that could occur over the assumed lifetime of the facility<sup>2</sup>, for comparison with relevant legal dose limits and constraints.

An assessment of the impact of potential accidental events on the facility is performed in order to demonstrate that the design and safety features are sufficiently robust to withstand such events.

The assessment seeks to identify uncertainties and provide consideration to their importance and possible approaches to the management of those uncertainties considered to be important for safety.

A generally conservative approach is taken in respect of assumptions and the assessment.

The following radiological safety criteria have been derived from international safety standards and are used as a basis for evaluation of safety and protection:

- The dose limit for workers from all planned exposure situations is an effective dose of 20 mSv in a year [I-24]. On the basis of past operation, storage facility refurbishment, measurements and dose assessment for workers in the CSF, ARAO proposed (within the safety report [I-25]) and the regulatory body approved an effective dose of 10 mSv/a as the dose limit for workers from all planned exposure situations. This criteria and its risk equivalent are not to be exceeded. A lower dose constraint may be established for radiation workers to ensure this limit is not breached.
- To comply with the public dose limit (1 mSv), a facility (considered as a single source) is so designed that the calculated dose or risk to the representative person who might be exposed as a result of the operation of the facility does not exceed a dose constraint of 0.1 mSv in a year [I-25].

Because the scope of activities at the CSF excludes conditioning of spent sources, doses to extremities or to the lens of the eye are not considered.

#### *I-6.1.1. Endpoints for the assessment*

The following quantitative assessment endpoints will be considered:

- Radiation dose to workers performing the various normal RW management activities at the CSF. It should be noted that the same CSF personnel may be performing all of the respective RW management activities at the CSF. Doses received during the various activities are therefore accumulated for these workers.
- Radiation doses to workers and the public due to anticipated operational occurrences.

Doses calculated through use of the different models and the SAFRAN tool will be evaluated against the safety criteria.

#### *I-6.1.2. Approaches to the assessment*

Quantitative deterministic assessments of worker doses are performed that consider the full range of activities performed by various occupational groups of the CSF. Assessments are

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<sup>2</sup> In 2022 all the waste in the CSF is anticipated to be disposed of in a LILW disposal facility; after which a decision will be made about future operation of the CSF.

based on the following assumed personnel requirements during normal operational activities performed at the CSF:

- Unloading of RW from transport container: 2 workers, 50 activities/a, 10 minutes/ activity.
- Control measurements: 2 workers, 50 activities/a, 10 minutes/ activity.
- Packaging: 2 workers, 50 activities/a, 10 minutes/ activity.
- Transfer of RW package to its storage location in the CSF.
- Monthly inspection and survey of the storage location and preventive maintenance (cleaning, change of light bulbs, fire protection system control, etc.): 2 workers, 120 h/a each.

In order to increase confidence in the results, hazards and initiating events relevant to the CSF were identified and assessed using two different methods. The first method that was used is referred to as the HAZOP (Hazards and operability analysis) method. The second method that was used was the SAFRAN Tool [I-5], which implements the GSG-3 [I-1] and SADRWMS [I-4] methodologies.

Quantitative assessments are performed of the potential impact to workers and the public from possible occurrences as well as specific preventative and mitigating measures. Using a risk-based approach, design basis and beyond design basis events are also considered for more detailed analysis as accident scenarios. The anticipated consequences associated with such events will be listed with comments and recommendations for further analyses and proposed preventative and mitigating measures. The SAFRAN tool [I-3], which implements the SADRWMS methodology [I-4], was used and forms the basis for the approach to the safety assessment.

A qualitative assessment is performed of the availability and level of implementation of an integrated management system to ensure a sustained level of safety with an emphasis on operational activities at the facility. The focus is on radiation protection, work procedures, quality assurance aspects (mainly record keeping and change management) and processes for the management of limits and conditions.

The results from the quantitative and qualitative assessment are compared to the proposed target and objectives established for the optimization of protection. No specific optimization comments or recommendations are made in the case of doses below 1 mSv/a.

A qualitative assessment is performed for the non-radiological hazards of the facilities and the listing of specific control measures. Non-radiological hazards are listed and categorized in terms of their hazard potential. Comments and recommendations are made per hazard as applicable.

Uncertainties inherent to the assumptions made in the quantitative assessments and any other uncertainties identified during the safety assessment will be evaluated to determine their impact on safety. Uncertainties with a significant impact on safety will be listed with recommendation for its management.

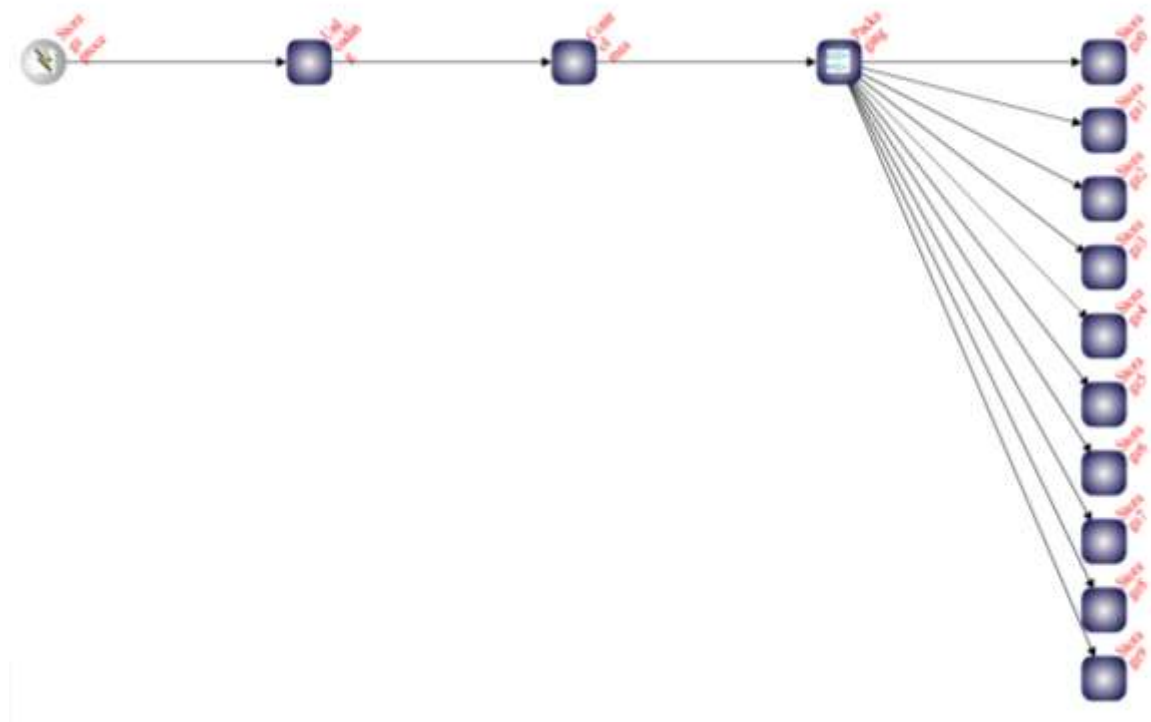
## **I-6.2. Description of safety elements and functions**

The main activity to be carried out in the facility is storage; other waste management operations are not considered. During normal operation, the key activities are related to:

- Unloading the waste drums/packages from the transport vehicle;
- Radiation and contamination monitoring of the transport vehicle and the waste drums/packages upon receipt;
- Transfer of the waste drums/packages into the storage building;
- Acceptance and placing of the waste drums/packages into their storage location within the storage building;
- Storage of the waste drums/packages for the total storage time;
- Periodic inspection and radiological monitoring of the storage building and of the waste drums/packages.

A simple process was defined in SAFRAN to describe the ongoing work in the CSF with the objective of defining activities and connecting them with rooms and waste components in SAFRAN (See FIG. 12). The following activities were defined:

- Unloading from transport container;
- Control measurement;
- Packaging;
- Storage 0 up to Storage 9 (represent the storage in different compartment).



*FIG. 12. Representation of the CSF Work Processes in SAFRAN.*

Taking into consideration Slovenian legislation and GSG-3 guidance, the safety functions and associated SSCs were identified for the CSF facility. All the SSCs were classified in 2 different classes considering Slovenian regulations and their importance for the safety of the facility. These classes are:

- SSC important for safety;
- SSC not important for safety.

The functions that were identified for the storage facility are:

- **Containment (C)** of the radioactivity – radionuclides stay during the operation of the facility limited inside the waste packages and storage facility respectively.
- **Shielding (S)** from the radiation that arises from the RW.
- **Protection (P)** of the waste – physical and technical security of the waste.
- **Supporting (Su)** function – supports the implementation of other safety functions.

Table 5 lists all the SSCs with their classification and safety functions they are performing.

TABLE 5. DEFINITION OF THE SSCS, THEIR CLASSIFICATION AND THEIR SAFETY FUNCTIONS

SSC	Function *	Safety classification Important for Safety (Yes/No)
Storage building	C, S	Yes
Horizontal sewerage	C	Yes
Underground tank	C	Yes
Sewerage to collect precipitations	C	Yes
Ventilation system	C, Su	Yes
Electricity supply	Su	Yes
Safety lighting	Su	No
Telecommunication	Su	Yes
Lightning rods	Su	Yes
Active fire protection	C	Yes
Passive fire protection	Su	Yes
Physical and technical security	P	Yes
RW packages	C, S	Yes
Pallets	Su	No
Transportation system inside the storage facility	Su	No
Radiological monitoring	Su	No
Hydrological monitoring	Su	No
Meteorological monitoring	Su	No

\* C = Containment, S = Shielding, P = Protection, Su = Supporting function

For all the SSCs that were classified as “important for safety functions” the special procedures for maintaining and inspection were prepared.

### I-6.3. Passive safety and defence in depth

#### I-6.3.1. Passive systems

Passive systems contributing to the safety of the facility and their operations were applied in three areas:



- The optimization of external exposure of workers and public;
- The minimization of the potential impact to the environment and the public, due to operational occurrences and accidents; and
- The prevention of unauthorized access to the facility.

The optimization of external exposure during the waste management operations is based upon:

- The shielding capacity of the external and internal wall structures due to their proper shielding characteristics;
- The labyrinth system used for the storage areas; and
- The physical delineation of different areas, which contributes to optimization during the working activities.

Operational occurrences and accidents that may cause a release of radioactive material are evaluated (e.g., decontamination activities that may involve the use of liquids). For such events, the storage building is designed in way that the run off by gravity is allowed from any interior area and there is a residue collection and retention system that permits monitoring before release to the environment (see FIG. 13 and FIG. 14). This passive system ensures the minimization of the potential impact in to the environment and the public caused by operational occurrences and accidents.



*FIG. 13. System for collection and retention of liquids.*



*FIG. 14. System for collection and retention of liquids, outer part.*

A perimeter fence restricts access by unauthorized persons to the facility and its surroundings. Safety evaluation demonstrates that a representative at any location at any point within the perimeter, even under conservative conditions, does not exceed dose limits established for the public. In addition to the fence, other passive barriers, specifically the security system, limit the unintentional access of a non-authorized person (see FIG. 15 and FIG. 16).



*FIG. 15. Video surveillance system monitor.*



*FIG. 16. Security system commands.*

To prevent the corrosion of the drums and other metallic material inside the CSF, a heating and moisture control system is installed and operated (see FIG. 17 and FIG. 18).



FIG. 17. Heating and moisture control system.

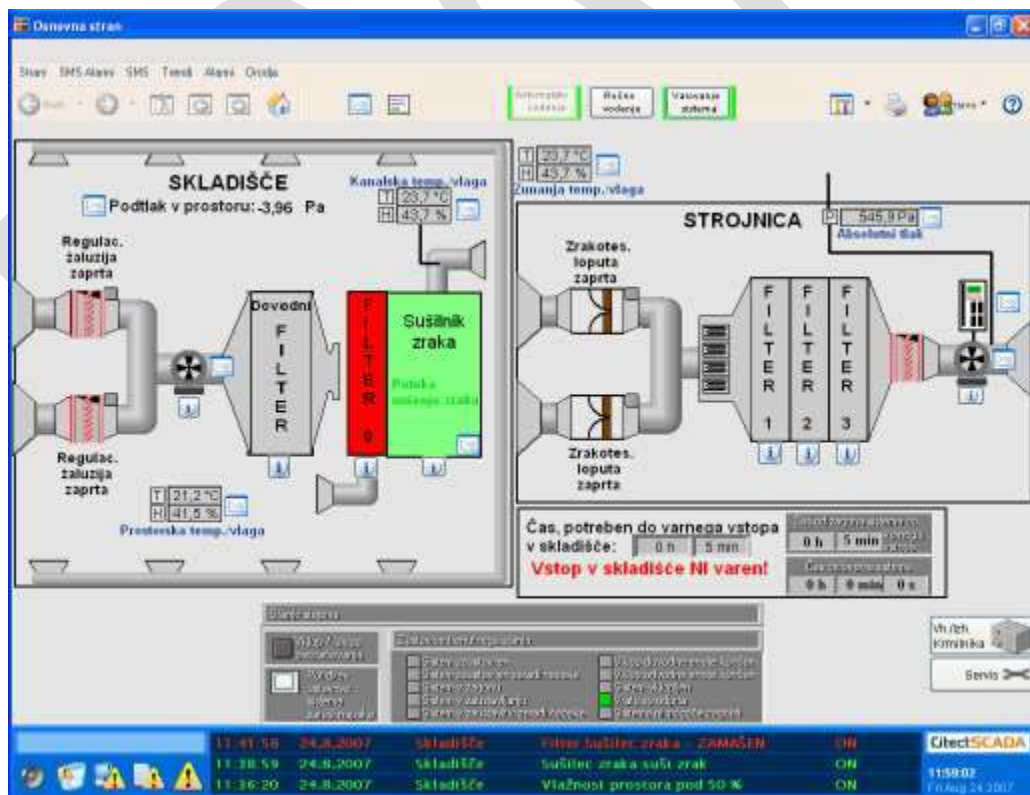


FIG. 18. Application to operate the moisture control system.



### **Prevention of unauthorized access to the facility**

The site of the storage building is located in a suburban area. Consequently, the establishment of an efficient physical protection system that prevents unauthorized access to the storage building it required. For this reason, the following barrier systems are considered:

- Site perimeter fence with a gate to control access;
- High integrity door to the personnel entrance (FIG. 19); and
- High integrity gate to the storage areas.



*FIG. 19. Entrance to the CSF.*

#### *I-6.3.2. Defense in depth*

Defense in depth principles were applied in three main areas:

- Storage of RW;
- Planned source and RW management operations; and
- Minimization of the potential impact to the environment and the public, due to operational occurrences and accidents.

### **Storage of RW**

Isolation of radioactive materials is one of the main objectives of storage. For this reason, the following physical and passive barriers were established:

- Facility perimeter fence;
- Storage building structure;

- Delineation of the storage areas with limited access to each (physical and technical protection);
- All the RW is packaged in proper containers (drums, overpacks, etc.) to meet the WAC (2 mSv/h contact dose).

These isolation barriers also work as containment barriers for a potential radioactive material release.

### **Planned waste management operations**

Storage of RW requires only limited operations. As explained previously, operations are mainly the reception of the RW, its placement in the storage area and routine inspection. During such operations, ample light is a factor important to ensuring safe performance (FIG. 20). The existence of auxiliary autonomous equipment enables to perform the operations conceived in the event of a failure of the lighting system.



*FIG. 20. Light system in the CSF.*

Because the CSF is partially an underground facility there is a lot of radon exhalation from underground. To protect the workers and the visitors a ventilation system is used before the facility is entered to reduce the concentration of the radon below 200 Bq/m<sup>3</sup>. To protect the public that can be around the CSF the filtration system is used (FIG. 21).



*FIG. 21. Ventilation and filtration system.*

### **Minimization of the potential impact to the environment and the public, due to operational occurrences and accidents**

Barriers conceived to reduce the impact of events that cause the release of radioactive material in the order in which they function are:

- Segregation of storage and operation areas in such a way that the potential contamination is limited.
- The floor slab has a steel floated finish with an epoxy paint coating to provide a durable and easily decontaminated surface.
- The storage building is provided with an internal floor drain system to direct any internal liquid traces generated to a sump pit.
- The sump pit permits the monitoring of the radioactivity content and is only evaluated when compliance with established restrictions is necessary.
- The fire protection alarm system is installed to reduce the potential of fire.

#### **I-6.4. Site characterization**

The characterization of the site was based upon:

- Relevant information from meteorological data from the near weather stations;
- Information provided by the appropriate authority related to the facilities and activities in the surrounding vicinity of the site;
- Samples from drilled boreholes (FIG. 22) and other performed tests; and
- Visual observation and sampling in the field.



*FIG. 22. Borehole system around the CSF is equipped as piezometer.*

Even though the information above is adequate to carry out the safety assessment, a conservative approach should be adopted for the following aspects:

- Relevant characteristics of the regional physical geography, stratigraphy and lithography, as well as a geological structural history of the region; and
- The current distribution of the population surrounding the facility, as well as that projected during its lifetime.

#### **I-6.5. Operational safety aspects**

Risks from operations not related to the management of CSF are not further considered. This is due to the following factors:

- The storage building is physically isolated from other activities;
- Facilities close to the storage building are not carrying out activities that may impact the safety of the storage building.

#### **I-6.6. Management system**

The management system is designed and implemented based on the international IAEA Safety Standards Series No. GS-R-3 “The management system for facilities and activities.” [I-22]. The system defines clearly the responsibilities at all levels reflecting the management commitment to security and safety of the installation. Quality management is applied throughout the design, construction and operation of the CSF.

#### **I-6.7. Waste management practices**

The outcome of the qualitative assessment of the waste management practice as implemented by the operating organization is described in Table 6.



TABLE 6. IMPLEMENTED OUTCOMES

Item	Requirement	Compliance Comments	Ref
1.	Clearly defined responsibilities for waste management.	The legal framework of Slovenia specifies the responsibilities for the generation and management of RW. The construction and operation of the waste management facilities demonstrate intent and commitment.	IRPNSA [I-26]
2.	Implementation of the principles of waste minimization and avoidance, namely, re-use or re-processing of waste, return to supplier, safe and secure storage and conditioning and final disposal of waste.	Principles defined in the legal framework and implemented in the case of RW to the point of conditioning. Final disposal for LILW is under final design.	Resolution on the 2006–2015 National Programme for Managing RW and Spent Nuclear Fuel [I-10]
3.	Hazards and the generation of secondary waste associated with all waste management operations (routine and ad hoc) are known, monitored, projected and managed by due management processes.	The treatment of RW from small producers is well planned and executed in the adjacent hot cell facility which is designed to mitigate exposure.	
4.	Interdependencies between the various steps of waste management are known and managed. Waste acceptance criteria are defined, waste management activities and the outputs of such activities are aligned with set waste acceptance criteria.	Consignments stored RW are assessed in accordance with appropriate waste acceptance criteria at the generators facility and again at the CSF as part of collection and transport procedure. It should be indicated how the current actions and specification are aligned with future disposal options and associated WAC.	WAC for CSF [I-6]
6.	Conditioned RW will be stored in a dedicated storage area with passive safety features and adequate access control.	Only conditioned waste packages are transferred and emplaced in a dedicated long term storage facility.	Procedures and WAC

## **I-6.8. Development and justification of scenarios**

### **I-6.8.1. Normal operation**

The following normal operations scenarios for which worker doses are assessed are identified in Section I-6.1.2:

- Unloading of RW from transport container.
- Control measurements.
- Packaging.
- Transfer of RW package to its storage location in the CSF.
- Monthly inspection and survey of the storage location and preventive maintenance (cleaning, change of light bulbs, fire protection system control, etc).

### **I-6.8.2. Identification and screening of hazards and initiating events**

In order to increase confidence in the results, hazards and initiating events relevant to the CSF were identified and assessed using two different methods. The first method that was used is referred to as the HAZOP method. The second method that was used was the GSG-3 guidance and SADRWMS methodology, which is implemented in the SAFRAN Tool.

HAZOP method activities were carried out during a series of meetings by the ARAO multi-disciplinary team of experts who were familiar with the facility and also with experience in safety assessment, radiation protection, operation of the facility, civil engineering, environment protection, geology, hydrology, and meteorology. Initial work focused on development of normal operational scenarios and then, using HAZOP method the hazards for the CSF were identified and then screened on the base of risk posed by each hazard. Risk was defined as a function of consequence and likelihood, where the consequences possibly result from the event are categorized within 4 classes:

- Class 1: critical event - requires an immediate response, the SSCs do not take anymore their safety functions, facility is damaged and emissions in the environment can occur.
- Class 2: serious event - without intervention some of the SSCs may be damaged and stop performing their safety functions. The facility is damaged but no release of radioactive material.
- Class 3: not so serious event - Attention needs to be paid on this event, the safety functions are performed but without backup. The impact on the workers is very small but measurable.
- Class 4: event with low importance – event doesn't have an effect on SSCs, although it may cause inconveniences especially for workers. The impact is not measurable.

Likelihood (probability that the event will occur) is divided in 5 classes:

- Likelihood 1: the event can occur every 5 years;
- Likelihood 2: the event can occur every 5 to 20 years;
- Likelihood 3: the event can occur every 20 to 50 years;
- Likelihood 4: the event can occur every 50 to 500 years;
- Likelihood 5: the event can occur every 500 years or more.

Risk is calculated as a function of the consequence and likelihood of the hazard scenario (Table 7). Hazard scenarios with a risk between 1 and 9 are considered for quantitative analysis as accident scenarios within the safety assessment.

TABLE 7. RISK AS A FUNCTION OF CONSEQUENCE AND LIKELIHOOD

Consequence ↓	Likelihood →				
	1	2	3	4	5
1	<b>1</b>	<b>3</b>	<b>3</b>	4	5
2	<b>2</b>	<b>4</b>	<b>6</b>	8	10
3	<b>3</b>	<b>6</b>	<b>9</b>	12	15
4	4	8	12	16	20

As a result of following the HAZOP assessment, the following scenarios were identified as requiring further analysis:

- Drop of the package or damaged package.
- Explosion at the CSF site – the scenario will be assessed through security assessment.
- Fire involving waste packages.

Theft of a RW package (hazard scenarios 13, 25, 26, and 27) was also identified as requiring further (quantitative) assessment, but will be assessed through a separate security assessment.

Table 8 presents the scenarios that were identified as relevant to the CSF and assessed using the HAZOP method.

TABLE 8. ASSESSMENT OF HAZARD SCENARIOS USING THE HAZOP METHOD

No.	Deviation	Cause	Consequences	Safety measures	C*	P*	Risk
1	Waste is not received in the CSF	Various causes	N/A				
2	Waste is received, but not accepted in CSF	Waste properties, inadequate documentation, mistakes, superficiality	RW doesn't meet WAC, discrepancy should be removed	Transparent procedures and instructions, education and training of employee, help producers with the preparation of packages for storage	4	4	16
3	In addition to planned receipt, unplanned receipt also occurs	Lack of information, carelessness	On the CSF site, there is more waste than planned	Extend working time or provide additional workers	4	3	12
4	Package not in compliance with guidelines	Lack of information, carelessness	The package is received but not placed inside the CSF, report for regulatory body should be prepared	Producers should be well informed	4	3	12
5	Waste is not received in the CSF	Unfavourable weather conditions	Receipt should be postponed - no influence on safety	The weather forecast should be checked			
6	Waste is not received in the CSF	Power outage, CSF ventilation system doesn't work	Receipt should be postponed - no influence on safety	Power backup or natural ventilation of the facility			
7	Waste is not received in the CSF	Earthquake or some other natural disaster	Receipt should be postponed - no influence on safety				
8	During receipt the unannounced visit of inspectors, or urgent receipt occurs	Coincidence, bad coordination	Receipt should be postponed - no influence on safety	Communication, planning			
9	-	-	N/A	-	-	-	-
10	-	-	N/A	-	-	-	-

No.	Deviation	Cause	Consequences	Safety measures	C*	P*	Risk
11	No transport	Forklift – truck doesn't work.	RW package is left outside the storage facility. Waste package is transported to the facility next day. There is no contamination.	Permanent check of transport equipment, regular services, competent and educated personnel. There should be an agreement about the fast service or the forklift – truck rental.	4	4	16
12	No transport	Hurrying, oversight	RW package is left outside the storage facility. Waste package is transported to the facility next day. There is no contamination.	More employees at the activity, competent and educated personnel, the platform in front of the facility should be checked before personnel leave the facility site.	3	3	9
13	No transport	Hurrying, oversight	RW package is left outside the storage facility. Package can be stolen from the site.	More employees at the activity, competent and educated personnel, the platform in front of the facility should be checked before personnel leave the facility site.	2	5	10
14	No transport	Hurrying, oversight	RW package is left outside the storage facility. Due to the bad weather conditions – rain, there is potential contamination of the surrounding.	More employees at the activity, competent and educated personnel, the platform in front of the facility should be checked before personnel leave the facility site. The water from the platform is directed through drainage system in to the system for water collection and retention.	3	4	12
15	-	-	N/A	-	-	-	-
16	Transport is not successful	The package drops during the transport.	Contamination of the surrounding, there is also potential of external and internal radiation of workers and other people around the accident (institute workers, security guards, farmers).	Permanent check of the transport equipment, regular services, competent and educated personnel.	2	4	8
17	Something else occurs (beside transport).	Hurrying, carelessness.	Collision with sharp object (doors, ventilation system, installations...). A package is damaged, potential of external and internal radiation of workers and other people around the accident exists.	Competent and educated personnel, the transport should comply with the guideline for internal transport.	2	4	8

No.	Deviation	Cause	Consequences	Safety measures	C*	P*	Risk
18	Something else occurs (beside transport).	Hurrying, carelessness.	Collision with sharp object (doors, ventilation system, installations...). The SSC important for the safety is damaged (ventilation system is damaged).	Competent and educated personnel, the transport should comply with the guideline for internal transport. During and after the transport control of the facility is necessary, if this event happened the responsible people should be informed.	3	4	12
19	Something else occurs (beside transport).	Hurrying, carelessness.	Collision with sharp object (doors, ventilation system, installations...). The SSC important for the safety is damaged (concrete construction is damaged).	Competent and educated personnel, the transport should comply with the guideline for internal transport. During and after the transport the control of the facility is necessary, if this event happened the responsible people should be informed.	4	4	16
20	Something else occurs (beside transport).	Hurrying, carelessness.	Collision with sharp object (doors, ventilation system, installations...). The SSC important for the safety is damaged (electrical installation is damaged).	Competent and educated personnel, the transport should comply with the guideline for internal transport. During and after the transport the control of the facility is necessary, if this event happened the responsible people should be informed.	4	4	16
21	Transport occurs too early.	Hurrying, carelessness.	The transport of the package to the storage facility occurs before it is checked for compliance w the WAC for storage. The increased radiation of the workers can occur.	Competent and educated personnel, the transport should comply with the guideline for internal transport. Double check before transport is necessary, if this event happened the responsible people should be informed.	3	4	12
22	Transport occurs too early.	Hurrying, carelessness.	The transport of the package to the storage facility occurs before it is checked. Package is not packed correctly, the drop of the package can occur.	Competent and educated personnel, the transport should comply with the guideline for internal transport. Double check before transport is necessary, if this event happened the responsible people should be informed.	3	3	9
23	Transport occurs too early.	Hurrying, carelessness.	Transport of the package to the storage facility before it is checked. Package contains liquid waste. The spill of the liquids can occur.	Competent and educated personnel, the transport should comply with the guideline for internal transport. Double check before transport is necessary, if this event happened the responsible people should be informed.	3	4	12

No.	Deviation	Cause	Consequences	Safety measures	C*	P*	Risk
24	Transport occurs too late.	Hurrying, carelessness.	Due to different reasons the package stays on the platform longer than is needed. In the meantime rain and potential contamination of the surrounding can occur.	The water from the platform is directed through drainage system into the water collection and retention system. Competent and educated personnel. The platform in front of the facility should be checked before personnel leave the facility site.	3	4	12
25	There is no more storage space for the packages.	Storage facility is destroyed due to airplane crash or terrorist attack. The majority of SSCs don't function anymore.	RW is scattered. The surrounding of the storage facility is contaminated.	The security of the facility should be sufficient. The employees should be educated and competent.	1	5	5
26	The package is not stored.	A worker steals a package from the CSF.	Increased internal and external radiation to members of the public.	The security of the facility should be sufficient. The employee should be educated and competent. The psychological health of the workers is checked.	2	4	8
27	The package is not stored.	A person steals a package from the CSF.	Increased internal and external radiation to members of the public.	The security of the facility should be sufficient. The employees should be educated and competent.	2	5	10
28	The storage facility is damaged	A low magnitude earthquake.	Due to the earthquake some damage – cracks on the building can occur.	The facility design and construction is “seismically safe”. The waste is packed in the drums that still provide their function of containment. After such an event the immediate repair is needed.	3	4	12
29	The storage facility is damaged	A high magnitude earthquake.	Due to the earthquake the building is demolished. The building structure falls on the packages, and contamination of surroundings is possible.	After such an event remediation of the waste and the site is needed.	2	5	10
30	The storage facility is damaged	Fire inside the storage facility.	Waste is burned as a result of the fire, contamination of surroundings is possible.	Fire protection system. Work performed inside the building complies with fire safety guidelines and regulations.	2	4	8

No.	Deviation	Cause	Consequences	Safety measures	C*	P*	Risk
31	The storage facility is damaged	Flood	Waste containers are damaged as a result of the flood. Transport of radionuclides in water is possible.	The CSF is constructed in area with very low probability of flooding (see FIG. 8)	3	5	15
32	The storage facility is damaged	Due to natural or artificial processes cracks in the concrete occur.	Water percolates into the CSF.	Drainage system inside the CSF. Some periodic inspection need to be done.	4	3	12
33	The storage facility is damaged	Due to natural or artificial processes corrosion of the drums and packages occur.	Waste containers are corroded as a result of moisture. Transport of radionuclides in water is possible.	Usage of suitable certified packaging. Regular inspection of the drums is prescribed [I-30]	4	3	12
34	-	-	N/A	-	-	-	-
35	-	-	N/A	-	-	-	-
36	-	-	N/A	-	-	-	-
37	-	-	N/A	-	-	-	-
38	-	-	N/A	-	-	-	-
39	CSF is abandoned	Different causes (natural disaster, social/political upheaval, etc.) result in the CSF is abandoned.	Natural degradation and disintegration of artificial natural barriers (SSC) important for safety. Water can percolate into the facility and containers. Radionuclides are released to biosphere	Robustness of engineering barriers, multifunctional concept.	2	5	10
40	CSF is not maintained.	Financing of CSF maintenance is stopped.	Some of the SSCs stop performing their safety function (ventilation, air drying system, technical security...). Faster degradation of the barriers due to corrosion, etc.	The permanent financing should be ensured.	3	4	12
41	CSF is not maintained.	Financing of CSF maintenance is reduced.	Deterioration of the CSF SSCs is not immediately addressed.	The permanent and sufficient financing should be ensured.	4	3	12
42	CSF is not monitored.	Financing of CSF monitoring is reduced.	Detection of CSF SSCs deterioration is not ensured, resulting in an increase in potential for accidents.	The permanent and sufficient financing should be ensured.	4	3	12
43	-	-	N/A	-	-	-	-
44	-	-	N/A	-	-	-	-



No.	Deviation	Cause	Consequences	Safety measures	C*	P*	Risk
45	Additional (unforeseen) activities on the CSF site	Careless or incompetent employee	Unnecessary external radiation or contamination can occur.	Adequate supervision on the activities in the CSF should be ensured. The employees should be educated and competent.	3	4	12
46	Work starts earlier.	Careless or incompetent employee	N/A	N/A			
47	Work starts late.	Careless or incompetent employee	Late maintenance of the SSCs important for the safety. The SSCs don't perform their functions well. Unnecessary external radiation or contamination	Adequate supervision on the activities in the CSF should be ensured. The employees should be educated and competent.	4	4	16
48	Other activities in the storage facility start late.	Careless or incompetent employee	Late monitoring. Due to unknown conditions inside the facility the radiological safety of the working place is assessed inappropriately and unnecessary external radiation or contamination can occur.	Adequate supervision on the activities in the CSF should be ensured. The employees should be educated and competent.	4	4	16

\*C = Consequence, P - Probability

The second method used to perform the assessment involved using the SAFRAN tool to identify and screen hazards and initiating events, and identify and analysis relevant accident scenarios. Figure 23 shows a screenshot of the postulated initiating events (PIEs) that were screened using the SAFRAN Tool.

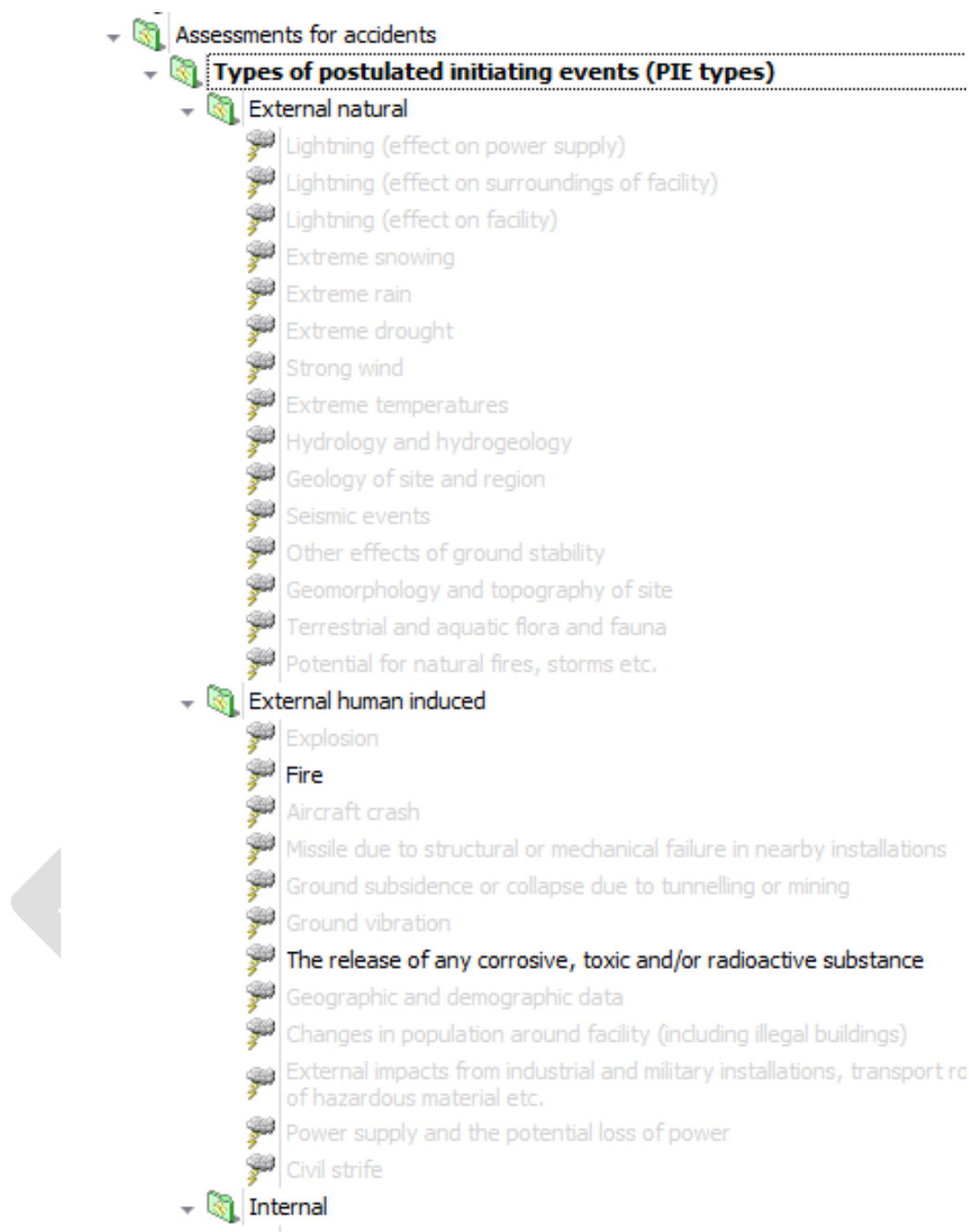


FIG. 23. Screening of PIES in the SAFRAN Tool.

The results of the screening of PIES are recorded in the SAFRAN file along with justification of any scenarios considered not to be relevant. These results are summarized in Table 9.

TABLE 9. ASSESSMENT OF HAZARD SCENARIOS USING SAFRAN

Name	Relevance	Relevance - justification (if not relevant)	Category
Lightning (effect on power supply)	Not relevant	The facility can operate (perform its basic function - storage) safely without electrical supply, all important systems have backup supply.	External natural
Lightning (effect on surroundings of facility)	Not relevant	Because the CSF is an underground facility - covered with a layer of soil, the lightning and the effect on the surrounding doesn't have an impact on a facility.	External natural
Lightning (effect on facility)	Not relevant	Because the CSF is an underground facility - covered with a layer of soil, the lightning and the effect on the surrounding doesn't have an impact on a facility.	External natural
Extreme snowing	Not relevant	Because the CSF is an underground facility - covered with a layer of soil, the extreme snowing doesn't have an impact on a facility.	External natural
Extreme rain	Not relevant	Because the CSF is an underground facility - covered with a layer of soil, the extreme rain doesn't have an impact on a facility and its safety. Also the groundwater is 10 m below the surface and above it lies very permeable layer that drains all the precipitations.	External natural
Extreme drought	Not relevant	Extreme draughts are not typical for the area of the facility.	External natural
Strong wind	Not relevant	Because the CSF is an underground facility - covered with a layer of soil, the strong wind doesn't have an impact on a facility and its safety.	External natural
Extreme temperatures	Not relevant	Because the CSF is an underground facility - covered with a layer of soil, the extreme temperatures don't have an impact on a facility and its safety.	External natural
Hydrology and hydrogeology	Not relevant	The storage facility lies on area that is 10 m higher than the river that flows 1 km from the site, also groundwater is 10 m below the surface.	External natural
Geology of site and region	Not relevant	The geology is well known and it is not expected that it will change in the near future.	External natural
Seismic events	Not relevant	The design and the construction of the facility is seismic safe.	External natural
Other effects of ground stability	Not relevant	There are no other effects of ground stability.	External natural
Geomorphology and topography of the site	Not relevant	Nothing from geomorphology or topography of the site can affect the safety of the facility.	External natural
Terrestrial and aquatic flora and fauna	Not relevant	The storage facility is well closed and flora and fauna can't affect the processes inside the facility.	External natural

Name	Relevance	Relevance - justification (if not relevant)	Category
Potential for natural fires, storms etc.	Not relevant	Due to the lightning rods system and because the surrounding of the facility is covered with grass, there is really low possibility for natural fire.	External natural
Flooding	Not relevant	Because the facility site lies 1 km from the river and it is on the elevation that is 10 m higher than river no flooding is expected (see Figure 7).	External natural
Explosion	Not relevant	Different reasons (e.g. terrorist attack) could cause an explosion in the CSF. The scenario will be analysed through the security assessment.	External human induced
Fire	Relevant		External human induced
Aircraft crash	Not relevant	The same as for the explosion scenario, the scenario will be assessed through security case	External human induced
Missile due to structural or mechanical failure in nearby installations	Not relevant	A missile due the structural or mechanical failure from nearby installations is not foreseen.	External human induced
Ground subsidence or collapse due to tunnelling or mining	Not relevant	CSF lies in a flat area where tunnelling is not foreseen and also the probability of the tunnel construction is low. There are no natural resources in the area suitable for mining and due to that no subsidence or collapse is foreseen.	External human induced
Ground vibration	Not relevant	In the vicinity of the CSF, there is no source that can cause ground vibration that can affect the CSF.	External human induced
The release of any corrosive, toxic and/or radioactive substance	Relevant	The PIE is included in drop and fire scenario.	External human induced
Geographic and demographic data	Not relevant	The impact of the facility is so low that change in geographic and demographic data can't affect the CSF.	External human induced
Changes in population around facility (including illegal buildings)	Not relevant	The impact of the facility is so low that change in geographic and demographic data can't affect the CSF.	External human induced
External impacts from industrial and military installations, transport routes of hazardous material etc.	Not relevant	There is no such route in the vicinity of the CSF.	External human induced
Power supply and the potential loss of power	Not relevant	The power supply is not necessary for the CSF operation.	External human induced
Civil strife	Not relevant	The CSF and the waste stored in CSF can't be seen important (this is LILW) in the case of civil strife.	External human induced

Name	Relevance	Relevance - justification (if not relevant)	Category
The acceptance (inadvertent or otherwise) of incoming waste, waste containers, process chemicals, conditioning agents, etc., that do not meet the specifications (acceptance criteria) included in the design basis.	Not relevant	If this event happened the consequences will be negligible for the human and the environment and this “state” will last for a short period, the waste package should be treated to meet the WAC for storage in CSF.	Internal
The processing of waste that meets acceptance criteria but that is subsequently processed in an inappropriate way for the particular type of waste (either inadvertently or otherwise).	Not relevant	CSF is not a processing facility.	Internal
A criticality event due to the inappropriate accumulation of fissile material, change of geometrical configuration, introduction of moderating material, removal of neutron absorbing material or various combinations of these.	Not relevant	It is not foreseen that in CSF so much fissile material will be stored that criticality event can occur.	Internal
Explosion due to the evolution of explosive gas mixtures	Not relevant	The CSF is the operating facility that is monitored on daily basis and also the WAC are such that the waste producing gas are not acceptable. The major gas that we can find in CSF is radon, because the facility is partial under the surface and covered with soil layer but due to the radon CSF also have the ventilation system that is used before the entrance in the facility. The occurrence of the mixture of the explosion gasses is not foreseen.	Internal
Spontaneous combustion	Not relevant	The WAC prevent to store the waste that can be spontaneously combusted.	Internal
Local hot spots generated by malfunctions of SSCs	Relevant	The PIE is included in fire scenario.	Internal
Sparks from machinery, equipment or electrical circuits	Relevant	The PIE is included in fire scenario.	Internal
Sparks from human activities such as welding or smoking	Relevant	The PIE is included in fire scenario.	Internal

Name	Relevance	Relevance - justification (if not relevant)	Category
Explosions	Not relevant	Different reasons (e.g. terrorist attack) could cause an explosion in the CSF. The scenario will be analysed through the security assessment.	Internal
Gross incompatibilities between the components of a process system and the materials introduced into the system.	Not relevant	The CSF is not a processing facility.	Internal
The degradation of process materials (chemicals, additives or binders) due to improper handling and storage.	Not relevant	The stored packages are inspected regularly and if the degradation is noticed some actions are required.	Internal
The failure to take account of the non-radiological hazards presented by the waste (physical, chemical or pathogenic).	Not relevant	The stored packages are inspected regularly and if the failure is noticed some actions are required.	Internal
The generation of a toxic atmosphere by chemical reactions due to the inappropriate mixing or contact of various reagents and materials.	Not relevant	All the stored waste should meet WAC. If anyhow this happened the facility is inspected regularly and some actions need to be taken. But the risk for the human and the environment is very low.	Internal
Dropping waste packages or other loads due to mishandling or equipment failure, with consequences to the dropped waste package and possibly to other waste packages or to the SSCs of the facility.	Relevant	Included in the drop scenario.	Internal
Collisions of vehicles or suspended loads with the SSCs of the facility or with waste packages, waste containment vessels and pipes.	Relevant	Included in the drop scenario.	Internal
Failures of SSCs	Relevant	Included in the drop and the fire scenario.	Internal
The generation of missiles and flying debris due to the explosion of pressurized components or the gross failure of rotating equipment.	Not relevant	No such type (that can generate missiles or flying debris) of the equipment is used in CSF.	Internal
The malfunctioning of heating or cooling equipment, leading to unintended temperature excursions in process systems or storage systems.	Not relevant	No heating or cooling equipment inside the CSF. Just the system to control the humidity inside the facility, but this system can't cause the unintended temperature excursions.	Internal

Name	Relevance	Relevance - justification (if not relevant)	Category
The malfunctioning of process control equipment.	Not relevant	No such type of equipment is used in the CSF.	Internal
The malfunctioning of equipment that maintains the ambient conditions in the facility, such as the ventilation system or dewatering system.	Not relevant	The malfunction of such systems doesn't affect the safety of the facility directly. If there are some malfunctions the operation of the facility need to be done under the instructions prepared for such events. In case the ventilation system doesn't work it is not allowed to enter the facility until the doors are opened and the facility is naturally ventilated.	Internal
The malfunctioning of monitoring or alarm systems so that an adverse condition goes unnoticed.	Not relevant	The monitoring and the ventilation system are regularly checked. The observed malfunctioning leads to immediate actions. If the adverse conditions occur their impact on the human and environment is negligible.	Internal
Incorrect settings (errors or unauthorized changes) on monitors, alarms or control equipment.	Not relevant	The settings need to be checked regularly. Short incorrect settings have negligible impact on human and environment.	Internal
The failure to function when called upon of emergency equipment such as the fire suppression system, pressure relief valves and ducts.	Not relevant	In the CSF there is no such active systems which failure can cause the problems with the operation of the facility.	Internal
The failure of the power supply, either the main system or various subsystems.	Not relevant	In the CSF there is no such active systems which failure can cause the problems with the operation of the facility.	Internal
The malfunctioning of key equipment for handling waste, such as transfer cranes or conveyors.	Relevant	Included in drop scenario.	Internal
The malfunctioning of SSCs that control releases to the environment, such as filters or valves.	Not relevant	Due to the waste in the CSF the possible releases to the environment in such case are so low that the impact is negligible.	Internal
The failure properly to inspect, test and maintain SSCs.	Not relevant	The safety functions of SSCs in CSF are multiplied and malfunction of one doesn't affect the safety of the facility. All inspections, tests and maintenance must be planned in ahead and controlled during the performance. Such a failure has low probability to occur.	Internal
Incorrect operator action due to inaccurate or incomplete information.	Not relevant	All the actions of the operator are controlled or doubled, due to that this event has very low probability.	Internal

Name	Relevance	Relevance - justification (if not relevant)	Category
Incorrect operator action in spite of having accurate and complete information.	Not relevant	All the actions of the operator are controlled or doubled, due to that this event has very low probability.	Internal
Sabotage by employees.	Not relevant	This is the part of the security case.	Internal
The failure of systems and components such as incinerator linings, compactor hydraulics or cutting machinery that poses the risk of significant additional radiation exposure of personnel called on to assist in effecting repairs or replacements.	Not relevant	In the CSF the waste is just stored.	Internal
Encountering an unanticipated radiation source in decommissioning (e.g. different in nature or amount) and not recognizing immediately the changed circumstances.	Not relevant	Decommissioning is excluded from the scope of this Safety case.	Internal
Removing or weakening a structure or component in decommissioning without realizing the possible effect on the structural competence of other structures and components.	Not relevant	Decommissioning is excluded from the scope of this Safety case.	Internal
Traffic accident when transporting waste on-site to processing facility or from processing facility to storage building	Not relevant	Partially included in drop scenario. Traffic is not allowed on the transportation road.	Internal



Following both methods resulted in the following scenarios being identified:

- Drop scenario;
- Fire scenario;
- Plane crash - explosion scenario – will be assessed through security case;
- RW package is stolen from the facility - will be assessed through security case.

The consequences of first two scenarios above will be evaluated further in this safety assessment as Accident Scenarios.

### Scenario 1 – Drop scenario:

Considering the different types of RW stored in CSF, 6 sub-scenarios (identified as P1 through P6) listed in Table 10 were identified.

TABLE 10. DROP SUB-SCENARIOS P1 THROUGH P6

RW type	Sub - scenarios	Scenarios consequences
Solid RW	P1: Drop of package that contains dried resin	- External radiation
	P2: Drop of package that contains U – 238	- Inhalation
		- Ingestion
		- Contamination
DSRS	P3: Drop of package and release of high activity sealed source	- External radiation
	P4: Drop and subsequent release of unconditioned DSRS	- Inhalation
	P5: Drop of package that contains conditioned DSRS	- Ingestion
	P6: Drop and subsequent release of smoke detectors	- Contamination

All of these scenarios (with the exception of scenarios P2 and P3) can occur in front of the CSF or inside the facility. Scenarios P2 and P3 were not assessed since, as subsequent or additional treatment of these packages is not foreseen, they are not transported outside the facility. The representatives of critical groups that can be exposed are:

- ARAO workers;
- Josef Stefan Institute workers close to CSF;
- Security guard performing routine inspections around the facility;
- Farmer behind the fence of the facility (60 m from the CSF).

#### *Dried resins package (P 1):*

This scenario involves a package containing dried resins that are packed in 210 l drum; the resin is contaminated with Co-60, Cs-137, Eu-152 and Eu-154. The mass of the resin is 130 kg. Table 11 presents the total radioactivity of each nuclide in the container.

TABLE 11. SCENARIO P1 RADIONUCLIDE ACTIVITIES

Radionuclide	Activity (Bq)
Co-60	3.8E+06
Cs-137	5.48E+07
Eu-152	3.0E+05
Eu – 154	2.0E+05

*Package that contains U-238 (P 2):*

This package contains U-238 in powder form, with a total activity 0,598 GBq.

*Package with high radioactive sealed source (P 3)*

This package contains DSRS containing Cs-137 (total activity is  $1.46 \cdot 10^3$  GBq) and it is assumed that during the drop the DSRS will be released from the drum. Table 12 shows the dose rates at 1 m and 10 m.

TABLE 12. SCENARIO P3 DOSE RATES

Radionuclide	Activity on 31.12.2012 [GBq]	Equivalent gamma factor [(mSv·m <sup>2</sup> /h)/GBq]	Dose rate at 1 m [mSv/h]	Dose rate at 10 m [mSv/h]
Cs-137	1.46E+03	0.103	150	1.5

*Package with unconditioned DSRS (P 4)*

This package with DSRS contains Ir-192 with the activity 90 kBq on 31.12.2011, and it is assumed that during the transport the source will be released from the shield. Table 13 shows the dose rates for this package at 1, 10, 30, 40, 60 and 100 m.

TABLE 13. SCENARIO P4 DOSE RATES

Radionuclide	Activity on 31.12.2011 [kBq]	Equivalent gamma factor [(mSv·m <sup>2</sup> /h)/GBq]	Dose rate at - distance [mSv/h]					
			1 m	10 m	30 m	40 m	60 m	100 m
Ir-192	90	0.160	570	5.7	0.63	0.36	0.16	0.06

Note: All the dose rates in this table are assessed for the bare source – released from the shield

*Package with conditioned – repackaged DSRS (P 5):*

The properties of the package are summarized in Table 14.

TABLE 14. SCENARIO P5 PACKAGE PROPERTIES

Radionuclide	Activity on 31.12.2011 [kBq]	Equivalent gamma factor [(mSv·m <sup>2</sup> /h)/GBq]	Dose rate at - distance [mSv/h]					
			1 m	10 m	30 m	40 m	60 m	100 m
Co-60	460	0.370	170.2	1.70	0.19	0.11	0.05	0.02
Eu-152	12	0.202	2.424	0.02	2.7E- 03	1.5E- 03	1.1E- 03	0.4E- 03

*Package with dismantled smoke detectors (P 6):*

The properties of the package are summarized in Table 15.

TABLE 15. SCENARIO P6 PACKAGE PROPERTIES

Radionuclide	Activity on 31.12.2011 [kBq]	Equivalent gamma factor [(mSv·m <sup>2</sup> /h)/GBq]	Dose rate at distance [mSv/h]					
			1 m	10 m	30 m	40 m	60 m	100 m
Am-241	7	241 $8.48 \cdot 10^{-2}$	593.6 E-03	5.94 E-03	0.66 E-03	0.37 E-03	0.16 E-03	0.06 E-03

## Scenario 2 – Fire scenario:

Due to the use of the different electrical equipment inside the storage facility (e.g. moisture control system) a fire can occur. In the CSF the following combustible materials can be found:

- Plastic baskets for disused personal health protection equipment;
- Combustible parts of electrical and engineering equipment;
- Combustible RW:
  - ZV 0 (see Figure 9) - smoke detectors with plastic casing – prepared for dismantling;
  - T1 and T3 (see Figure 9) – paper, wood, fabric, cotton wool, polymers.
- Wooden benches.

It is assumed that the CSF is closed when a fire occurs and that all ventilation openings are not totally closed due to a failure of fire detection system. It is assumed that the fire lasts 90 minutes and that 10% of the activity of the burnable waste is released into the environment as a result of the fire. Representatives exposed to the radioactive smoke are:

- Guard;
- Worker of the Institute Josef Stefan (IJS) in the offices close to CSF;
- Worker of IJS working in a hot cell facility near to CSF;
- IJS visitors;
- Farmer behind the fence;
- Inhabitants of the village nearby (1 year old child, 7–10 years old child, an adult – more than 18 years).

### I-6.9. Formulation and implementation of assessment models

In order to perform the calculations for the safety assessment for the RW storage activities, certain measured and calculated data are used. In those instances where data is not available, certain assumptions are made based on experience performing similar types of activities elsewhere in the world. Further justification for the applied dose rate data is provided. The assumptions made are generally conservative.

### I-6.10. Performance of calculations and analysis of the results

#### I-6.10.1. Radiological impact assessment for normal operation

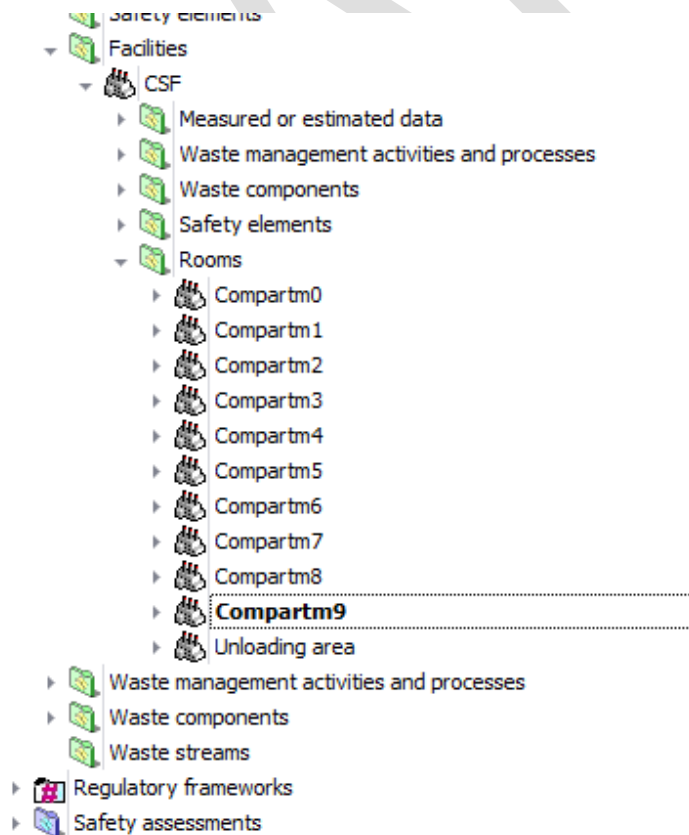
The assessment to the extent possible makes use of the data related to the characteristics of the facility, operations, and waste described in previous sections.

As shown in FIG. 24, the waste is segregated by radionuclide into storage compartments that are separated by half-walls; each storage compartment is characterized by unique dose rates.

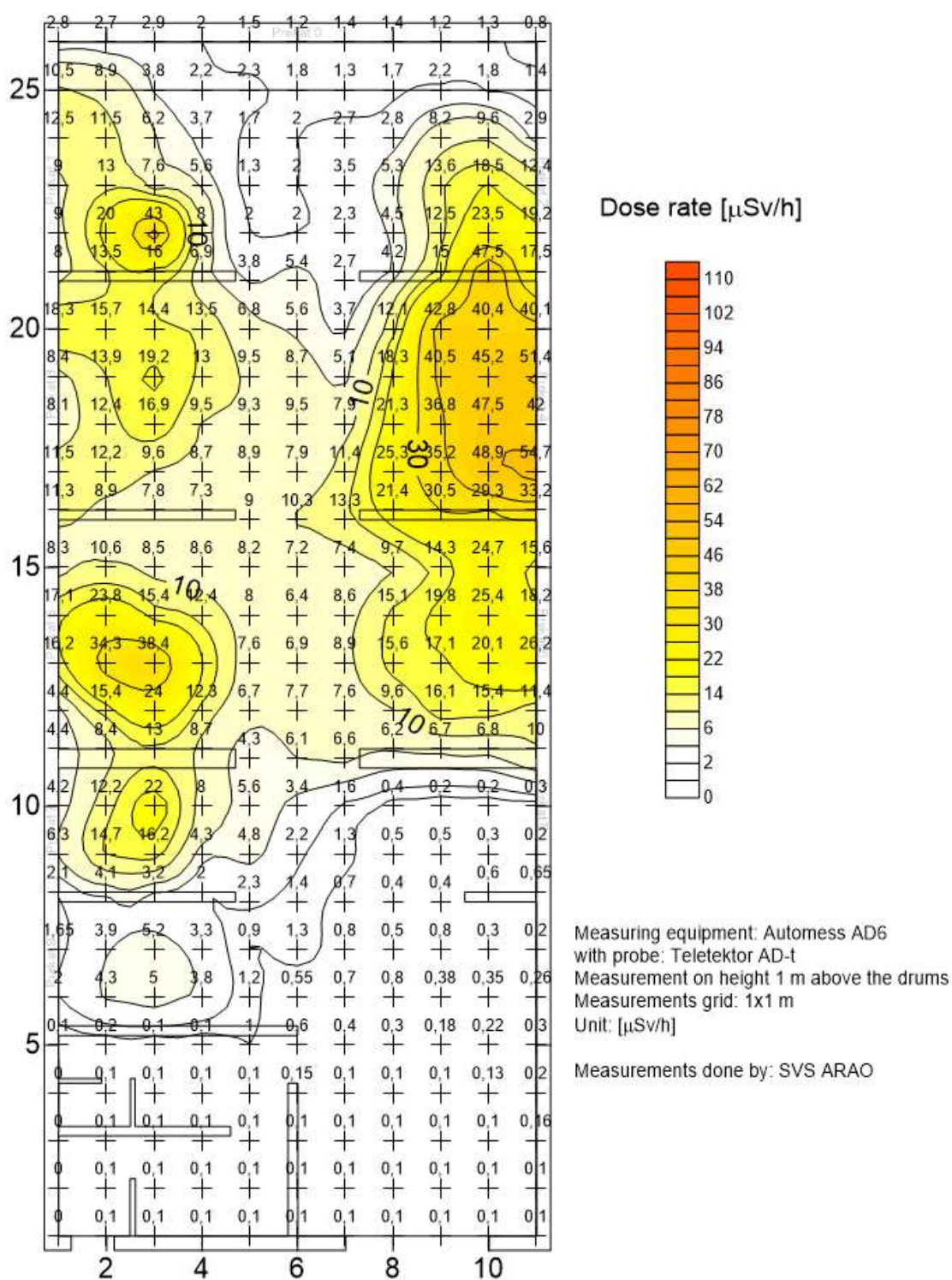


*FIG. 24. Individual storage compartments in the CSF.*

For the purpose of performing the safety assessment using SAFRAN, the storage facility was represented as a facility with ten rooms (FIG. 25), which allowed the consideration of the different dose rates in the individual compartments (FIG. 26).



*FIG. 25. Rooms defined in SAFRAN.*



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FIG. 26. Dose rate inside the CSF.

Doses to the worker performing transfers of waste to the storage location are assessed using conservative values for dose rates in the individual compartments and time required to perform each operation. Table 16 presents the activity duration and dose rates used to assess doses to the worker during normal operations.

TABLE 16. ASSUMPTIONS USED TO ASSESS DOSES TO WORKER DURING NORMAL OPERATIONS

Operation	Duration of activity [min/a]	Dose rate [mSv/h] conservatively assessed
Unloading of RW	150	0.020
Control measurement	200	0.020
Packaging	150	0.020
Transfer to storage location:		
Compartment 0	100	0.009
Compartment 1	60	0.043
Compartment 2	200	0.047
Compartment 3	600	0.019
Compartment 4	100	0.047
Compartment 5	700	0.038
Compartment 6	600	0.025
Compartment 7	600	0.022
Compartment 8	2000	0.0006
Compartment 9	2240	0.004

Dose rates are assessed on the basis of regular measurements and the time on the basis of the experiences from previous years. It is also conservatively assumes that a single worker performs the work. Table 17 presents doses for ARAO workers in CSF were assessed on the basis of the data listed in Table 16.

TABLE 17. DOSES TO WORKERS (NORMAL OPERATIONS)

Operation	Doses to workers [mSv/a]
Unloading of RW	0.050
Control measurement	0.067
Packaging	0.050
Transfer to storage location:	
Compartment 0	0.015
Compartment 1	0.043
Compartment 2	0.157
Compartment 3	0.190
Compartment 4	0.078
Compartment 5	0.443
Compartment 6	0.250
Compartment 7	0.220
Compartment 8	0.020
Compartment 9	0.149
Sum	1.732

As described in Section I-6.3.2, radon (and its progenies) is also present in the CSF. Due to this the impact of radon on doses on workers is also assessed. The concentration of radon in the CSF after the ventilation system has been operational for an hour is 200 Bq/m<sup>3</sup>. The assessment was performed in accordance with Slovenian regulation SV 5 [I-27]. Due to the short-lived nature of radon progenies and on the basis of the assumptions listed in Table 16, the additional dose to the worker resulting from exposure to radon progenies is calculated to be 0,005 mSv/a, while the dose to the worker inside the facility from radon is assessed at 0,0003 mSv/a.

The total dose for the worker during normal operations in the CSF is presented in Table 18.

TABLE 18. DOSE TO WORKER DURING NORMAL OPERATIONS (INCLUDING RADON)

Source	Dose [mSv/a]
External radiation	1.732
Short-lived radon progenies	0.005
Radon	0.0003
Sum	1.7373

Table 19 presents the total doses to the worker during normal operation calculated using the SAFRAN tool.

TABLE 19. DOSE TO WORKER DURING NORMAL OPERATIONS (SAFRAN)

Impact	Dose [Sv/a]
Unloading from transport container	5.00E-05
Control measurement	6.66E-05
Packaging	5.00E-05
Transfer to Storage Location	
Storage0	1.50E-05
Storage1	4.30E-05
Storage2	1.57E-04
Storage3	1.90E-04
Storage4	7.85E-05
Storage5	4.43E-04
Storage6	2.50E-04
Storage7	2.20E-04
Storage8	2.00E-05
Storage9	1.49E-04
Total	1.73E-03

The calculated doses for workers are below the dose limit of 10 mSv/a prescribed by Slovenian regulation but, due to the use of the conservative approach, are much higher than the actual (measured) doses. Actual (measured) annual doses for the ARAO workers in the storage facility are below 100  $\mu$ Sv/a.

#### *I-6.10.2. Radiological impact assessment for accidents*

The scenarios as defined above are assessed using simple calculations. Analyses of the results are presented in Section I-6.11.

#### **Scenario 1 – Drop scenario:**

This scenario assesses the consequences from the drop of a waste package inside the facility. Because the scenario occurs inside the facility, it is assumed that, due to the design and the construction, ventilation (building is under negative pressure) and technical protection measures, only the ARAO workers are exposed. It is assumed that the worker needs 1 minute to move away from the accident and 10 min to protect the area.

Table 20 presents the assumptions used to calculate doses to the worker.

TABLE 20. DROP SCENARIO, ASSUMPTIONS USED TO CALCULATE WORKER DOSES

Representative	Distance from source [m]	Time of exposure [min]	Breathing rate [m <sup>3</sup> /h]
ARAO worker	1	1	1.5
	10	10	1.5

It is assumed that, as a result of the drop and the subsequent release, 0.1 % of total activity is released in the air at a height of 2 m.

The effective dose for the ARAO workers is calculated using MS Excel as follows:

$$E = \sum_i E_i = \sum_i \dot{E}_i \cdot t \quad (1)$$

where

E is total effective dose;

$E_i$  is effective dose due to external radiation, inhalation and ingestion;

$\dot{E}_i$  is effective dose rate due to external radiation, inhalation and ingestion;

t is time of exposure.

It is also conservatively assumed that 10% of the inhaled radionuclides is additionally ingested.

#### ***Drop of spent dried resins container (P 1)***

It is assumed that, as a result of the drop and the subsequent release, an area within a 5 m radius is contaminated. Table 21 presents the dose rates calculated for selected distances using MicroShield v.6.04.

TABLE 21. DROP SCENARIO P1, DOSE RATES AT SELECTED DISTANCES (MICROSHIELD)

Dose rate [μSv/h] at distance [m]					
1	10	30	40	60	100
0.038	0.010	0.001	<0.001	<0.001	<0.001

Assuming than 0.1% of the activity is released into the air with a volume of 160 m<sup>3</sup>, the assessed concentration of the radionuclides in the air is:

24 Bq/m<sup>3</sup> for Co-60;

342 Bq/m<sup>3</sup> for Cs-137;

2 Bq/m<sup>3</sup> for Eu-152;

0,1 Bq/m<sup>3</sup> for Eu-154.

Table 22 presents the results of calculations assessing doses to the worker from external and internal radiation using MS Excel.



TABLE 22. DROP SCENARIO P1, TOTAL DOSE TO WORKER FROM EXTERNAL AND INTERNAL RADIATION (MS EXCEL)

Representative	Assessed dose due to external radiation [ $\mu\text{Sv}$ ]	Assessed dose due to internal radiation [ $\mu\text{Sv}$ ]	Total dose [ $\mu\text{Sv}$ ]
ARAO worker	< 0.01	0.37	0.37

The SAFRAN tool was used to calculate doses to the ARAO worker resulting from 2 external exposure scenarios, assuming an exposure time of 1 min and a distance of 1 m and an exposure time of 10 min at distance 10 m. Because the data for radionuclide Eu-152 was not included in the SAFRAN database at the time of this assessment, only the activity for Eu-154 was considered in the calculation. The results are presented in Table 23.

TABLE 23. DROP SCENARIO P1, EXTERNAL EXPOSURE OF WORKER (SAFRAN)

Exposure Conditions	Nuclide	Activity [Bq]	Dose rate [Sv/h]	Dose [Sv]
Exposure time = 1 min, distance = 1 m	Cs-137	3.80E+06	4.17E-08	7.10E-10
	Co-60	5.48E+07	2.43E-06	4.14E-08
	Eu-154	3.20E+05	7.27E-09	1.24E-10
	Total		2.48E-06	4.22E-08
Exposure time = 10 min, distance = 10 m	Cs-137	3.8E+06	2.86E-09	5.06E-10
	Co-60	5.48E+07	1.67E-07	2.95E-08
	Eu-154	3.20E+05	4.98E-10	8.82E-11
	Total		1.70E-07	3.01E-08

Dose due to inhalation was also assessed using the SAFRAN tool. Table 24 presents the input parameters and results of the calculations.

TABLE 24. DROP SCENARIO P1, INHALATION DOSE TO THE WORKER (SAFRAN)

Nuclide	Activity [Bq]	Airborne Release Factor	Room volume [m <sup>3</sup> ]	Dispersion factor [h/m <sup>3</sup> ]	Protection factor	Dose [Sv]
Eu-154	3.20E+05	1.00E-03	200	1.18E-03	0	5.67E-08
Co-60	5.48E+07	1.00E-03	200	1.18E-03	0	1.89E-06
Cs-137	3.8E+06	1.00E-03	200	1.18E-03	0	9.06E-08
Total						2.04E-06

### *Package that contains U-238 (P 2)*

Table 25 presents the results of calculations assessing doses to the worker from external and internal radiation using MS Excel.

TABLE 25. DROP SCENARIO P2, TOTAL DOSE TO THE WORKER (MS EXCEL)

Representative	Assessed dose due to external radiation [ $\mu\text{Sv}$ ]	Assessed dose due to internal radiation [ $\mu\text{Sv}$ ]	Total dose [ $\mu\text{Sv}$ ]
ARAO worker	< 0.01	3.1E+03	3.1E+03

Table 26 presents the results of calculations using SAFRAN to determine:

- External exposure for worker that spent 1 min on distance 1m.
- External exposure for worker that spent 10 min on distance 10 m.

TABLE 26. DROP SCENARIO P2, EXTERNAL EXPOSURE OF WORKER (SAFRAN)

Exposure Conditions	Nuclide	Activity [Bq]	Dose rate [Sv/h]	Dose [Sv]
Exposure time = 1 min, distance = 1 m	U-238	5.98E+08	7.39E-10	1.26E-11
Exposure time = 10 min, distance = 10 m	U-238	5.98E+08	8.27E-12	1.46E-12

Table 27 presents the inhalation dose calculated with SAFRAN together with the input parameters that were used to perform the calculations.

TABLE 27. DROP SCENARIO P2, INHALATION DOSE TO THE WORKER, AT DISTANCE 1 M, FOR 1 MIN

Nuclide	Activity [Bq]	Airborne Release Factor	Release inside [Bq]	Room volume (m3)	Dispersion factor [h/m3]	Protection factor	Dose [Sv]
U-238	5.98E+08	1.00E-03	5.98E+05	200	1.18E-03	0	1.55E-02

#### ***Package with high radioactive sealed source (P 3)***

Table 28 presents the results of calculations assessing doses to the worker from external and internal radiation using MS Excel.

TABLE 28. DROP SCENARIO P3, TOTAL DOSE TO THE WORKER (MS EXCEL)

Representative	Dose due to external exposure [μSv]	Dose due to internal exposure [μSv]	Total dose [μSv]
ARAO worker	2.75E+03	-	2.75E+03

Table 29 presents the results of calculations using SAFRAN to determine:

- External exposure for worker that spent 1 min on distance 1m.
- External exposure for worker that spent 10 min on distance 10 m.

It is assumed that inhalation is not possible due to the properties of the package and the radioactive sealed source precluding contamination of the room and of the air.

TABLE 29. DROP SCENARIO P3, EXTERNAL EXPOSURE OF WORKER (SAFRAN)

Exposure Conditions	Nuclide	Activity [Bq]	Dose rate [Sv/h]	Dose [Sv]
Exposure time = 1 min, distance = 1 m	Cs-137	1.46E+12	1.10E-01	1.94E-03
Exposure time = 10 min, distance = 10 m	Cs-137	1.46E+12	1.23E-03	2.18E-04

#### ***Package with not conditioned DSRS (P 4)***

Table 30 presents the results of calculations assessing doses to the worker from external and internal radiation using MS Excel.

TABLE 30. DROP SCENARIO P4, TOTAL DOSE TO THE WORKER (MS EXCEL)

Representative	Assessed dose due to external radiation [μSv]	Assessed dose due to internal radiation [μSv]	Total dose [μSv]
ARAO worker	10.45E+3	-	10.45E+3

In the SAFRAN common database the data for Ir-152 is not yet included. Although it is possible for the assessor to introduce new data or change existing data for individual radionuclides into the SAFRAN database, all needed parameters must be known or available. Because the necessary parameters were not available at the time of the preparation of this report, it was decided not to include this calculation in the SAFRAN calculation.

***Package with conditioned – repacked DSRS (P5)***

Table 31 presents the results of calculations assessing doses to the worker from external and internal radiation using MS Excel. In this case, dose assessment calculations involving Eu-152 is performed in accordance with IAEA Safety Report Series 19 [I-28].

TABLE 31. DROP SCENARIO P5, TOTAL DOSE TO THE WORKER (MS EXCEL)

Representative	Assessed dose due to external radiation [μSv]	Assessed dose due to internal radiation [μSv]	Total dose [μSv]
ARAO worker	316	-	316

***Package with dismantled smoke detectors (P 6)***

Table 32 presents the results of calculations assessing doses to the worker from external and internal radiation using MS Excel.

TABLE 32. DROP SCENARIO P6, DOSE TO THE WORKER (MS EXCEL)

Representative	Dose from external radiation [μSv]	Dose from internal radiation [μSv]	Total dose [μSv]
ARAO worker	10.88	0.24	11.12

Table 33 presents the results from SAFRAN calculations for external exposure:

- External exposure for a worker that spent 1 min at a distance of 1 m;
- External exposure for a worker that spent 10 min at a distance of 10 m.

TABLE 33. DROP SCENARIO P6, EXTERNAL EXPOSURE OF WORKER (SAFRAN)

Exposure Conditions	Nuclide	Activity [Bq]	Dose rate [Sv/h]	Dose [Sv]
Exposure time = 1 min, distance = 1 m	Am-241	7E+09	1.99E-05	3.52E-07
Exposure time = 10 min, distance = 10 m	Am-241	7E+09	2.23E-07	3.94E-08

Table 34 presents the inhalation dose calculated with SAFRAN together with the input parameters that were used to perform the calculations.

TABLE 34. DROP SCENARIO P6, INHALATION DOSE TO THE WORKERS (SAFRAN)

Nuclide	Activity [Bq]	Airborne Release Factor	Release inside [Bq]	Room volume (m3)	Dispersion factor [h/m3]	Protection factor	Dose [Sv]
Am-241	7E+09	4.00E-09	28	1200	1.18E-03	0	3.87E-06

Drop in front of CSFIt is assumed that the ARAO worker needs 1 minute to move away from the accident and 10 min to protect the area. The security guard is assumed to be at the time of the drop near the CSF and needs 2 min to move away and an additional 15 min at a distance

of 30 m to inform personnel about the accident. It is assumed that the representatives remain in the plume of contaminated air for 5 min. Due to the movement of the air, it is assumed that this plume will expand quickly and that the particles will not reach the farmer located 60 m from the accident. It is also assumed that 0,1 % of total activity is released in the air and that the plume has a volume of 1000 m<sup>3</sup>.

Table 35 presents the distances, exposure times and breathing rates used to calculate doses to the representatives as a result of the Drop Scenario.

TABLE 35. ASSUMPTIONS USED IN DROP SCENARIO

Representative	Distance from the source [m]	Exposure Time [min]	Breathing rate [m <sup>3</sup> /h]
ARAO worker	1	1	1.5
	10	10	1.5
Security guard	10	2	1.5
	30	15	1.5
IJS worker close to CSF	40	30	1.5
Farmer behind the fence	60	60	1.5

***Drop of spent dried resins container (P 1)***

Table 36 presents the results of the assessment of doses to the workers and the public from external and internal radiation as a result of the drop scenario.

TABLE 36. DROP SCENARIO P1 DOSES TO THE WORKER AND THE PUBLIC (MS EXCEL)

Representative	Dose [μSv]		
	External radiation	Internal radiation	Total
ARAO worker	<0.01	0.29	0.29
Security guard	<0.01	0.29	0.29
IJS worker close to CSF	<0.01	0.29	0.29
Farmer behind the fence	<0.01	-	<0.1

Table 37 presents the external radiation to the ARAO worker resulting from exposure outside the facility (using SAFRAN).

TABLE 37. DROP SCENARIO P1 EXTERNAL EXPOSURE OF WORKER (SAFRAN)

Exposure Conditions	Nuclide	Activity [Bq]	Distance [cm]	Dose rate [Sv/h]	Exposure time [h]	Dose [Sv]
Exposure time = 1 min, distance = 1 m	Cs-137	3.8E+06	100	2.86E-07	1.77E-02	5.06E-09
	Co-60	5.48E+07	100	1.67E-05	1.77E-02	2.95E-07
	Eu-154	3.20E+05	100	4.98E-08	1.77E-02	8.82E-10
	Total			1.70E-05		3.01E-07
Exposure time = 10 min, distance = 10 m	Cs-137	3.8E+06	1000	2.86E-09	1.77E-01	5.06E-10
	Co-60	5.48E+07	1000	1.67E-07	1.77E-01	2.95E-08
	Eu-154	3.20E+05	1000	4.98E-10	1.77E-01	8.82E-11
	Total			1.70E-07		3.01E-08

Table 38 presents the input parameters and results for the inhalation dose assessed with SAFRAN tool.

TABLE 38. DROP SCENARIO P1 INHALATION DOSE TO THE WORKER (SAFRAN)

Nuclide	Activity [Bq]	Airborne Release Factor	Release outside [Bq]	Dose Conversion Factor [Sv/Bq]	Dose [Sv]
Cs-137	3.80E+06	1.00E-03	3800	2.03E-13	7.71E-10
Co-60	5.48E+07	1.00E-03	54800	5.27E-13	2.89E-08
Eu-154	3.20E+05	1.00E-03	320	2.67E-13	8.54E-11
Total					2.97E-08

The results for the inhalation are assumed to be the same for all representatives (ARAO worker, Security guard, IJS worker close to CSF, farmer) who are located within a 60 m radius of the drop. It is assumed that all particles settle on the ground within the 60 m radius. Because the farmer is located at a distance greater than 60 m from the accident, it is assumed that he does not receive any inhalation dose as a result of the drop.

It is assumed that the security guard is performing a regular inspection when the drop occurs, and that he spends 2 minutes at a distance 10 m from the source to identify what is occurring). Table 39 presents the results of using SAFRAN to assess external exposure.

TABLE 39. DROP SCENARIO P1 EXTERNAL EXPOSURE TO SECURITY GUARD, INITIAL 2 MIN (SAFRAN)

Nuclide	Activity [Bq]	Distance [cm]	Dose rate [Sv/h]	Exposure time [h]	Dose [Sv]
Cs-137	3.8E+06	1000	2.86E-09	3.30E-02	9.43E-11
Co-60	5.48E+07	1000	1.67E-07	3.30E-02	5.50E-09
Eu-154	3.20E+05	1000	4.98E-10	3.30E-02	1.64E-11
Total			1.70E-07		5.61E-09

After 2 min, the security guard moves to distance 30 m from the drop and takes 15 min to inform responsible persons about this accident, after which time he moves away from the exposure zone of the accident. Table 40 presents the results using SAFRAN to assess the external exposure for this 15 min period.

TABLE 40. DROP SCENARIO P1 EXTERNAL EXPOSURE TO SECURITY GUARD, SUBSEQUENT 15 MINUTES (SAFRAN)

Nuclide	Activity [Bq]	Distance [cm]	Dose rate [Sv/h]	Exposure time [h]	Dose [Sv]
Cs-137	3.8E+06	3000	3.51E-10	2.50E-01	8.78E-11
Co-60	5.48E+07	3000	2.05E-08	2.50E-01	5.12E-09
Eu-154	3.20E+05	3000	6.12E-11	2.50E-01	1.53E-11
Total			2.09E-08		5.22E-09

It is assumed that the IJS worker is in his office (located at a distance of 40 m from the accident) during the accident and that he needs 30 min to move away from the site. Table 41 presents the results using SAFRAN to assess the external exposure for this event.

TABLE 41. DROP SCENARIO P1 EXTERNAL EXPOSURE TO THE IJS WORKER (SAFRAN)

Nuclide	Activity [Bq]	Distance [cm]	Dose rate [Sv/h]	Exposure time [h]	Dose [Sv]
Cs-137	3.8E+06	4000	1.99E-10	5.00E-01	9.93E-11
Co-60	5.48E+07	4000	1.16E-08	5.00E-01	5.79E-09
Eu-154	3.20E+05	4000	3.46E-11	5.00E-01	1.73E-11
Total			1.18E-08		5.91E-09

Table 42 presents the results from using SAFRAN to calculate doses to the farmer who works 60 min at a distance 60 m away from the accident.

TABLE 42. DROP SCENARIO P1 EXTERNAL EXPOSURE TO FARMER (SAFRAN)

Nuclide	Activity [Bq]	Distance [cm]	Dose rate [Sv/h]	Exposure time [h]	Dose [Sv]
Cs-137	3.8E+06	6000	8.87E-11	1	8.87E-11
Co-60	5.48E+07	6000	5.17E-09	1	5.17E-09
Eu-154	3.20E+05	6000	1.54E-11	1	1.54E-11
Total			5.27E-09		5.27E-09

***Package with unconditioned DSRS (P 4)***

Due to the properties of the DSRS packaged while in storage at the CSF, contamination of the air as well as internal radiation and inhalation are not considered. For this sub-scenario the calculation with SAFRAN is not possible at the moment, because Ir-192 is not yet included in the SAFRAN database.

Table 43 presents the dose due to external and internal radiation to each representative.

TABLE 43. DROP SCENARIO P4 EXTERNAL AND INTERNAL DOSES (MS EXCEL)

Representative	Dose due to external radiation [ $\mu$ Sv]	Dose due to internal radiation [ $\mu$ Sv]	Total dose [ $\mu$ Sv]
ARAO worker	10.45E+03	-	10.45E+03
Security guard	350	-	350
IJS worker close to CSF	180	-	180
Farmer behind the fence	160	-	160

***Package with conditioned – repackaged DSRS (P 5)***

The dose assessment for Eu-152 for this scenario is performed in accordance with IAEA Safety Report Series 19 [I-28]. Table 44 presents the assessed dose due to external and internal radiation to each representative.

TABLE 44. DROP SCENARIO P5 EXTERNAL AND INTERNAL DOSES (SRS 19)

Representative	Assessed dose due to external radiation [ $\mu\text{Sv}$ ]	Assessed dose due to internal radiation [ $\mu\text{Sv}$ ]	Total dose [ $\mu\text{Sv}$ ]
ARAO worker	316	-	316
Security guard	104.8	-	104.8
IJS worker close to CSF	55.8	-	55.8
Farmer behind the fence	51.1	-	51.1

***Package with dismantled smoke detectors (P 6)***

Table 45 presents the assessed dose (calculated using MS Excel) due to external and internal radiation to each representative.

TABLE 45. DROP SCENARIO P5 EXTERNAL AND INTERNAL DOSES (MS Excel)

Representative	Assessed dose due to external radiation [ $\mu\text{Sv}$ ]	Assessed dose due to internal radiation [ $\mu\text{Sv}$ ]	Total dose [ $\mu\text{Sv}$ ]
ARAO worker	10.88	0.24	11.12
Security guard	0.36	1.20	1.56
IJS worker close to CSF	0.19	1.20	1.39
Farmer behind the fence	0.16	-	0.16

Table 46 presents the distances, exposure times and dose rates used to calculate doses using SAFRAN due to external exposure to the Am-241 source (activity of  $7\text{E}+09$  Bq) to the different representatives.

TABLE 46. DROP SCENARIO P6 EXTERNAL EXPOSURES AM-241 (SAFRAN)

Representative	Exposure Conditions	Nuclide	Dose rate [ $\text{Sv/h}$ ]	Dose [ $\text{Sv}$ ]
ARAO worker	Exposure time = 1 min, distance = 1 m	Am-241	$2.91\text{E}-06$	$5.15\text{E}-08$
	Exposure time = 10 min, distance = 10 m	Am-241	$1.99\text{E}-07$	$3.52\text{E}-08$
Security Guard	Exposure time = 2 min, distance = 10 m	Am-241	$1.99\text{E}-07$	$6.57\text{E}-09$
	Exposure time = 15 min, distance = 30 m	Am-241	$2.45\text{E}-08$	$6.11\text{E}-09$
IJS worker	Exposure time = 30 min, distance = 40 m	Am-241	$1.38\text{E}-08$	$6.92\text{E}-09$
Farmer	Exposure time = 60 min, distance = 60 m	Am-241	$6.18\text{E}-09$	$6.18\text{E}-09$

In order to calculate the dose due to inhalation to the ARAO worker, Security guard, and IJS worker close to CSF (all of whom are located within a radius of 60 m of the drop), it is assumed that all particles settle on the ground within the 60 m radius. Because the farmer is located at a distance greater than 60 m from the accident, it is assumed that he does not receive any dose due to inhalation. Table 47 presents the results of the assessment performed using SAFRAN.

TABLE 47. DROP SCENARIO P1 INHALATION DOSE TO THE WORKERS (SAFRAN)

Nuclide	Activity [Bq]	Airborne Release Factor	Release outside [Bq]	Dose Conversion Factor [Sv/Bq]	Dose [Sv]
Am-241	7E+09	1.70E-08	119	2.09E-11	2.49E-09

**Scenario 2 – Fire scenario:**

This scenario assumes a fire in the CSF caused by an electrical fault in the facility that expands to other combustible materials inside the facility. Table 48 presents the total quantities and activities of combustible waste stored in the CSF.

TABLE 48. COMBUSTIBLE WASTE STORED IN THE CSF

Type of RW	Volume [m3]	Activity [GBq]
T1- solid, compressible, combustible	18.1	0.95
T3 - solid, non-compressible, combustible	3.35	0.12
ZV0 – smoke detectors	7.55	6.61
Total	29.1	7.68

To analyze the fire scenario the following conservative assumptions are adopted:

- There are no ARAO workers at the site at the time of fire.
- The doors of the facility are closed when the fire occurs.
- The fire protection system is activated and the security guard checks the situation, as required.
- The fire hatches don't close completely due to technical problems.
- The duration of the fire is 90 min (includes initiation of the fire, situation check by the security guard, summoning of the firefighting service, conduct of the firefighting, extinguishing of the fire, and cessation of smoke from the fire).
- Smoke contaminated with radioactive particles escapes from the facility through the partially closed fire hatches as well as through the damaged ventilation system (it is also assumed the filters are damaged as a result of the fire), resulting in 10% of the total activity released inside the facility escapes into the atmosphere.

Table 49 presents the representatives and parameters used to assess the doses to the representatives (includes both workers and public).

TABLE 49. REPRESENTATIVES AND PARAMETERS USED IN FIRE SCENARIO

Representative	Distance from source [m]	Exposure time [min]	Breathing rate [m3/h]
Security guard	10	2	1.5
	40	15	1.5
IJS Worker in offices close to CSF	40	25	0.54
IJS worker in hot cell facility adjacent to CSF and IJS visitors	40	25	0.54
Farmer behind the fence	60	30	1.5
Inhabitants of nearby village (child 1 y)	500	90	0.35
Inhabitants of nearby village (child 7-10 y)	500	90	1.12
Inhabitants of nearby village (adult)	500	90	1.5



The methodology described in IAEA-TECDOC-1162 [I-29] (Procedure E5a) was used to assess the impact of the fire on the representatives presented above. Table 50 presents the radionuclides and the associated Fire Release Fractions considered by the model. Table 51 presents the results of the assessment.

TABLE 50. RADIONUCLIDES AND FIRE RELEASE FRACTIONS CONSIDERED IN FIRE SCENARIO

Radionuclide	Fire release fraction
Cs-137	0.01
Eu-152	0.01
Am-241	0.001
Co-60	0.001
Pu-239	0.001
Ra-226	0.001
U-238	0.001

TABLE 51. FIRE SCENARIO DOSES TO REPRESENTATIVES (IAEA-TECDOC-1162)

Representative	Distance from source [m]	Dose due to inhalation [μSv]		Dose due to ingestion [μSv]	
		Sunny	Cloudy	Sunny	Cloudy
Security guard	10	64.7	524	9.63E-3	7.8E-2
	40	64.7	524	9.63E-3	7.8E-2
IJS Worker in offices close to CSF	40	11.9	99.6	1.78E-3	1.48E-2
IJS Worker in hot cell facility adjacent to CSF and IJS visitors	40	33.5	279	4.98E-3	4.15E-2
Farmer behind the fence	60	20.1	1.5	2.99E-3	2.9E-2
Inhabitant of nearby village (child 1 y)	500	Less than adult	Less than adult	Less than adult	Less than adult
Inhabitant of nearby village (child 7-10 y)	500	Less than adult	Less than adult	Less than adult	Less than adult
Inhabitant of nearby village (adult)	500	0.5	10	7.47E-5	1.49E-3

Doses received as a result of exposure to the fire scenario were also assessed using the SAFRAN tool. However, as Eu-152 is not included in the common SAFRAN database, it was not considered in the calculation. Table 52 presents the doses to the public; doses for the workers are assumed to be the same as for the public.

TABLE 52. FIRE SCENARIO DOSES TO REPRESENTATIVES (SAFRAN)

Nuclide	Release inside [Bq]	Filtration efficiency	Release outside [Bq]	Dose Conversion Factor [Sv/Bq]	Dose [Sv]
U-238	2.17E+05	9.00E-01	2.17E+04	2.05E-12	4.45E-08
Ra-226	6.00E+04	9.00E-01	6.00E+03	9.51E-12	5.71E-08
Pu-239	4.31E+04	9.00E-01	4.31E+03	2.50E-11	1.08E-07
Am-241	6.64E+06	9.00E-01	6.64E+05	2.09E-11	1.39E-05
Cs-137	3.16E+06	9.00E-01	3.16E+05	2.03E-13	6.41E-08
Co-60	1.16E+05	9.00E-01	1.16E+04	5.27E-13	6.11E-09
Total					1.42E-05

#### *I-6.10.3. Interdependencies*

Activities performed in neighboring facilities such as IJS may impact in the safety of the CSF. The development of activities that could introduce additional or new hazards to the CSF, such as the production and handling of explosives or the performance of activities that could pose a fire risk may impact the safety of the CSF. Discussions will be carried out with the regulatory authority to address this issue.

#### *I-6.10.4. Management of uncertainties*

While performing the safety assessment, the most significant source of uncertainty that could potentially impact the assessed safety of the facility and activities at the CSF concerns the level of confidence in the characterization of the RW inventory. It is important that any insufficiencies in the characterization of the current inventory of RW at the CS could not negatively impact the result of the safety assessment. In order to address this uncertainty, a conservative approach was taken in the selection of conservative but realistic inventory data and assumptions. Furthermore, the “screening” method was used to evaluate the influence of important input data and assumption on worker and public exposure.

Ageing of the existing facility is also considered to be another important source of uncertainty, and to address this a Periodic safety review is performed every ten years. The results from the Periodic Review are used to revise the Safety case and extend the operating license.

### **I-6.11. Analysis of assessment results**

The following sub-sections compare the results obtained during the quantitative and qualitative assessments for both normal operations and accident conditions against the proposed targets and objectives set for the optimization of protection.

#### **Normal Operation**

Table 53 presents the results of the safety assessment for normal operation obtained using “classical” calculations as well as those obtained using SAFRAN. All of the doses, calculated using conservative assumptions, are below (by a factor of 10) the dose limit of 10 mSv/a prescribed by Slovenian regulation, and are well below the actual (measured) annual doses to the ARAO worker (below 100  $\mu$ Sv/a). The results obtained using “classical” calculations versus the SAFRAN tool are the same.

TABLE 53. COMPARISON OF DOSES TO THE WORKER DURING NORMAL OPERATIONS

Operation	Using “classical” calculations [mSv/a]	Using SAFRAN [mSv/a]
Unloading of RW	0.050	0.050
Control measurement	0.067	0.067
Packaging	0.050	0.050
Transfer to storage location:		
Compartment 0	0.015	0.015
Compartment 1	0.043	0.043
Compartment 2	0.157	0.157
Compartment 3	0.190	0.190
Compartment 4	0.078	0.079
Compartment 5	0.443	0.443
Compartment 6	0.250	0.250
Compartment 7	0.220	0.220
Compartment 8	0.020	0.020
Compartment 9	0.149	0.149
Total	1.732	1.732

#### Accident Scenarios

#### Drop scenario inside the facility

Table 54 summarizes the results of the dose assessment using “classical” calculations and using SAFRAN for the accident scenarios involving the drop of a RW container inside the facility. Doses that are less than 0,01  $\mu\text{Sv}$  are presented as “< 0.01”. As Table 55 shows, the results are well below the prescribed dose limits of 20E+03  $\mu\text{Sv}$  for the ARAO worker. In most cases, the SAFRAN Tool resulted in more conservative (higher) doses to the worker

TABLE 54. COMPARISON OF DOSES TO THE WORKER RESULTING FROM CONTAINER DROP ACCIDENTS INSIDE THE FACILITY

Scenario, Dose Representative	Classical calculations			SAFRAN tool		
	External radiation [ $\mu\text{Sv}$ ]	Inhalation [ $\mu\text{Sv}$ ]	Total dose [ $\mu\text{Sv}$ ]	External radiation [ $\mu\text{Sv}$ ]	Inhalation [ $\mu\text{Sv}$ ]	Total dose [ $\mu\text{Sv}$ ]
P1, package containing dried resins						
ARAO worker	< 0.01	0.37	0.37	<0.01	2.04	2.04
P 2, package containing U-238						
ARAO worker	< 0.01	3.1E+03	3.1E+03	<0.01	15.5E+03	15.5E+03
P 3, package containing high activity Cs-137 sealed source						
ARAO worker	2.750E+03	-	2.75E+03	2.158	-	2.16E+03
P 4, package containing unconditioned Ir-192 source						
ARAO worker	10.45E+03	-	10.45E+03	Note 1		
P 5, package containing conditioned Co-60 and Eu-152 sources						
ARAO worker	316	-	316	Note 1		
P 6, package containing dismantled Am-241 smoke detectors						
ARAO worker	10.88	0.24	11.12	0.39	3.87	4.26

Notes:

1. The assessment with SAFRAN was not performed (see Section I-6.8.2.).

## Drop scenario outside the facility

Table 55 summarizes the results of the dose assessment using “classical” calculations and using SAFRAN for the accident scenarios involving the drop of a RW container outside the facility. As Table 56 shows, doses to all of the representatives are well below the prescribed dose limits of 20E+03  $\mu\text{Sv}$  for the ARAO worker and 1E+03  $\mu\text{Sv}$  for non-ARAO workers and the public.

TABLE 55. COMPARISON OF DOSES TO THE WORKER FOR CONTAINER DROP ACCIDENTS OUTSIDE THE FACILITY

Representative	Classical calculations			SAFRAN tool		
	Ext. radiation [μSv]	Inhalation [μSv]	Total dose [μSv]	Ext. radiation [μSv]	Inhalation [μSv]	Total dose [μSv]
P1, package containing dried resins						
ARAO worker	<0.01	0.29	0.29	0.33	0.03	0.36
Security guard	<0.01	0.29	0.29	0.01	0.03	0.04
IJS worker close to CSF	<0.01	0.29	0.29	0.01	0.03	0.04
Farmer behind the fence	<0.01	-	<0.1	0.01	0.03	0.04
P 2, package containing U-238						
P 2	Note 1					
P 3, package containing high activity Cs-137 sealed source						
P 3	Note 1					
P 4, package containing unconditioned Ir-192 source						
ARAO worker	10.45E03	-	10.45E03	Note 2		
Security guard	350	-	350	Note 2		
IJS worker close to CSF	180	-	180	Note 2		
Farmer behind the fence	160	-	160	Note 2		
P 5, package containing conditioned Co-60 and Eu-152 sources						
ARAO worker	316	-	316	Note 2		
Security guard	104.8	-	104.8	Note 2		
IJS worker close to CSF	55.8	-	55.8	Note 2		
Farmer behind the fence	51.1	-	51.1	Note 2		
P 6, package containing dismantled Am-241 smoke detectors						
ARAO worker	10.88	0.24	11.12	0.09	<0.01	0.09
Security guard	0.36	1.20	1.56	0.01	<0.01	0.01
IJS worker close to CSF	0.19	1.20	1.39	0.01	<0.01	0.01
Farmer behind the fence	0.16	/	0.16	0.01	<0.01	0.01

Notes:

1. The assessment was not performed (see Section I-6.8.2).
2. The assessment with SAFRAN was not performed (see Section I-6.8.2.).

## Fire scenario

Table 56 summarizes the results of the dose assessment using “classical” calculations and using SAFRAN for the accident scenarios involving a fire. As Table 57 shows, all of the results are well below the limit of 1E+03  $\mu\text{Sv}$  for all representatives. While the doses calculated using SAFRAN are less conservative than “classical” assessments for the more exposed representatives and are more conservative for less exposed representatives, the results are still considered comparable.

TABLE 56. COMPARISON OF DOSES TO THE WORKER FOR FIRE ACCIDENTS

Representative	CLAS					SAF
	Limit [ $\mu\text{Sv}$ ]	Dose – inhalation – sunny [ $\mu\text{Sv}$ ]	Dose – inhalation – cloudy [ $\mu\text{Sv}$ ]	Dose – ingestion – sunny [ $\mu\text{Sv}$ ]	Dose – ingestion – cloudy [ $\mu\text{Sv}$ ]	Dose [ $\mu\text{Sv}$ ]
Security guard	1E03	64.7	524	<0.01	0.08	14.2
	1E03	64.7	524	<0.01	0.08	14.2
Worker of IJS in the offices close to CSF	1E03	11.9	99.6	<0.01	0.01	14.2
Worker of IJS working in hot cell facility near to CSF and IJS visitors	1E03	33.5	279	<0.01	0.04	14.2
Farmer behind the fence	1E03	20.1	1.5	<0.01	0.03	14.2
Inhabitants of the village nearby (child 1 y)	1E03	Less than adult	Less than adult	Less than adult	Less than adult	14.2
Inhabitants of the village nearby (child 7-10 y)	1E03	Less than adult	Less than adult	Less than adult	Less than adult	14.2
Inhabitants of the village nearby (adult)	1E03	0.5	10	<0.01	<0.01	14.2

## Assessment of Uncertainties

Table 57 presents the main sources of uncertainties that may impact the quantitative assessment of doses to the workers and the public at the CSF, along with recommendations for their management.

TABLE 57. ASSESSMENT OF UNCERTAINTIES

Item	Uncertainty	Recommendations for Management of Uncertainty
1.	Uncertainty regarding the dose rate information used in the safety assessment. This issue was resolved by the use of conservative data.	Monitoring should be performed to verify the dose rate assumptions to the extent possible to update exposure scenarios and data.
2	The data used for accidental scenarios assessment were taken from literature.	The licensee should put more effort to get as much realistic data as possible.
3	There is uncertainty regarding the radiological characterization of the waste stored in the facility.	The licensee should put more effort to improve the data and knowledge about the waste radiological characteristics.
4	Uncertainty regarding the data about the mixed waste (toxic waste) exists in characterization of the waste.	The licensee should put more effort in: <ul style="list-style-type: none"> <li>• Identification of toxic substances</li> <li>• Characterization of stored waste regarding toxic components</li> </ul>

## I-7 ITERATION AND OPTIMIZATION

The evaluation of the design of the CSF and the safety assessment have been undertaken with the best available data and applying a qualitative approach based on expert judgement.

Nevertheless, aspects such as those mentioned below could impose the necessity for iteration in the safety assessment process:

- New data about the site may become available.
- The building design or the supported systems may need to be modified.
- The features of the security system, to be defined in the near future, may interfere with the safety measures proposed.
- Due to the development of the knowledge and technology the new good practices or systems will be developed.

An appropriate management system controlling and registering the information should play an important role in this iterative process.

## I-8 IDENTIFICATION OF SAFETY MEASURES

The assessment undertaken indicates that if the storage facility is operated and maintained according to the provisions set out in this Safety Case, it will comply with international safety standards and meet the relevant dose limitation criteria with respect to workers and members of the public. The assessment has been carried out using conservative assumptions and straightforward methodology. No particular consideration has been given to the sensitivity of the assumptions used as the dose assessment made only a few simple assumptions, such as the distance of the building from the fence, the residence time of the members of the public and occupancy time of workers in or near the storage building.

Radiation shielding is provided by the walls and internal structures, source containers, and packaging. These are simple, passive, engineered components with a strong level of robustness and reliability. The isolation of the RW is provided by the building structure and the site boundary fence, which as stated earlier are simple, passive, engineered components

with a similarly strong level of robustness and reliability. Control of access to the building is achieved by the boundary fence, gate and the access doors to the building.

Limits are placed on the acceptance of RW for storage to ensure that all conditions of storage are met; operating procedures will be in place to ensure compliance with limits.

Inspection and maintenance programmes are in place and a management system providing for trained personnel, formalized procedures, records, reports and an assurance regime over all aspects important to safety and security is also established.

The building is of a strong monolithic design, which ensure its ability to withstand the impact of severe winds, storms and any possible ground erosion and slippage.

This Safety Case presents the second assessment of the safety of the CSF and will be updated and revised in the future.

The tabulated list of Safety functions – Safety features can be found in Table 4.

## **I-9 LIMITS, CONTROLS AND CONDITIONS**

Based on the safety assessment, the following facility operational limits, controls, and conditions are derived:

- On the basis of the Safety Case results the existing WAC are confirmed;
- When WAC for the future disposal facility are developed, the inventory should be checked if it meets the prescribed WAC for disposal and, if necessary, the WAC for the storage should be revised;
- Based on this Safety Case a limitation on the total activity of the facility is not foreseen, because the capacity of the facility is limited by volume. Therefore, the maximum volume of waste that can be stored in the facility needs to be better derived and specified.

## **I-10 CONCLUSIONS**

### **I-10.1. Comparison with safety criteria**

The results of the quantitative safety assessment as reflected above are well within the national and international safety criteria for workers and the public. During the preparation of the Safety Case, a very conservative approach was used (the maximum inventory value was typically taken into account) and all the assessment results are well below the prescribed limits.

The Safety Case for the RW storage facility and storage operations, defined above, is supported subject to a formal plan and schedule to address the identified unresolved issues as covered above.

The key findings and conclusions for the safety of operations within the CSF are as follows:

- Strategy: The CSF facility and its associated operations to store RW are in line with the national policy and strategy.
- Facility Design and Engineering: The CSF is a robust facility with features that indicate that safety and security have been considered.
- Facility Operation: The safety assessment indicates that the facility can be operated well within the current safety criteria identified in this document.

Uncertainties exist mainly regarding characterization of RW and assumptions regarding data used for assessment. As described above, management of such uncertainties requires continued action on the verification of assumptions and scientific data. Some facility specific limits and conditions have also been recommended in order to mitigate some uncertainties.

- **Optimization of protection:** The margin for optimization of protection associated with the RW activities is limited in view of the relative low consequences and conservatism of assumptions made. Some facility design and procedural changes could, however, be considered for further optimization of protection. An operational optimization of protection programme that is based on activity specific radiation protection surveillance, personal dosimetry results and scheduled optimization review sessions is recommended.
- **Waste Management Practice:** Good waste management practice is generally evident from the intent of the legal framework, organizational arrangements and defined responsibilities for establishing the CSF and its operations. The interdependencies amongst the various waste management steps seem to be considered up to now. The alignment between conditioning, storage and disposal will need to be considered. Recommendations regarding unresolved issues are covered in Section I-10.2 below.
- **Integrated Management System:** Practically the whole management systems and procedures have been implemented, further development of the Management system is required in the sense of the optimization.
- **Uncertainties:** The identified uncertainties are neither of such a nature nor extent that the associated detriment in confidence in the Safety Case would result in the recommendation of drastic measures. As stated in Section I-6.11, uncertainties are managed by implementation of specific facility limits and conditions, use of waste acceptance criteria and implementation of monitoring and inspections.

#### **I-10.2. Identification of issues requiring clarification**

Table 58 presents aspects that were identified during the assessment as requiring further clarification, along with the commensurate proposed management recommendations and actions.



TABLE 58. ASPECTS REQUIRING FURTHER CLARIFICATION

Item	Aspects Requiring Clarification	Recommendation/Action
1. Implemented Waste Management Practice		
1.1	Waste acceptance criteria.	Check that WAC will be in compliance with the WAC for RW disposal
1.2	Interdependencies related to disposal	National waste management plan and strategy should be implemented and realized to make provision for disposal. Could take into account longer term action but commitments related to disposal are necessary.
2. Implementation of a new Waste Management Practice		
2.1	Possibility to temporarily store unconditioned liquid waste.	Perform the related safety assessment for this new activity
3. Interfaces between safety and security		
3.1	Interfaces between safety and security	Develop a security assessment for the CSF considering the site features. Consider the possible need for modification of the safety case
4. Interdependencies between CSF and other facilities		
4.1	Interdependencies between CSF and other facilities	Consider the possible impact on safety

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## **ANNEX II.**

### **ILLUSTRATIVE SAFETY CASE AND SAFETY ASSESSMENT FOR THE RETRIEVAL OF WASTE FROM HISTORICAL RADON-TYPE FACILITY**

#### **II-1 INTRODUCTION**

This document presents an illustrative example of a safety case for radioactive waste (RW) retrieval operations from a typical RADON-type historical waste storage facility. Specifically, the safety case only considers retrieval of radioactive waste from Vault 1 of the RADON facility. This illustrative safety case follows the guidance provided in the International Atomic Energy Agency (IAEA) Safety Standard General Safety Guide GSG-3, “The Safety Case and Safety Assessment for Predisposal Management of Radioactive Waste” [II-1] and illustrates the assessment of normal operational and accident dose scenarios using the methodology developed in the framework of the IAEA International Project on Safety Assessment Driving Radioactive Waste Management Solutions (SADRWMS Project) [II-2]. Doses arising from normal operations and situations operations were determined using the Safety Assessment Framework (SAFRAN) software tool (version 2.3.2.7) [II-3] to demonstrate application of the assessment methodology.

The RADON facility comprises four concrete storage vaults filled with approximately 185 m<sup>3</sup> of miscellaneous low and intermediate level solid wastes and two empty liquid waste storage tanks. The scope of the activities will result in retrieval of all wastes, repackaging and consignment of the items to another processing and storage facility elsewhere off site. This safety case considers a simple and flexible methodology for RW retrieval activities that has been developed using a combination of manual and semi-remote techniques. Retrieval activities are anticipated to take approximately 100 workdays.

The safety case demonstrates compliance with national and international dose limits and constraints. Results of the safety assessment indicate a maximum dose to the worker of 6.2 mSv under normal conditions and 7.0 mSv under accident conditions. The maximum dose to a member of the public under accident conditions is 0.8 µSv, with negligible public dose under normal conditions.

##### **II-1.1. Characteristics of radon-type facilities**

In the late 1950s, the Soviet Union created a chain of specialized sites to conduct the collection and disposal of RW generated outside of the nuclear fuel cycle. These sites eventually became known as the RADON network, or RADON system.

RW storage facilities (RWSF) of “RADON type” were built in the 1960s in various regions of the former USSR, as well as in a number of East European countries (former USSR block countries). These facilities were constructed according to a standard design, with specific modifications to address local conditions of the storage locations and predicted volumes of RW.

The RADON-type facilities took their name from the RADON system that was established in the former Soviet Union for collecting, transportation, processing and near surface disposal of low and intermediate level institutional RW including disused sealed radioactive sources (DSRS).

There were 35 RADON-type facilities located in most cases close to regional scientific centers and covering all territory of the former Soviet Union. Near surface RADON facilities were sited, designed, constructed and operated as disposal facilities according to typical

design based on the understanding of safety and the level of knowledge of that time.

In most cases a RADON facility is a trench in clayey rock approximately 4 meters depth in which rectangular vaults were constructed using reinforced concrete and covered with concrete slabs equipped with loading hatches. Some of these were subdivided into several sections using wooden or concrete walls, effectively created independent vaults. The typical initial design of a RADON facility includes three or four disposal vaults of 200 m<sup>3</sup> each and one or two 200 m<sup>3</sup> underground tank of stainless steel for temporary storage of liquid RW.

During the 1960s-1980s, RW management technologies were limited to placement of RW into disposal facilities, either packaged into various overpacks or in bulk heaps. The design solutions of the time did not include provisions for subsequent retrieval. RW was disposed of without treatment or conditioning and with very simple waste acceptance criteria (WAC), sometimes without any criteria.

Initial characteristics of the waste and packages may have changed over time due to a variety of degradation mechanisms, such as corrosion, biodegradation, chemical reactions and radioactive decay. Therefore, the original waste package documentation cannot be relied upon to describe completely the current status of the waste and waste packages.

RW stored in the RADON type facilities are commensurate with the categories of very low level wastes, low level wastes and intermediate level wastes. They are characterized by a wide variety of radionuclide compositions and forms. The storage/disposal vaults were filled with RW via hatches in the top of the vaults or in the case of large-sized packages these were loaded into the vaults by removing covers (concrete finger slabs).

Initially the RADON-type facilities were considered disposal facilities for RW. However, in compliance with the current regulations many such storage facilities fail to meet safety requirements and are only considered as interim storage. Therefore, there may be a need to retrieve the RW and transfer it to other appropriate facilities in order to facilitate decommissioning of the legacy RADON-type facilities.

## **II-1.2. Historical background**

Before a decision was made on waste retrieval from the RADON-type historical facility, two options were considered within the framework of historical RW management strategy.

The first option envisaged removal of all RW from the storage facility and remediation of the site. The activities include retrieval of the waste, loading into containers (with or without prior conditioning), transportation, transfer of the containers in a new storage facility, and dismantling of the old facility structures. This option would provide for a complete remediation of any negative impact of historical RW facility on the environment and public, which is particularly important for sites with residential communities in the vicinity, and create new engineered barriers around the retrieved RW made of modern materials and compliant with the latest requirements for safety, reliability and longevity. Disadvantages of this option are as follows: long implementation time and high costs, increased risk of accidents, and the need to put in place extensive measures for radiation protection of personnel and the environment.

The second option envisaged entombment of RW in the existing storage vaults. After upgrading the storage facility, a monitoring system would be established, including the drilling and arrangement of a network of wells for periodic collection and radiometric

examination of water samples. Monitoring would remain in place until the facility was decommissioned, after which the RW would no longer pose a danger to the environment and human health.

There were a number of reasons why waste in the RADON-type historic facility required retrieval and reconditioning. These included:

- Recognition of a real or potential problem that could lead to negative safety, environmental and radiological impacts, specifically through human intrusion scenarios (e.g. leaching of contaminants into groundwater or impending structural failure of the facility);
- Risks associated with RW that is not properly stored increasing over time as retrieval is delayed;
- Lack of RW inventory data (e.g. significant uncertainty over the quantity of long lived radionuclides in a facility designed for short lived waste);
- Degradation of RW packages and facility structures in a way that may compromise the current or future safety of the facility;
- Implementation of a conditioning programme for RW stored in an unconditioned state;
- A desire to consolidate several smaller facilities into a larger facility;
- As a precursor to the decommissioning of the historic facility;
- Changes in national regulations.

### **II-1.3. Legal and regulatory framework**

Although the details in the national legislation may differ, the safety case typically comprises the following:

- A demonstration of the required level of safety of the facility;
- A demonstration of the protection of the environment both in the short and long term perspective;
- An assurance that the generation of secondary RW in the facility is kept to the minimum practicable;
- A demonstration that account is taken of interdependencies among all steps in RW management;
- An assurance that any processing of RW will be compatible with the anticipated type and duration of the storage and the need for retrievability of the RW from storage;
- The cost estimates of the waste management facilities and the liability of the operator with regard to the management of RW in the long term;
- An assurance that account is taken of anticipated waste arisings, accountability of waste, disposal options and safety considerations;
- An assurance of acceptance/tolerance of the facility by the public;
- An assurance of adequate physical security.

The retrieval and subsequent management of RW was performed in conformity with the national strategy for management of RW and with national legislation.

#### *II-1.3.1. National Federal Laws*

**The Federal Law № 170-FZ of 21.11.1995 “On the Use of Atomic Energy”** [II-4] is the fundamental document regulating relationships in the field of the use of atomic energy, which is aimed at environmental protection, protection of health and life of people by the use of atomic energy and determines the legal basis for regulation of safety.

This law (Article 44) stipulates that the State policy in the management of nuclear materials, radioactive substances and RW should provide for an integrated solution of issues related to normative regulation of their production, generation, use, physical protection, collection, registration and accounting, transportation, storage and disposal.

The Articles 45-48 of the law stipulate that during the transportation, storage and reprocessing of nuclear materials (including Spent Nuclear Fuel [SNF]) and RW, as well as by the disposal of RW, the reliable protection of workers of objects of the use of atomic energy, population and environment should be ensured against radiation impact and radioactive contamination impermissible in accordance with norms and rules valid in the field of use of atomic energy and legislation of Russian Federation in the field of environmental protection.

**Federal Law № 3-FZ of 9.01.1996 “On the Radiation Safety of Population”** [II-5] defines the legislative basis to ensure the radiation safety of the population in order to protect its health. The law establishes main principles to ensure radiation safety, main hygienic normative standards (permissible dose limits) of exposure to irradiation in the territory of Russian Federation as a result of the use of ionizing radiation sources.

The following terms are used in the framework of the Federal Law:

- Public radiation safety (hereinafter referred to as radiation safety) is the condition of protection of the current and the future generations of people against the harmful effect of ionizing radiation on their health.
- Ionizing radiation is the radiation resulting from radioactive decay, nuclear transformations, and deceleration of charge particles in the substance, and that generates ions with different charges when interacting with the media.
- Natural radiation background is dose of ionizing radiation generated by the cosmic radiation and radiation from natural radionuclides contained in ground, water, air, and other biosphere elements, food and human body.
- Technologically modified natural radiation background is natural radiation background changed as a result of human activity.
- Effective dose is the value of action of the ionizing radiation used as a measure of risk of the long-term effects of exposure of a human body and its parts considering their radiosensitivity.
- Control area is the territory around a source of ionizing radiation where the level of public exposure under normal operation conditions of the source can exceed the dose limit for public. Both temporary and permanent residence are prohibited in the control area; the restricted regime of economic activities is introduced in the control area, and radiation monitoring is conducted there.
- Supervised area is the territory beyond the boundaries of the control area where the radiation monitoring is performed.
- Employee is a physical person who directly works with sources of ionizing radiation on permanent or temporary terms.
- Radiation accident is the loss of control over a source of ionizing radiation due to equipment malfunctioning, erroneous personnel actions, natural disasters or other causes which could have led or led to irradiation of people beyond the established limits or to radioactive contamination of environment.

Article 3 of the Law establishes principles of radiation safety assurance. The main concepts of radiation safety assurance are:



- The normalizing principle is non-exceedance of the allowable public individual exposure doses from all the sources of ionizing radiation.
- The principle of justification is inhibition of all types of activity on the use of sources of ionizing radiation unless positive results for the human and society achieved by these activities exceed the risk of possible harm caused by radiation in addition to the natural background.
- The principle of optimization is maintenance of individual radiation doses and the number of exposed individuals due to use of any ionizing radiation source at as low as reasonably achievable level considering economic and social factors.

In case of a radiation accident, the public radiation safety assurance system adheres to the following principles:

- Suggested measures for mitigation of radiation accident consequences should have more advantages than disadvantages.
- Types and scope of activity on mitigation of radiation accident consequences are implemented in a way ensuring maximum advantages from the decrease of ionizing radiation dose, without the harm inflicted by this activity.

Article 9 of the Law establishes the following hygienic standards (permissible dose limits) of exposure in the territory of Russian Federation due to use of ionizing radiation sources:

- The average annual effective dose for public is 0,001 Sv or effective dose for the life span (70 years) is 0,07 Sv; in some years, large effective dose values are allowed provided that the average annual effective dose calculated for five successive years does not exceed 0,001 Sv.
- The average annual effective dose for the personnel is equal to 0,02 Sv, or effective dose for the period of professional life (50 years) is 1 Sv; the annual effective dose of 0,05 Sv is allowed provided that the average annual effective dose calculated for five successive years does not exceed 0,02 Sv.
- In case of radiation accidents, exposure greater than the prescribed basic hygienic standards (allowable dose limits) is allowed during a certain period of time and within the limits specified in sanitary codes and regulations.

According to the Russian legislation (Article 12), public associations have the right for public control of compliance with the requirements of the codes, standards, and regulations in the field of radiation safety assurance.

According to Article 14 “Requirements to Radiation Safety Assurance in Handling Sources of Ionizing Radiation”, organizations are required to do the following while handling sources of ionizing radiation:

- Follow the rules of the given Federal Law, other federal laws and regulatory legal acts of the Russian Federation, and other laws and regulatory legal acts of the Constituent Entities of the Russian Federation, codes, rules and standards in the field of radiation safety assurance;
- Plan and implement measures aimed at radiation safety assurance;
- Assure radiation safety of new (upgraded) products, materials, substances, technological processes and production which are the sources of ionizing radiation, for human health;
- Systematically conduct production control of radiation situation at workplaces, in premises, sites, control and supervised areas, and of release and discharge of radioactive substances;
- Control and account individual exposure doses of employees;

- Provide radiation safety assurance training and qualification of managers and specialists performing activities, production control specialists and other individuals who permanently or temporarily work with ionizing radiation sources;
- Arrange of preliminary (pre-employment) and periodical medical examinations of employees (personnel);
- Regularly inform employees (personnel) on ionizing radiation levels at their workplaces and on amount of their individual exposure doses;
- Timely inform the federal executive bodies which are authorized for state regulation and supervision in the field of radiation safety assurance, executive authorities of the Constituent Entities of the Russian Federation, about emergencies, deviations from the process regulations jeopardizing radiation safety assurance;
- Implement conclusions, decrees, prescriptions of authorities of the authorized executive bodies which exercise state regulation and supervision in the field of radiation safety assurance;
- Ensure enforcement of rights of the citizens in the field of radiation safety assurance.

**Federal Law № 190-FZ of 11.07.2011 “On the Radioactive Wastes Management”** [II-6] regulates the relationships occurred by the management of accumulated and being formed RW, stipulates principles of functioning and structure of unified State system for RW management, establishes organizational and legal basis for RW management.

According to this law in Russian Federation is created the Unified State System for management of RW, the main aim of which is to organize and ensure the safe and economically effective RW management, including their disposal.

The article 20 of the law stipulates the creation of the national operator for RW management – organization, defined by the Government of Russian Federation according to the proposal of State authority, which administer RW management, - to plan, organize and carry out activities of RW management, including their long-term storage and disposal. For financial provision of the RW management activities, it is envisaged by the law to use the special reserve Fund, which is created on the basis of regular payments by the producers of RW.

*Main statements of Federal Law of Russian Federation N 190 from 11.07.2011 “On Radioactive Waste Management”:*

- Basic terms definition;
- RW classification:
  - Special RW and retrievable (disposable) RW:
  - Classes of retrievable RW (based on disposal option).
- For special (nonretrievable) RW:
  - Emplacement site: and
  - Site for conservation.
- Deep well injection of liquid LLW and ILW on operating sites.

Initial RW registration is provisioned in the Article 23 of the Federal Law “On Radioactive Waste Management” and has been implemented during the first phase of development of the a Unified State System of RW management starting from the January 15, 2013 till December 31, 2014 inclusively. The surveys have been carried out in all facilities having RW that are subject for the initial registration.

Based on the survey results special commissions will draw up the acts of initial registration, on the basis of which proposals will be developed to classify RW storage facility into a particular category of RW storage facilities.

The State Corporation “Rosatom” has confirmed the schedule for survey and initial registration of the storage facilities (sites) for RW generated before 15.07.2011. Initial RW registration will provide the necessary information to form a registry of RW and the inventory of the RW storage facilities (sites). From a legal point of view, the initial RW registration will allow:

- To assign the status of “accumulated waste” to the waste generated before the Federal Law “On Radioactive Waste Management” has entered into force;
- To define the categories and types of storage facilities and of the accumulated RW according to the new Russian legal framework (retrievable and special waste, the temporary and long term storage, sites of emplacement and sites of conservation of special waste).

The type of RW and of the category of RW storage facility are crucial for planning of treatment of previously accumulated waste in accordance with the requirements of the Article 24 of the Federal Law “On Radioactive Waste Management”. Within the context of this Federal Law, RW is grouped into:

- Retrievable RW – RW for which radiological and other risks, as well as cost of its removal from storage facilities and subsequent management, including disposal, do not exceed risks and costs of its in-situ disposal;
- Special (non-retrievable) RW – RW for which radiological and other risks, as well as cost of its removal from storage facility and subsequent management, including disposal, exceed risks and costs of its in-situ disposal.

Retrievable RW is categorized based on the following characteristics:

- Half-life of radionuclides present in RW: long lived RW, short lived RW;
- Specific activity: high level waste, intermediate level waste, low level waste, very low level waste;
- Aggregate state: liquid RW, solid RW, gaseous RW;
- Nuclear material inventory: RW containing nuclear material, RW not containing nuclear material;
- Spent sealed radiation sources;
- RW resulting from mining and processing of uranium ore;
- RW produced as a result of non-nuclear mining and processing activities with mineral and organic raw materials with high content of natural radionuclides.

According to Article 24 of the Law, accumulated RW which are classified as retrievable RW are to be retrieved, processed, conditioned and disposed.

#### *II-1.3.2. Federal Norms and Rules of Nuclear and Radiation Safety*

Federal norms and rules valid in the field of use of atomic energy are elaborated on the basis of normative legal Acts of Russian Federation, the Convention on nuclear safety, the Joint Convention on the Safety of Spent Fuel Management and the Safety of RW Management, taking into account the recommendations of the international organizations acting in the field of use of atomic energy, in whose work Russian Federation takes part.

Safe management of RW is regulated by a series of Federal norms and rules, elaborated taking into account the recommendations of the International Commission on Radiological Protection and the Organization for Economic Cooperation and Development, as well as IAEA standards in the field of RW management (including Safety Series №111-F “The Principles of RW Management” and № WS-G-1.2 “Management of Radioactive Waste from the Mining and Milling of Ores”, № WS-R-1 “Near Surface Disposal of Radioactive Waste” and others<sup>3</sup>).

**“Radioactive Waste Management Safety. General Provisions” (NP-058-04) [II-7]** establishes the aims and the principles to ensure safe RW management, as well as the general requirements to ensure safety.

**Norms and rules NP-019-2000 [II-8], NP-020-2000 [II-9], NP-021-2000 [II-10]** establish requirements to ensure safety during the collection, reprocessing, storage and conditioning of liquid, solid and gaseous RW, correspondingly, at nuclear facilities, radiation sources, storage facilities of nuclear materials (NM) and radioactive substances (RS), and RW storage facilities.

**“Radioactive Waste Disposal. Principles, Criteria and Basic Safety Requirements (NP-055-04)” [II-11]** establishes principles, criteria and main safety requirements for the near-surface RW disposal and for the RW disposal in deep geological formations.

**“Near-surface Disposal of Radioactive Wastes. Safety requirements (NP-069-06)” [II-12]** develops and concretizes the requirements from Federal norms and rules NP-058-04 and NP-055-04 regarding safety achievement for the near-surface disposal of RW.

**Safety Regulations for Transport of Radioactive Material (NP-053-04) [II-13]** establish main technical and organizational requirements for systems transportation of NM, RS and RW, including SNF, aimed to ensure safety during the storage and transportation of NM, RS and RW at the objects of use of atomic energy.

**“Radiation Safety Standards” (NRB-99/2009) [II-14].** In accordance with the requirements of Radiation Safety Standards in Russian Federation NRB-99/2009 the annual dose limit for radiation workers is established to be 20 mSv/a and for the general public to be 1 mSv/a.

**Basic Sanitary Rules of Radiation Safety Assurance (OSPORB-99/2010) [II-15].** According to the rules annual effective dose to the critical population group from RW management activities and facilities cannot exceed 0.1 mSv.

#### *II-1.3.3. Regulatory Guidelines*

**Administrative Procedures for the Public Service of Licensing Activities in the Field of Atomic Energy Use to be Provided by the Federal Environmental, Industrial and Nuclear Supervision Service [II-16].**

The Regulatory body of Russia (the Federal Environmental, Industrial and Nuclear Supervision Service of Russia [ROSTECHNADZOR]), provides guidance on the detailed contents of documents to be submitted to the regulatory body in support of the application for

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<sup>3</sup> Note that, even though these documents have been superseded, they are still considered in the Russian legal Framework.

authorization of RW processing and storage facilities and the ways of obtaining the required information.

Requirements on the content of the set of documents justifying radiation safety of operation of the radiation source, storage facility of radioactive substances, RW storage, the management of radioactive substances, RW, as well as the use of radioactive substances for Research and Development (R&D) works, include the following:

- Safety analysis report of the nuclear facility for its operation or in the exercise of the declared activity;
- Operational regulations for the nuclear facility;
- Radiation safety instruction(s);
- Reference of personnel training and assessment of knowledge of radiation safety codes and standards, personnel appraisal, briefing and working authorizations for radiation-hazardous operations;
- Instruction on prevention and mitigation of accidents and fires, and their mitigation;
- Criteria for decision-making in event of a radiation accident (may be incorporated into instructions for accident and fire prevention and mitigation);
- Action plan to protect personnel and the population against radiation accident and its consequences;
- Description of the structure and composition of radiation safety service;
- Reference of the documents that define the procedure for radiation-hazardous operations, including process regulations and instructions, operational instructions, and maintenance and repair instructions (documents to be provided to ROSTECHNADZOR at request);
- List of the documents that specify requirements on safety of the nuclear facility and the declared type of activity (federal codes and standards, safety guides, regulations of ROSTECHNADZOR, national standards, organization in-house standards and documents of the license applicant). Information on documentation completeness in the applicant organization and the system of their accounting and amending;
- Certificate of accounting and control of radioactive substances and RW;
- Certificate of assurance of physical protection;
- Description of the existing quality management system of the applicant organization in the exercise of the declared activity;
- Quality assurance program for the declared activity;
- Information on organizations that render engineering and technical support of the declared activity and engage in works and provide services in the field of atomic energy use in the exercise of that activity, listing the scope of works (services);
- Reference of certificates for the applied equipment, devices and technologies for radiation sources, storing facilities of radioactive substances and RW storages;
- Procedure instruction for road traffic collisions (to be provided only for a license for management of radioactive substances and/or waste in their transportation).

## II-2 CONTEXT OF THE SAFETY CASE

### II-2.1. Purpose of the safety case

This illustrative Safety Case takes into consideration IAEA General Safety Requirements (GSR) Part 5 on the Predisposal Management of RW [II-17], IAEA Safety Guide GSG-3 [II-1], and GSR Part 4 on Safety Assessment for Facilities and Activities [II-18]. Safety criteria are taken from the Russian regulatory framework [II-14, II-15] and IAEA GSR Part 3 on

According to the licensing processes in Russia, the operator is required to attach to the license application a Safety Analysis Report that includes justifications for the selected site, covering safety-related issues, giving general description of the nuclear facility and its safety impact on the environment and population, and containing preliminary safety and physical protection analysis taken as required by regulations in force.

In order to follow international practice and requirements, the philosophy of Safety Case has been implemented for justification of waste retrieval from historical RADON-type facility. The principal purposes of this Safety Case are:

- To demonstrate safety of the RADON-type facility during historical waste retrieval;
- To justify continued operations and identify areas for decommissioning of the facility.

As a result of the iterative development of the Safety Case through the facility lifecycle, the following results are achieved:

- The systematic collection, analysis and interpretation of the necessary scientific and technical data;
- The development of plans for operation;
- Iterative studies for design optimization, operation and safety assessment with progressively improving data and comments from technical and regulatory reviews.

The following specific aspects will be addressed in this Safety Case:

- Demonstration of safety of the RADON-type facility;
- Demonstration of safety of various RW management activities performed by Operator;
- Optimization of the respective waste management activities;
- Management systems implemented in support and to ensure the safety of the respective waste management activities;
- Definition of limits, controls and conditions that will be applicable to the facilities and the respective activities; and
- Input to the improvement of existing radiation protection programs and activity procedures.

## **II-2.2. Scope of the safety case**

The full scope of the Safety Case includes the retrieval of solid RW from the RADON-type historical facility as a precursor to its decommissioning, historical waste packaging and preparation of waste packages for further transportation to existing authorized waste storage site.

The process of waste retrieval from each Vault is divided into the following phases:

- Phase I. Unloading of large-sized RW packages available for gripping and retrieval;
- Phase II. Unloading of small-sized RW packages;
- Phase III. Accomplishment of unloading of large-sized RW packages released from under the debris;
- Phase IV. Collection and packaging of spillages.

For illustrative purposes only the waste retrieval from Vault 1 is considered in this Safety Case. Waste retrieval operations from Vault 1 are anticipated to take approximately 100 workdays.

An assessment of the non-radiological hazards of the facility and activities and associated identification of specific control measures is outside of the scope of this safety case.

To take into account variation of dose rates from different packages, operations performed during Phase I have been divided into four sub-phases:

- Sub-phases I1. Retrieval of waste containers K4 – K7, B9;
- Sub-phases I2. Retrieval of waste containers K3, B3 – B5, B8;
- Sub-phases I3. Retrieval of waste containers K1, K2, K8, K9, B2;
- Sub-phases I4. Retrieval of waste containers B6, B7.

Table 1 provides a detailed list of these activities.

TABLE 1. OPERATIONS PERFORMED DURING RETRIEVAL FROM VAULT 1

Activity	Area
Phase I1, Initial monitoring of package in the vault	Area A
Phase I1, Entering the vault for slinging	Area A
Phase I1, Slinging package and leaving the vault	Area A
Phase I1, Lifting package to the height of 10 cm	Area A
Phase I1, Entering the vault and additional slinging (if necessary)	Area A
Phase I2, Initial monitoring of package in the vault	Area A
Phase I2, Entering the vault for slinging	Area A
Phase I2, Slinging package and leaving the vault	Area A
Phase I2, Lifting package to the height of 10 cm	Area A
Phase I2, Entering the vault and additional slinging (if necessary)	Area A
Phase I3, Initial monitoring of package in the vault	Area A
Phase I3, Entering the vault for slinging	Area A
Phase I3, Slinging package and leaving the vault	Area A

TABLE 1. OPERATIONS PERFORMED DURING RETRIEVAL FROM VAULT 1  
(CONT’)

Activity	Area
Phase I3, Lifting package to the height of 10 cm	Area A
Phase I3, Entering the vault and additional slinging (if necessary)	Area A
Phase I4, Initial monitoring of package in the vault	Area A
Phase I4, Entering the vault for slinging	Area A
Phase I4, Slinging package and leaving the vault	Area A
Phase I4, Lifting package to the height of 10 cm	Area A
Phase I4, Entering the vault and additional slinging (if necessary)	Area A
Phase II, Entering the vault and slinging DSRS	Area A
Phase II, Checking of slinging (lifting to the height of 10 cm) and leaving the	Area A

vault	
Phase III, Initial monitoring of package in the vault	Area A
Phase III, Entering the vault for slinging	Area A
Phase III, Slinging package and leaving the vault	Area A
Phase III, Lifting package to the height of 10 cm	Area A
Phase III, Entering the vault and additional slinging (if necessary)	Area A
Phase IV Cleaning the vault and retrieval of debris (not finished)	Area A
Phase I1, Parking of transport container in area B	Area B
Phase I1, Loading of waste package into transport container	Area B
Phase I1, Checking dose rate and contamination	Area B
Phase I1, Removal of slinging from waste package	Area B
Phase I1, Removal of loaded transport container from area B	Area B
Phase I2, Parking of transport container in area B	Area B
Phase I2, Loading of waste package into transport container	Area B
Phase I2, Checking dose rate and contamination	Area B
Phase I2, Removal of slinging from waste package	Area B
Phase I2, Removal of loaded transport container from area B	Area B
Phase I3, Parking of transport container in area B	Area B
Phase I3, Loading of waste package into transport container	Area B
Phase I3, Checking dose rate and contamination	Area B
Phase I3, Removal of slinging from waste package	Area B
Phase I3, Removal of loaded transport container from area B	Area B
Phase I4, Parking of transport container in area B	Area B
Phase I4, Loading of waste package into transport container	Area B
Phase I4, Checking dose rate and contamination	Area B
Phase I4, Removal of slinging from waste package	Area B
Phase I4, Removal of loaded transport container from area B	Area B
Phase III, Parking of transport container in area B	Area B
Phase III, Loading of waste package into transport container	Area B

•  
• TABLE 1. OPERATIONS PERFORMED DURING RETRIEVAL FROM VAULT 1 (CONT')

Activity	Area
Phase III, Checking dose rate and contamination	Area B
Phase III, Removal of slinging from waste package	Area B
Phase III, Removal of loaded transport container from area B	Area B
Parking of transport container in area C	Area C
Placing DSRS on the deactivation platform	Area C
Checking dose rate from "BGI" DSRS, working distance 10cm	Area C
Checking dose rate from "other" DSRS, working distance 10cm	Area C
Transfer "BGI" DSRS to transport platform	Area C



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Fixing “BGI” DSRS on the transport platform	Area C
Loading transport platform to transport container	Area C
Handling “BGI” DSRS at distance of 100 cm	Area C
Handling “other” DSRS at distance of 100 cm	Area C
Loading damaged DSRS into shielded container	Area C
Transfer shielded container to storage location	Area C
Personnel stay in area D	Area D
Personnel stay in area E during phase I	Area E
Personnel stay in area E during phases II, III and IV	Area E
Phase I1, Truck loading with transport container	Area F
Phase I2, Truck loading with transport container	Area F
Phase I3, Truck loading with transport container	Area F
Phase I4, Truck loading with transport container	Area F
Phase II, Truck loading with transport container	Area F
Phase III, Truck loading with transport container	Area F
Phase IV, Truck loading with transport container	Area F

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### **II-2.3. Demonstration of safety**

This section describes the approach to demonstration of safety; specifically, the applicable safety objectives, safety principles, and regulatory requirements. Taking cognizance of the scope of the Safety Case and the application of the graded approach as described in Section 2.4, the safety of the waste retrieval activities will be evaluated and demonstrated as described below.

#### **Approach to Basic Engineering Analysis**

A combined qualitative and quantitative assessment will form the basis of the basic engineering analysis, which will cover the following aspects:

- Basic site characteristics and credible external events considered in the design of the hangar facility;
- Quality assurance considered in the design, construction and commissioning of the new facility;
- Application of national construction codes and standards;
- Inspection and maintenance plans;
- Formal processes for the evaluation, approval and implementation of modifications;
- Safety and security aspects.

The following specific assessments will be performed:

- For normal operations, quantitative deterministic assessments of worker dose resulting from the range of activities performed by workers, including determination of the allowed working hours in Supervised and Controlled areas;
- For anticipated operational occurrences, quantitative deterministic assessments of worker and public doses as applicable;
- For all other credible accident scenarios, a quantitative and qualitative assessment of the impact of other occurrences with identification of specific preventative and mitigating measures.

## **Approach to safety assessment**

The radiological assessment will be based upon a realistic and conservative approach taking into consideration measured data from surveys.

Uncertainties inherent to the assumptions made in the quantitative assessments or any other uncertainties identified during the safety assessment will be evaluated to determine their impact on safety. Uncertainties with a significant impact on safety will be listed with recommendations for their management.

A qualitative assessment will be performed of the availability and level of implementation of an integrated management system to ensure a sustained level of safety. This assessment focuses on radiation protection, work procedures, quality assurance aspects and processes for the management of operating limits and conditions.

### **II-2.4. Graded approach**

A graded approach is applied to define the extent and depth of this safety case by the use of qualitative assessment of hazards and deterministic analysis of doses to potential receptors (i.e. workers and public). This takes into consideration the relative safety significance and complexity of operations and the maturity of the operator.

The steps to undertake waste retrieval are comparable to decommissioning activities and are in fact a relatively straightforward precursor to decommissioning itself. Therefore, elements of the graded approach applied to decommissioning, as emphasized in IAEA Safety Guide WS-G-5.2 [II-20] will be applied herein, including the following factors:

- The RADON facility is a relatively small, stand-alone facility with no surrounding nuclear installations;
- The radioactive inventory of the facility is relatively low;
- Low complexity of the waste retrieval operations;
- Good quality characterization data for the stored wastes;
- Simplicity of engineering safety measures provided for the retrieval operations.

Since there is a significant amount of manual operations to undertake waste retrieval activities, a detailed breakdown of the steps (divided into phases and sub-phases) will enable a comprehensive dose assessment to be undertaken for normal operations.

### **II-2.5. Strategy for safety**

This section describes the strategy for safety, including the approach that was taken in the facility design and all the respective waste retrieval activities to comply with the regulatory requirements and to ensure that good engineering practice has been adopted and that safety and protection are optimized.

In view of the scope of the Safety Case, the following strategies for demonstrating safety are adopted:

- Safety principles – all the safety principles defined by IAEA requirements and resumed in Federal Laws of Russia are met.
- Step by step approach is used with principle that the facility and the activities performed in the facility can adapt to good new findings and practice.

- Defense in depth – Care is taken to ensure that multiple safety layers are established. This principle is considered to ensure that no important safety argument is based on a single level of protection.
- Passive safety – The use of passive safety systems wherever possible.
- Shielding – Ensuring that doses to workers and the public are as low as possible. This also includes the optimization of shielding usage during all waste management activities is considered.
- Optimized waste management procedures – Clear roles and responsibilities; trained and competent staff; Use of radiation surveys and dose monitoring to inform procedures; Use of remote or semi-remote equipment to undertake higher dose-rate activities.

## **Overall approach to safety of the facility**

The first step for implementing the retrieval process is to set up a controlled area around the retrieval site. In this Safety Case a construction of temporary structure (hangar) is considered. The purpose of this structure is to limit access to the area during waste retrieval and to control the potential spread of contamination that may be created by disturbing the waste. The structure also protects the work area and workers from sun, rain and wind.

A simple robust design has been adopted for the construction of the hangar and associated waste retrieval equipment so as to make operations within the facility simple and easy to undertake. The facility design and construction provides defense in depth and is designed to rely predominantly on passive safety features. No single design feature will be relied on for the overall safety of the facility.

All activities in connection with the retrieval of old waste will be carried out in full conformity with radiation protection quality and safety requirements as defined by national legislation.

## **II-3 DESCRIPTION OF THE SITE, THE RADON-TYPE FACILITY AND THE WASTE**

According to GSG-3 [II-1] the safety case includes: a full description of the structures, systems and components (SSCs) of the facility and their importance for safety; the quantity and characteristics of the waste to be handled at the facility; the range of conditions under which the facility may operate; the hazards to which the facility may be exposed; and the required performance criteria.

### **II-3.1. Description of the site**

#### *II-3.1.1. General Description of the Site*

The site that accommodates the historical RADON facility is leveled and partially laid with asphalt. There are some oversized boulders on the site, their size reaching 2.2 m across. Absolute elevations range from 220 to 229 m per the Baltic Height System.

Topsoil in the RWSF location area is not fertile. The surrounding territory is not used for agricultural purposes. Ground water is not used as a fresh water source for domestic purposes.

The RWSF location area is not characterized by any notable level of man-induced radioactive contamination. The largest contribution to the gamma-radiation dose rate is introduced by

natural radioactive elements (uranium, thorium and potassium), which are contained in the rocks. Prevailing radiation levels in the whole territory of the region are rather low. Radiation levels over boggy terrains are especially low are.

The annual radiation dose exposure to natural background radiation for population of the RWSF location area does not exceed 1 mSv. Thus, background radiological situation allows for monitoring of the facility with a good sensitivity.

Climatic conditions of the RWSF site create no significant impediments for its operation.

The territory is seismically calm. Some phenomena in the rocks can lead to a 6 magnitude earthquake. The systems important for safety, for instance, transportation and ventilation systems, are designed to withstand an earthquake of such magnitude.

Ground water in the territory adjacent to the RWSF occurs at depths between 0.5 - 1.3 m. Groundwater is unconfined. Expected water table rise is to 0.0 m. The RWSF was constructed on top of a man-made soil fill over 1.5 m high; therefore, its flooding is not expected. Still, rain and melt water ingress inside the storage is taking place. Ingressing water flow is rather slow, about 30 m<sup>3</sup> per year. During the 2000s water was pumped out and purified twice. Monitoring has registered no observed radioactive effluents from the storage facility.

The geological section of the site is represented by (from top to bottom) (1) fill-up soil with boulders, pebbles, gravel, up to 1 m thick; (2) glacial sediments (sandy loam and sand with boulders, pebbles, gravel) - up to 1.8 m; (3) crumbling rocks. Rocks are characterized by a rather high perviousness. Filtration factor is 0.04 m/day for glacial sediments, and up to 30 m/day for rocks.

The location of the RWSF is shown in Figure 1.

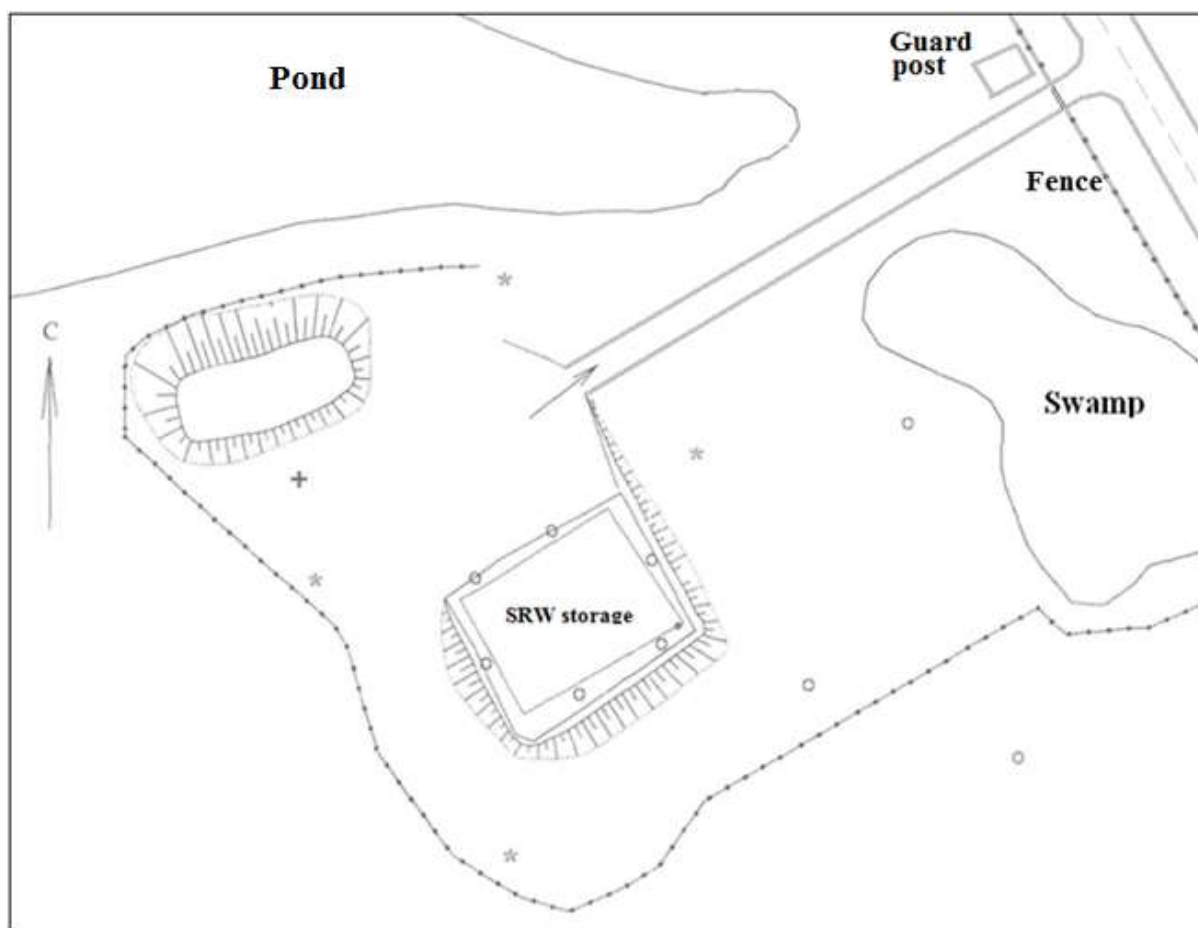


FIG. 1. Location of historical RADON-type facility.

#### II-3.1.2. Population

The average population density for the entire RWSF location area is 6 people per km<sup>2</sup>.

There are no urban communities near the RWSF, and the average rural population density for the RWSF location area is 0.5 people per km<sup>2</sup>.

The nearest community is 10 km from the RWSF.

#### II-3.1.3. Topography

The RWSF location area occupies the north-eastern edge of the crystalline shield formed by Precambrian and upper Paleozoic rocks. The surface represents a system of uplands and depressions smoothed over under the action of the glacier. The northern coast is steep and split by deep and narrow bays. The eastern and southern coasts are lowland.

The relief of the RWSF location area is relatively smooth due to the position of the dome-shaped top of moraine rocks. A small water body lies 17 meters to the north-west of the site. This pond was formed by atmospheric precipitation after road construction in the territory of the RWSF, and has no organized water discharge. A boggy area was formed on the other side of the road; its larger part lies outside the site.

Some areas of the RWSF are covered with low shrubs and trees. Vegetation period is 80 to 130 days.

The RWSF site is leveled and partially laid with asphalt. There are separate standing boulders at the site; their dimensions reach 2.2 m across. Absolute elevations range from 220 to 229 m per the Baltic Height System.

#### *II-3.1.4. Demography*

Industrial development of the RWSF location area began at the end of the 1920s and was connected with the exploitation of mineral deposits.

The largest city is located in the center of the RWSF location region with its population of approximately 325,000 people. At the beginning of 2005 population of the whole region was 872,000 people with urban population constituting 798,000 people and rural population 74,300. Populated areas occupy 0.4 % of the territory of the region, and agricultural lands 0.2 %.

The average population density for the entire RWSF location area is 6 people per km<sup>2</sup>. There are no urban communities near the RWSF, therefore rural population density can be quoted equaling 0.5 people per km<sup>2</sup>.

The major contributors to population employment are: industry (27%), social security, education, culture, science (21.25%), trade, sales, procurement (16.4%), transportation and communication (10.1 %) and construction (4.5%).

The distance from the RWSF to the nearest community is 10 km. A large open water body (lake) is located 1000 m from the RWSF, nearest river - 10 km from the RWSF.

Topsoil in the RWSF location area is not fertile. The surrounding territory is not used for agricultural purposes. Ground water is not used as a fresh water source, for domestic or medical purposes.

In the RWSF location area – within a radius exceeding the radius of the controlled area – there are no gas/oil trunk lines, industrial facilities or plants; warehouses, water reservoirs.

#### *II-3.1.5. Meteorology*

Winds from the seas bring humid air that contributes to cloudiness and precipitation. Days are overcast 198 days on average in a year, with fully clear days averaging only 16 days a year.

The annual precipitation is 488 mm, including 166 mm during cold season, and 322 mm during warm season. Average seasonal precipitation is as follows: spring – 14%, summer – 40%, autumn – 29%, winter – 17%. The maximum daily precipitation is 58 mm. Precipitation falls almost 150 days a year, mostly in summer.

As summer is short and cool, only a small portion of precipitation turns into vapor, and the remaining portion is discharged; which is why the surrounding land is rich in rivers, lakes and swamps. The rivers cut into solid crystalline rocks; therefore, the area features many rapids and waterfalls. Most rivers flow out of or through the lakes, which regulate river discharge. Several large lakes are located in the RWSF location area. The number of small lakes in the area is over twenty thousand.

Typical snowfall begins in late in September. However, stable snow cover is formed only by the second week of November. Snow cover is uneven, and depends mainly on relief and prevailing winds. Snow depth varies between 25 cm and 75 cm. Snow melts at the end of

May or early in June. The snow cover is deepest late in March. Duration of snow cover is 200 days. The number of snow storm days ranges from 23 to 111; snow storms usually begin in October and end in May.

In winter, average air temperature in the RWSF area is similar to central areas of the European part of the country. Average annual air temperature in the area is plus 0.2°C. The temperature changes frequently: thaws can occur in any winter month, and light frosts can occur in summer due to collision of cold air masses with warm air currents.

Winter lasts for 5 months – November to March. Average air temperature of January is minus 8°C on the seaside, and minus 13°C in the internal areas. Considerable air temperature fluctuations are possible: from -50°C to 4-10°C. Frosty days with average daily temperature below minus 20°C, minus 25°C, minus 30°C are relatively seldom. The number of days with persistent frost is 140-160.

The average air temperature of the warmest month of the year (July) is 12 to 14°C. In summer the number of hot days (temperatures over 20°C) is about 16 to 27 in the central areas of the region. The first light frost can occur as early as August, and the last of the light frosts can occur late in May and in June. Duration of the frost-free period varies from 50 to 100 days. The depth of frost penetration in clay and loamy soils is 130 cm. The RWSF location area is outside the permafrost region, and only in some places ground temperature is below zero all the year round. Annual average temperature of the ground is plus 1-3°C depending on the cover and protection.

Wind conditions in the RWSF location area are highly diverse. Winds of southern directions prevail in the RWSF location area in winter; winds of northern directions prevail in summer. Prevailing winds in winter are south and south-west; in summer winds of northern directions prevail. Winds in transitional seasons are less stable, though the winds of southern direction prevail.

Erosive processes are practically non-existent in the territory of the RWSF location area.

Foggy fumes appear over the non-freezing gulf in cold season. Sometimes they are very thick and reduce the visibility down to 2-5 m. In summer, fog is often observed on the seaside, when the winds are onshore.

Because of significant cloudiness, average annual insolation is just slightly over half of potential insolation for the given latitude. And only during the mainly clear months – March and April – it comes to 2/3 of the potential. Solar spectrum contains UV radiation only from April to September.

#### *II-3.1.6. Site Geology and Hydrology*

Hydrogeological conditions within the survey depth are characterized by one water-bearing system, which is confined to unbroken glacial sediments and crumbling rock.

Groundwater in loose thickness of Quaternary sediments is opened by two pits (bore pits 1688 and 1690), which are located in the south-eastern part of the surveyed site (outside the territory of the RWSF), at the depth of 0.5 and 1.3 meters.

When building the RWSF, the surface was leveled using fill-up soil (1.5 m and higher). Ground water within the site is opened by two drilled bores in rock at a depth of 2.2 m – 4.9 m. Groundwater is unconfined.

Engineering and geological holes (open stoppings and separate bore pits) were used as monitoring wells to measure groundwater level. The results are shown in Table 2.

TABLE 2. RESULTS OF OBSERVATIONS OF GROUND WATER DEPTH AND LEVEL

Well number	Distance from the ground surface and absolute elevations are indicated for every measurement, meters						
	Date observed						
	28.11.02	03.12.02	04.12.02	09.12.02	23.12.02	04.01.03	23.01.03
1680	-	5.1	4.0	3.2	2.2	2.2	2.2
		220.92	222.02	222.82	223.82	223.82	223.82
1681	-	-	2.2	2.2	2.2	2.2	2.2
			224.13	224.13	224.13	224.13	224.13
1682	-	2.4	2.4	2.4	2.4	2.4	2.4
		224.14	224.14	224.14	224.14	224.14	224.14
1683	-	-	5.0	4.9	4.5	4.4	4.4
			221.48	221.58	221.98	222.08	222.08
1684	5.1	4.4	4.4	4.4	4.3	4.3	4.3
	223.3	224.00	224.00	224.00	224.10	224.10	224.10
1685	no	no	no	no	no	no	4.9
							223.83
1694	-	-	-	-	4.6	4.5	4.4
					224.03	224.13	224.23

When drawing the groundwater contour, the data for well No.1683 was mapped out as it could not be unambiguously interpreted, and at the present time it is impossible to confirm and revise the hydrogeological situation in its location area, since well No.1683 was destroyed in 2007 in the course of preliminary construction works connected with the impending reconstruction of the RWSF.

On the whole, groundwater flow follows the general direction of lower elevations. The prevailing direction of groundwater flow from the area of the RWSF location is south-east. Within the local fill-up plateau which accommodates the RWSF, groundwater stays practically at the same elevation (224.1 m). An average slope of the aquifer to the southeast can be determined from comparison of the data for well No.1685 near the northwest corner of the storage and bore pit No.1688, which is located approximately 115 m to the southeast. The difference in water levels for these holes is 1.4 m, and hydrodynamic gradient is estimated to be 0.012.

During spring floods and high levels of precipitation, underflooding can occur up to the depth of 1.5 m in the storage territory and reaching land surface outside its boundaries; seasonal perched water in the lows can also occur.

Basic characteristics of the underground water are:

- Aquifer number (top to bottom): 1;
- Underground water type and character: free aquifer;
- Aquifer depth of occurrence:
  - During the survey period: 0.5-4.9;
  - Expected maximum: 0.0;
  - Expected minimum: 4.9.



- Water-bearing rocks: unbroken glacial sediments and crumbling rocks;
- Aquifuge: untapped;
- Aquifer boundary conditions:
  - Feed: infiltration of precipitation.
  - Discharge (drainage): outside the site.

The following negative characteristics of natural environment in the RWSF location area were identified:

- High groundwater level, which occur in immediate proximity to the bottom of the RWSF;
- A water body (pond) is located near the RWSF;
- Poor thickness of Quaternary and moraine sediments;
- The old storage is located in crumbling rocks.

#### *II-3.1.7. Site seismology*

The geological processes prevailing in the territory of the RWSF location area are diverse in genesis and intensity of manifestation. On the whole, the territory is seismically calm. However, the RWSF location area is characterized by highly irregular distribution of stresses. Abnormally high stresses in crystalline rocks cause inrush, bounce and rock bursts in mine works. That is connected with block faulting along northwest faults that can lead to 6-magnitude earthquakes.

#### *II-3.1.8. Radiological Conditions in the Vicinity*

A survey was carried out in 2002-2003 in order to develop a RWSF reconstruction design. 6 boreholes were drilled and 32 pits developed at a distance from 0.5 m to 20 m from the storage wall. Water and soil samples were studied in the state sanitary and epidemiological control center of the region. Soil and ground samples were extracted from 0 to 5 meter boreholes near the storage.

The results demonstrated:

- Near field concentration of  $^{137}\text{Cs}$  is insignificant, at the level of 0-2.7 Bq/kg (measurement error over 100%), there is no clear dependence of activity on the sample depth.
- Low concentration of  $^{137}\text{Cs}$  in the samples extracted near the storage – both at a depth and on the surface, where earthwork was underway and therefore the ground was perturbed – also counts in favor of the conclusion that  $^{137}\text{Cs}$  with the concentration of 100-180 Bq/kg in the samples of the unperturbed ground surface farther from the storage is a product of global fallouts.
- $^{40}\text{K}$ ,  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  nuclides present in concentrations of natural origin.

$^{137}\text{Cs}$  and  $^{90}\text{Sr}$  specific activity in the soils near the RWSF correspond to the average values that are characteristic of the area.

Tritium samples were taken in the lakes to the south-west and north-east of the storage facility. In the water bodies high content of tritium was not found. No cases of  $\beta$ -activity exceeding background values were found in the water of the water bodies inside the controlled area.

Radiation dose rate at the RWSF ceiling ranges from 0.3 to 2.0  $\mu\text{Sv/h}$ ; over the hatches up to 100  $\mu\text{Sv/h}$ ; the rest of the storage site from 0.07 to 0.25  $\mu\text{Sv/h}$  (corresponding to the background values in the locality).

Annual average individual doses of the RWSF personnel were from 0.37 to 1.56 mSv in the time period from 2002 to 2008; and maximum values for some employees ranged from 0.63 mSv in 2008 to 1.9 mSv in 2005.

### II-3.2. Description of the historical radon-type facility

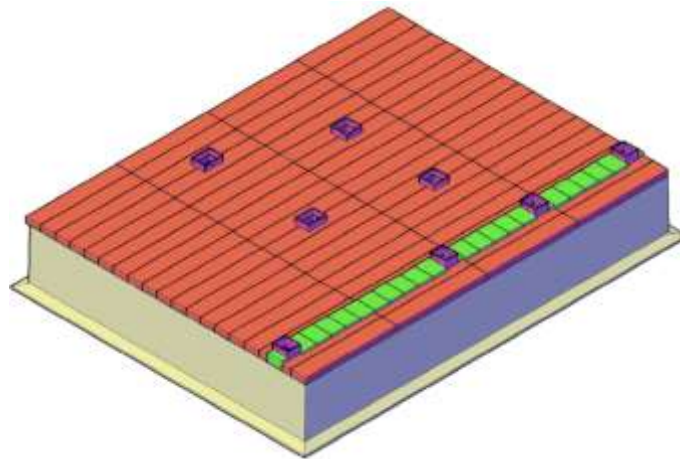
RWSF design includes: four buried vaults with the capacity of 200 m<sup>3</sup> each, intended for storage of solid RW (SRW). RWSF as seen prior to waste retrieval is presented in Figures 2 and 3. Details on RW storage vaults are presented in Table 3.

TABLE 3. DESIGN OF RW STORAGE VAULTS

RADON-type facility	Number of vaults	Brief description
SRW storage vaults: — Length: 15 m; — Width: 5 m; — Depth: 3 m; — Storage capacity of 200 m <sup>3</sup> .	4	Reinforced-concrete buried vaults (Design TP-4891)



FIG. 2. RADON-type facility as seen prior to and after the construction of the hangar.



*FIG. 3. Ceilings of RADON-type vaults.*

### **II-3.3. Description of the historical waste in the radon facility**

At most of the Radon-type facilities, there are a few common problems relating to waste inventory records. One specific problem relates to the uncertainty associated with insufficient information on the waste inventory, e.g. the waste is commonly labeled as ‘mixed fission products’ or simply ‘RW’.

The absence and inadequacy of waste inventory records makes the issue of restoring records and transferring them to a modern records management system a rather complex and cumbersome task, if at all practical. In cases, when data restoration and verification using administrative methods are not feasible, or available records are not adequate, the actual retrieval of the waste or waste packages may need to be undertaken to generate relevant data on the waste inventory.

#### *I-10.1.1. Available Records on Historical Waste*

The major sources of data on the RW being in the vaults of the RADON historical facility are two volumes of the “SRW Vaults Loading Register”. The first of these was kept from December 1961 to December 1976 and the second one was kept from January 1977 to June 1993. A review of the entries in the registers has shown the following.

Vault 1: Most of contents were loaded in October 1976 when 20 containers with ion-exchange resin of total capacity  $190 \text{ m}^3$  were loaded. Later, additional amounts were loaded occasionally in the period from May 1977 to July 1987. According to the register records, the amount of the waste loaded during this time is about  $11 \text{ m}^3$ , which makes a total of  $201 \text{ m}^3$  together with the initially loaded quantity. This value exceeds the tank capacity value. The cause of this discrepancy is likely to be an incorrect estimation of the initial load amount.

Vault 2: The vault was loaded fairly regularly from December 1961 to April 1991. An entry with respect to the total SRW amount loaded in the last year was made in the Register practically every year (there are no records for the years 1970, 1971 and 1984 to 1986). Summing up all of the above amounts gives a total of  $\sim 251 \text{ m}^3$  of SRW loaded into the vaults, which exceeds the available tank capacity by a considerable amount.

Vault 3: The vault was loaded fairly regularly from June 1991 to June 1993. Summing up all of the above amounts gives a total of  $\sim 26 \text{ m}^3$  of SRW loaded into the tank.

Vault 4: There are no records on the loading of vault 4, indicating that the vault is empty.

The RW in storage in the vaults consist mostly of DSRS and are composed of gamma relays, level gages, thickness gages, gamma-ray flaw deflectors, medical sources and radiation standards.

Apart from the above RW, the tanks contain wastes that were packed in paper and plastic bags (overalls, PPE, laboratory utensils, tools, rags).

After summing up the radionuclide activities based on the Loading Register records and taking into account the gamma-source decay process, it can be concluded that the activity in the SRW storage tanks is as follows:  $9.6 \cdot 10^{13}$  Bq of Cs-137,  $1.7 \cdot 10^{12}$  Bq of Sr-90,  $1.3 \cdot 10^{13}$  Bq of Ra-226 and  $1.3 \cdot 10^{12}$  Bq of Pu-239. These estimates are approximately the same as the data given in the 2006 SRW Inventory Taking Statement. The containers with ion-exchange resin in tank 1 are attributed the activity of approximately  $3.7 \cdot 10^{14}$  Bq, though the Loading Register entry of 19 October 1976 gives the activity of  $4.4 \cdot 10^{12}$  Bq for all containers. The cause for such discrepancy is a 1993 letter of the Shipping Company, which stated that the total activity of the ion exchangers loaded into the tank was estimated at  $3.7 \cdot 10^{14}$  Bq (as of 1993). It should be noted that the letter only identifies ten containers and not twenty as noted in the Registers.

#### *I-10.1.2. Radiation and Visual Survey Results*

Vault 1:

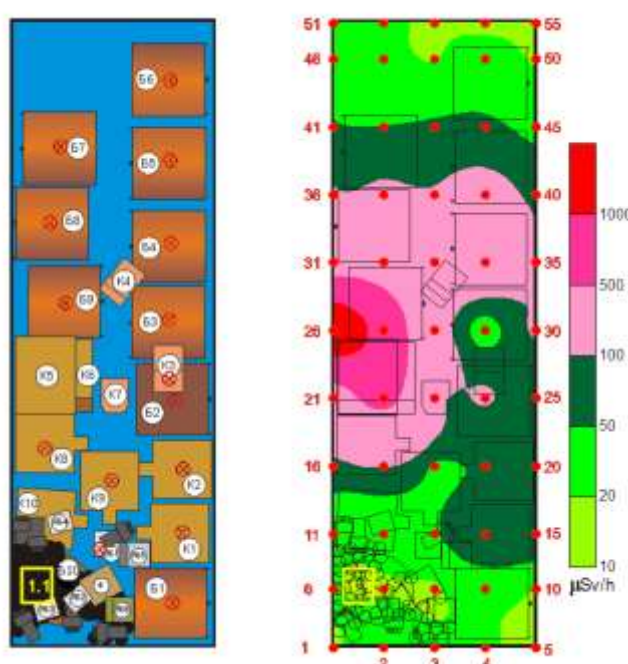
The following items were found in Vault 1:

- 10 cylindrical metal containers of 1.7 m in diameter, 1.75 m height and volume  $\sim 4 \text{ m}^3$  each. On the layout in Figure 4 they are shown as B1-B10.
- 7 metal containers with lateral dimensions of  $1.7 \times 1.8 \times 1.4 \text{ m}$  and volume of  $\sim 3.6 \text{ m}^3$  each. On the layout in Figure 4 they are shown as K1-K2, K5-K6, K8-K10.
- 2 metal containers with the dimensions of  $0.7 \times 0.7 \times 0.95 \text{ m}$  and volume of  $0.68 \text{ m}^3$  each. On the layout they are shown as K4 and K7.
- 1 metal container with the dimensions of  $0.65 \times 0.65 \times 0.8 \text{ m}$  and volume of  $0.47 \text{ m}^3$ . On the layout it is shown as K3.
- 6 wood cases embedded in concrete from the inside with the volume up to  $0.2 \text{ m}^3$  each. On the layout they are shown as ЯБ1-ЯБ6.
- One wood case with air filters of volume up to  $0.2 \text{ m}^3$ . On the layout it is shown as  $\Phi$ .
- About 40 blocks of gamma-ray sources (BGI) of E-1M type representing steel ball-shaped containers and containing a gamma-ray source inside, with the diameter of  $\sim 30 \text{ cm}$  and volume of not more than  $0.015 \text{ m}^3$ . On the layout they are shown as dark balls.

- Construction debris and rubbish that occurred as a result of cracking and destruction of RW packages (hereinafter to be referred to as “spillages”).

The total amount of SRW in the Vault 1 makes up less than 70 m<sup>3</sup>. The majority of SRW (B1-B10 cylindrical containers and K1-K10 containers) was loaded into the vault when the upper coating slabs were removed and spread relatively evenly inside the vault. Other objects (blocks of gamma-ray sources, cases embedded in concrete and etc.) were loaded through the designed loading hatch, thus they are located directly under the hatch. The wood encasement of the embedded in concrete cases has been spalted and partially peeled off over the period of storage. Data was obtained from the storage radiation survey and measuring exposure dose rates (EDRs) on the surfaces of containers piled inside the Vault 1.

The RW layout and EDR distribution at the ceiling level inside the Vault 1 is provided in Figure 4.



*FIG. 4. Layout of Vault 1 and EDR distribution at the ceiling level inside the Vault 1.*

EDR values in measurement points for certain containers are presented in Table 4.

TABLE 4. GAMMA-RAY EDR FROM CERTAIN PACKAGES IN VAULT 1

Packages	EDR from certain objects, $\mu\text{Sv/h}$				
	Center	North	South	West	East
B1	15	50	7	30	20
B2	200	120	70	160	150
B3	70	1000	120	56	18
B4	500	600	1000	<b>2000</b>	<b>2000</b>
B5	40	8	600	50	21
B6	19	2	10	12	13
B7	60	50	24	50	50
B8	70	24	70	12	600
B9	340	70	700	65	150
B10	N/A*	500	N/A	N/A	500
K1	450	60	80	230	120
K2	30	64	60	20	N/A
K3	55	N/A	60	190	30
K4	100	320	100	55	350
K5	700	1300	350	620	550
K6	700	80	220	N/A	140
K7	150	100	200	170	N/A
K8	600	140	25	150	220
K9	30	65	40	40	16
K10	15	85	320	5	60

Note: N/A means no access

Details on radionuclides determining radiation from packages in Vault 1 are presented in Table 5.

TABLE 5. RADIONUCLIDES DETERMINING RADIATION FROM PACKAGES IN VAULT 1

Package	Main radiation
B2, B3, B4, B5, B8, B9 K5, K6, K8, K9	Radiation of $\text{Cs}^{137}$
K1	Radiation of $\text{Cs}^{137}$ + radiation with the energy of more than 700 keV
B1, B6, K2	Radiation of $\text{Cs}^{137}$ + radiation of $\text{Eu}^{152}$ on the container surface
B7, K3, K10, Я61, Я62, Я63	Scattered radiation of $\text{Cs}^{137}$

Based on the measurement results the major radiation source in the packages is  $\text{Cs}^{137}$ . Apart from  $\text{Cs}^{137}$ ,  $\text{Eu}^{152}$  was detected on the surface of some packages.

The gamma EDR was measured at the ceiling level inside the tank using an MKS-14ETs gamma dosimeter. The data obtained will help to assess the radiation situation over the tank after the concrete ceiling is removed.

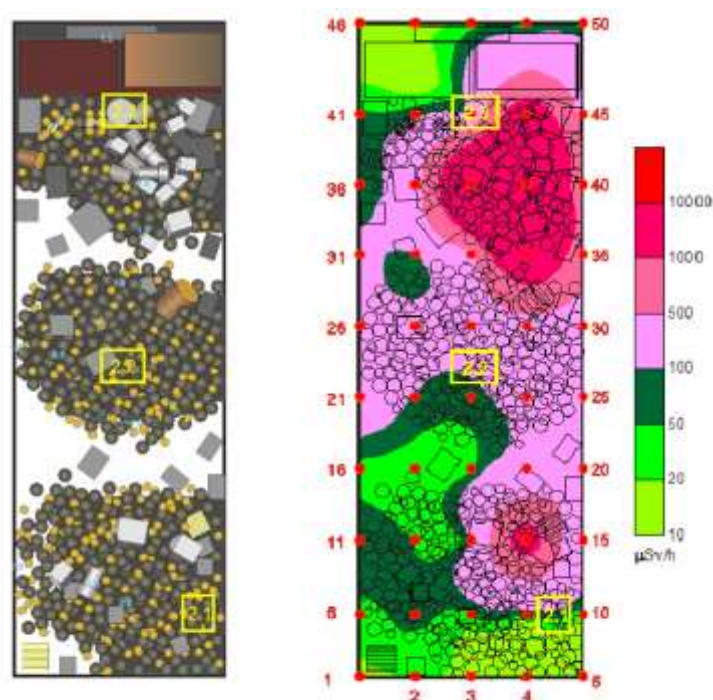
### Vault 2:

Up to 70% of all SRW in the tank are the BGI E-1M and BGI-75 gamma source units. The said units are steel spherical containers with a gamma source inside with the diameter of  $\sim 30$  cm (see Figure 4.9) and the capacity of about  $0.015 \text{ m}^3$ . In addition, the tank contains:

- Not less than 5 concrete-grouted metal drums of  $0.1$  to  $0.2 \text{ m}^3$ ;
- Not less than 30 concreted wooden cases of  $0.2 \text{ m}^3$  each;
- Several radioisotope level gages (ur-8 and others), radioisotope smoke detectors (rid-1, rid-5), containers for beta sources (tsr-m), bags with ipe and other small objects.

The total amount of SRW in tank 2 is about  $100 \text{ m}^3$ .

The RW layout and EDR distribution at the ceiling level inside Vault 2 is provided in Figure 5.



*FIG. 5. Layout of Vault 2 and EDR distribution at the ceiling level inside the Vault 2.*

The gamma EDR at the ceiling level was measured inside the vault using an MKS-14ETs gamma dosimeter. The major gamma emitter in Vault 2 is Cs-137.

### Vault 3:

The BGI E1M and BGI-75 gamma source blocks account for about 50% of all SRW in the vault. Some 35-40% are concrete blocks in a wooden formwork, i.e. these are just concreted packages and concrete-grouted metal drums. The capacity of the packages is from  $0.2$  to  $0.3 \text{ m}^3$ . The number of the packages is not less than 15. The number of the drums is not less than 4. The capacity of the drums is up to  $0.1 \text{ m}^3$ . Most of the formwork has rotted and fragment when touched. The metal drums are rather strong. The concrete blocks are damaged in part. The remaining 10-15% of the SRW include other objects, namely fire alarms, metal boxes



with sources and metal containers of different shape. The total SRW amount in Vault 3 is not more than 15 m<sup>3</sup>.

The RW layout and EDR distribution at the ceiling level inside Vault 3 is provided in Figure 6.

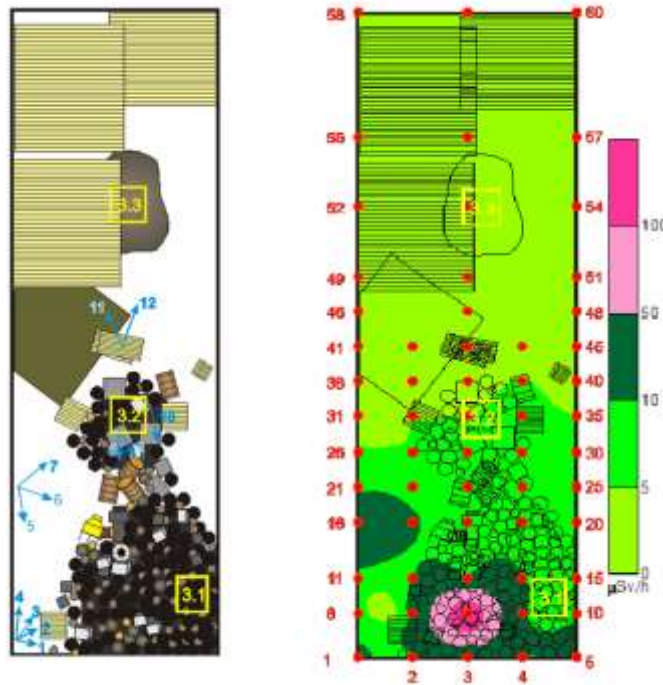


FIG. 6. Layout of Vault 3 and EDR distribution at the ceiling level inside the Vault 3.

The gamma EDR was measured at the tank ceiling level using an MKS-14ETs gamma dosimeter. The EDR measurement points, illustrated in red in Figure 6, also gives a graphic representation of the gamma EDR distribution at the tank ceiling level. The major gamma emitter in Vault 3 is Cs-137.

Vault 4:

Reviews of the available data resulted in the conclusion that RW has never been loaded into Vault 4. The measurements showed that the gamma EDR in the vault did not exceed 0.5 μSv/h and the beta-particle flux from the walls did not exceed the lowest instrument measurement limit, i.e. 20 part/(cm<sup>2</sup>min).

### Dose Burden during Examination

Personal monitoring of the specialists was done using DKG-AT2503 dosimeters that recorded the equivalent gamma dose value at the breast level.

The preliminary examination of the SRW storage vaults involved four specialists. The collective dose for the work period was 140 man-μSv. The maximum personal dose was 58 μSv.

The main examination stage involved five specialists. The collective dose for the work period was 1760 man-μSv. The maximum personal dose was 700 μSv.



The total collective dose load for all measurements was 1.9 man-mSv. The maximum personal dose was 0.74 mSv.

### **Evaluation of Air Volumetric Activity**

According to measurements of air samples, the concentration of radon-222 in the air inside the storage vault is up to 22 kBq/m<sup>3</sup>.

### **Summary of RW Examination**

The following results of examining the RADON-type storage facility have been obtained:

- According to the Loading Registers and with regard for the decay, the total SRW activity in the storage tanks is as follows: Cs-137 – 9.6·10<sup>13</sup> Bq, Sr-90 – 1.7·10<sup>12</sup> Bq, Ra-226 – 1.3·10<sup>13</sup> Bq and Pu-239 – 1.3·10<sup>12</sup> Bq.
- Most of the tank ceiling outside has the gamma EDR in the range from 0.2 to 1 µSv/h. The EDR over the hatches beneath which there are SRW heaps (hatches 1.1, 2.1, 2.2, 2.3, 3.1 and 3.2) is 2.5-8.6 µSv/h. The exclusion is hatch 2.3 with the EDR over this being 61 µSv/h. The said value is determined not by the concreted object stuck therein (a washing machine drum) but by radiation from the tank. The EDR may grow threefold to fourfold if this object is withdrawn.
- The total amount of the SRW in the tanks is about 185 m<sup>3</sup>, of which:
  - 70 m<sup>3</sup> are in tank 1;
  - Some 100 m<sup>3</sup> are in tank 2; and
  - Some 15 m<sup>3</sup> are in tank 3 (tank 4 is empty and contains water).
- Plans and 3-D models of the tanks and the SRW therein have been developed. The tanks have the following dimensions: length 14.75 m, width 4.75 m, height 2.95 m.
- The gamma EDR in tank 1 is determined by radiation from metal containers (up to 2 mSv/h on the surface). On the tank ceiling the maximum EDR value is about 1 mSv/h with the EDR not exceeding 100 µSv/h on the two thirds of the ceiling area.
- The maximum gamma EDR value in tank 2 is 32 mSv/h on the surface of the SRW heap under hatch 2.1 and 111 mSv/h on the surface of the heap under hatch 2.3. The radiation sources are practically point ones and are covered with other objects. These may be Cs-137 sources that fell out of the GSUs during dropping.
- The said sources create the maximum EDR of 2.7 mSv/h at the ceiling level and the EDR of over 1000 µSv/h on 60% of the ceiling area.
- At the ceiling level near hatch 3.1 in tank 3, the maximum EDR value is 170 µSv/h. This is determined by radiation from the GSU without a plug on the SRW heap surface. The second such GSU without a plug was also found in the heap under hatch 3.2 but radiation from this is directed towards the tank wall. The EDR at the outlet of the openings in such units without plugs is 36 mSv/h. It can be suggested that the plugs and the sources could fall out of the GSUs when these were dropped into the tanks.
- The metal containers in tank 1 have a layer of radioactive corrosion products and deposits. These containers are classified as low level SRW in terms of contamination level.
- Tank 2 contains superficially contaminated objects that have long been beneath the water. The oily deposit layer on the objects is classified as low level waste.
- No such deposit has been found in tanks 3 and 4.
- The above deposit layer in tank 2 is about 1 cm. No sludge has been found on the tank bottoms but it can be assumed that there is a layer of such deposit on the bottoms of tanks 1 and 2.

### **II-3.4. Interacting processes**

The following processes interact with the development of the Safety Case:

- Involvement of interested parties;
- Independent review;
- The management system utilised to develop the Safety Case.

#### *II-3.4.1. Involvement of Interested Parties*

Waste retrieval activities involve a number of organizations such as the owner of the waste, the consignors, the provider of the storage or disposal facility, the regulatory body.

Relevant interested parties are engaged in the early stages of the development of the Safety Case to allow an understanding of the arguments included in the Safety Case. This includes the regulatory body responsible for nuclear safety, the environmental regulator and national governmental officials.

In compliance with the Environmental Impact Assessment Provision of the State Committee of Russia for Environmental Protection (order N372, 16.05.2000) [II-21], the operating organization is responsible for organizing public hearings in order to collect and take into consideration recommendations and suggestions from the public. In general, these public hearings are only conducted in relation to construction of new facilities.

Under normal circumstances, following completion of the Safety Case Report, including incorporation of independent review comments, the Safety Case will be submitted to the Regulatory body for approval and issue of a license to operate the facility in accordance with the national regulatory requirements. However, since this is an illustrative safety case, this will not be done in this instance.

#### *II-3.4.2. Independent Review*

Under normal circumstances, the operator will ensure that the safety case has been subjected to independent review in line with the requirements of GSG-3 [II-1], through the use of independent personnel to check and verify the assumptions, models and assessment results. The output and response to the independent review would be summarized with a reference or provided in an appendix to the safety case.

Although independent reviews of this illustrative safety case were not performed, the safety case was reviewed during the course of the CRAFT Technical Meetings and consultancy meetings. Review comments resulting from these meetings were discussed and addressed.

#### *II-3.4.3. Management System*

The management system for the program of waste retrieval activities incorporates the individual management systems of a series of operators carrying out successive steps in the retrieval, transportation, handling, storage and disposal of waste.

In developing the management processes for waste retrieval activities, care was taken:

- To ensure the continuity of control of the waste and waste management activities;
- To maintain linkages and relationships between organizations if more than one organization is involved;
- To allow for the potentially long duration of the waste management activities.

Management of retrieval of historical RW requires special attention, specific preparation and appropriate implementation. Initiation of retrieval activities introduces many challenges associated with the selection of appropriate techniques, instrumentation, protective equipment and WAC.

#### *Description of the Operator's Management System*

The operating organization of the RADON-type facility performs centralized collection, segregation, transportation, conditioning, and interim storage of low and medium level RW throughout the country.

The management system of the Operator is based on the principles of ISO-9004 [II-22] and GS-R-3 [II-23]. The management system of the Operator integrates safety, health, environmental, security, quality and economic elements. Safety is the fundamental principle upon which the management system is based.

The integrated management system of the Operator defines that regulators and stakeholders play a significant role in defining requirements as inputs. The integrated management system of the Operator addresses customer satisfaction by requiring the enhancement of interested party satisfaction, as long as safety is not compromised, in the activities and interactions of the organization.

The management system of the Operator exists in the form of complete operation documentation, job descriptions, radiation and fire safety instructions, emergency preparedness measures. The documentation is being updated on a regular basis.

The documentation of the Operator's management system includes:

- The policy statements of the Operator;
- A description of the management system;
- A description of the structure of the organization;
- A description of the functional responsibilities, accountabilities, levels of authority and interactions of those managing, performing and assessing work;
- A description of the processes and supporting information that explain how work is to be prepared, reviewed, carried out, recorded, assessed and improved;
- Detailed work control documents (e.g. instructions, checklists, process control cards and forms).

#### *Organizational structure of the operating organization*

The management structure of the operating organization is based on the following principles:

- One person is appointed as the head of the RADON-type facility in which is vested complete responsibility and accountability for the operation and safety of the facility.
- Sufficient numbers of staff is appointed to cover the range of waste retrieval tasks.
- The tasks of safety and quality are independent of operational responsibilities. The person(s) appointed to manage those tasks has (have) a direct reporting line to the head of the facility.
- Persons appointed to key tasks are suitably qualified and experienced. If either qualifications or experience are lacking then opportunity to remedy the deficiency is made available prior to taking up the post.

- The management structure endures even when the facility is quiescent. The continuation of the management structure, with its defined accountabilities and responsibilities, will demonstrate a prudent approach to the management of radioactive materials.

The staff includes experienced health physicists, drivers of specialized vehicle, workers of the RADON-type facility.

The activities of the operator are authorized by the license of ROSTECHNADZOR, Sanitary, Epidemiological and Environmental Authorities.

Senior managers of the Operator hold the licenses of ROSTECHNADZOR for the right to carry out activities in the field of RW management, accounting, control and physical protection of radioactive substances and waste.

For the period of waste retrieval operations a team of 8 specialists will be set up. Experienced specialists of other organizations can be invited for the works.

The Operating Organization has an established procedure for personnel selection, training and work authorization.

### **Senior management**

The Operating Organization (also referred to in this document as the Enterprise) is managed by the Director.

### **Project manager**

Project manager is responsible for providing technical leadership, advice and guidance to customers and the company's business on RW throughout the waste lifecycle.

### **Middle management**

Middle management of the Operator includes:

- Supervisor (operations manager);
- Quality manager.

### **Operational staff**

Operational staff includes:

- Health physicist;
- RW Processer (Slinger);
- Hoist man (Handler);
- RW Accounting Person (Check man);
- Decontamination Person.

Other staff who are not directly involved in the retrieval activities (and not further considered in this document) include drivers of special vehicles and security guards.

### *Planning of waste retrieval*

Management of waste retrieval projects requires careful planning procedures. The RADON-type facility contains a variety of waste with a wide range of radiological and physical properties. Therefore, more than one retrieval technique is required. In addition, the waste retrieval plan for the RADON-type waste retrieval project recognizes that the initial characteristics of the waste and packages may have changed over time due to a variety of degradation mechanisms, such as corrosion, biodegradation, chemical reactions and radioactive decay.

The waste retrieval plan for the RADON-type waste retrieval project identifies:

- The overall plan for waste retrieval and management of the RADON-type facility;
- The waste data and characterization required to select and/or support retrieval processes;
- Where retrieval and processing actions fit into the overall remediation sequence;
- The further waste characterization required to define potential downstream processes;
- The final waste product to be produced for interim storage and/or disposal;
- The operators and managers responsible for each set of actions;
- The interfaces with other functional activities;
- The project schedule and budget;
- Cooperation and interface with the regulatory authority;
- The change control process for incorporating and approving changes in the plan that may occur over the project life.

The safety and environmental protection factors considered in the waste retrieval plan include:

- A risk assessment of occupational exposure to ionizing radiation;
- Utilization of adequate and acceptable practical means and available technology to minimize the impact on the environment and protect workers and the general public;
- Utilization of the as low as reasonably achievable (ALARA) concept;
- Minimization of disruption of adjacent areas, including waste storage or disposal areas not subject to the remediation (e.g. the effects of inadvertent removal of shielding from adjacent areas).

These factors are important for the safe execution of the waste retrieval project and may lead to decisions regarding the selection of remotely operated technologies versus hands-on practices.

An important input to the planning process is the information from the initial characterization on dose rates and contamination levels necessary to ensure that the work can be accomplished without undue exposure of the staff and spread of contamination to the environment.

The steps of the waste retrieval process are shown in Figure 7.

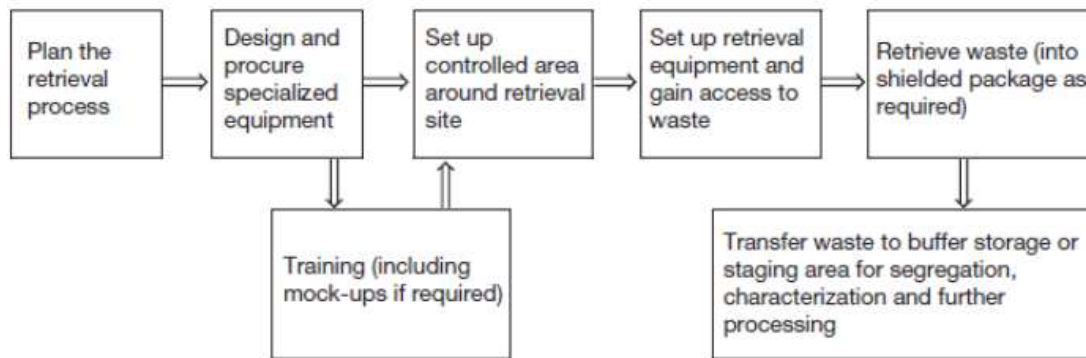


FIG.7. Steps of the waste retrieval process.

### *Distribution of responsibility*

#### RESPONSIBILITIES OF THE OPERATOR

The prime responsibility for the safety of waste retrieval from the RADON-type facility rests with the Operator.

The responsibility of the Operator is:

- To ensure that the generation of secondary RW is kept to the minimum practicable;
- To establish and implement a suitable waste retrieval program with an appropriate management system to ensure compliance with conditions of authorization;
- To ensure that RW is managed by providing appropriate collection, segregation, characterization, classification, packaging, storage and transportation arrangements, including timely transfer between waste management steps;
- To ensure that equipment is available to carry out waste retrieval operations safely;
- To ensure that suitable staff are adequately trained and have operational procedures available to perform their duties safely;
- To maintain an awareness of practices in waste management and to ensure the feedback of relevant operating experience;
- To conduct safety assessment of the waste retrieval project;
- To establish and keep records of information on the generation, packaging and storage of RW, including the maintenance of an up to date inventory of RW;
- To ensure the monitoring, recording and reporting to the regulatory body of discharges in sufficient detail and accuracy to demonstrate compliance with any discharge authorization;
- To report promptly to the regulatory body any discharges or releases exceeding the authorized amounts;
- To provide an inventory of RW held, discharges made and radioactive material removed from the RADON-type facility to the regulatory body at such intervals, in such a form and containing such details as the regulatory body may require;
- To assess the integrity of the waste control measures and facilities to ensure that they are fault tolerant;
- To establish contingency plans and emergency procedures;
- To notify the regulatory body of events and accidents;
- To provide any other information on RW as required by the regulatory body.

The fulfillment of these responsibilities is achieved through the operator's management system together with selection and provision of appropriate equipment for retrieval and storage of RW.

## MANAGEMENT RESPONSIBILITY

The management system of the Operator defines clearly the responsibilities at all levels reflecting the management commitment to security and safety of the facility. Management of the Operator communicates to individuals at all levels the need to adopt these values and behavioral expectations as well as to comply with the requirements of the management system.

Senior management of the Operator has developed values and behavioral expectations for the organization to support the implementation of the management system. Quality and safety policies are also developed by senior management of the Operator.

Senior manager of the Operator is ultimately responsible for the management system and ensures that it is established, implemented, assessed and continually improved.

Senior manager is responsible for the organization and implementation of waste retrieval, its planning, selecting and using the available technologies and resources.

### *Supervisor*

A supervisor with practical experience with the handling of radioactive material and quality control is responsible for supervising day to day operations.

The supervisor is responsible for coordination of actions among work participants, decision-making based on the results of radiation monitoring and performing supervisory control over works.

The duties and responsibilities of the supervisor include:

- Receiving, storing and conditioning all RW in accordance with quality arrangements;
- Segregating RW based on its characteristics;
- Maintenance of records of receipt, storage and conditioning of RW for the appropriate period of time;
- Management of the operational staff.

### *Quality manager*

The quality manager is an experienced radiochemist or a radiophysicist trained to university degree level with experience in RW management. The duties and responsibilities of the quality manager include:

- Implementation, management and maintenance of the defined quality system;
- Audit, internal and external, of the workings of the quality system;
- Ensuring that non-compliances and corrective actions are followed-up promptly and to their proper and logical conclusion.

## RESPONSIBILITIES OF THE OPERATIONAL STAFF

The list of operations assigned to every job position is presented in Table 6.

TABLE 6. RESPONSIBILITIES OF THE OPERATIONAL STAFF

No.	Job position	Works/operations to be performed
1	Health physicist	<p>The health physicist is experienced in radiological protection procedures and regulations. The duties and responsibilities of the radiation protection supervisor include:</p> <ul style="list-style-type: none"> <li>— Establishment of the necessary monitoring regime;</li> <li>— Receiving and assessing the results from the dosimetry service;</li> <li>— Maintenance of the dosimetry records for the appropriate period of time;</li> <li>— Taking necessary action on the basis of the radiation records and dosimetry.</li> </ul> <p>Radiation monitoring and radiation survey of as follows:</p> <ul style="list-style-type: none"> <li>— Vaults with RW and neighboring space;</li> <li>— Work areas;</li> <li>— RW packages;</li> <li>— Transport containers in the course of and upon their charging with SRW;</li> <li>— Supervision over works performed by RW Processor.</li> </ul>
2	RW Processor (Slinger)	<p>Slinging of gamma-ray source blocks, small packages and SRW containers inside the vault.</p> <p>Applying of slings and handling group to lift the damaged RW packages.</p> <p>Plugging of the open collimator of the gamma-ray source block.</p> <p>Fixing of the gamma-ray source block on the transport platform.</p> <p>Collection of spillages into polyethylene sacks, loading them onto the pallet.</p> <p>Loading of SRW packages into the transport container.</p> <p>Loading of transport containers onto a special vehicle.</p>
3	Hoist man (Handler)	<p>Parking in the work areas of as follows:</p> <ul style="list-style-type: none"> <li>— Pallet for lifting of cargoes;</li> <li>— Transport platform for gamma-ray source blocks;</li> <li>— Decontamination pallet to carry out EDR measurements for the items;</li> <li>— Transport containers.</li> </ul> <p>Placement of items on the transport platform.</p> <p>Lifting and transportation of SRW items from the vault.</p>
4	RW Accounting Person	<p>Accounting and comparison with the recorded data.</p> <p>Installation of tamper indicating devices (TIDs).</p>
5	Decontamination Person	Decontamination of contaminated surfaces



## PROVISION OF RESOURCES

Senior management determines the amount of resources necessary and provides the resources to carry out the activities of the Operator and to establish, implement, assess and continually improve the management system.

The information and knowledge of the Operator is also managed as a resource.

## HUMAN RESOURCES

Senior management of the Operator determines the competence requirements for individuals at all levels and provides training or take other actions to achieve the required level of competence.

Senior management ensures that individuals are competent to perform their assigned work and that they understand the consequences for safety of their activities.

The staff has received appropriate education and training, and has acquired suitable skills, knowledge and experience to ensure their competence. The staff is aware of the relevance and importance of their activities and of how their activities contribute to safety in the achievement of the Operator's objectives.

### *Organization of personnel selection and training*

The internal documents of the Operator establish that only persons aged 18 and older with the required skills, subjected to preliminary medical examination, introductory and primary trainings on the site, and trained for safe methods of operation and having the appropriate certificates, are admitted to operations with ionizing radiation sources.

In addition to the introductory and primary training a periodical instruction is carried out twice a year. When preparing for non-typical radiation hazardous works it is provided to carry out the unscheduled training. Results of the trainings are documented in the log-books.

The Program for personnel training related to the radiation safety is enforced. The program includes such sections as the ionizing radiation sources; measurement units; biological radiation effect; radiation source work (practical part); regulatory and technical; documentation. The training course is designed for 40 hours.

Examination of knowledge is carried out annually by a committee appointed by the Order of Enterprise. Results of the examination are recorded in the protocols. In addition to the radiation safety issues the committee examines whether the personnel know the rules of transportation of RW, fire safety regulations, rules of handling of the portable electrical equipment.

The examination of personnel knowledge is performed in the presence of a representative of the Inspection department of radiation hazardous facilities.

### *Developing and Implementation of Processes*

For an organization to function effectively, it has to determine and manage numerous linked activities. An activity or set of activities using resources, and managed in order to enable the transformation of inputs into outputs, can be considered as a process.

Operational processes of the Operator with a focus on waste retrieval from RADON-type facility include:

- Receipt of vehicles carrying empty waste packages;
- Off-loading of empty waste packages from the transport vehicle;
- Transfer of the waste packages into the facility;
- Unloading of large-sized RW packages;
- Unloading of gamma-ray source blocks;
- Accomplishment of unloading of large-sized RW packages released from under debris;
- Collection and packaging of spillages;
- Radiation and contamination monitoring of the wastes;
- Loading of waste packages with retrieved waste;
- Acceptance and placing of the waste packages into special vehicle;
- Maintenance of storage records;
- Periodic inspection and radiological monitoring of the storage building and of the waste packages;
- Maintenance of the RADON-type facility and all associated equipment;
- Ensuring physical protection of the RADON-type facility;
- Operator radiation safety, e.g. possible monitoring of operating and maintenance staff on exit from the RADON-type facility.

The development of each process ensures that the following are achieved:

- Process requirements, such as applicable regulatory, statutory, legal, safety, health, environmental, security, quality and economic requirements, are specified and addressed.
- Hazards and risks are identified, together with any necessary mitigatory actions.
- Interactions with interfacing processes are identified.
- Process inputs are identified.
- The process flow is described.
- Process outputs (products) are identified.
- Process measurement criteria are established.

The following generic processes are developed in the management system of the Operator:

- Control of documents;
- Control of products;
- Control of records;
- Purchasing;
- Communication.

*Quality assurance program*

The quality assurance program for waste retrieval from the RADON-type historical facility was developed by the Operator. The program was developed according to the regulatory requirements for quality assurance programs NP-090-11 [II-24]. The program establishes a procedure for sharing the responsibilities between top managers and chief specialists of the Operator.

The program document is structured according to cover the following quality system elements: “Metrological support”, “Supply Management”, “Equipment Control”, “Document Control”, “Control of Non-Conformances”, “Personnel Training”, “Corrective Measures”, and “Inspection”. These sections characterize the methods of fulfillment of respective activities and emphasize the most important aspects of individual procedures.

Periodic inspection and testing is defined for main and auxiliary equipment. Inspection results are registered. Manufacturing documents (certificates, passports, forms) are made available for all instruments and equipment. Outside organizations performing work are required to be licensed for respective activities.

Newly arriving equipment is registered through relevant documentation. The quality program also includes periodic calibration of instruments. Should a calibration error be found, the results of respective measurements are cancelled and a decision will be taken as to further actions with regard to restoring the calibration, or performing repairs or exceptional verification of the instruments.

## **II-4 SAFETY ASSESSMENT**

### **II-4.1. Assessment context**

The context for the assessment involves the following key aspects: the purpose of the assessment, the philosophy underlying the assessment, the regulatory framework, the assessment end points and the time frame for the assessment.

The assessment is carried out to demonstrate safety of retrieval operations at the RADON-type historical facility. It provides assessments of radiation doses to workers and members of the public during normal operation of the facility and during accidents that could occur over the assumed lifetime of the facility, for comparison with dose limits and constraints. For the purposes of this Safety Case, the total duration of activities to empty Vault 1 of the historical facility is 100 workdays.

An assessment is performed of the impact of potential accidental events on the facility with a view to demonstrate that the design and safety features are sufficiently robust to withstand such events. The assessment seeks to identify uncertainties and provide some consideration to their importance and possible approaches to the management of those uncertainties considered to be important for safety. A generally conservative approach is taken in respect of assumptions and the assessment.

It is necessary to reiterate that the safety assessment provided in this Section is not a fully comprehensive and complete assessment. This Safety Case is an illustrative example of how the IAEA GSG-3 [II-1] methodology can be applied to waste retrieval from RADON-type historical facility.

A detailed assessment of the dose arising from normal operations of waste retrieval from Vault 1 of the facility is modeled using the SAFRAN tool (version 2.3.2.7) [II-3]. Selected

accident scenarios are modeled to demonstrate application of the SADRWMS methodology [II-2] and SAFRAN tool [II-3].

#### *II-4.1.1. Endpoints for the Assessment*

The following quantitative assessment endpoints will be considered:

- Radiation dose to workers performing the various normal RW management activities at the RADON-type historical facility;
- Radiation doses to workers and the public due to anticipated operational occurrences.

Doses are evaluated against the safety criteria through use of different models and the SAFRAN Tool.

Doses will be evaluated against the safety criteria and will also be compared with annual dose limits for occupationally exposed persons recommended by national and international standards. The assessments will cover activities taking place over a period of less than one year, currently estimated to be 100 working days.

In accordance with the requirements of NRB-99/2009 [II-14] the annual dose limit for radiation workers is established to be 20 mSv/year and for the general public to be 1 mSv/year.

In order to maintain individual dose rates at ALARA level taking account of economic and social factors, control levels of radiation exposure are established by the Operator for the waste retrieval from the RADON-type historical facility. Accordingly, a dose constraint of 10 mSv/year is established for workers, which corresponds to half of the dose limit. The public dose constraint is set at 0.1 mSv/year, in accordance with [II-15].

#### *II-4.1.2. Approaches to the Assessment*

For normal operation, quantitative deterministic assessments of worker doses due to the range of activities by various occupational groups have been calculated.

A qualitative assessment will be performed on the implemented waste management practices. In the approach to waste management the following will be regarded as contributing to safety:

- Clearly defined responsibilities for waste management;
- Implementation of the principles of waste minimization and avoidance, namely, re-use or re-processing of waste, return to supplier, safe and secure storage and conditioning and final disposal of waste.
- Hazards of the generation of secondary waste associated with all waste management operations (routine and ad hoc) are known, monitored, projected and managed by due management processes.
- Interdependencies between the various steps of waste management are known and managed.

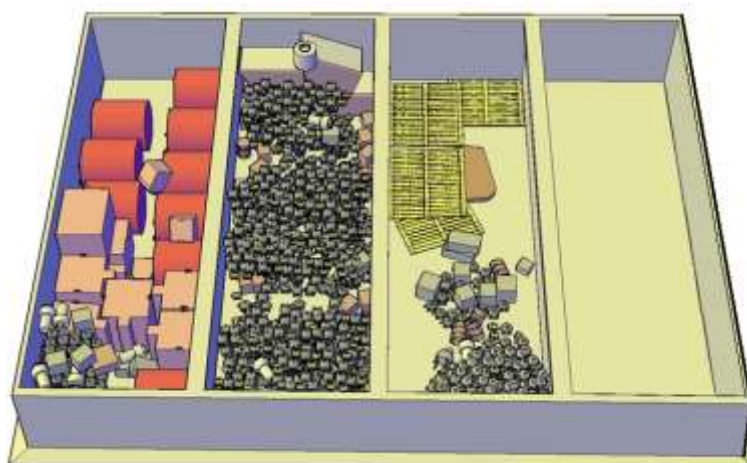
A qualitative assessment of the availability, level of implementation of an integrated management system to ensure a sustained level of safety during the operational phase of the facility will be performed. This assessment will focus on radiation protection, work procedures, quality assurance aspects (mainly record keeping and change management) and processes for the management of limits and conditions.

Uncertainties inherent to the assumptions made in the quantitative assessments or any other uncertainties identified during the safety assessment will be evaluated to determine their impact on safety. Uncertainties with a significant impact on safety will be listed with recommendation for its management.

## **II-4.2. Description of the predisposal waste management facility and the waste**

### *II-4.2.1. Description of the Waste*

A 3-Dimensional illustration of SRW storage facility model is presented in Figure 8.



*FIG. 8. Illustration of the contents of the four SRW storage vaults.*

The following waste types (of the aforesaid types) were selected to create by their example a model for safety assessment of operations related to RW retrieval from the storage:

1. Blocks of gamma-ray sources of E-1M type (Figure 9);
2. Large-sized metal containers (Figure 10);
3. Spillages.



*FIG. 9. Illustration of a block of gamma-ray source (E-1M type).*



FIG. 10. Large-sized metal containers.

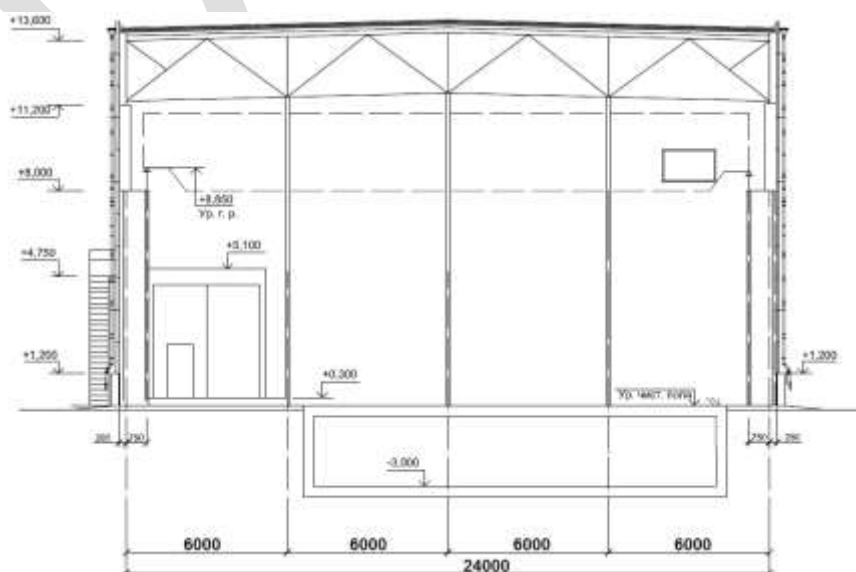
#### II-4.2.2. Description of the Predisposal Waste Management Facility

##### Hangar Building

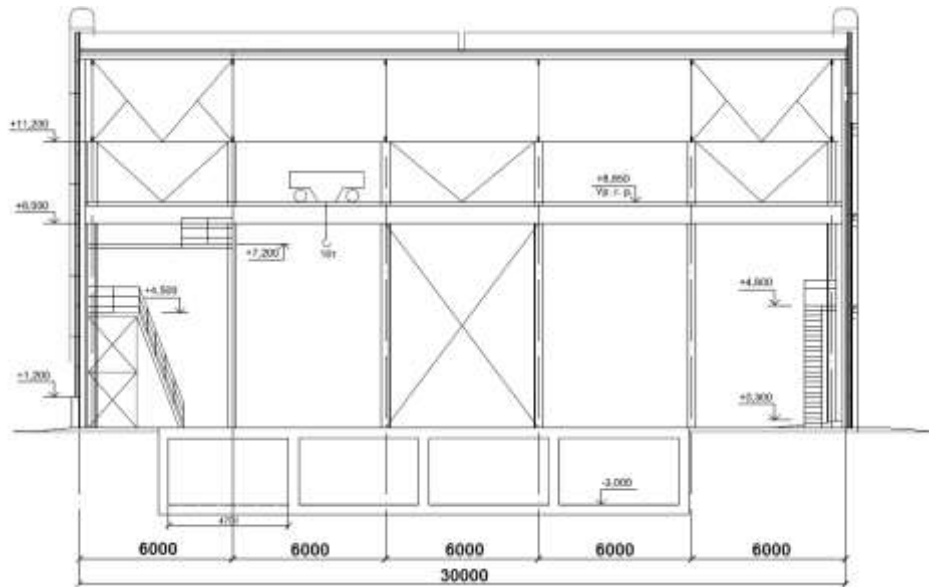
The steel framework, cladding and roof have been designed to support all superimposed structural loads including all applicable live and dead loads. The equipment, materials and items were selected by the designer with account taken of the climatic conditions in the area of construction and environmental factors. Specific external effects of man-induced and natural origin were not considered.

Civil structures of the storage are designed for standard loads and stresses and with no account taken of the loads from specific external effects (aircraft crash, seismicity at the level of maximum design basis earthquake, explosion, tornado, etc.).

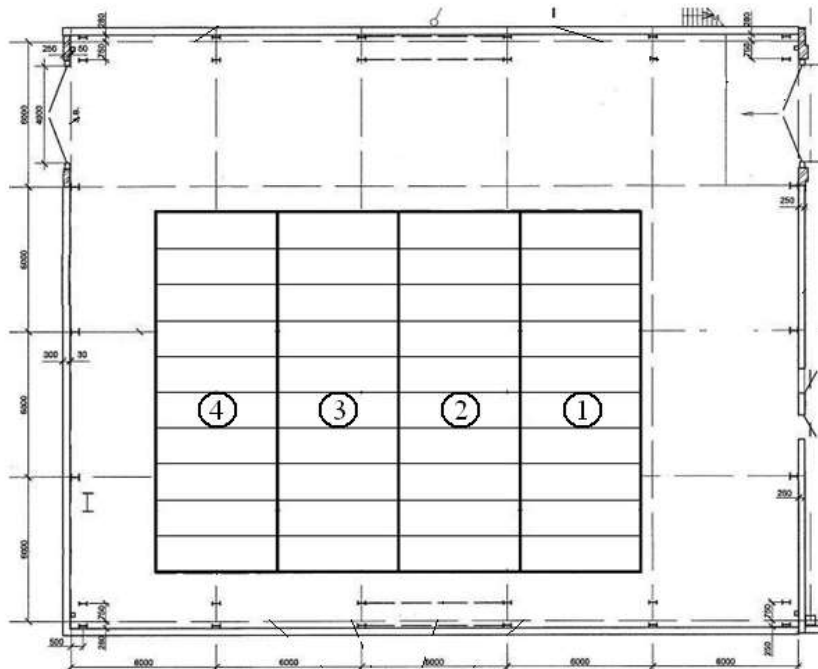
The building is rectangular in plan with axial dimensions 24m x 30m (Figures 11 - 14). The building has rolled-strip roofing with downpipes as a water drain. The roofing material includes (bottom to top): vapor seal (IzoPlastHPP); lightning protection grid; heat insulation (Izover, Finland); sandy concrete cover for making inclinations; insulation material (2 layers, IzoPlastHPP and IzoPlast EKP).



*FIG. 11. Schematic representation of the building (front view).*



*FIG. 12. Schematic representation of the building (side view).*



*FIG. 13. Schematic representation of the vaults (plan view).*



*FIG. 14. View of the SRW storage hangar.*

The load-bearing frame is all-metal using standard steel structures. It is provided with an electric supported overrunning crane with a lifting capacity of 16 tons and span 22.5 m. Columns of the building frame are series 1.424-4, issue 1, ceiling trusses are L=24m, provided with parallel chords in accordance with series 1.460.2-10/88.1. Crane girders L=6m are series 1.426.2-7, issue 3.

The floor slab is able to support the concentrated point loads of the waste containers and live loads of vehicles/equipment used to load the packages.

The RWSF building site is located on top of the hill. “Zero” elevation of the building (top of the old storage facility) is 1.5 m higher than the elevations of the adjacent territory and corresponds to the absolute elevation 229.0 m per the Baltic Height System. Surface water discharge is designed with an outlet to a water course to the south of the building. A concrete flume with a section of 0.4m x 0.4m is designed along the wall of the building, to be combined with a blind area. The existing circular drainage with a leak control well will be kept after the reconstruction, since it fits within the limits of the RWSF building.

The flooring in the assembling hall, which will be arranged upon completion of the RW retrieval operations, is inclined towards the channel with sumps located along the perimeter of the building, in order to collect condensate from the walls and floor of the room, and also various kinds of leaks. Water is removed to the liquid RW reservoirs or special sewerage tanks. The concrete floor in the assembling hall has a damp proof membrane installed.

### *Shielding*

The facility building structure does not provide any significant shielding from radiation as it is a steel-framed structure with a profiled cladding system. There is therefore no safety function in the building walls that will limit exposures outside the building. Instead, localized shielding will be used within the facility when waste retrieval operations are in progress to provide sufficient dose attenuation factors that achieve dose rate objectives.

Figure 15 identifies the following areas that are established within the facility during waste retrieval operations, noting that these are dynamic areas that will change as waste retrieval operations progressing from Vault 4 through to Vault 1. Note that waste retrieval process starts from vault 3, and that areas C1 and C2 will always be above empty vaults.



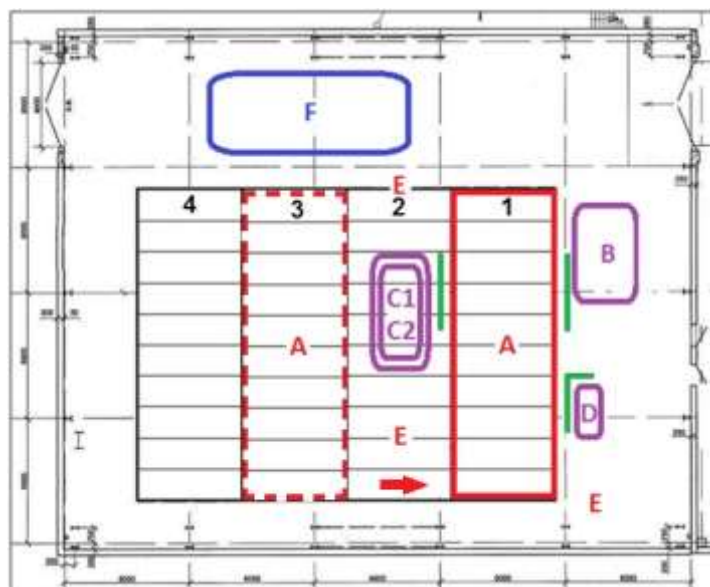


FIG. 15. Location of work areas during RW retrieval from Vault 1.

A description of work performed in different areas is presented in Table 7.

TABLE 7. DESCRIPTION OF WORKS PERFORMED IN DIFFERENT AREAS

Areas	Description of work
A	RW storage vault
B	Area for performance of radiometric measurements, decontamination of large-sized containers with RW and their loading into the transport container
C	Area for conduct of radiation monitoring of gamma-ray source blocks and other small-sized wastes, as well as spillages, for their decontamination, placement of gamma-ray source blocks onto transport crates and loading into the transport container
D	Radiation protection area
E	Area for non-permanent attendance beyond the limits of the assigned work areas
F	Area for loading of filled containers onto the transport vehicle

Note: Two symbols - C1, C2 - are used for Area C due to differences in conditions of personnel dose rate calculation at performance of different operations in this area.

Area E is the area for short-term attendance of RW Processer (Slinger) and Health physicist and primary attendance of Supervisor and Hoist man. Considering that the amount of waste in the area will be reduced over the course of retrieval activities, and taking into account the complexity of movements in this area and variability in the EDR field, the EDR is assumed to be the average EDR value along the long side of the vault neighboring Area B (where operations are performed during this phase) over the entire period that operations are performed in Phase I.

For other phases, the approximate EDR for Area E is assumed to be half the minimum EDR value of the vault. This value is based on the EDR value calculated for the upper slab level resulting from spillage on the bottom of the vault.

The EDR associated with Area F depends on the work phase. In order to determine the EDR in Area F in Phases I and III, it is taken into account that three large-sized RW packages can be located in one UKTN-24000 transport container. The transport container slinging is carried out by means of eye-rings located in the upper part. It conservatively assumed that slinging of the container is performed by means of the slinging platform and requires participation of the Slinger only in certain cases when an abnormal option of slinging occurs. The probability of an abnormal option is associated with the expected EDR based on radiation characteristics of packages that may be located in the transport container. Values of external radiation dose rates in work areas are presented in Table 8.

TABLE 8. VALUES OF EXTERNAL RADIATION DOSE RATES IN WORK AREAS

Area	External radiation dose rates in work areas, $\mu\text{Sv/h}$			
	Phases I	Phases II	Phases III	Phases IV
A	Table 12	50	70	14
B	Table 12	-	70	-
C1/C2	-	0.073/0.32	-	14
D	1,8	1.8	1.8	1.8
E	~ 60	7	7	7
F	~ 60	7	7	7

#### *Access and Physical Security*

A security service is provided with responsibilities for security and protection of the RW storage facility. Compensatory measures are in place against failures of any component of the engineered facilities providing physical protection. Approved procedures are in place for arrangement and maintenance of the RWS physical protection. Contracts are in place with special organizations that provide armed guards.

Measures are in place to ensure compliance with requirements for the RWS physical protection system. There is an authorization-based system in place for access of staff (personnel), business travelers, visitors and vehicles to the secured rooms, buildings and territory, where work with radioactive sources, substances and waste takes place.

Activities of the security service are aimed at the following:

- Protection of the RWS facility against unauthorized actions;
- Access control with regard to radioactive sources and substances within the RWS facility;
- Operation of engineered facilities of the RWS physical protection;
- Timely detection of unauthorized actions and proper response;
- Suppression of unauthorized actions.

#### *Fire protection*

Fire protection measures are based on the following design concepts.

Classification of productions by fire safety and classification of explosive and fire-hazardous premises of the storage, based on [II-25] are as follows:

- Fire resistance rating of the building – II (the second of five, where the fifth is the least fire-resistant buildings); it means that the fire resistance limit of load-bearing

structural elements is 90 min, external non-load-bearing walls – 15 min, intermediate floors – 45 min, other signs of ultimate states.

- Class of design fire safety – C0 (less hazardous, total 4 classes – C0 to C3); it means that the fire safety class of all structural units – K0 (fire-proof); they include: columns, girders, trusses, exterior walls, interior walls, partitions, walls of the stairwells and fire barriers; others.
- Functional fire hazard – Class F5.1 (by method of use – “production buildings and structures, laboratory rooms, workshops”, depending on the class the requirements to arrangement of fire rescue paths, stairs, and stairwells are regulated).

All the structures of the storage facility are made of non-combustible materials, and wastes are stored in non-combustible reinforced-concrete containers.

The fire-fighting measures include:

- Access of fire-fighting vehicles is provided from three sides of RWSF.
- Access way via the RWSF transport access is finished with a turning circle with sizes of 12×15 m for turning of vehicles.
- Water will be taken from the pond that is located at 70 m distance from the building. For these purposes a retaining wall will be made of concrete building blocks at 2.0 m height, and a parking lot 12×12m for two fire-fighting vehicles. Water consumption for external fire fighting is assumed in accordance with the regulatory requirements based on one fire (area of the territory of at least 150 ha) and equal to 15 l/s.
- For entrance of fire-fighting vehicles provisions are made for the gates in the existing chain link fence, and the access way of 4 m width with pitch-grouted macadam.

### *Ventilation*

The hangar building is provided with a ventilation system that was installed to provide nominal air changes.

A specific local extract ventilation system will be installed via one of the access hatches in the vault where waste retrieval operations are being undertaken. A containment tent, measuring approximately 2.8m x 1.1m x 2.3m high will be installed around the hatch. The extract rate will be 12860 m<sup>3</sup>/hr.

The ventilation system is designed for removal and coarse purification of the air from RW storage compartments. The system is connected to the general building ventilation system by means of a flexible air pipe with a diameter of 900 mm.

The air removed by local exhaust from the compartments of the storage goes through the following stages of filtration:

- Prefilter; efficiency – 75 %;
- High efficiency aerosol filter FU-350/F-23; efficiency - 90 %.

The rate of air extracted from the working compartment (the compartment from which the RW are being removed) is calculated assuming that the area of the opening is 6 m<sup>2</sup>, and that the air speed in the opening is 0.3 m/sec.

### *Electrical Power and Lighting*

Electrical power is provided for lighting, use of small power tools and detection/warning equipment. All installations and equipment are of high quality and comply with national standards. Good levels of lighting are provided throughout the facility and additional local lighting will be installed as required to support waste retrieval operations.

#### *II-4.2.3. Operational Safety Measures*

##### *Operational Radiation Protection*

The facility is designated as a radiologically controlled area and people working in the facility are designated as occupationally exposed persons with the necessary training, dosimetry and medical control.

The radiation protection program is implemented and covers routine monitoring of the facility and its environment, monitoring of specific operations such as waste retrieval activities and any special monitoring that may be required from time to time. The program makes provision to monitor external radiation levels and surface contamination.

In areas where the dose rate may vary during the process of retrieval, the health physicist performs continuous monitoring of dose rates as well as performing regular surveys. All persons working in such environments are required to carry electronic dosimeters that alarm at pre-set levels. This method provides an immediate warning to the individual if he or she enters a high dose rate area or if the work activity results in a sudden increase in the dose rate.

##### *Contamination Control*

Radiation protection controls at and adjacent to the retrieval area includes personnel contamination monitors, portable radiation instruments and personal dosimetry and appropriate personnel protective gear. If there is a potential for internal contamination, whole body counting or bioassay may be appropriate.

Any equipment or waste package will be removed from the control area only after checking the surface for loose radioactive contamination by swipe tests. A lock system and administrative procedures are established to ensure positive control over material and equipment movement.

In higher dose rate situations, such as with intermediate level waste (ILW), the use of supplemental portable shielding and remote handling techniques is required; worker scheduling and rotation has also to be considered.

##### *Radiation Monitoring Prior to Transportation*

Gamma radiation dose rate measurement is made during acceptance of radiation cargo from the external surface of each radiation package at a distance of one meter.

During the loading of radiation packages into the special vehicle, the radiation supervisor checks that the dose rate at any point of the external vehicle body surface at a distance of 1m and in driver's cabin does not exceed the acceptable levels: 0.1 mSv/h and 0,012 mGy/h respectively. Packages with II and III category waste and spent ionizing radiation sources are loaded in the last turn into the back part of the vehicle body.

In order to ensure that packages and containers are reliably fixed in the vehicle body, the vehicle body is equipped with the tools for fastening radiation packages, as well as preventing the RW packages and containers from tilting along its transportation route.

Prior to RW shipping the representative of specialized plant has to make sure that the RW package is reliable in order to prevent contamination of external environment with radioactive substances.

#### *II-4.2.4. Passive Safety and Defense in Depth*

Passive systems contributing to the safety of the facility and their operations are applied in three areas:

- The optimization of external exposure of workers and public;
- The limitation of facility impact during accidents leading to radioactive contamination; and
- The limitation of public exposure due to non-authorized access to the facility.

The optimization of external exposure during the waste retrieval operations is based upon:

- Use of localized shielding to minimize worker dose based on real-time radiation surveys in addition to preliminary calculations and assessments.
- Dose limitation is achieved by adherence to the rules established by radiation safety instructions, radiation control of practices in accordance radiation safety instructions and techniques, using a wide range of engineering and organizational measures.
- Removal of high dose waste components early to reduce background dose rates.
- Zoning of the areas:
  - Area of possible contamination (RWSF inside the fence);
  - Controlled area (500 m radius with the center in the storage location);
  - Monitored area (within 1 km radius).
- Mechanization of work where necessary; remote control of mechanisms.
- Using basic personal protection equipment in accordance with the class of work to be carried out, and additional personal protection equipment depending on the kind and conditions of work.
- Training and testing personnel knowledge of radiation safety regulations and standards.
- The principle of optimization (ALARA) is implemented by limiting the number of exposed persons, rational organization of the industrial process, keeping individual doses to personnel as low as reasonably achievable. The documents acting at the Enterprise establish control levels of radiation parameters for all categories of exposed persons. The values of control levels are established lower than the values of principal dose limits and derived controlled parameters. The outcome of commissioning operations may require revision of the internal radiation safety documents of the Enterprise, and adjustment of the controlled levels, if necessary.

Defense in depth principles were applied primarily to plan waste management operations as follows.

- Radiation protection of personnel is ensured by using room zoning, ventilation systems, radiation protection structures, and continuous radiation control, as well as by using necessary administrative measures.
- Shielding structures to be used include:

- Radiation protection wall of lead bricks; standard lead bricks will be used; thickness – 50 mm, height – 2 m.
  - Vertical radiation-protection steel structure; represents a steel plate with eyes for slings; the size is 3×5 m, thickness – 50 mm, weight – 6 tons.
  - Horizontal radiation-protection steel structure is used for covering the working opening of the storage compartment for 2/5 or 4/5 of its area in the process of RW retrieval, and also for complete covering of the opening at the end of the shift; represents a 3x6 m steel plate with eyes for slings; thickness – 50 mm, weight – 7.2 tons.
  - Mobile radiation-protection structures; material of these screens is bismuth-based metal polymer; the size is 3×1.7 m, thickness – 40 mm, weight – 16 tons; a 10-fold reduction of Co-60 radiation will need a 19-mm layer of BIECOM material; these items are used for shielding container NZK in the process of its filling with the wastes retrieved from the old storage.
- Use of active ventilation systems and containment tents to reduce the impact of airborne activity on both workers and the public. This includes a localized ventilation extract as well as the building ventilation system.
  - Use of Radiological Protection equipment to prevent worker internal doses, such as respirators, powered air-fed respirators and/or air-fed pressurized suits as required by the conditions.
  - Use of area gamma monitors to warn of abnormal dose rates during waste retrieval operations in addition to localized Health Physics surveys.
  - Use of personnel dosimetry (TLDs).

#### *II-4.2.5. Engineering Systems Ensuring Safety*

Taking into consideration Russian legislation and also article 4.53 of GSG-3, the safety functions and associated SSCs were identified for the RADON-type historical facility. All the SSCs were classified in 4 different classes considering Russian regulations and their importance for the safety of the facility.

According to national federal norms and rules NP-016-05 [II-26], systems and components with respect to their safety are divided into:

- Systems and components important to safety;
- Other systems and components not related to safety.

Systems and components are divided by their functions into:

- Systems and components of normal operation (N);
- Safety systems and components.

Safety systems and components are divided into four safety classes:

- Protection systems (P);
- Localising systems (L);
- Support systems (S);
- Control systems (C).

These four safety classes are given a ranking that reflects the safety significance of their components.

Safety Class 1 includes the components which failures can become initiating events of beyond design basis accidents leading to exposure of employees (personnel) and (or) population, release (discharge) of radioactive substances to the environment which overrides the limits established for design basis accidents.

Safety Class 2 includes components which failures can be initiating events leading to design basis accidents.

Safety Class 3 includes:

- Components of safety important systems not attributed to Safety Classes 1 and 2 but important for safety;
- Components that contain radioactive and (or) toxic substances, which ingress into the premises and (or) the environment in the event of failures of such components may lead to an excess of levels established in accordance with the regulatory documents;
- Components that perform monitoring functions of radiation protection of the employees (personnel) and population.

Safety Class 4 includes components of normal operation, which do not affect safety and are not attributed to Safety Classes 1, 2 or 3.

Components used for accident management, which are not included in Safety Classes 1, 2 or 3, but that also pertain to Safety Class 4.

In Table 9 all the SSCs are listed with their classification and safety functions they are performing.

TABLE 9. CLASSIFICATION AND SAFETY FUNCTIONS OF SSCs

SSC	Safety Function	Safety Class of components
Hangar structures	N	2
System of physical barriers	P	3
RW packages	N	2
Radiation control system	N	3
Transportation system inside the RWSF	S	2
Industrial television	N	3
Automatic fire-alarm system	N	3
Communication system	N	3
Ventilation system	N	3
Electricity supply system	N	3

Engineering aspects that ensure safety during normal operations are:

- The engineering characteristics of the building. Information expressed in the building design document show the engineering features. Its design ensures structural stability under extreme environmental conditions.
- The lighting system is adequate and permits the performance of operations in a safe manner.
- Each delineated area has sufficient physical space to ensure a minimal probability of accident occurrence during waste management operations.

- Local ventilation systems minimize the spread of any contamination and its impact on workers, the public or the environment.

For situations of operational occurrences and accidents the engineering systems ensuring safety are:

- Floor and wall finishes allow easy decontamination;
- The facility has its own fire response equipment;
- Local ventilation systems minimize the spread of any contamination and its impact on workers, the public or the environment.

Basic and robust engineering systems have been selected to provide high reliability. There are no complex control systems and interacting engineering processes.

### **II-4.3. Description of the waste retrieval activities**

#### *II-4.3.1. Methods Used for Waste Retrieval*

For retrieval of unconditioned LLW, simple industrial equipment may be used, such as backhoes, remotely controlled clamshell diggers, forklift trucks, small mobile cranes and similar equipment. For retrieval of ILW, more sophisticated, remotely operated or shielded equipment may be required. This may include robotic arms, shielded transfer casks, long reach cranes, remote grappling devices and similar equipment.

Standard industrial equipment often can be used, but sometimes custom designed devices are needed for a specific job; for example, large volumes of soil, sand and gravel that are sometimes used for backfill of waste repositories can be removed using conventional digging equipment, or if it is loosely packed it can be removed with vacuum equipment. However, it is important to remember that all removed soil, sand and gravel may be contaminated and needs to be monitored. In situations in which it can be shown to be only very slightly contaminated, much of this material may be cleared for conditional or free release, depending on the national regulations. Alternatively, the material could be reused for backfill or in the construction of other waste disposal facilities.

Table 10 identifies the equipment that would be employed to retrieve the various wastes.

**TABLE 10. EQUIPMENT EMPLOYED DEPENDING ON WASTE CATEGORY**



Waste category	Equipment employed	Comments
Loose LLW, low dose rate	Manual removal, clamshell bucket, small crane	Some initial characterization and segregation may occur at the retrieval site (e.g. have several receiving containers, properly identified by colour coding or numbering, available to sort the waste at source); waste is typically placed in a container suitable for transfer to a buffer storage or staging area for further segregation, characterization, treatment, etc.
Waste in intact containers	Crane, forklift truck	Depending on the condition of the original container, it may be placed into a secondary container or overpack for transfer to a buffer storage or staging area
Higher dose rate waste	Remotely operated crane (required capacity depends on the size and weight of the shielded package), custom designed robotics, remote grapple, shielded casks	Waste is usually retrieved remotely and placed immediately into a shielded container or cask for transfer to a buffer storage or staging area; retrieval of higher dose rate waste typically requires a high degree of planning in order to avoid radiation exposure of the workers
Waste that was previously subject to in-situ conditioning	Cutting equipment such as diamond saws or jackhammers to remove the waste from the conditioning matrix or to cut the monolith into pieces that can be handled, crane	Approach and equipment selected to minimize the risk of cutting through waste objects such as spent sealed sources or through containers of unconditioned, mobile waste such as ion exchange resins and sludge; depending on the dose rate, remote operated equipment may be required; if concrete was used as the conditioning matrix, the dose rate may rapidly increase as the concrete (shielding) is removed; a high level of loose or airborne contamination may result from breaking up the matrix or by cutting through a discrete waste item during matrix cutting and removal

#### *II-4.3.2. Preliminary Work - Hangar Building*

Preliminary work is the first stage of waste retrieval. A building structure (hangar) is constructed above the existing SRW storage to prevent dispersion of radionuclides by wind during this stage. A sanitary inspection room is provided for the personnel who are engaged in waste retrieval works (Figure 16).



*FIG.16. Sanitary inspection room.*

In accordance with Russian safety rules NRB-99/2009 [II-14], the effective dose limit for personnel is set to 20 mSv/year. Personnel working time is 1700 hours a year. Jobsite permissible dose rate is 12  $\mu$ Sv/h under such conditions, which is considerably lower above the vaults. The staff who are engaged in construction of the hangar can work without limitation of time (36 hours a week).

The hangar accommodates all equipment and systems, which are necessary for retrieval operations. It also accommodates ventilation and water supply systems.

Atmospheric emission of air from rooms of the second zone and the first zones is carried out via gas-cleaning systems to prevent contamination of the environment.

#### *II-4.3.3. Work Procedure for Waste Retrieval from the Vault*

##### *Overview of Work Performance*

The process of RW retrieval from the storage vault consists of the following sequence of operations at the storage site:

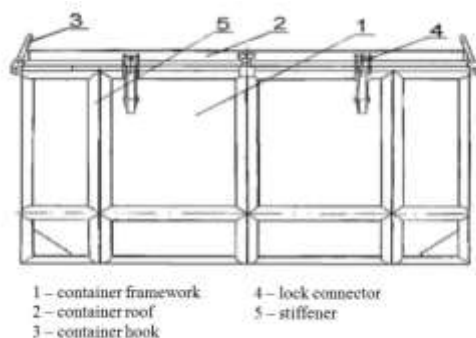
- Placement of the package containing RW (hereinafter to be also referred to as the item) on the load-lifting mechanism;
- Lifting and withdrawal of the package from the vault;
- Characterization of the package;
- In some cases placement of packages onto the transport crate;
- Loading of the RW package or the transport crate into the transport container;
- Placement of the packed transport container onto the vehicle.

Waste are transported to the centralized waste management facility are transported in accordance with transport requirements and are packaged in accordance with the WAC of receiving facility.

SRW is received and transported in radiation packages of different transport categories (I, II and III) in an amount not exceeding 10 package in one vehicle. The equivalent radiation dose rate at any point of external surface of special vehicle cannot exceed 2 mSv/h, at a distance of 1 m from this surface - 0.1 mSv/h.

The following types of containers are envisaged to be loaded with retrieved RW:

- Waste of relatively small size is loaded in KTO-800 solid waste containers shown in Figure 17. Overall dimensions of KTO-800 container are (in mm): Length - 1266; width - 1120; height - 865. Weight of KTO-800 container is (in kg): 240. Transport category - III.



*FIG. 17. Structural design of KTO-800 container.*

- Sources with partial or complete loss of shielding are placed into a UKT1B-100 container shown in Figure 18. Overall dimensions of the internal shielded container are as follows (in mm): diameter - 248, height - 415. Shielded container weight is (in kg): 180. Overall dimensions of UKT1B-100 transport packaging set is (in mm): diameter - 640, height - 730. Weight of UKT1B-100 transport packaging set is 350 kg. Transport category - III.



*FIG. 18. UKT1B-100 container.*

- Large-sized low-level RW is placed into UKTN-24000 containers, shown in Figure 19. Transport category - III.



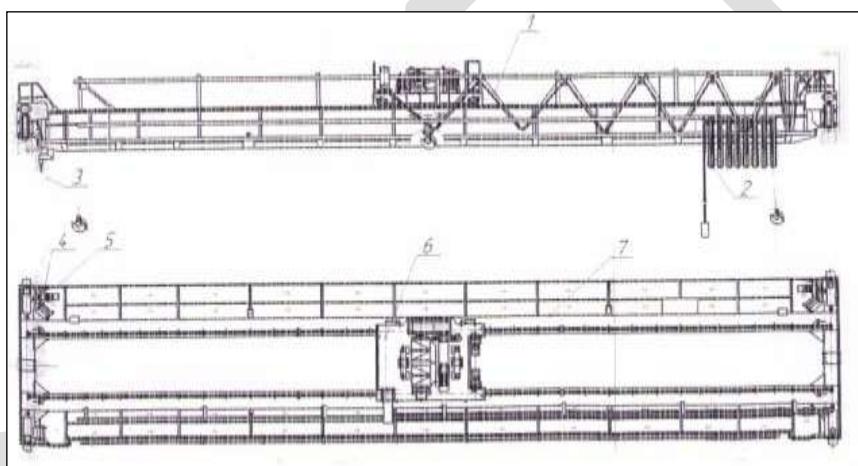
*FIG. 19. UKTN-24000 container.*

Figure 20 shows the special vehicles that are used for transportation of RW packages.



*FIG. 20. Waste transportation vehicle.*

Lifting and handling of RW packages inside the hangar are performed by means of a bridge crane with the load-lifting capacity of 16 tons, see Figure 21.



*FIG. 21. Bridge crane.*

### *Operations to be performed*

The section contains the description of work phases and operations per each phase specifying the job positions involved in the operations. This work is divided into phases as shown in Table 11.

TABLE 11. WORK PHASES

Phase	Description of Phases
I	Unloading of large-sized RW packages
II	Unloading of small-sized RW packages (gamma-ray source blocks)
III	Unloading of large-sized RW packages released from under debris
IV	Collection and packaging of spillages

Activities performed during each of these phases are represented in SAFRAN in Figure 22. A detailed list of activities performed during each work phase is provided in Table 1.



FIG. 22. The structure of grouping of works, performed at activity phases.

#### II-4.4. Development and justification of scenarios

The term ‘scenario’ is defined as a postulated or assumed set of events and conditions that can lead to human exposure and/or environmental contamination. Scenarios that are selected for safety assessment strongly influence the assessment results and their relevance and credibility. Development and justification of scenarios was made using systematic approach to identify and screen hazards taking into account the description of presented above facility and activities.

To identify potential hazards the list of postulated initiating events from the Annex I of GSG-3 [II-1] was considered and analyzed taking into account waste retrieval and supporting activities, the inventory, activity, physical conditions and location of the waste packages and working procedures predefined by the retrieval project. Because of the limited time of considered waste retrieval operations (no erosion, landslides etc., no loose of control within 100 days), predefined summer season (no snow, extreme freezing etc.), very long distance from the sea coast (no tsunamis), thin layer of clay and loamy soil (not sand storm), average precipitation and temperature regime for this area and other specific features significant amount of PIE was screened out as not relevant and only the rest PIEs were assessed in terms of possible consequences and screening in terms of hazard (see section II-4.3.2 ).

Following screening, the consequences of the relevant postulated initiating events were evaluated in this safety assessment as either anticipated operational occurrences or accident scenarios.

Doses under normal operations and postulated accidents were modelled using SAFRAN to demonstrate application of the assessment methodology.

#### *II-4.4.1. Normal Operation Scenario of Waste Retrieval*

Prior to beginning of RW retrieval from Vault 1, the following sequence of preliminary works are performed:

- Lighting equipment is installed.
- A segment of the intermediate slabs are removed.
- Preliminary radiation survey is performed.
- Ladders for getting inside the vault are installed.
- Radiation protection structures are mounted.

The process of waste retrieval from Vault 1 is divided into four Phases described below in paragraphs 4.4.1.1 – 4.4.1.4.

##### *Phase I. Unloading of Large-Sized RW Packages Available for Gripping and Retrieval*

The sequence and duration of operations during RW retrieval in Phase I is presented in Table 12. The duration of each operation is specified as a potential range or an average value.

TABLE 12. SEQUENCE OF WORKS AND DURATION OF OPERATIONS ON RW RETRIEVAL FROM VAULT 1 (PHASE I)

Operation		Personnel attended areas				Operation duration, min	
		Supervisor	Slinger	Hoist man	Health physicist	min	max
Phase I. Unloading of large-sized RW packages available for gripping and retrieval							
1	Action for Health physicist together with the Processor – Slinger: get inside Vault 1 and check visually the large-sized RW packages and exit the vault thereafter.	E	A	E	A	10	25
2	Park UKTN-24000 container on the ground near the exit from Vault 1.	E	B	B	D	15	30
3	Action for Processor – Slinger: get into Vault 1 and come to the container.	E	A	D	D	0.5	2
4	Sling the large-sized RW package with the help of load-handling accessories (or sling around in case the eye rings are damaged) and exit the vault.	E	A	D	D	2 (10)	8 (20)
5	Action for Hoist man: lift the large-sized RW up to the height of about 100 mm and ascertain in reliability of the catching accessory and slinging.	E	D	E	D	1	3
6	Action for Hoist man: load the item into UKTN-24000 container.	E	B	E	D	10	20
7	Action for Health physicist: measure gamma and neutron radiation EDR on the container outer surfaces and take swabs to check surface contamination.	E	D	D	B	2	5
8	Action for Slinger: remove the slings.	E	B	B	D	1	5
9	Fulfill Operations 3-8 to achieve the permissible weight for load-lifting capacity of a 16 tons bridge crane. Thereafter transport the filled UKTN-24000 container to the place of interim storage.	E	B	E	D	15	30
10	Perform Operations 2-9 to accomplish unloading of large-sized RW that is not underneath the debris from Vault 1.	-	-	-	-		
11	Action for Slinger in response to a command from Supervisor: sling the container; reload it by means of the bridge crane onto the previously prepared place for storage of packed RW.	E	D	E	O	10	25

Note: it is assumed that operations are performed in response to Supervisor commands.

When loading the RW that has been withdrawn from the vault to RW transport containers, Accounting Person marks each item by means of labeling it with an individual number. For the purposes of this illustrative Safety Case actions of Accounting Person, and also of Decontamination Person, are not included into the Table.

It is noted that EDR values in Vault 1 vary in the process of RW retrieval. To take account of EDR variation in Vault 1 (Area A), it is assumed that large-sized containers are characterized by highest EDR values according to Table 4 and Figure 4 and are retrieved first.

Accordingly, Phase I was divided into four Sub-phases. EDR values in Area A obtained on the basis of maximum values of EDR predicted for these Sub-phases of Phase I are given in Table 132. Table 12 also provides the averaged EDR values of containers for the mentioned Sub-phases obtained on the basis of Table 4.

TABLE 13. DESCRIPTION OF SUB-PHASES OF PHASE I AND MAXIMUM VALUES OF PREDICTED EDR AT SUB-PHASES OF PHASE I

	SUB-PHASE I1	SUB-PHASE I2	SUB-PHASE I3	SUB-PHASE I4
Containers to be retrieved	K4 – K7, B9	K3, B3 – B5, B8	K1, K2, K8, K9, B2	B6, B7
Number of cycles of operations	5	5	5	2
EDR_A, $\mu\text{Sv/h}$	1000	220	150	100
EDR_B, $\mu\text{Sv/h}$	320	370	160	30

*Phase II. Unloading of Small-Sized RW Packages*

Sequence of works and duration of operations on RW retrieval through Phase II is presented in Table 14.



TABLE 14. SEQUENCE OF WORKS AND DURATION OF OPERATIONS ON RW RETRIEVAL FROM VAULT 1 (PHASE II)

Operation		Personnel attended areas				Operation duration, min	
		Supervisor	Slinger	Hoist man	Health physicist	min	max
Phase II. Unloading of small-sized RW packages							
1	Action for RW Processor: park the container and the transport pallet in the work area.	D	C1	C1	D	2	5
2	Action for RW Processor: get inside Vault 1. Sling a certain gamma-ray source block to the hook of the bridge crane with the operating eye ring (if there is no eye-bolt, perform slinging around).	E	A	E	D	2	5
3	Action for Hoist man: lift the gamma-ray source block up to the height of about 100 mm; Action for Slinger: ascertain in reliability of the eye-bolt and slinging and exit the vault.	E	A	E	D	0.5	0.5
4	If any damaged gamma-ray source blocks are detected at unloading of RW layers, take operations on their removal from the work area as a priority.	Refer to Table 15					
5	Action for Hoist man: lift the gamma-ray source block above the intermediate slab level up to the height of about 500 mm and load it onto the decontamination pallet.	E	C1	E	C1	1	3
6	Action for Health physicist: measure EDR of the gamma-ray source block and based on the results of measurements verify the integrity of the package protection properties. In case of damaged protection – refer to Action 10.	C1	C1	C1	C2	2	4
7	Action for Hoist man: load the gamma-ray source block onto the transport crate.	C1	C1	C1	D	1	2
8	Action for RW Processers: fix the gamma-ray source block on the transport crate (6 pcs.).	C1	C2	C1	D	2	5
9	Action for Hoist man: load the transport crate into the certified KTO-800 container.	C1	C2	C1	D	1	3
10	In case of damaged protection the gamma-ray source block to be placed into a separate barrel-type container, which is further loaded into KTO-800 transport container.	C1	C2	C1	D	2	5
11	Action for RW Processor and Hoist man upon loading of KTO-800 container: reload the container to the place specified for interim storage.	E	E	C1	D	5	10
12	Repeat Operations 1-11 till unloading of all small-sized RW packages from Vault 1.	-	-	-	-		

When performing work in Area C under normal operation mode, it is assumed that the RW Processor and Health physicist perform their actions at a distance of 0.1 m from a gamma-ray source block, while the Supervisor and Hoist man do not approach to the item closer than for 1 m.

Expert-calculated estimates of the EDR from E-1M gamma-ray source blocks are given in Table 15.

TABLE 15. EDR AT DISTANCE FROM THE SOURCE

Ionizing radiation source	EDR at Calculation point, $\mu\text{Sv/h}$		
	on the surface	10 cm from the source	100 cm from the source
E-1M gamma-ray source block	0.436	0.157	0.073

EDR values given in Table 15 for a single source are used to predict the EDR during the course of operations performed to fix the gamma-ray source block on the transportation crate. Since a crate is envisaged for up to 6 pcs. of gamma-ray source blocks, the conservative EDR value will be determined considering radiation emitted by 6 gamma-ray source blocks. However, it is required to take account of the sequence of loading the gamma-ray source blocks onto the crate and the difference in distances between each of them and Operator. In this regard, the average EDR value during loading of gamma-ray source blocks onto the crate is approximately twice that of the EDR value from a single source.

The sequence of work performed during unloading of damaged small-sized RW packages from vault 1 is provided in Table 16.

TABLE 16. SEQUENCE OF WORK PERFORMANCE AT UNLOADING OF DAMAGED SMALL-SIZED RW PACKAGES FROM VAULT 1

Operation		Personnel attended areas				Operation duration, min	
		Supervisor	Slinger	Hoist man	Health physicist	min	max
Unloading of damaged gamma-ray source blocks							
1	Action for Health physicists: visual and radiometric survey of damaged gamma-ray source blocks.	E	D	D	E	2	5
2	Action for Slinger: if the eye-bolt of the damaged gamma-ray source block is available, grip the gamma-ray source block from the intermediate slabs by means of the process hook. Engage the second end of the process hook equipped with the eye-ring with the hook of the bridge crane. Lift the damaged gamma-ray source block up to the height of not more than 100 mm. Reload it to the side of SRW debris and load it to the vault bottom near the wall. The collimator's opening should be directed to the wall.	E	E	E	E	5	10
3	In case if the damaged gamma-ray source block is unavailable for handling from the intermediate slabs, it is required to determine clearly the direction of the radiation ray.	E	D	D	E	2	5

TABLE 16. SEQUENCE OF WORK PERFORMANCE AT UNLOADING OF DAMAGED SMALL-SIZED RW PACKAGES FROM VAULT 1 (CONT')

Operation	Personnel attended areas				Operation duration, min	
	Supervisor	Slinger	Hoist man	Health physicist	min	max
Unloading of damaged gamma-ray source blocks						
3.1 Action for Slinger: get into the vault from the side of the lowest EDR value, sling the gamma-ray source block (by the process hook), engage the sling fitting with the crane hook. Action for Slinger: exit the vault.	E	A	E	D	0.5	4
3.2 Action for Hoist man: lift the damaged gamma-ray source block up to the height of not more than 100 mm. Reload it to the side of SRW debris and load it to the vault bottom near the wall. The collimator's opening should be directed to the wall.	E	A	E	E	1	5
4 If performance of Operations 2 – 3 makes risk of personnel exposure above the established level, use the remotely controlled machine. In response to the Supervisor command the machine lowers down to the bottom of the vault.	E	D	E	E	10	20
4.1 By means of a gripper lift the damaged gamma-ray source block and reload it to the side from the SRW debris to the vault wall with its opening directed to the wall.	D	D	D	D	10	30
5 Action for RW Processor: get into the vault and install the protection plug onto the collimator.	E	A	D	E	1	3
6 If it is impossible to install the plug, the damaged gamma-ray source block is to be totally relocated to the shielded container that is preliminarily placed onto the bottom of the vault.	E	A	E	E	1	3
7 Lift the gamma-ray source block or the shielded container with the gamma-ray source block to the work area.	E	C	E	E	1	3
8 Perform necessary surveys for the gamma-ray source block.	C	D	D	C	2	10
9 If the collimator of the gamma-ray source block is closed, fulfill Operations 7-9, 11,12 of Phase II. If the plug for collimator is impossible to be installed or there is damage to the protection of the gamma-ray source block, fulfill Operations 10-12 of Phase II.	-	-	-	-		
10 Repeat Operations 1-9 at handling of the next damaged gamma-ray source block.	-	-	-	-		

Note: All operations are required to be performed in response to Supervisor commands.

When loading the RW withdrawn from the vault to RW transport containers, Accounting Person marks each item by means of labeling it with an individual number. Actions of Accounting Person, and also of Decontamination Person, are not included into the Table.

### *Phase III. Unloading Large-Sized RW Packages Released from under Debris*

Sequence of works and duration of operations on RW retrieval through Phase III is presented in Table 17.

TABLE 17. SEQUENCE OF WORKS AND DURATION OF OPERATIONS ON RW RETRIEVAL FROM VAULT 1 (PHASE III)

Operation	Personnel attended areas				Operation duration, min	
	Supervisor	Slinger	Hoist man	Health physicist	min	max
Phase III. Accomplishment of unloading of large-sized RW packages released from under debris						
1 Perform sequentially Operations 1–9, 11 of Phase I.	-	-	-	-		

*Phase IV. Collection and Packaging of Spillages*

Sequence of works and duration of operations on RW retrieval through Phase IV is presented in Table 18.

TABLE 18. SEQUENCE OF WORKS AND DURATION OF OPERATIONS ON RW RETRIEVAL FROM VAULT 1 (PHASE IV)

Operation	Personnel attended areas				Operation duration, min	
	Supervisor	Slinger	Hoist man	Health physicist	min	max
Phase IV. Collection and packaging of spillages						
1 Action for RW Processor – Slinger and Hoist man: park KTO-800 container in the work area.	E	C	C	C	2	5
2 Action for RW Processor – Slinger: localize the spillages into the shape-forming packages by using the shovel and under supervision of Health physicist. Placement of shape-forming packages onto the lifting pallet.	E	A	D	A	2	5
3 Action for Hoist man when the pallet is loaded: move the pallet to the work area. Action for Health physicist: measure EDR on the surface of packages.	E	A	E	C	1	3
4 Action for RW Processors: load the shape-forming packages into KTO-800 container manually.	C	C	D	D	5	10
5 Perform Operations 1-4 till complete unloading of RW spillages from Vault 1.	-	-	-	-		
6 Action for Hoist man upon radiation survey: reload the filled containers by means of a bridge crane onto the place specified for interim storage of packed RW.	E	E	E	D	5	10

In order to estimate EDR of external radiation at the phase of collection of spillages and due to unavailability of measurements, the minimum EDR value measured in the vault charged with wastes and given in Figure 2.1 are used as the upper limit. However, it is possible to

obtain the estimate value by means of calculation. For this purpose the following assumptions are used:

- Spillages contain low level RWs which include Cesium-137 and Radium-226.
- Spillages are evenly spread within the area of vault basement shaping a layer of about 1 cm, which corresponds to approximate weight of 1200 kg.

EDR is also estimated for one sack, containing spillages and weighting 30 kg and sacks located on the pallet.

#### *II-4.4.2. Hazard Identification and Screening*

For the purpose of this illustrative Safety Case only hazards related to radiation exposures were considered; namely, external exposure from radiation sources and internal exposure due to inhalation of radionuclides.

A systematic approach was taken to the identification of hazards and the following steps were applied to identify normal and accident scenarios that could lead to the exposure of workers and members of the public:

- Identification of hazards and initiating events;
- Hazard screening;
- Identification of scenarios.

#### *Identification of Hazards and Initiating Events*

The following potential initiating events were considered in the hazard identification process for waste retrieval activities:

- (a) External initiating events:
  - Natural events such as adverse meteorological conditions (e.g. wind, snow, rain, ice, temperature, flooding, lightning), earthquakes or biological intrusion;
  - Human-made events such as aircraft accidents (with or without subsequent fires), explosions, fires, loss of electric power or other services, and human intrusion (mainly in cases where the facility is in a state of deferred dismantling).
- (b) Internal initiating events at the facility or on the site, such as fire, explosion, structural collapse, leakage or spillage, failure of ventilation, dropping of heavy loads and failure of protective measures (e.g. failure of shielding or of personal protective equipment).
- (c) Human induced initiating events, such as operator errors and violations, and misidentifications leading to the performance of incompatible activities.

The analysis of evolution of the initiating events was carried out using the Event Tree Analysis technique [II-27].

#### *Hazard Screening*

Hazards lacking the potential to cause harmful consequences for workers, the public and the environment to an extent that is not in compliance with relevant safety requirements or criteria, as well as hazards that could not be realized in view of the scope of the waste retrieval activities being assessed, were screened out from the subsequent hazard analysis.

The following potential exposure pathways through which the identified hazards could cause harmful consequences for workers were considered in the screening process:

- (a) External exposure due to direct radiation from gamma emitting radionuclides from radioactive material (e.g. sealed sources, RW packages).
- (b) Internal exposure due to inhalation or ingestion from airborne releases (e.g. aerosols and particulates from spillages), or in fires (for the purpose of this illustrative safety case, fire scenarios are not further considered).
- (c) A combination of radiological contamination and physical injuries (e.g. the contamination of wounds).

The results of the screening are recorded in the SAFRAN file along with justification of any scenarios that were not considered to be relevant. These results are summarized in Table 19.

TABLE 19. RESULTS OF QUALITATIVE HAZARD SCREENING

Name	Relevance	Relevance - justification (if not relevant)	Category
Lightning (effect on power supply)	Not relevant	The facility can operate (perform its basic function – storage of waste and its retrieval) safely without electrical supply, all important systems have backup supply	External natural
Lightning (effect on surroundings of facility)	Not relevant	Because the RADON-type facility is an underground facility - covered with concrete pavement, the lighting doesn't have an impact on the surrounding of the facility	External natural
Lightning (effect on facility)	Not relevant	Because the RADON-type facility is an underground facility - covered with concrete pavement and subsequently with hangar structures, the lighting doesn't have an impact on the facility	External natural
Extreme snowing	Not relevant	Because waste retrieval activities is planned for summer season	External natural
Extreme rain	Not relevant	Because hangar structures are designed with account taken of extreme rain	External natural
Extreme drought	Not relevant	The extreme draughts are not typical for the area of the facility	External natural
Strong wind	Not relevant	Because hangar structures are designed with account taken of strong wind	External natural
Extreme temperatures	Not relevant	The extreme temperatures are not typical for the area of the facility	External natural

TABLE 19. RESULTS OF QUALITATIVE HAZARD SCREENING (CONT')

Name	Relevance	Relevance - justification (if not relevant)	Category
Hydrology and hydrogeology	Not relevant	Because waste retrieval activities is planned for summer season when groundwater is far below the surface	External natural
Geology of site and region	Not relevant	Geology is well known and it is not expected that it will change in the near future	External natural
Seismic events	Not relevant	The design and the construction of the facility is seismic safe	External natural
Other effects of ground stability	Not relevant	There is no other effects of ground stability	External natural
Geomorphology and topography of site	Not relevant	Nothing from geomorphology or topography of the site can effect safety of the facility	External natural
Terrestrial and aquatic flora and fauna	Not relevant	The RADON-type facility is well closed and flora and fauna can't effect the processes inside the facility	External natural
Potential for natural fires, storms etc.	Not relevant	Because within a radius exceeding the radius of the controlled area of the facility there are no gas/oil pipelines, industrial facilities, warehouses, water reservoirs etc.	External natural
Flooding	Not relevant	Because in the territory adjacent to the facility ground water is opened at a depth from 0.5 to 1.3 m. Groundwater is unconfined. Expected water table rise is to 0.0 m. The RADON-type facility was constructed in a man-made soil fill over 1.5 m high, therefore, its flooding is unrealistic especially in summer season.	External natural
Aircraft crashes; Nearby military activities	Not relevant	There are no military objects and/or military activity nearby the facility. Taking into account that there are no regular airlines routs in the vicinity of facility only light firefighting and traffic monitoring vehicles could in principle crash in the vicinity of facility with very low probability. Potential consequences of these events should be evaluated	External human factors

#### *II-4.4.3. Identification of Scenarios*

As a result of this being an illustrative safety case, although a hazard identification and screening assessment has been undertaken, only certain anticipated operational occurrences and accident scenarios have been selected for detailed hazard analysis to demonstrate the use of SAFRAN and its implementation of the SADRWMS methodology for accident scenario modelling.

*Accident Scenario - Radiation Source Dropped from Gamma-Ray Source Block in Work Area*

In the course of work with gamma-ray source blocks in RW vault an accidental situation related to opening of the collimator's opening or to the source drop-out from the block is likely to occur. As a result, the EDR increases abruptly. In the first case, the direction of radiation exposure will be narrow; in the latter, the direction will cover a wide area.

Prior to commencement of works a thorough visual inspection of the gamma-ray source block is performed to detect open collimator's openings (if any), to establish the direction of a "beam" and to close the openings thereafter. In the course of lifting up of gamma-ray source blocks, there can occur a gamma-ray source block with the open collimator's opening, which was initially covered by the uplifted objects. In case of visual detection of such gamma-ray source block its radiometric survey are conducted with further decision-making on closure of the opening with the operating/standby plug or on placing of this gamma-ray source block to a concrete container.

Such an event is considered as unlikely to happen. However, there cannot be excluded a possibility that the initially shielded radiation source will open or will drop out from the shielded container in the course of works. In case of detection of such sources the following actions are to be performed immediately:

- Workers leave the SRW vault.
- Radiometric survey is carried out by Health physicist.
- Based on the survey results the decision on loading of the dropped-out source to UKT-100 container is taken by Supervisor.
- Additional technical tools such as manipulators or remote grippers are used by Decontamination person.

#### *Accident Scenario - Loss of Ventilation Due to Power Supply Failure*

In the event of a failure of the ventilation system, it is assumed that Radon-222 begins to accumulate, and that personnel exposure increases due to inhalation. However, natural convection is assumed to limit the accumulation of Radon-222 in the room.

#### *Accident Scenario - Dropping of a RW Container from Height (Malfunction of Lifting Equipment)*

Dropping waste packages or other loads due to mishandling or equipment failure resulting in damage to the dropped waste package and possibly to other waste packages or to the SSCs of the facility, is considered a viable accident scenario.

In such an event workers will be immediately evacuated from the place of accident, and the immediate area will be subject to visual inspection and radiation survey.

## **II-4.5. Formulation of models and identification of data needs**

### *II-4.5.1. Estimation of Personnel Exposure under Normal Operation*

Dose rate estimates are based on the assumption that personnel perform their duties in accordance with technical specifications. It is assumed that, at any single time, only one operation prescribed in the specifications can be performed, i.e. there can be no overlapping of operations. Therefore, personnel involved in an operation are assumed not to take part in other work activities and to stay in the protection zone during breaks from work.



In order to calculate the duration of work activities and associated doses to persons involved in the work, the following equations are used:

Duration of work of “i” job position during “n” phase:

$$T_{i,n} = \sum_j T_{i,n,j} \quad (1)$$

Dose rates of “i” job position during “n” phase:

$$D_{i,n} = \frac{1}{60} \sum_j W_{i,n,j} \cdot T_{i,n,j} \quad T_{i,n} = \sum_j T_{i,n,j} \quad (2)$$

Annual dose rate of “i” job position:

$$D_i = \sum_n D_{i,n} \quad D_{i,n} = \frac{1}{60} \sum_j W_{i,n,j} \cdot T_{i,n,j} \quad (3)$$

Where:

i is the job position in compliance with the number (No.), provided in Table 8;

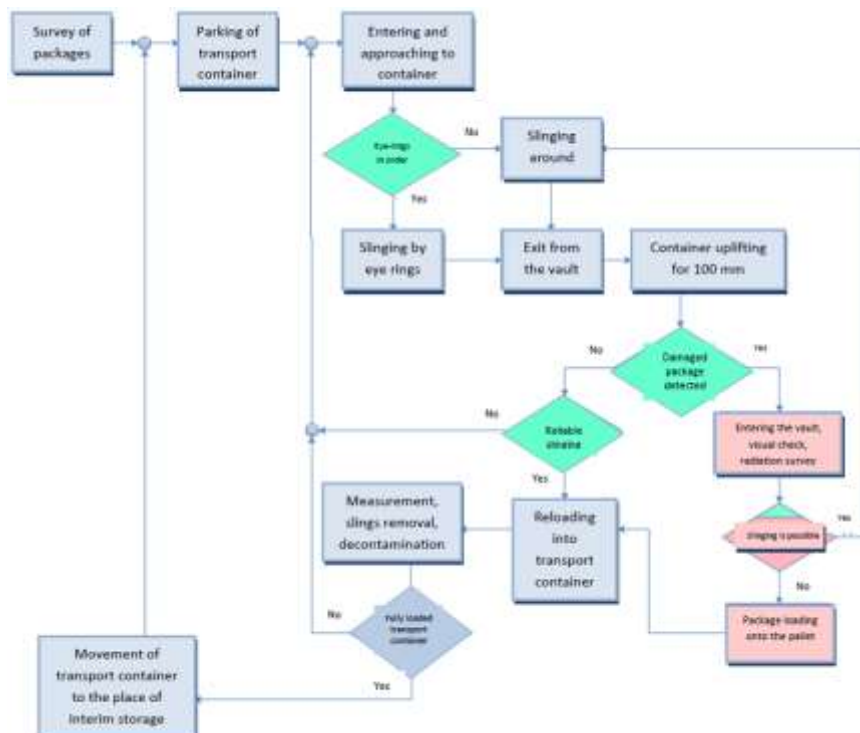
n is the phase number;

j is the operation number;

$T_{i,n,j}$  is the duration of work performed by “i” job position (min).; and

$W_{i,n,j}$  is the EDR in the work area of “i” job position in the relevant operation ( $\mu\text{Sv/h}$ ).

Flowcharts of work performance in each of the phases are shown in Figure 23 (Phases I and III), Figure 24 (Phase II), and Figure 25 (Phase IV).





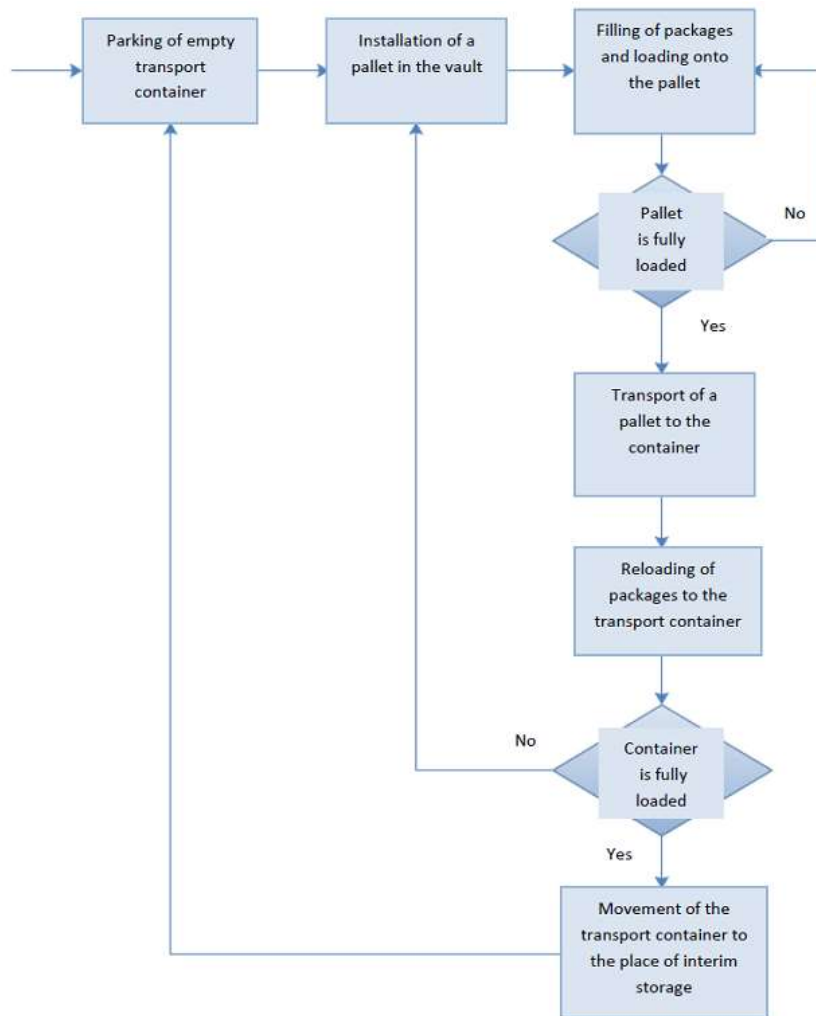


FIG. 25. Flowchart for works performed at Phase IV.

#### II-4.5.2. Assessment of Doses Using the SAFRAN Tool

The SAFRAN tool (version 2.3.2.7) [II-3] was used to perform safety assessment in this document. The SAFRAN tool was developed within the International Project on Safety Assessment Driving Radioactive Waste Management Solutions (SADRWMS Project) (2005-2010) to implement methodologies for safety assessment [II-2]. The main objective of the SAFRAN tool is to assist operators, regulators and technical support specialists in performing systematic and structured safety assessments of predisposal RW management facilities in compliance with national regulations, relevant international safety standards, and good international practice. The software tool was designed to be generic and to cover all kind of predisposal waste management activities, including management of DSRS. The SAFRAN tool aids the user in:

- Describing predisposal RW management activities in a systematic way;
- Conducting the safety assessment with clear documentation of the methodology, assumptions, input data and models;
- Establishing a traceable and transparent record of the safety basis for decisions on proposed waste management solutions;
- Demonstrating clear consideration of and compliance with national and international safety standards and recommendations.

The SAFRAN tool includes the following databases:

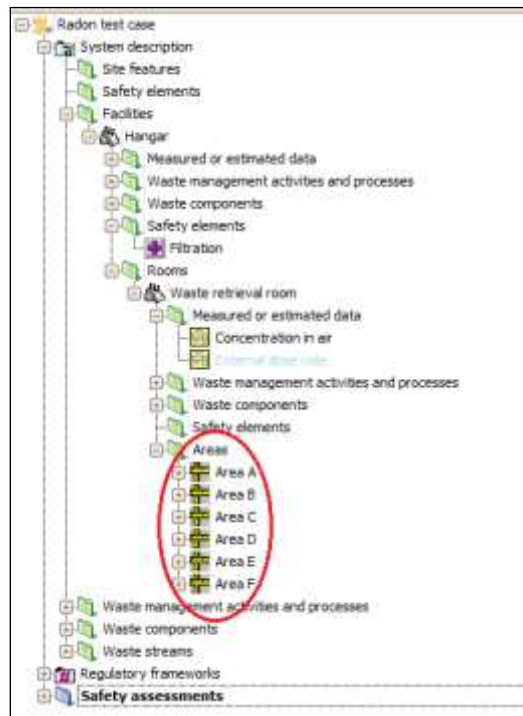
- Radionuclide half-lives;
- Clearance levels;
- Gamma constants – dose rates at 1 m from a point source;
- Screening dose rates for normal and accidental situations;
- Screening release rates for normal operation;
- Screening releases for accidental situations;
- Release fractions;
- Dispersion factors;
- Dose Conversion Factors for Normal and Accidental situations.

The SAFRAN tool also supports a number of features, both in terms of usability and applicability. This can greatly assist in the elaboration of the safety case. These include:

- Help pages to guide the users in filling the various forms within SAFRAN;
- Comments boxes that allow both users and reviewers to record comments, and thus provide a means of dialogue;
- Link to documents and other electronic material (e.g. pictures, maps) for uploading as part of the safety assessment; and
- Exporting data (including results of hazard screening, assessment calculations, and results, etc.) To MS Excel, PDF or other formats data about all the properties of the object.

Within the SAFRAN tool, a “model” site is defined which the user performs a safety assessment of; the model consists of a user-specified configuration of facilities, rooms, areas, and processes that describe the RW operations and the area where these operations are performed. Once the model is created, the user can then specify parameters that will be used to perform the safety assessment calculations; these parameters include specific nuclides, concentration of radionuclides in the air, external EDR, etc. The user then defines the RW that is processed within the model site, assigning properties to the RW as it is “processed” in the model (including RW properties that may be affected during processing such as activity concentration or volume). The user then defines the scenarios that will be considered, including normal operations and accident conditions. Doses for each scenario are calculated summarily for the areas, assuming that all people who are involved in the activity are located in one area and are in similar conditions of radiation exposure and under the same duration of the exposure.

The development of the safety assessment in the SAFRAN Tool starts with the description of the facility in which the activity is performed (see Figure 26). In this illustrative safety case, the model consists of a single unit of the facility, “Hangar”, consisting of a single compartment, “Waste retrieval room”. Within this compartment six areas are distinguished (as was shown in Figure 26).



*FIG. 26. Description of areas.*

For each of the areas the types of activities to be performed are assigned. The activities are grouped according to work phases. Where values are set up for external EDRs at work performance phases, the following phases are specified:

- WM in phase I1;
- WM in phase I2;
- WM in phase I3;
- WM in phase I4;
- WM in phase II;
- WM in phase III;
- WM in phase IV.

The structure reflecting the grouping of works is given in Figure 27.

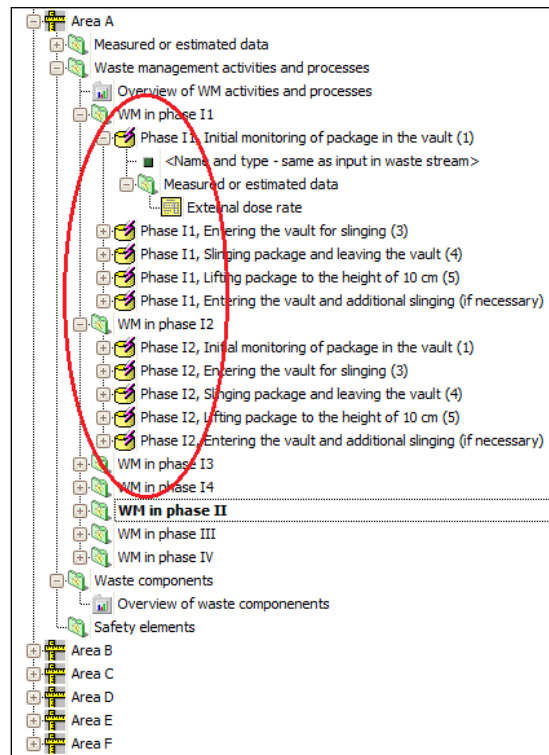


FIG. 27. Structure of grouping of work activities performed during each phase.

In addition to showing the division of work activities into phases, Figure 27 shows the contents of work phases: “WM in phase I1” and “WM in phase I2”. These phases are composed of similar sets of operations that are performed under different values of external EDRs. External EDR values are established for each of the operations.

The general list of operations to be performed (listed in Table 1) is presented in the folder “Overview of WM activities and processes” and is illustrated in Figure 28.

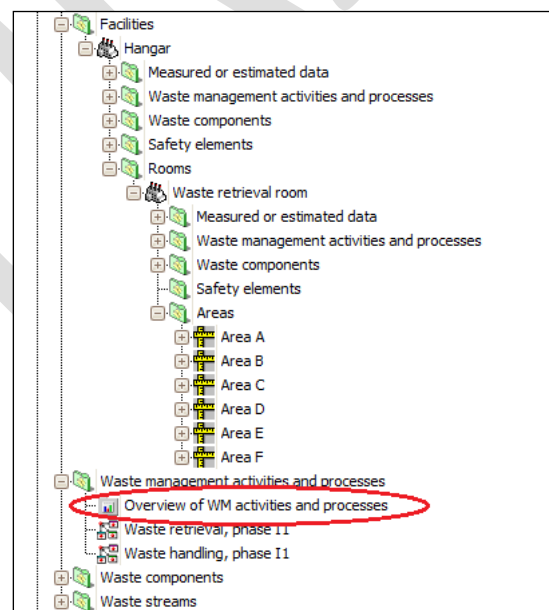


FIG. 28. Folder “Overview of WM activities and processes”.

The folder “Incoming waste” is used to describe the RW components (Figure 29) which are to be retrieved during the mentioned sub-phases.

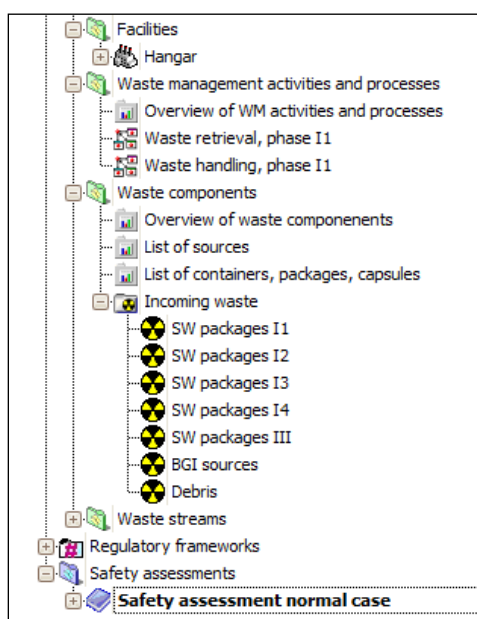


FIG. 29. Description of RW.

As an example, Figure 30 illustrates the properties of “SW packages I1”. In the case of this safety assessment, the content of radioactive substances is not entered in this component of the SAFRAN tool, since this data is not used to estimate EDRs of personnel involved in the work.



FIG. 30. Description of “SW packages I1”.

#### II-4.5.3. Assessment of Doses during Normal Operations

Safety assessment is carried out for normal operation modes of RW retrieval. Receptors are defined by their job descriptions under “Endpoints” (Figure 31).

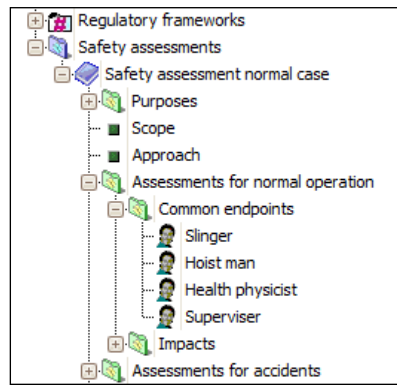


FIG. 31. Introduction into the model of job positions performing works.

The establishment of the structure of impacts (exposures) during work in Phases I through III is shown in Figure 32. Phase I is divided into sub-phases I1 – I4, each of which assigned to work areas. Inside the structure of these areas, impacts are assigned for each of the activities defined.

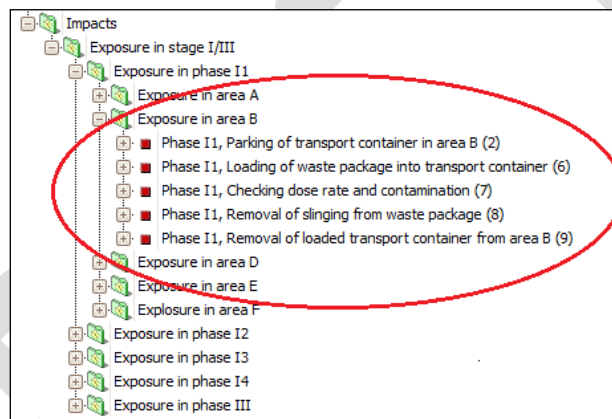


FIG. 32. Establishment of the structure of impacts.

It is assumed that, inside the hangar the air mixes evenly and, therefore, the concentration of radionuclides in the air is assumed to be equivalent in all of the areas, and is assigned a common value – the value established for the “Waste retrieval room”. During normal operation conditions (with an operational ventilation system) it is assumed that one radionuclide that considerably affects personnel in the room is available in the air of the room (Rn-222). Based on calculated estimates, the concentration of Rn-222 under operating ventilation is assumed to be  $262 \text{ Bq/m}^3$ .

A coefficient of filtration for the ventilation system is assumed for both the “Waste retrieval room” and for the “Hangar” (which in this case is not realistic). The filtration coefficient value is assumed to be 0.9.

EDRs were entered for each area and for each sub-phase of work. In order to calculate doses, an exposure time was also entered. For this purpose, a table was created, where the data concerning work performance time intervals are generalized with the account taken of the number of repeated operations. Table 20 presents the minimum and maximum values of the predicted duration of work under normal operation conditions for Phases I and III.



TABLE 20. PREDICTED DURATION OF WORK PERFORMED UNDER NORMAL OPERATION MODE

No.	Area	Personnel job position	Operation	Duration, hour									
				Phase I1		Phase I2		Phase I3		Phase I4		Phase III	
				min	max	min	max	min	max	min	max	min	max
1	A	Slinger	Entering the vault, visual inspection of large-sized RW package	0.17	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2			Entering the vault, approaching to the container	0.04	1.67	0.04	1.67	0.04	1.67	0.02	0.67	0.03	1.00
3			Slinging of a large-sized package	0.17	0.67	0.17	0.67	0.17	0.67	0.07	0.27	0.10	0.40
4		Health physicist	Entering the vault, visual inspection of large-sized RW packages	0.17	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	B	Slinger	Parking of transport container for large-sized RW packages	0.50	1.00	0.50	1.00	0.25	0.50	0.25	0.50	0.25	0.50
6			Loading of large-sized package into the transport container	0.83	1.67	0.83	1.67	0.83	1.67	0.33	0.67	0.50	1.00
7			Removal of slings from the large-sized package	0.08	0.42	0.08	0.42	0.08	0.42	0.03	0.17	0.05	0.25
8			Slinging of the transport container upon its loading	0.33	0.83	0.33	0.83	0.17	0.42	0.17	0.42	0.17	0.42
9	D	Hoist man	Parking of transport container for large-sized RW packages	0.50	1.00	0.50	1.00	0.25	0.50	0.25	0.50	0.25	0.50
10			Removal of slings from the large-sized package	0.08	0.42	0.08	0.42	0.08	0.42	0.03	0.17	0.05	0.25
11		Health physicist	Survey of the large-sized package	0.17	0.42	0.17	0.42	0.17	0.42	0.07	0.17	0.10	0.25
12		Slinger	Staying in area D	0.42	0.67	0.42	0.67	0.42	0.67	0.17	0.27	0.25	0.40
13	E	Hoist man	-----"	0.38	1.25	0.38	1.25	0.38	1.25	0.15	0.50	0.23	0.75
14		Health physicist	-----"	2.71	6.00	2.71	6.00	2.04	4.58	1.22	2.68	1.49	3.32
15		Supervisor	Work in area E	3.04	6.83	2.88	6.42	2.21	5.00	1.28	2.85	1.59	3.57
16		Hoist man	-----"	2.25	4.83	2.25	4.83	2.08	4.42	0.93	2.02	1.32	2.82
17	F	Slinger	Reloading of transport container onto the platform of the special vehicle	0.50	1.00	0.50	1.00	0.25	0.50	0.25	0.50	0.25	0.50

The data provided in Table 20 for each exposure and each operation are entered into the calculation model (circled in Figure 33) labeled "Min dose" and "Max dose". Data are also entered under "Use in cumulative results" to specify whether the result related to this component will be accounted in the summary estimates.

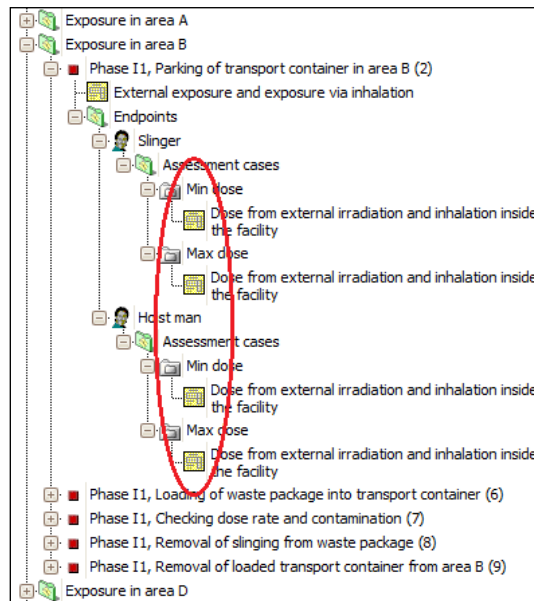


FIG. 33. Components of the calculation model, wherein the values of the predicted minimum and maximum durations of works performance are to be entered.

At this point all the input data necessary to calculate personnel dose rates during waste retrieval under normal operation mode is complete. Calculated EDR values are reflected in the form of a table “Comparison of doses inside” in the folder “Analysis” (Figure 34). The data are also available in the SAFRAN Tool in the form of bar charts. The results of Sub-phase II are provided in Section 4.6.

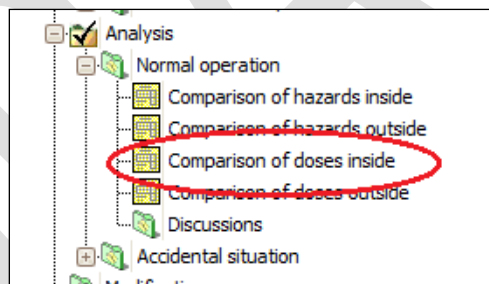


FIG. 34. Bookmarks “Comparison of doses inside” inside the folder “Analysis” containing the results of personnel dose rate calculation.

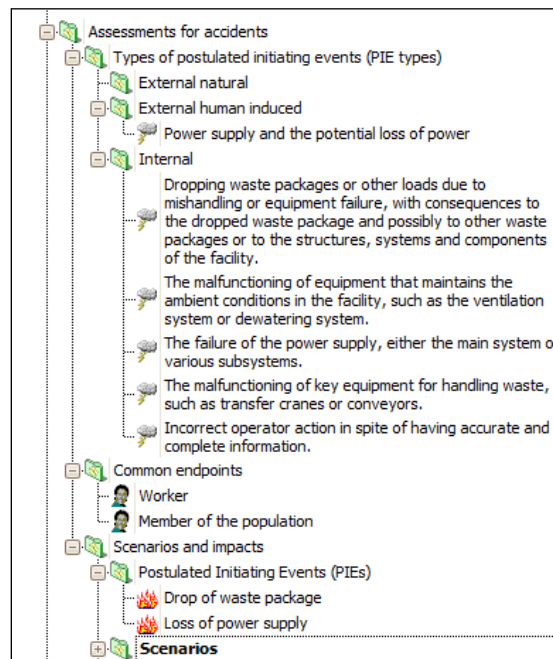
#### II-4.5.4. Radiation Source Dropped from Gamma-Ray Source Block in Work Area

The methodology for modeling an accidental situation is demonstrated by the example of works performed at Phase II, related to retrieval of gamma-ray source blocks. This has been done with the use of the SAFRAN Tool.

The following initiating events selected from the list provided in GSG-3 [II-1] and illustrated in Figure 35 are considered:

- External human induced:
  - Power supply and the potential loss of power.
- Internal:

- Dropping waste packages or other loads due to mishandling or equipment failure, with consequences to the dropped waste package and possibly to other waste packages or to the SSCs of the facility;
- The malfunctioning of equipment that maintains the ambient conditions in the facility, such as the ventilation system or dewatering system;
- The failure of the power supply, either the main system or various subsystems;
- The malfunctioning of key equipment for handling waste, such as transfer cranes or conveyors;
- Incorrect operator action in spite of having accurate and complete information.



*FIG. 35. Initiating events for accidental scenarios.*

The scenarios selected to determine the potential consequences of the considered PIEs (impacts) are illustrated in Figure 35:

- Drop of waste package;
- Loss of power supply.

Workers and members of population are collectively addressed as endpoints for the scenarios.

The SAFRAN representation of the scenarios is given in Figure 36.

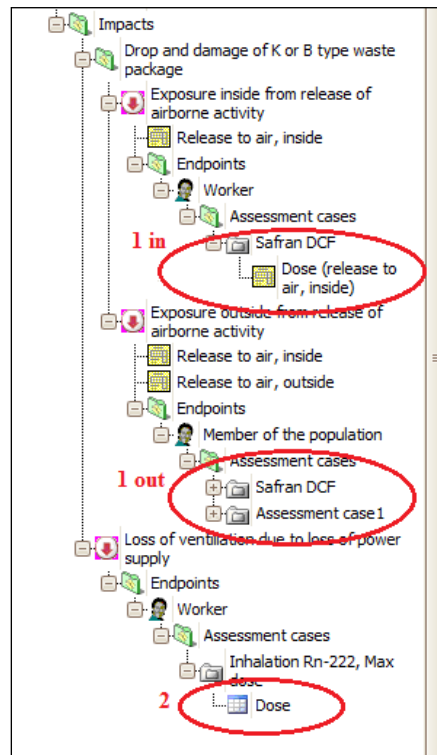


FIG. 36. SAFRAN representation of the impacts.

#### II-4.5.5. Drop of Waste Package

At first accidental scenario it is assumed, that the accident leads to loss of leak tightness of a metal package containing  $2 \times 10^{13}$  Bq of Cesium-137 and  $2 \times 10^{13}$  Bq of Strontium-90, ingress of the radionuclides into air of the room and escape of the radionuclides away from the hangar (taking into account a filtration efficiency of 0.9).

In order to calculate propagation of radionuclides in the room air the transfer model (described in Annex 1 of [II-2]) (folder “1 in” in Figure 36) was used. The SAFRAN tool provides the possibility to select model parameters from a predefined set of values.

The following values were used for this accident scenario:

- Room volume –  $3000 \text{ m}^3$ ;
- Distance from the place of accident – 2 m;
- Exposure duration – 10 min;
- Airborne release fraction -  $10^{-6}$ .

The parameters and results obtained are illustrated in Figure 37.

Waste component	Nuclide	Activity (...)	ARF	Release i...	Room volu...	Distance (m)	Exposure tim...	Dispers...	.	Dose
SW packages I1 - IPhas...	Cs-137	2E+13	1.00E-006	2E+07	3000	2	10	3.56E-004	0	1.44E-004
SW packages I1 - IPhas...	Ra-226	0	1.00E-006	0	3000	2	10	3.56E-004	0	0
SW packages I1 - IPhas...	Sr-90	2E+13	1.00E-006	2E+07	3000	2	10	3.56E-004	0	6.41E-004

FIG. 37. The window for selection of parameters and results obtained with regard to exposure inside the room at the first accidental scenario.

#### *II-4.5.6. Loss of Ventilation*

Under the second accidental scenario (element “2” in Figure 36) the consequences of ventilation malfunction are considered, due to which the room starts accumulating Radon-222, and personnel exposure increases due to inhalation. In the case of unavailability of forced ventilation and permanent ingress of Radon-222 into a room, its concentration value is influenced by two processes:

- Air outlet from the room due to natural convection;
- Radioactive decay (half-life period 3.823 days).

### **II-4.6. Performance of calculations and evaluation of results**

#### *II-4.6.1. Assessment of Doses during Normal Operations (Direct External Exposure)*

The following procedure is applied to assess doses resulting from direct external exposure. Within the SAFRAN tool, the user selects the affected waste components and identifies the number of packages and total inventory for each radionuclide in the hazard screening step. Doses are calculated using the following equation:

$$\text{Dose (i,k)} = \text{DoseRate (i,k)} * \text{time (k)} \quad (4)$$

where

i is radionuclide;

k is a particular waste component;

DoseRate(i,k) is dose rate from a single component; and

time(k) is exposure duration.

Calculation of external EDRs from a single waste component can be carried out using the SAFRAN models for external exposure calculations. There are models for several geometries (cube, cylinder, sphere, point source, and disc). For complex situations it is necessary to use other tools. The SAFRAN models allow for performing calculations with consideration of shielding or without consideration of shielding. Common parameters necessary for the models are Inventory (Bq) and Distance (cm). The SAFRAN tool automatically collects and sends the values for these parameters to the models.

Once doses resulting from each radionuclide have been evaluated, the total dose from all radionuclides in the affected waste component can be calculated as follows:

$$\text{Dose (k)} = \text{SUM (Dose (i, k))} \quad (5)$$

EDRs calculated for normal operation in Phase I are presented in Table 21.

TABLE 21. RESULTS OF EDR CALCULATIONS FOR PHASE I

Personnel	Doses to personnel at different sub-phases of phase I, Sv/y					Total dose (Phase I), Sv/y
	Area A, B				Area D, E, F	
	I1	I2	I3	I4		
Slinger	3.1E-3	1.7E-3	6.5E-4	9.8E-5	1.9E-4	5.8E-3
Hoist man	4.5E-4	5.3E-4	1.5E-4	2.1E-5	9.9E-4	2.1E-3
Health Physicist	5.5E-4	1.66E-4	6.8E-5	5.2E-6	3.7E-5	8.3E-4
Supervisor	-	-	-	-	1.3E-3	1.3E-3
Check man (RW						
Accounting	1.3E-4	1.5E-4	6.8E-5	5.2E-6	2.1E-4	5.6E-4
Person)						
Decontaminator	1.3E-4	1.5E-4	6.8E-5	5.2E-6	3.8E-5	3.9E-4

Table 22 presents values of cumulative doses calculated for the full duration of waste retrieval operations.

TABLE 22. DOSES TO PERSONNEL AT DIFFERENT PHASES OF WASTE RETRIEVAL

Personnel	Doses to personnel at different phases of waste retrieval, Sv/y				Total dose, mSv/y
	Phase I	Phase II	Phase III	Phase IV	
Slinger	5.8E-3	1.9E-4	1.9E-4	7.7E-5	6.2
Hoist man	2.1E-3	7.4E-5	7.6E-5	2.4E-5	2.3
Health Physicist	8.3E-4	5.7E-5	2.6E-5	5.7E-5	0.97
Supervisor	1.3E-3	8.9E-5	2.7E-5	4.9E-5	1.5
Check man (RW					
Accounting Person)	5.6E-4	5.2E-5	2.8E-5	3.1E-5	0.67
Decontaminator	3.9E-4	3.3E-5	2.1E-5	5.1E-5	0.49

Graphical illustrations of doses to the different groups of workers for the period of retrieval operations are presented in Figures 38 through 43.

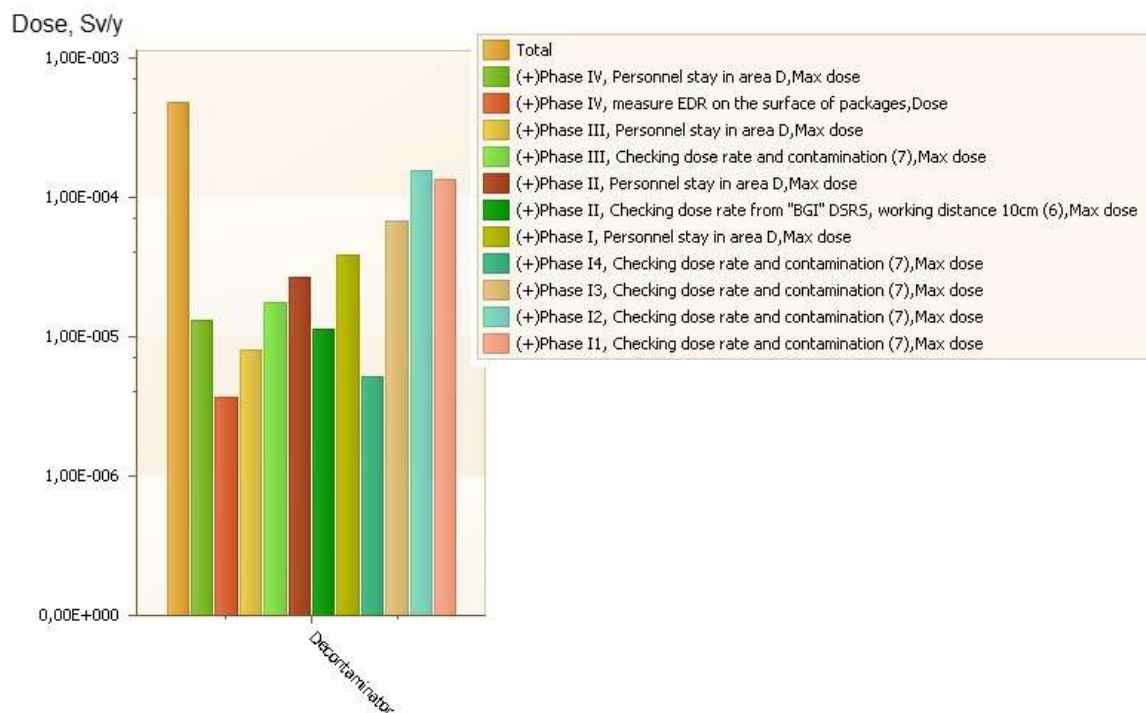


FIG 38. Doses to Decontaminator During Retrieval Operations.

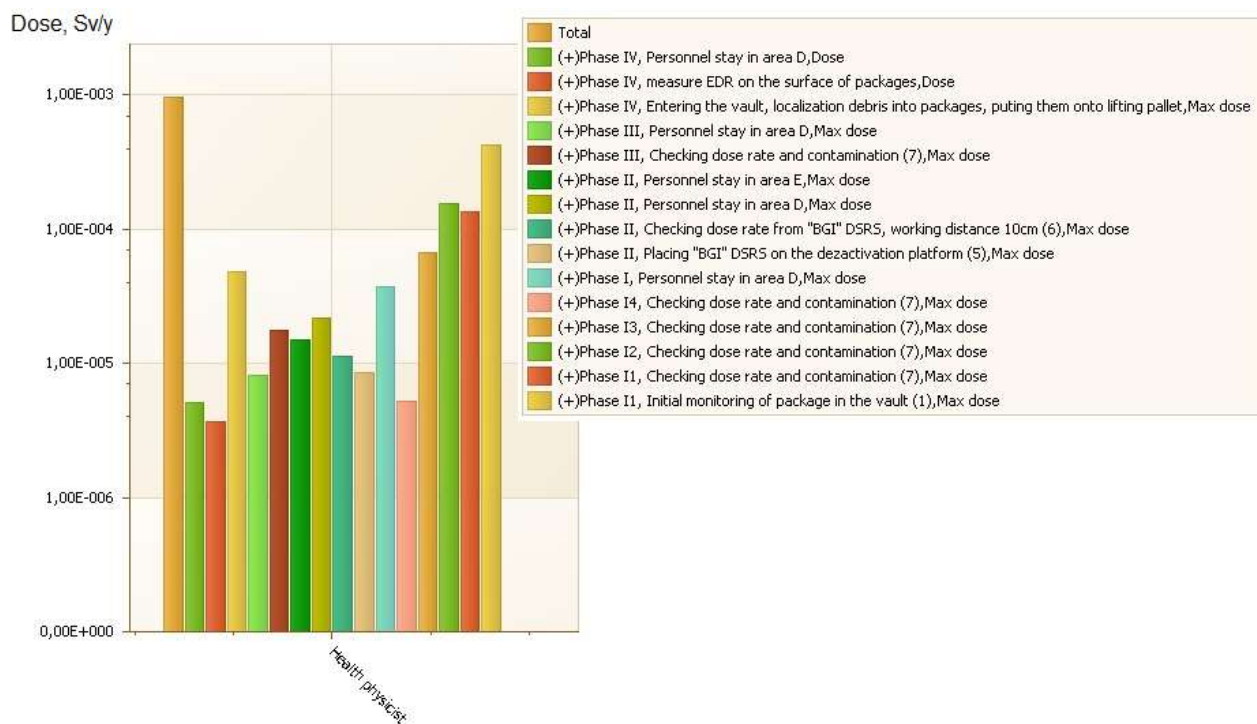


FIG 39. Doses to Health Physicist During Retrieval Operations.







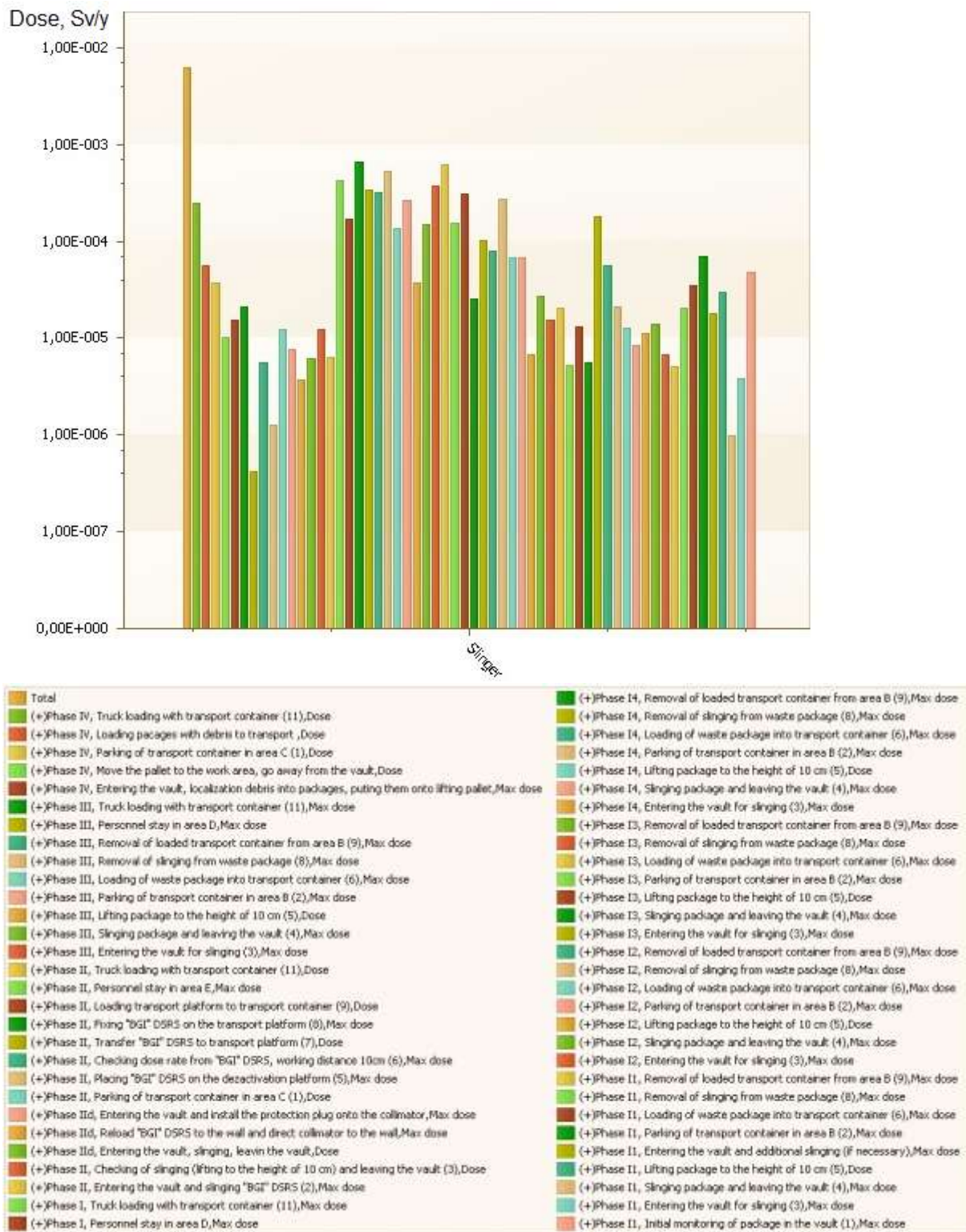


FIG 42. Doses to Slinger During Retrieval Operations.

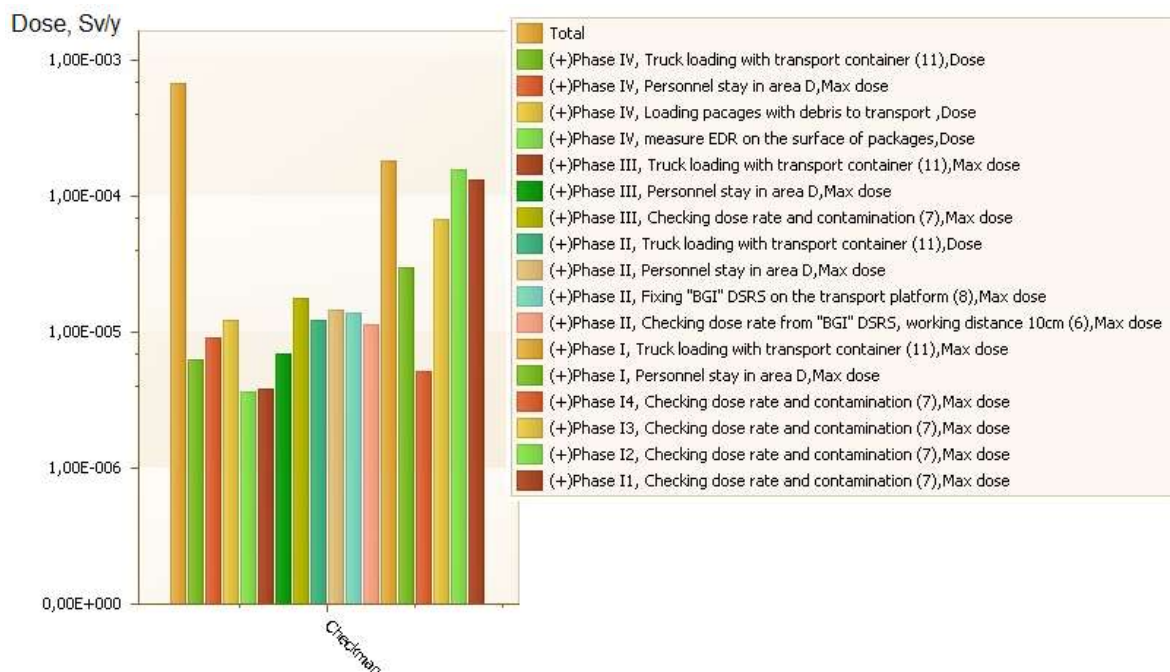


FIG 43. Doses to Check Man During Retrieval Operations.

#### II-4.6.2. Accident Scenarios

##### Radiation Source Dropped from Gamma-Ray Source Block in Work Area

In case of such an accident a gamma survey is carried out by Health physicist. Tools such as remote grippers are used by Decontamination person to load the dropped-out source to UKT-100 container. It is expected that the gamma survey takes conservatively 1 minute and loading of the dropped-out source to a special container takes 5 minutes. The length of the remote gripper is 1 m.

Expert-calculated estimates of the EDR resulting from exposure to an unprotected E-1M gamma-ray source block are given in Table 23.

TABLE 23. EDR DEPENDING ON THE DISTANCE FROM THE SOURCE

Radiation source	EDR at calculation point, mSv/h	
	10 cm from the source	100 cm from the source
DSRS	$7.48 \cdot 10^2$	7.45

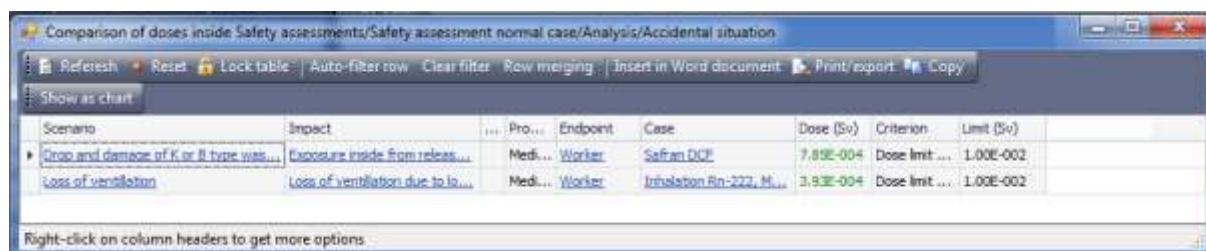
The results of dose assessment for this anticipated operational occurrence are presented in Table 24.

TABLE 24. DOSES TO PERSONNEL FROM DROPPED-OUT SOURCE

Personnel	Doses to personnel, mSv
Health physicist	0.12
Decontamination person	0.37

### Loss of Ventilation

The dose assessment was carried out using SAFCALC module of SAFRAN Tool (model AAir\_Worker\_Inside.eco). Assuming a one hour period and an equilibrium value of Radon-222 concentration in the room under long-term loss of ventilation, the dose to the worker is calculated to be 0.393 mSv (Figure 43).



Scenario	Impact	Pro...	Endpoint	Case	Dose (Sv)	Criterion	Limit (Sv)
Drop and damage of K or R type waste	Exposure inside from release...	Medi...	Worker	Safran DCP	7.89E-004	Dose limit ...	1.00E-002
Loss of ventilation	Loss of ventilation due to lo...	Medi...	Worker	Inhalation Rn-222, M...	3.93E-004	Dose limit ...	1.00E-002

FIG. 43. Doses to personnel for accident scenarios.

### Drop of Waste Package

In order to calculate EDRs outside the building (element “1 out” in Figure 35) the Gaussian model for atmospheric dispersion for different diffusion categories is used. Calculation is carried out using the SAFRAN module SAFCALC.

Parameters necessary to perform calculation include the radionuclide composition, in this case Cs-137 and Sr-90, as well as:

- “Accident released activity” (ingress of radionuclides in the air outside the building in the content of inhaled fraction):  $2 \cdot 10^6$  Bq (equal for Cs-137 and Sr-90);
- “Building height” and “Building width”: 8 m and 30 m, respectively;
- “Exposure location” (distance from the emission source to the place of exposure) – assumed to be 500 m.

Radiation doses are calculated taking into account these following exposure pathways:

- External exposure from the radioactive plume;
- Internal exposure due to inhalation;
- External exposure from contaminated ground.

Consideration of the paths of exposure excludes intake of radionuclides into the human body through swallowing of contaminated food and water, since at a distance of some kilometers from the facility the usage of open sources for portable water supply and the production of agricultural products are excluded. Calculation results for radiation doses obtained for all the considered exposure pathways and for different diffusion categories at the site boundary (located at a distance of 500 m from the emission source) are provided in Table 17.

TABLE 25. INDIVIDUAL DOSE FOR POPULATION AT A DISTANCE OF 500 M FROM THE EMISSION SOURCE

Diffusion categories (Atmospheric stability conditions)	Dose ( $\mu\text{Sv}$ )
Class A	0.175
Class B	0.329
Class C	0.350
Class D	0.434
Class E	0.775
Class F	0.368

Atmospheric stability conditions are as follows:

- Class A is extremely unstable;
- Class B is moderately unstable;
- Class C is slightly unstable;
- Class D is neutral (applicable to heavily overcast day or nighttime conditions);
- Class E is slightly stable;
- Class F is moderately stable.

For Class E (slightly stable atmospheric stability conditions) the individual exposure dose for the population is approximately  $0.8 \mu\text{Sv}$ .

#### II-4.7. Analysis of assessment results

In summary, based on the available evidence and safety analysis, the conclusion of this safety case, which is not a fully comprehensive and complete assessment, is that the waste retrieval operations can be safely undertaken and provide a solution to the hazards currently posed by the interim storage of wastes at the historical RADON-type facility. The key findings and conclusions for the safety of operations within the RADON facility are as follows.

##### II-4.7.1. Comparison with Safety Criteria

The results of the quantitative safety assessment for the retrieval of the waste from the Vault 1 as reflected above are well within the national and international safety criteria for workers and the public.

The assessed dose for workers for normal operation is  $6.2 \text{ mSv}$  in comparison to the dose constraint of  $10 \text{ mSv/a}$ .

The assessed dose for workers for accident scenario is  $7.0 \text{ mSv}$ .

The assessed dose for public for accident scenario is  $0.8 \mu\text{Sv}$  in comparison to the dose constraint of  $0.1 \text{ mSv/a}$ .

##### II-4.7.2. Use of SAFRAN Tool

A detailed assessment of doses arising from normal waste retrieval operations from Vault 1 of the facility is modeled using the SAFRAN tool (version 2.3.2.7) [II-3]. Selected accident scenarios are modeled using the SAFRAN tool to demonstrate application of the assessment methodology.

The given calculated example of safety assessment of the activity on RW retrieval from the storage facilities of RADON type has demonstrated the useful application of SAFRAN tool for this purpose. The general sequence of work performed using the SAFRAN tool included the following steps:

- Description of the facilities;
- Creation of the area structure, where works are to be performed, and parameters of exposure in work areas;
- Description of operations performed in the course of the activity;
- Establishment of the control levels of exposure, according to the national regulations;
- Description of the regulatory framework for normal and accidental situations;
- Input of personnel job positions, who are assigned to perform aforesaid operations;
- Establishment of a list of impacts relevant to performed operations, and setting up of time parameters for operations performance;
- Analysis of the results for the primary mode and abnormal operation mode;
- Establishment of accidental mode scenarios and calculation of the relevant EDRs by means of applying the SAFRAN Tool's Safcalc module.

Application of SAFRAN tool allows processing of the input data, creation of the demonstrative safety assessment structure and analysis of the alternative options for personnel response actions, occurring in the course of implementation of the concerned activity – under normal operation mode, abnormal operation mode and accidents.

Certain inconveniences in application of SAFRAN tool occur due to lack of the possibility for simple mathematical processing of data directly inside the program body. Therefore, in order to perform the analysis for abnormal operation modes there is the need to create separate files or additional structures inside the program, which leads to considerable expansion of the calculation model.

## II-5 MANAGEMENT OF UNCERTAINTIES

In general, historical RW are those that are generated without a complete traceable characterization program or quality management system in place. This introduces potential uncertainty in the contents and condition of the stored wastes.

Characteristics of historical wastes in RADON-type facility were the following:

- Unconditioned or partially treated;
- Poor or no information/traceability;
- Cannot conclusively identify originating process/location;
- Waste streams may be mixed;
- Incomplete history;
- Incomplete or improper characterization/treatment; and
- Quality system did not cover the whole life cycle at the time of generation.

During the safety assessment, some uncertainties have been identified that may impact the safety of the facility and waste retrieval activities. Sources of uncertainty were categorized as:

- Data and/or parameter uncertainty;
- Scenario uncertainties.

In order that uncertainties associated with poor characterization of the current inventory of RW do not unduly influence the results of the safety assessment, a conservative safety

evaluation has been carried out. Conservative but reasonable values were used as input data and the “screening” method was used to evaluate the behavior of the main indicators of the impact in occupational and public exposure.

Specific uncertainties identified for this Safety Case and the possible approaches to their management are described below:

- Uncertainty over the exact inventory and condition of the wastes stored in the vaults has been minimized through a thorough intrusive characterization survey. However, uncertainties remain throughout the retrieval operations.
  - A flexible retrieval methodology has been adopted to enable innovation within the bounds of the safety case. This makes use of a combination of manual and remote/semi-remote operations as the situation requires.
  - The safety case has taken a realistic and conservative approach to give flexibility during waste retrieval operations.
  - Conservative estimates of time taken to deal with each package. This allows for unexpected situations, where waste packages are in poor condition and retrieval operations are extended.
  - A variety of waste packages have been identified for use to cater for emergent situations, such as historically degraded or damaged waste packages.
  - Final characterization of the waste for consignment will be carried out as wastes are retrieved.
- Uncertainty of the radiation levels within the vaults has been minimized through surveys. However, not all areas were accessible and there may be some self-shielding by the waste items themselves.
  - Real time dose monitoring will be undertaken, with advice from the Health Physics advisor and Supervisor.
  - Local shielding will be available to enable operators to retreat from high dose items if required.
- Concentrations of activity in air are not known for retrieval operations.
  - Air sampling has been undertaken to establish a quiescent baseline and to enable conservative modeling in the safety assessment.
  - A local ventilation system has been designed to reduce airborne activity levels during retrieval operations. The performance parameters of the system have been overspecified to ensure flexibility to changing conditions.

In order to minimize internal dose uptake, in addition to the use of the ventilation system, operators will wear Radiological Protection Equipment.

### **II-5.1. Data uncertainty**

Data uncertainties have been treated by obtaining data on:

- The radiation situation and radioactive contamination of the storage facility;
- The quantity and range of RW in the tanks (vaults) and their respective radiation characteristics.

The tasks of the examination were to:

- Collect and review the available initial data;
- Take photographs and videos of the storage tanks;
- Update the parameters and range of the tank contents;

- Create plans and 3-d models of the tanks, including their respective contents;
- Carry out dose rate, radiometric and spectrometric measurements in the tanks;
- Identify the tank contents being the major sources of radiation and determine their spectral characteristics;
- Sample the tank contents and further measure their radioactivity;
- Process and review the measurement results.

The activities were conducted in accordance with the Work Program in two stages:

- Preliminary examination which included collection of the available “Radon” data on the states and filling levels of the SRW storage tanks, measurement of hatches and monitoring of the radiation situation near these, and determination of the accessibility of the vaults through the existing hatches; and
- Main examination.

The summary of waste examination of the RADON facility is presented in Section 3.3.2.

## **II-5.2. Scenario uncertainty**

Scenario is a postulated or assumed set of conditions and/or events. They are most commonly used in analysis or assessment to represent possible future conditions and/or events to be modeled, such as possible accidents at a nuclear facility, or the possible future evolution of a repository and its surroundings.

This safety assessment of waste retrieval is concerned with the impact of the waste on workers over the period of retrieval operations.

Incomplete knowledge about current state of historical waste packages is a major source of uncertainty in this safety assessment. For example, some of gamma-ray sources blocks in the RADON facility have lost their collimator’s plugs and eyebolts. Handling of such blocks can lead to an accident situation with dropping-out of gamma-ray source from the block and exposure of workers.

Scenario uncertainties have been treated by assessing doses to workers through different scenarios described in section II-4.3.3.

## **II-6 ITERATION AND OPTIMIZATION**

The evaluations of the waste retrieval techniques and the safety assessment have been undertaken with the best available data and applying expert judgment.

Nevertheless, aspects such those as mentioned below could result in the need for iteration of the safety case:

- New data about the waste becomes available as waste retrieval operations progress.
- The unforeseen issues may be identified during waste retrieval, such as performance issues with remote equipment.

Specific actions to optimize dose protection can be summarized as:

- The use of ventilation systems to minimize airborne activity, resulting in lower doses to workers and the public;
- Providing of shielded areas for workers to reduce doses during retrieval operations;



- Removal of high radiation dose wastes from the vaults first, to reduce general background doses;
- Use of remote or semi-remote tools to assist in retrieval activities;
- Real-time dose monitoring to assist operators and supervisors in decision making;
- Use of appropriately shielded waste containers to receive the waste;
- Timeliness in carrying out waste retrieval operations.

## II-7 IDENTIFICATION OF SAFETY MEASURES

The assessment undertaken indicates that if the retrieval operations are implemented according to the provisions set out in this safety case, it will comply with the required national safety standards and meet the relevant dose limitation criteria with respect to workers and members of the public. The assessment has been carried out using conservative assumptions and straightforward methodology.

The hangar structures itself does not provide any significant shielding. However, localized shielding will be in place to reduce doses to workers.

Inspection and maintenance programs will be in place for the installed and portable equipment and a management system providing for trained personnel, formalized procedures, records, reports and an assurance regime over all aspects important to safety and security will also be established.

## II-8 LIMITS, CONTROLS AND CONDITIONS

According to national regulations and guidance documents, a set of limiting conditions and controls will be implemented to ensure safety of operations as follows:

- The current assessment assumes no more than 185 m<sup>3</sup> of solid RW are to be retrieved from Vaults 1 to 4.
- Waste retrieval operations are only undertaken with the use of a local ventilation system operating at the vault, to ensure that airborne activity concentrations are minimized.
- The maximum dose rate assumed in the SAFRAN model for manual intrusive work is 1 mSv/hr at 1 m from the source. Items with dose rates higher than this would require use of additional localized shielding or semi-remote retrieval operations to ensure that total doses are optimized.

All waste will be packaged and recorded in compliance with the Waste Acceptance Criteria of the receiving waste management facility.

## II-9 CONCLUSION

As stated earlier in this document, a fully comprehensive safety assessment has not been performed in this illustrative version of the safety case. However, the results of the quantitative safety assessment for the retrieval of the waste from the Vault 1 as reflected above are well within the national and international safety criteria for workers and the public. Therefore, based on the available evidence and safety analysis, the conclusion of this safety case is that the waste retrieval operations can be safely undertaken and provide a solution to the hazards currently posed by the historical wastes in the RADON facility.

The assessed dose to workers during normal operation is 6.2 mSv, in comparison to the dose constraint of 10 mSv/a.



The assessed dose to workers as a result of the accident scenario is 7.0 mSv.

The assessed dose to the public as a result of the accident scenario is 0.8  $\mu$ Sv, in comparison to the dose constraint of 0.1 mSv/a.

The results of the quantitative safety assessment are well within the national and international safety criteria for workers and the public. The safety case for the operations is supported by a formal plan to address identified unresolved issues.

Evaluation of uncertainties has been undertaken and each area of uncertainty has been managed appropriately. A list of key unresolved issues has been identified and planned steps to resolve them have been cited.

The key findings and conclusions for the safety of waste retrieval operations are as follows:

- **Strategy:** The facility and its associated activities to retrieve, package and dispatch the waste is in line with the national policy and strategy.
- **Facility Design and Engineering:** A simple approach has been taken to design and engineer a waste retrieval facility, with a balance of engineered and operational safety measures appropriate to the hazards. All engineering features are anticipated to perform their operational and safety functions adequately. A key item of equipment is the local ventilation system, which will maintain low levels of airborne activity within the facility.
- **Facility Operation:** A detailed series of activities has been described and assessed for waste retrieval operations. Implementation of these operations is expected to result in safe retrieval of the wastes.
- **Optimization of protection:** A series of optimization measures have been identified in Section 6, which will result in doses that are as low as reasonably practicable to workers and the public.
- **Waste Management Practice:** Good waste management practice is generally evident from the intent of the legal framework, organizational arrangements and defined responsibilities.
- **Integrated Management System:** Although some management systems and procedures have been implemented, further development of the management system is required. Management of unresolved issues as covered above address recommendations regarding the development of an integrated management system.
- **Uncertainties:** Uncertainties have been identified and mitigating actions put in place, either in the assessment itself or in the subsequent waste retrieval activities.

## PLANS FOR ADDRESSING UNRESOLVED ISSUES

The safety case indicates some information gaps that need to be addressed before it will be regarded as a document that can be submitted to the regulatory authority for review and approval.

The identified aspects requiring further clarification with commensurate management recommendations and actions are described in Table 26.

TABLE 26. ASPECTS REQUIRING FURTHER CLARIFICATION

Item	Aspects Requiring Clarification	Recommendation/Action
1. Legal and regulatory framework		
1.1	None identified.	
2. Basic Engineering Analysis		
2.1	None identified.	
3. Optimization of Protection		
3.1	Optimization for normal operation related exposures.	Development and implementation of a formal operational optimization program where actual doses are measured and specific reduction strategies are considered and implemented during waste retrieval activities.
3.2	Identification of hazards, hazard screening and full hazard assessment for Anticipated Operational Occurrences and Accidents has not been carried out in this illustrative safety case. Nominal scenarios have been assessed as exemplars only.	If this safety case is to be used in a real application, full safety assessment needs to be completed.
4. Non-Radiological Hazards		
4.1	Comprehensive assessment of non-radiological hazards has not been carried out.	Plan, schedule and conduct a comprehensive non-radiological hazard assessment.
5. Implemented Waste Management Practice		
5.1	None identified.	
6. Integrated Management System		
6.1	Detailed supporting information on the Management system is not currently referenced.	Provide details of the Management System and safety culture in the safety case.
7. Management of Uncertainties		
7.1	None identified.	
8. Facility Specific Limits and Conditions		
8.1	None identified.	

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#### **Consultant's Meetings**

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