Strål
säkerhets
myndigheten
Swedish Radiation Safety Authority

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Research

2010:24

On Cost Estimate for Decommissioning of one Isotope Central

Report number: 2010:24 ISSN: 2000-0456
Available at www.stralsakerhetsmyndigheten.se

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The present study has been financed by a research grant from the Swedish Radiation Safety Authority, SSM.

SSM perspective

Background

The present generation has the responsibility to ensure and guarantee that sufficient financial resources are accrued into the Swedish Nuclear Waste Fund to cover all future costs. Thus, the next generation, as well as any succeeding generations, will have the financial resources required in order to undertake the necessary measures, in an appropriate manner, for the decommissioning and dismantling of the nuclear facilities and for the construction and operation of long-term storages for the radioactive waste generated. These measures must be congruent and compliant with the environmental and health codex in Sweden.

The ability of the Society to take care of the future environmental liabilities will support a sustainable and long term credibility of the Swedish financing system for nuclear waste liabilities.

SSM conducts systematic examinations and reviews of the estimates submitted by the Swedish nuclear industry in order to ensure the adequacy and accuracy of the costs estimations for each of those individual nuclear facilities, which will become candidates for decommissioning and dismantling within a foreseeable future.

Purpose of the project

The main scope of this study has been to calculate the future cost for decommission and dismantling the Isotope central at the Studsvik site using the OMEGA CODE.

Detailed empirical information is used in the study for “bench-marking” purposes, in such cases when there is a need to supplement and correct field data from the industry. In the present study, data has been retrieved and organized such that the estimated costs for decommissioning of the Isotope Central become transparent and reliable. This approach gives a preliminary qualitative indication about the accuracy of the cost estimate delivered by the industry.

Results

The study has resulted in the following conclusions and lesson learned:

1) A reasonable level for the future costs for decommissioning and dismantling (including contingencies) of the Isotope Central falls within the range of 29,3 to 30,3 M€.
2) Estimated number of man-power hours needed are in the range 196 000 to 203 000.
3) Some costs associated with declassification activities warrant further analysis if a further sharpening of the accuracy is required.
4) The present methodology for estimation of future nuclear waste liabilities is a good example of how transparent cost estimates can be modeled, presented and scrutinized.
5) The way to handle the uncertainty and risk is always a trade-off between the accuracy of the measurement of the level of contamination vis-a-vis more extensive levels of radiological mapping at an individual facility.

Continued work

There is always a need for future studies to develop better estimates. In the short term, our understating and communication can be improved if similar studies are undertaken that reproduce the present study. Likewise, more effort is needed in order to enhance the didactic dimension of the result, so that the dialogue with different stakeholder groups can be more focused and efficient.

Effects on SSM work

SSM will use the current study as support in the review of the year 2010 of the future decommissioning costs for the older nuclear facilities that fall under the Studsvik Act. (The Isotope Central is per se not a nuclear facility, but the cost for decontamination and dismantling of this facility is included in the Studsvik Act).

Project information

Staffan Lindskog has supervised and co-ordinated the project on behalf of SSM. Similarly, Marek Vasko has co-ordinated the project on behalf of DECOM. He has leaded the project group with determination and skill.

SSM reference: SSM 2009/2104

CONTENTS

ABBREVIATIONS

CA	-	controlled area
CS	-	carbon steel
EC	-	European commission
EU	-	European Union
FRC	-	fibre reinforced concrete
IAEA	-	International Atomic Energy Agency
LLW/ILW	-	Low Level Waste/Intermediate Level Waste
LRAW	-	Liquid RAW
NPP	-	Nuclear power plant
NRC	-	Nuclear Regulatory Commission
OECD	-	Organization for Economic Co-operation and Development
OMEGA	-	Oracle Multicriterial General Assessment of Decommissioning
PE	-	polyethylene
PP	-	polypropylene
PSL	-	A Proposed Standardised List of Items for Costing Purposes
RA	-	radioactive
RAW	-	radioactive waste
SS	-	stainless steel
NRC	-	Nuclear Regulatory Commission

REFERENCES

[1] KRISTOFOVA, K. et al., A Model Study of Costs Estimates of Decontamination and Decommissioning with an Emphasis to Derive Cost Functions for Alpha-Contaminated Material Using OMEGA Code, SKI Report 2005:38, December 2004

[2] KRISTOFOVA, K. et al., An Applied Study of Implementation of the Advanced Decommissioning Costing Methodology for Intermediate Storage Facility for Spent Fuel in Studsvik, Sweden with special emphasis to the application of the Omega code, SKI Report 2007:19, January 2007

[3] MÖLLER J., CRONSTRAND P., Ågesta rivningsstudie Uppdatering av underlag för kostnadsberäkningar. T-CKV 08-007. Vattenfall Power Consultant AB, april 2008

[4] IAEA, Decommissioning of Small Medical, Industrial and Research Facilities, IAEA-TRS-414, IAEA, Vienna 2003.

[5] IAEA, Handling, Conditioning and Storage of Spent Sealed Radioactive Sources, IAEA-TECDOC-1145, IAEA, Vienna 2000.

[6] NUCLEAR REGULATORY COMMISSION, "Expiration and termination of licenses and decommissioning of sites and separate buildings or outdoor areas", Code of Federal Regulations, Title 10, 10 CFR Sec. 30.36, 10 CFR Sec. 40.42, 10 CFR Sec. 70.38, NRC, Washington, DC (2001).

[7] MASSAUT, V., "Decommissioning of nuclear laboratories and other small nuclear facilities", lecture 13.C, IAEA regional training course, Argonne National Laboratory, IL, 2000.

[8] GRIFFITHS C., Lessons Learned In Decommissioning Laboratory Facilities, Proc. Lessons Learned from the Decommissioning of Nuclear Facilities and the Safe Termination of Nuclear Activities, Athens, 2006.

[9] A Proposed Standardised List of Costs Items for Decommissioning Purposes, OECD/NEA, EC, IAEA, 1999

[10] F.-W. Bach and coll., Handbook on decommissioning of nuclear installations, Nuclear science and technology, European Commission, EUR 16211 EN, 1995

[11] R. Wampach and coll., Decommissioning of nuclear installations, European Commission, 1995

[12] DUFAULT, R. et al., Reducing Environmental Risk Associated with Laboratory Decommissioning and Property Transfer, Environmental Health Perspectives, Volume 108, Supplement 6, pp. 1015-1022, December 2000.

[13] HEDVALL, H.R. et al., Project Evaluation of the Decommissioning of a Laboratory Plant in Studsvik, WM´06 Conference, Tucson, Arizona, February 26-March 2, 2006.

[14] VASKO, M. et al., On tentative decommissioning cost analysis with specific authentic cost calculations with the application of the Omega code on a case linked to the Intermediate storage facility for spent fuel in Sweden, SKI Report 2007:21, March 2007

[15] EUROPEAN COMMISSION, Council Directive 96/29 EURATOM, May 1996

EXECUTIVE SUMMARY OF THE PROJECT

The Project 'On cost estimate for dismantling of the Isotope Central' aims to demonstrate the tentative application of the advanced costing methodology of decommissioning applied to the Isotope Central in Studsvik, using the OMEGA code. The result of the project is a report consisting of 14 chapters. Their content is following:

Chapter 1 Introduction describes the position of laboratories and their decommissioning within nuclear and radiological facilities. Purpose of the Isotope Central building as radiological laboratory is briefly explained. The basic principles of decommissioning costing and advanced decommissioning costing are discussed. The steps how to achieve the aim of the Project are listed.

Chapter 2 Worldwide D&D Approach to Research Laboratories and Hot Cells is based on bibliographic research and represents overview of relevant information accessible. Common features of research laboratories to be decommissioned are discussed. The decommissioning strategy for research facilities and hot cells is described. Then examples of national experience are given covering decommissioning of nuclear laboratories at SCK•CEN (Belgium), decommissioning of nuclear medicine department and radioisotope workplace in the Czech Republic, lessons learned in decommissioning laboratory facilities in the UK, the US approach to reduce environmental risk associated with laboratory decommissioning, and finally on-site experience from laboratory plant D&D in Studsvik.

Chapter 3 Brief Survey of Isotope Central Building is reported. Since no sufficient and relevant input data on Isotope Central Building material and radiological inventory had been accessible, a site walk-down in Isotope Central building has been performed and recorded in the survey report in this Chapter. Survey report contains not only our observations but also information obtained from accompanying Isotope Central staff.

Chapter 4 Description of Decommissioning Cost Calculation Code Omega provides a brief introduction to the computer code OMEGA, developed at DECOM, a.s. This software is an option oriented calculation and optimization code for applications in decommissioning decision making processes for nuclear facilities of various types and radiological properties. The Omega calculation code has been chosen for the performance of cost calculations for Isotope Central Building decommissioning planning and costing.

Chapter 5 Conditions for Tentative Decommissioning Calculations describes what input data have been used for calculation and what scope of decommissioning activities has been taken into consideration. Inventory input data comes from site walk-down because of lack of original information and 3 surface contamination levels as alternatives have been taken into consideration. Labour costs unit factors come out from Swedish conditions. These costs have major influence on overall costs. Other cost unit factors like prices of materials, chemicals, media, fuel, electricity etc. come from either international or slovak conditions. Manpower unit factors come from international conditions.

Chapter 6 Development of Database for the Input Data Applied in Calculations is based on the room oriented inventory database structure suitable for application of the OMEGA code. The developed data include the data for buildings, floors, rooms and equipment in individual rooms. These data are based on the site walk-down (material data) and on expert estimation (material and radiological data), using also information gathered from similar facilities.

Data include also unit factors and other parameters, mentioned in previous paragraph for Chapter 5.

Chapter 7 Definition of Extent of Decommissioning Activities. Methods for definition of extent of decommissioning activities are presented. The preparatory activities before starting dismantling are given in a tentative extent. The decommissioning activities relevant for room oriented approach are identified, listed and characterised for dismantling, decontamination of building surfaces, final building RA-survey. The activities for site restoration, demolition and release of site are described.

Waste management activities for treatment, conditioning and disposal of individual types of waste as resulted during decommissioning are identified and described.

The management, support activities, maintenance and surveillance activities were developed in a tentative extent.

Chapter 8 Definition of Waste Management Scenarios for Isotope Central Building in Studsvik presents a general approach to waste management scenarios. Following waste management scenarios are presented, as applied in the code OMEGA: waste scenario for solid radwaste (metal RAW and non – metal solid RAW), waste scenario for liquid RAW, and general scheme for waste management.

Chapter 9 Development of Standardized Decommissioning Calculation Structure presents the overview of the standardized cost structure for decommissioning. The general methods and experience from implementation of this structure are described, as well as the implementation of the structure in the computer code OMEGA.

The procedure for development of the standardised calculation structure for the Isotope Central building is also introduced.

Chapter 10 Performing of Tentative Calculations. The tentative decommissioning cost calculations were performed for 3 options which differ in level of contamination of equipment surfaces in order to present the capabilities of the methodology and the code applied and influence of contamination on main output parameters. Following set of parameters was calculated:

- Main decommissioning parameters, such as costs, manpower and collective dose equivalent characterizing each decommissioning option, formatted in standardized structure.

- Results characterizing distribution of materials arisen from decommissioning.
- Tentative decommissioning time schedule.

Chapter 11 Identification of Differences in Calculation Conditions Resulting from Swedish and Slovak Decommissioning Infrastructure. Typical identified areas of differences between Slovak decommissioning infrastructure as applied in the tentative cost calculations and Swedish conditions are identified as follows:

- The endpoints for waste arisen from the decommissioning process, unconditional, possible conditional releasing of materials and disposal at available (or planned) repositories (HLW, LLW, ILW, VLLW).
- Waste management technologies including their technological parameters.
- Differences in project management, engineering and various support activities.
- The local values of cost unit factors.

Chapter 12 Conclusions. Point out the results and targets achieved. Chapter 13 2 contains 2 Annexes.

1. INTRODUCTION

A significant number of nuclear facilities are smaller sized comparing to nuclear power plants or reprocessing facilities. This includes such installations as radio diagnostic and radiotherapy hospital equipment or laboratories, research facilities and laboratories using radioactive material, hot cell laboratories etc. Decommissioning of these facilities is often seen as a trivial and low priority activity. This may result to underestimating the preparation of decommissioning process and consequently to increase of real costs and possible delays of decommissioning.

It is recognized that the strategies and specific requirements for small facilities may be much less difficult than for large ones such as nuclear power plants or fuel processing facilities. However, many of the same principles may be applied.

In nuclear medicine departments or laboratories unsealed sources are used both for diagnostics and therapy (in vivo techniques). These types of sources are also used in laboratory tests (in vitro techniques). Most medical radionuclides are, however, short-lived and they will decay quickly to acceptable levels.

The Isotope Central Building located in Studsvik, Sweden belongs to this type of facilities. Radioisotopes with short half-lives for diagnostics and treatment were prepared there. These isotopes were produced in nearby reactor R2 in immediate vicinity of the Isotope Central building. The isotopes were transported to the Isotope Central Building and they were modified to required form in its hot cells and laboratory rooms. It is assumed that besides these short-lived radionuclides also the traces of radionuclides with longer half-lives (e.g. cobalt, caesium or alphas) may occur, mainly in contamination of the hot cells and in ventilation systems.

Although the Isotope Central Building is not classified as a nuclear facility, the decommissioning of this facility should come out from the same principles as the decommissioning of nuclear facilities. This also includes an estimation of costs, potential exposure and amount of generated waste arising from the decommissioning process, as well as waste treatment.

The planning and implementation of decommissioning strategies for nuclear facilities requires a careful cost calculation analysis of the whole process. Since the number of decommissioning projects has increased, an application of standardised cost structure within the advance decommissioning costing methodology seems to be a suitable solution how to achieve transparent, traceable and comparable results with various decommissioning projects in various countries. The standardised cost calculation structure for decommissioning was issued and recommended commonly by OECD/NEA, EC and IAEA [9].

The costing methodology used in this Project implements this standardised cost calculation structure. The methodology relays directly on the real inventory of the nuclear installation to be decommissioned (structure, materials, weights of materials, contamination levels, nuclide composition and others). It means, this approach uses the generic costing methodologies and not the comparative costing methodologies. Methodology implements directly also the local factors like labour costs, decommissioning infrastructure including the technologies for dismantling and decontamination, treatment, conditioning and disposal of waste and other technologies for decommissioning. The costing methodology implements the elements which model the real material and radioactivity flow in whole decommissioning process. The radioactivity flow should be nuclide resolved and the radioactive decay for each nuclide should be respected.

For a proper implementation of the advanced generic costing methodology it is necessary to develop the inventory database and calculation databases with structures, which support and enable using the advanced costing methodology.

The advanced decommissioning costing methodology with these properties was developed recently in the company DECOM a.s. and implemented into the computer code OMEGA.

The implementation of the advanced costing methodology and also the use of the computer code OMEGA is country specific or decommissioning project specific. It means that following aspects should be considered:

- inventory database for nuclear facility to be decommissioned should be developed with the structure relevant for the advanced costing methodology,
- local decommissioning infrastructure should be analysed and implemented into the decommissioning scenarios in order to develop/evaluate relevant decommissioning options, specific for the country and for the nuclear installation to be decommissioned,
- local unit factors and other country specific calculation data should be implemented into the calculation database.

Respecting these implementation principles, the advanced costing methodology and also the computer code can be used practically for each nuclear facility in each country.

The main purpose of the presented study is to demonstrate the trial application of the advanced costing methodology using OMEGA code for Isotope Central Building in Studsvik. Within the project, the following activities were carried out in order to perform the tentative decommissioning calculations by OMEGA code:

1) obtain relevant input data on Isotope Central Building, if possible, by studying of available technological and civil engineer drawings, lists of equipment, radiological records and measures and other documents together with interviewing of involved personnel and visual facility inspection,
2) introduce available information on decommissioning of facilities similar in purpose and size to Isotope Central Building,
3) assemble an inventory database suitable for standardised decommissioning cost calculations including radiological parameters,
4) propose a range of decommissioning calculations and define an extent of decommissioning activities,
5) define a waste management scenario for particular material waste streams,
6) develop a standardised cost calculation structure applied for decommissioning calculation,
7) perform the trial decommissioning calculations by OMEGA code.

The above mentioned activities are specified in detail in the following chapters of this document.

2. WORLDWIDE D&D APPROACH TO RESEARCH LABORATORIES AND HOT CELLS

It is intended in this section to sum up aspects of decommissioning and gathered published experience from various small nuclear facilities covering medical, industrial and research ones. Emphasize is given to laboratories and hot cells representing small-scale decommissioning projects similar to Swedish Isotope Central Building in Studsvik. Finally, several examples of national experience and valuable lessons learned from various laboratory decommissioning are provided.

2.1 *COMMON FEATURES OF RESEARCH LABORATORIES TO BE DECOMMISSIONED*

Research laboratories are typically equipped with fume hoods, gloveboxes and/or hot cells. A wide range of radionuclides may be handled. Fume hoods, gloveboxes and hot cells have connection to an active ventilation system and may also have a connection to an active drainage system. The drains may become contaminated with any or all of the radionuclides that were used in these enclosures. Active drains are therefore an important component of the decommissioning process. The spread of airborne contamination in the ventilation ducts associated with hot cells and gloveboxes is also a potential issue for decommissioning [4].

For decommissioning purposes it is important to record not only the type of contamination (beta, gamma and/or alpha) but also whether the facility was used for mechanical (e.g. cutting) or chemical activities. In case of chemical activities carried out during an operation inside a hot cell or a glovebox the residual material and equipment may be more difficult to decontaminate.

Immediate dismantling is often the optimal strategy for decommissioning of most small facilities to have an opportunity to use the operational staff familiar with the facility. However the strategy depends on type, status of the facility and the presented radioactive waste inventory.

Unfortunately, no action strategy is the common practice for many small facilities with terminated operation, because they can be easily shutdown for periods of non-use or maintenance. The longer periods of no action are, the higher risks of loss of documentation and non availability of the adequate operational history from the former staff leading to higher decommissioning costs undertaken.

2.2 *DECOMMISSIONING STRATEGY FOR RESEARCH FACILITIES AND HOT CELLS*

According to IAEA recommendations [4] the selection of a suitable strategy for small facilities is typically simpler than for nuclear power plants or fuel cycle facilities. There may be variations in detail among the strategies for medical, research and industrial facilities and also variations within these types of facility.

It is necessary to take into account in the strategy all the sealed sources if they are included in the shut down facilities. These sources pose significant hazards that must be addressed and alternative exposure scenarios should be considered according to the potential harm the source could cause to workers, the public or the environment.

When a radiation source is no longer to be used for its original purpose, the following management options may be considered [5]:

- transfer to another user for application elsewhere,
- return to the manufacturer or supplier,
- storage for decay of sources containing radionuclides with a short half-life, followed by disposal as non-radioactive material,
- transport to a centralized interim storage facility until a conditioning facility is available,
- transport to a central conditioning facility, followed by interim storage,
- on-site conditioning of the source followed by interim storage until a centralized storage or disposal facility is available,
- transport of the conditioned source to a disposal facility, if available,
- final disposal in a licensed repository.

In general, most of the research facilities exist in industrialized countries. As one example, in the USA the decommissioning of these facilities has received considerable attention. Up to about 1994 there was no clear guidance on when facilities should be decommissioned, and many stood idle for long periods of time [4]. The NRC has more recently amended the license rules to include the timeliness of submitting decommissioning plans and the completion of decommissioning. A maximum delay period of two years after shutdown has been specified by the NRC before it is obligatory to begin the decommissioning process [6].

In European Union there is a tendency to suggest a strategy of immediate decommissioning after shutdown or as soon as possible thereafter if facilities and sites have remained idle for many years. Regulatory requirements and public involvement have forced decommissioning strategies to be addressed.

From the technical point of view, the specific decommissioning activities carried out on research facilities are as follows [4]:

- to remove any potential sources of radiation exposure remaining on the equipment,
- to carry out a preliminary decontamination process to decrease the risks and exposure of the workers during the subsequent decommissioning phases (i.e. at least eliminating removable contamination),
- to perform a dismantling of the hot cells and gloveboxes in a ventilation controlled chamber or protective tent or, for fume hoods, in a controlled area,
- to minimize waste production by addressing appropriate waste management techniques (i.e. recycle and/or reuse, decontamination to meet release criteria or removal as radioactive waste).

It is concluded that the currently preferred decommissioning strategy for contaminated medical, research and industrial facilities is to perform dismantling and decontamination activities promptly with no significant technical problems (in comparison to power reactors and large nuclear facilities) and to store waste in an approved manner until disposal routes become available.

2.3 *EXAMPLES OF NATIONAL EXPERIENCE*

This section reports several national experience from decommissioning projects carried out and lessons learned to be applied for further similar projects in other countries.

The first provided experience is from a successful project for dismantling a heavily contaminated hot cell, as well as research and development laboratories, carried out by the Belgian Nuclear Research Centre (SCK•CEN), reported in Ref. [7]. The second lessons learned come from the decommissioning of nuclear medicine department and radioisotope workplace in the Czech Republic published in Ref. [4]. The third lessons learned from decommissioning of laboratory facilities represent the summarized experience from various projects within the United Kingdom [8]. The fourth one is the US general system approach to laboratory decommissioning and its application published in Ref. [12]. The last valuable lessons learned come from on-site experience from laboratory decommissioning in Studsvik published in Ref. [13].

2.3.1 Decommissioning of nuclear laboratories at SCK•CEN, Belgium

In addition to several nuclear reactors, the Belgian Nuclear Research Centre (SCK•CEN) in Mol is comprised of research laboratory buildings with hot cells, gloveboxes and fume hoods. These were used for post-irradiation research on fuel and reactor material, tests on fuel reprocessing, the characterization of waste and studies and analyses of the effects of radiation and contamination on animals and plants.

The final goal of the selected decommissioning strategy was to obtain a release for the unrestricted reuse of the site by removing radioactivity as well as keeping valuable non-nuclear infrastructure and equipment. By removing contaminated parts, the building can then be used for new industrial purposes outside the nuclear field. One of the buildings, physics building consisted of laboratories using C-14, Cs-137, Co-60, Ba-133 and Sr-90 radionuclides for experiments and measurements. The total wall and floor surface of these laboratories, including offices and waste storage room covered approximately 700 m^2. Average contamination levels were below 2.5 Bq/cm^2, with hot spots of up to 30 Bq/cm^2 for beta and gamma emitters and 0.1 Bq/cm^2 for alpha emitters. The radiological characteristics of physics building might be similar to chosen test decommissioning calculation facility - Isotope Central Building in Studsvik.

Decommissioning process consisted from the following activities:

- scanning for alpha, beta and gamma contamination on loose material and equipment inside the controlled area (non-contaminated objects released, potentially contaminated or contaminated items brought to the decontamination area and finally either free released, released with restrictions or treated as radioactive waste),
- the devices anchored to the walls and floors (ventilation pipes, fume hoods, waste-piping) were demolished and removed to the decontamination area for treatment;
- vacuum cleaning and washing the floor and walls;
- mapping all surfaces and contamination was removed by scabbling, shaving and/or drilling; All the surfaces washed again and washwater collected and sampled. In case meeting the release criteria, the demarcation of the zone was removed.

Simple decommissioning tools were chosen, such as standard saws for dismantling, electrical nibblers or shears for ventilation pipes. Contaminated wall plaster, concrete, stone and tiles were removed using electric and pneumatic scabblers and drills.

Decommissioning of hot cell and gloveboxes were performed in the following steps: Preparation – transfer of the waste generated during the operational period. The equipment inside is then dismantled using tongs, manipulators or gloves. The box or the cell is decontaminated (mechanical polishing and vacuum cleaning or high pressure cleaning) after the equipment is dismantled and the waste generated by these activities is removed. An airtight enclosure is constructed around the hot cell or the glovebox to perform its dismantling by disk grinders or plasma arc cutters.

Lessons learned from the project:

1) The decommissioning of contaminated laboratories and hot cells can be carried out simply, with existing tools, provided that the work is efficiently organized.
2) The management and minimization of the generated waste is important, as this part of the operation has a large impact on the total cost of the decommissioning.
3) The characterization before, during and after the operation, to establish the scope of the decommissioning, to sort material by its radioactivity content and to characterize the flow of the material generated during the decontamination.

2.3.2 Decommissioning of nuclear medicine department and radioisotope workplace in the Czech Republic

A hospital department in which radiopharmaceuticals were administered to patients was moved to a new building after 40 years of operation. It had been decided that the original area would be reused for non-radiological purposes and therefore had to be decommissioned. The work was completed in 1998. Owing to the short half-lives of the radionuclides used, such as Tc-99m, I-131 and others in Table 2-1, it was decided to decommission the building using the delay–decay method. This method involved three major steps [4]:

- the transfer of the sources (both opened and sealed) to the new facility,
- the identification of contaminated surfaces and equipment,
- regular checking of the contamination levels of the contaminated surfaces and equipment until they reached the prescribed limit, see Table 2-2.

Table 2-1 Radioisotopes approved for use in the department [4]

Isotope	H-3	C-14	P-32	Ga-67	Y-90	Tc-99m
Half-life	12.3 a	5730 a	14.3 d	3.3 d	2.7 d	6 h
Allowed activity	40 MBq	10 MBq	10 MBq	200 MBq	4 GBq	40 GBq
Isotope	**In-113m**	**I-123**	**I-125**	**I-131**	**Au-198**	**Tl-201**
Half-life [a]	1.7 h	13.2 h	60.1 d	8 d	2.7 d	3 d
Allowed activity	4 GBq	2 GBq	70 MBq	40 GBq	400 MBq	100 MBq

Table 2-2 Summary of contamination checking in the department of nuclear medicine

Checked space and/or item	Surface contamination level at the date of measurement (Bq/cm^2)		
	March 9, 1998	June 5, 1998	August 25, 1998
Floor – female cloakroom	<0.5	<0.5	<0.5
Floor – wards	1	<0.5	<0.5
Floor – corridor	<0.5	<0.5	<0.5
Floor – isotope application area	1	<0.5	<0.5
Device for emptying urine pots	150	30	<0.5
Air hood	200	40	<0.5
Shower – patients	2	<0.5	<0.5
Floor – male patients' toilet	2	<0.5	<0.5
Toilet bowl – male patients' toilet	3	<0.5	<0.5
Floor – female patients' toilet	1.5	<0.5	<0.5
Toilet bowl – female patients' toilet	3	<0.5	<0.5

The decommissioning plan for medicine department was submitted to the regulator for approval, together with a radiological map of the building. The whole decommissioning process was represented by mainly radiological survey: checking the surface contamination and measurements of the specific radioactivity of the items. The radioactivity of the equipment decayed below the free release limits confirmed by documented measurements, see Table 2-2. Therefore the equipment were free released or treated as non-radioactive waste. Based on the radiological survey completed in the building, a proposal for its release for unrestricted use was submitted to the regulator.

However the decommissioning process of the State Radiological Institute where research activities were carried out was a bit more complicated due the remaining contamination estimated at 100 GBq principally caused by H-3, C-14, Co-60, Sr-90, Cs-137, Ra-226 and Am-241. Performed decommissioning activities of the building involved [4]:

- the detailed mapping of contaminated areas, surfaces and movable items,
- the creation of a new support area for decommissioning personnel and a new laboratory for personal dosimetry (installed new cloakrooms, showers, dosimetry and administrative spaces),
- the decontamination of the radioisotope laboratories,
- clearing out the excess material and equipment from the building,

- the dismantling of equipment (e.g.: air hoods, alpha boxes),
- the systematic decontamination of all surfaces and equipment to be left on the site (using wet and non-invasive mechanical processes),
- an evaluation of the effectiveness of the decontamination,
- the submission of an application for the release of the building for non-radioactive uses (i.e. closing down the radioisotope workplace).

All equipment released from the building was monitored for contamination before being disposed of at a municipal dump or in the repositories of Bratrství and Richard (when found to be contaminated with radium and with other isotopes, respectively). Some larger items contaminated with radium were placed in the disposal pond of a uranium ore milling plant.

The Ra-226 isotope was identified as the principal source of the contamination. In order to remove contamination from structural materials it was necessary to demolish large volumes of material, including: plaster, flooring and fill layers removed, excavated contaminated soil in the basement. These were disposed of as radioactive waste. Subsequent confirmatory measurements showed that, in all the affected places, contamination by Ra-226 and its progeny was below regulatory limits and the building was free released for other reuse.

Lessons learned from the projects:

1) The operation of older facilities is not usually well recorded and therefore whenever possible a member of the original staff should be involved in planning and/or performing the decontamination and dismantling of a facility.
2) Skilled and experienced personnel should be involved in planning and implementing a decommissioning.
3) The more information is recorded and retained about the technical and radiological aspects of the decommissioning of a facility the better for managing future cases.

2.3.3 Lessons learned in decommissioning laboratory facilities, UK

A comprehensive decommissioning plan is necessary even for the decommissioning of small facilities if costly delays and errors are to be avoided. Often a small nuclear laboratory engages the services of a specialist decommissioning company to carry out some aspects of the decommissioning plan.

It is never too soon to consider the need for decommissioning and the records that will facilitate such action. Lessons learned from past projects have identified how making assumptions without validating them can result in protracted delays and escalating costs not originally envisaged [8].

Lack of finance should not be used as an excuse to avoid making progress with decommissioning.

Supervision of an experienced decommissioning consultant contributes to keeping the overall costs of decommissioning as low as possible. (e.g.: contractor to carry out dismantling/demolition works, the cutting up of dismantled materials into manageable pieces for further characterization and radionuclide activity quantification, etc.). Such experts can provide training to the existing work staff (e.g.: to enable existing staff to characterize and quantify the waste, especially those that are suitable for free release). The confidence to decide that waste can legitimately be free released to a landfill site or scrap metal for recycling can dramatically reduce the overall costs.

Early discussions with the regulatory bodies are to be encouraged, as well as with stakeholders and residents to avoid generating unnecessary concern. Providing information during the whole decommissioning process is helpful to all parties.

The owners of small laboratories scheduled for decommissioning often have no previous relevant experience, so that a 'lessons learned' program from other similar facilities is very useful and cost and time-effective.

Wherever possible, simple, tried and tested techniques and tools should be applied throughout the decommissioning project, especially for decontamination techniques as part of waste minimization.

2.3.4 The US approach to reduce environmental risk associated with laboratory decommissioning

In order to mitigate environmental risk and reduce financial liabilities associated with laboratory decommissioning a functioning system, environmental due diligence auditing, has evolved over time and used by organizations. This system involves a 4-phase approach to identify, document, manage and clean up areas of environmental concern [12]. Environmental due diligence auditing includes:

- historical site assessment,
- characterization assessment,
- remedial effort,
- final status survey.

Phase I: Historical Site Assessment is undertaken to identify potencial areas of environmental concern, including contamination. Four processes are conducted to track various uses of hazardous substances in the laboratory:

1) interviews with the current property owner,
2) a review of documents and records,
3) a site visit to observe the current uses,
4) a written report to document Phase I findings, observations and recommendations.

The result of the report should determine either the potential contamination exists or not.

Phase II: Characterization Assessment

Potential areas of contamination identified in the Phase I are evaluated by sampling and analyses. These should provide extent of contamination and if the contaminant is present at levels above the clean up or release criteria and remedial effort is necessary or not. Instruments e.g., Geiger-Mueller counters, destructive sampling techniques and environmental media sampling are used. All findings and recommendations including whether remediation is necessary should be documented in a Phase II report.

Phase III: Remedial Effort

If the laboratory is contaminated by hazardous substances resulting to unreasonable risk to human health or environment, decontamination must be applied. The selection of decontamination method depends on the nature of contamination (radiation, microbiological, chemical), specific contaminant and contaminated surface (impervious vs porous, structural vs nonstructural). Decontamination can lead to complete removal of contaminated surface/structure for disposal (e.g. asbestos containing materials), stripping off a contaminated layer from the surface (scabbling devices are used) or cleaning (washing by solvents, vacuuming, brushing). Once a decontamination method is selected, a decontamination plan is prepared. After the plan has been implemented, the decontamination methods must be documented in a Phase III report.

Phase IV: Final Status Survey is to document the final conditions of the laboratory after remediation has been completed. For a remedial effort involving radioactive contamination, the U.S. Department of Energy has developed a certification protocol, the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM). However there is no standard for final status survey for remedial effort involving chemical contamination [12].

Application of environmental due diligence auditing system for laboratory decommissioning contaminated by H-3, C-14 and I-125 radionuclides

Phase I: H-3, C-14 and I-125 are routinely used in a biomedical research laboratory on benchtops, in chemical hoods and sometimes spilled on floors or dumped in sinks.

Phase II: Areas to survey include benchtops, hoods, gloveboxes, sinks, floors surfaces. Sink drains and waste disposal areas. Potentially contaminated surfaces can be located beneath the floor tiles and behind the hoods. Survey techniques are represented by surface scanning, direct measurements of surface activity and smears. A Geiger Mueller detector can be used for C-14, sodium iodide detector for I-125. Smears are used to measure removable activity from these contaminants by liquid scintillation counting. It is necessary to know the acceptable release criteria for these radionuclides.

Phase III: A decontamination plan ranging from simple techniques (washing, wiping surfaces) to equipment removal (hoods or sink drain lines). H-3 is difficult to completely decontaminate (it diffuses into surfaces and offgases from these surfaces), I-125 is volatile, so contamination can be widespread in the laboratory especially on metal surfaces.

Phase IV: The final status survey can be planned using the MARSIIM. The same survey techniques used to characterize contamination can be used also to demonstrate meeting the release criteria.

2.3.5 On-site experience from laboratory plant D&D in Studsvik

The decommissioning of the former nuclear Active Chemical Laboratory plant (ACL) and Active Chemical Filter building (ACF) performed by AB SVAFO had been under way since 1998. In 2005, an application for free release of the buildings was made.

The ACL building with more than 70 glove boxes was used as a research facility reprocessing spent fuel, for material testing in hot cells, production of radiation sources and storage of fissile materials. The ACF building was a filter and ventilation building for radioactive air streams from the ACL laboratory. Both buildings were contaminated mainly by Co-60, Cs-137, Sr-90, H-3 and transuranic nuclides such as Pu and Am [13].

At the start of decommissioning, the authority had no clear directives for free release limitations. Therefore specific decommissioning clearance levels were decided to use for the performance of the project, see Table 2-3.

Table 2-3 Specific Decommissioning Clearance Levels for ACL [13]

Nuclide	Activity (kBq/m^2)
Co-60	1E+01
Cs-134, 137	1E+02
Sr-90	1E+03
H-3	1E+05
Pu-238, 239, 240	1E+01
Am-241	1E+01
Pu-241	1E+03

As for the surface final survey, one sample was taken per 1 m^2 of floor and wall up to 2 m. Above this level and on the ceiling, one sample was taken per 4 m^2. Manual hand-held dose rate instruments were used and as a complementary check, 8-hour measurements with an in-situ gamma spectrometry technique were used.

Produced decommissioning waste was divided into these streams:

- combustible waste was sent to incineration facility in Studsvik,
- scrap metal (steel and aluminium) was sent to the melting facility (95% of the metals were free released as ingots),
- removed concrete, asbestos and insulating materials were deposited at a community dump,
- mixed waste in 200 l drums were sent to interim storage (crushed concrete and dust, PVC linoleum, rubber and glass.

Lessons learned from the decommissioning of the former nuclear Active Chemical Laboratory plant (ACL) performed by AB SVAFO concerning planning, organization, management and used instrumentation, are summarized form Ref. [13]:

1) There have to be check routines in place to be in compliance with timetable and at the same time maintain the quality of the work performed.

2) Strong partnership purchaser-contractor is important to deal with unexpected events during decommissioning.
3) An action plan for staff turnover for free releasing and decontamination work is necessary.
4) The strategy for cost evaluation is the key issue.
5) An advantage of open dialogue with authorities with prepared communication plan.
6) Updated drawings available and exchange of experience are essential to project planning.
7) The choice of measurement instrumentation had an effect on efficiency. The gamma in-situ spectrometry had several benefits, such as: discovery of sub-surface contamination not detectable with hand-held equipment and should have been used also during pre-studies.

3. BRIEF SURVEY OF ISOTOPE CENTRAL BUILDING

The Isotope Central Building is a radiopharmaceuticals preparation facility. The Isotope Central Building started its operation in 1960; a termination of operation was in June 2005.The main activity during the operation of the Isotope Central Building was the preparation of a broad range of about 200 radioisotopes with short half-lives (e.g. I-125, P-42, P-43, Ir-192). These nuclides were produced in the reactor R2 in the vicinity of the Isotope Central Building. The isotopes were transported to the Isotope Central Building by tube post and they were modified to required form in hot cells, fume hoods and glove boxes within laboratory rooms. It is assumed that short-lived radionuclides are no more present in current contamination of the Isotope Central Building equipment but pollutant radionuclides with longer half-lives such as cobalt, caesium or alphas will occur, mainly in contamination of air ducts of active ventilation from hot cells, fume hoods, glove boxes and in tube post system.

According to Swedish categorization of institutions / facilities dealing with radioactive materials, the Isotope Central Building is considered to be a ‘non nuclear facility’. The categorization itself depends on many factors, including operational history, chemical substance and nature of radio-nuclides having been presented or being presented, their total/specific radioactivity, encapsulation, types of activities having been performed with radioactive materials.

Neither a spent nuclear fuel has been handlednor liquid radioactive waste has been stored in the area of the Isotope Central Building. Contamination is presented on some constructions and in some equipment.

The decommissioning process is expected to be performed in two phases:

- 1st phase represents decommissioning, including release of the building out of radiological control, without demolition,
- 2nd phase represents demolition of the Isotope Central Building, remediation of site.

Each level of decommissioning strategy development, and consequently decommissioning parameters estimation/calculation, need some appropriate level of knowledge of input data, i.e. qualitative and quantitative information on building and technology to be decommissioned.

Since such collated input data (drawings, figures, parameters of civil construction and equipment to be decommissioned) have not been available for us, a site visit to make a very brief look over the AB Studstvik Isotope Central premises, has been performed. A limited number of rooms, assuming the rooms with the most contaminated equipment having been included, were visited, as well as the corridors. Another source of information was interviewing involved persons during the site visit of the Isotope Central Building.

There is a short output coming from our brief look over, in the next few paragraphs. This description does not cover all the rooms of the Isotope Central premises.

General remarks

Assumed outer dimensions of building are 30 x 15 x 12 m. Isotope Central Building consists of four floors – basemen, 1st floor, 2nd floor and attic. On these floors, elevator, corridors, laboratories, offices and service rooms are situated.

There are six hot cells in the Isotope Central Building, three of them are higher contaminated. The level of contamination has not been available.

Poly-chloride biphenyls were measured close to windows frames. The results were negative.

Asbestos can be expected within the premises. Possible sources of asbestos are the fire-protection door (asbestos covered by iron sheet on both sides), roof covering, cupboards, insulation and black glue located under the floor covering.

Basement

The floor is covered by a dense oil paint.

Corridor

There is an old pipe channel/duct under the floor through the whole length of the corridor. The surface of the pipe channel/duct is non-contaminated. There is a pipeline in the pipe duct with highly contaminated surface due to liquid radioactive waste. Therefore, the lower part of the pipe duct is covered by the steel slabs, and the slabs are grouted with the concrete layer. The upper part of the pipe duct over the concrete layer houses 2 plastic pipelines of diameter 10 cm, 15 cm respectively, low contaminated; and 1 stainless steel pipeline of diameter 8 cm, higher contaminated. The upper part of the pipe duct is covered by the concrete slabs in the corridor. The pipe duct branches to several rooms from the corridor.

The corridor houses a cable duct with lot of cables and a pipe duct/channel right-angle bending to the reactor building (R2), estimated length of which is 7 m. There is a significant amount of cables under the ceiling. A lift is located at the end of the corridor, connecting all the storeys. The majority of the contamination is allocated in the basement.

New laboratory

Plain concrete floor, walls covered by washable wallpapers, ceiling made of concrete slabs. Estimated size is 6 x 8 x 4 m. The room contains only dismantled parts of the hot cell which was operated in the room. The room was planned to house new equipment to run new business; however, the process is currently stopped.

E-003

The room contains office furniture (tables & chairs), lab tools and 2 fume hoods. Preparation of radioisotopes P-42, P-43 (protein markers) was performed in this room.

E012

The vault of dimensions approx 3.5 x 3.5 m houses a tube-post outlet and the fixed store positions for samples sent by tube-post, so called ‘magazines’. There is also an iron shielding door of thickness approx. 70 cm.

The samples were adopted here from the reactor via the tube-post, then stored and consequently sent off again via the tube-post to the hot cells. The tube-post branches also to the laboratory next to this vault.

E-013

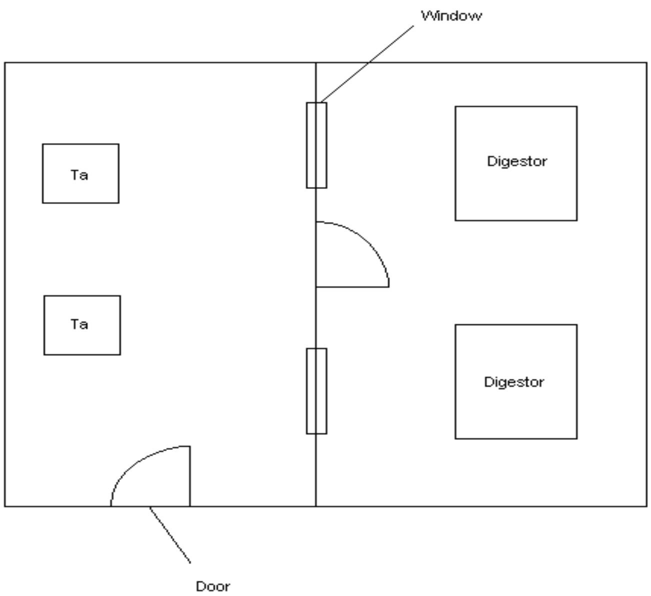
A rough layout of the room is shown in the

Figure 3-1. Preparation of radioisotopes I-125 was performed in this room.

E-002

The room contains 1 large hot cell (3 x 2 x 2.5 m), 2 small hot cells (1 x 1 x 1 m) and a portal rail crane. The room was reviewed from the door-sill. There was an aluminium barrier in the doorframe up to height of 30 cm from the door-sill. A smear sample should exists, however information on contamination level is not available.

Figure 3-1 Simplified layout of the room E-013



Ground floor (comprises approx 10 rooms)

Corridor

There are a few large cubical switchboards.

116 A

The room contains a hot cell, which is higher contaminated, 2 portal cranes (each of lifting capacity 1.5 ton), 2 cranes (each of lifting capacity 1 ton).

The floor is covered by polyester-laminate. The walls are slightly oil-colour painted. There are laboratory desks and residual laboratory tools.

The hot cell (approx 3 x 2 x 2.5 m) consists of iron skeleton filled with lead blocks of width approx. 30 cm. There are also 2 lead-glass eye-sights and 2 two-handed stainless steel manipulators in the hot cell. The lead inner surface of the hot cell is covered by a cracked plastic covering. The hot cell houses also aluminium grates and tools, measuring glasses and test-tubes.

A tube-post is contaminated.

Offices

3 offices were visited. There is a linoleum floor, concrete ceiling with aluminium soffit and pipelines.

1st Floor

E204

There are 2 fume hoods, 1 box made of lead shielding blocks (80 x 80 x 80 cm), a tube-post control panel, a bunch of pipes of the tube-post, laboratory desks, 1 ceramic sink.

The floor is covered by linoleum. The walls are slightly oil-colour painted. An aluminium soffit is on the ceiling.

E 205

This is a laboratory room housing 3 fume hoods having been used for radiological measurements. The floor is covered by linoleum. The walls are oil-colour painted. An aluminium soffit is on the ceiling.

E 206

The room was used as a laboratory; in the time of visit it was empty. The floor is covered by linoleum.

E 208

The room was used as a larger laboratory. In the time of visit it was used as a temporary store of material, which will be removed prior to decommissioning. There are also 4 laboratory desks.

The floor is covered by linoleum. Oil painting on the walls is cracked. An aluminium soffit is on the ceiling.

Offices

Further rooms on the 1st floor are supposed to be offices. Not visited.

Attic

The floor and walls are covered by a rough concrete without any additional covering. The ceiling is made of porous concrete. 7 doors were identified at the attic.

E304

The floor is thick-painted, the walls are common painted. The ceiling is made of porous concrete panels, the height of ceiling is approx 2.5 m.

There is also a zinc-covered sheet piping of diameter 30 cm. Vent tubes are made of either ferrous sheet or plastic.

This is a passable room to the store room, where RA waste is stored in the small steel sheet drums with lids, each of volume approx 25 l; tens of drums are stored there. The drums contain rags, textiles, plastics, plastic foils, and stainless steel joints.

E 305

The floor is covered by polyester-laminate, the walls are oil colour-painted. The ceiling is made of porous concrete panels; the height of ceiling is lowered against the corridor.

This is a ventilation machinery room providing ventilation for common rooms. A contamination is low level.

The plastic piping which diameter is 50 cm and higher, prevails over the ferrous sheet piping. There are also filter drums (10 pcs, diameter 0.75 – 1 m), wooden skeleton filter cartridges, 2 big blowers including electro-motors (power approx 10 kW) and 1 small blower including electro-motor (power approx 5 kW).

E 306

The floor and walls are covered by oil-colour painting. There is a fire protection door with asbestos slab

(1.3 x 2.5 m).

This is a ventilation machinery room providing ventilation for medium and higher contaminated rooms and facilities (e.g. hot cells).

Approximately 90 % of vent tubes are made of ferrous sheet (rectangular cross-section, approx

1 x 0.4 m).The rest of vent tubes are made of plastic of diameter min 50 cm. There are several big rectangular filters.

The above mentioned facts obtained from walkdown of the facility and interviewing operational personnel in the Isotope Central Building together with professional assessment of equipment types, material amounts and composition and physical parameters were used for creation of model inventory database described in Chapter 6.

4. DESCRIPTION OF DECOMMISSIONING COST CALCULATION CODE OMEGA

For the performance of cost calculations for Isotope Central Building decommissioning planning, the Omega calculation code has been chosen.

The computer code OMEGA, developed at DECOM, a.s., is an option oriented calculation and optimization code for applications in decommissioning decision making processes for nuclear facilities of various types and radiological properties with following purposes:

1) Definition of the set of decommissioning calculation options according to the standardised structure for facilities with various building and technology inventory structure and with various radiological parameters.
2) Calculation of costs and other decommissioning parameters (such as manpower needs, collective effective dose, waste distribution from decommissioning process etc.) for individual calculation options, for calculated data processing and evaluation.
3) Optimisation of individual calculation options and waste management within the individual options.
4) Comparison of options and selection of the most suitable one based on multi attribute analysis.

Basic properties of the calculation code OMEGA for applications on the level of the calculation options [1]:

- Activity based costing was implemented, based on the Proposed Standardised List of Costs Items (PSL) [9] issued commonly by OECD, IAEA and EC which enables to use the code for various types of nuclear facilities.
- Automatic generation of the standardised calculation structure based on the template calculation structures, and conditions defined by the user and based on inventory data. This automatic generation of the calculation options facilitates significantly the multi option work.
- The code was originally developed for Jaslovske Bohunice A-1 NPP costing with complicated radiological situation. A new concept of calculation modelling of material and radioactivity flow control was implemented in order to increase the accuracy of calculation and for optimisation of radioactive waste management. The code can be used for facilities with various radiological states. The accuracy of calculation of decommissioning parameters is significantly higher then using the traditional costing methodologies where the amounts of waste are estimated.
- The calculation process is nuclide-resolved. This enables to use limits on the nuclide level for treatment / conditioning / disposal / release (unconditional and conditional) of materials as well as calculation of the radioactivity decay to study the effect of deferred activities.
- On-line optimisation of decommissioning options in standard Microsoft Project software using the work breakdown structure, constructed as the upper layer over the standardised structure.

The pre-requisite for efficient work with the OMEGA code is the inventory database of the facility with relevant systems, buildings and radiological data and the calculation database with relevant data for processes, profession / work time data, material / nuclide data and other data.

Main calculated parameters are costs in standardised structure, manpower and exposure items (total values and profession resolved items), material items and nuclide resolved radioactivity items linked to these material items (so called waste distribution), time parameters such as starts and duration of elementary activities and of phases of the process and equipment planning items.

Based on described features of OMEGA code decommissioning calculation a simplified scheme of OMEGA data processing can be created:

Figure 4-1 Simplified scheme of OMEGA data processing

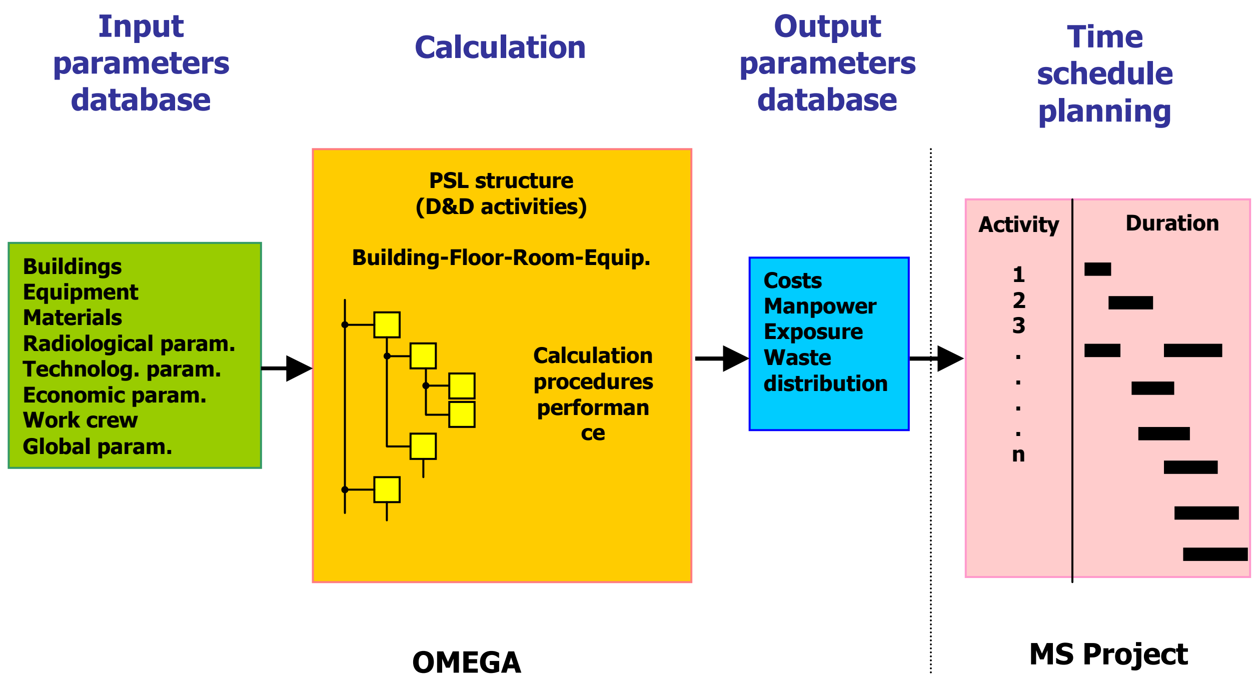


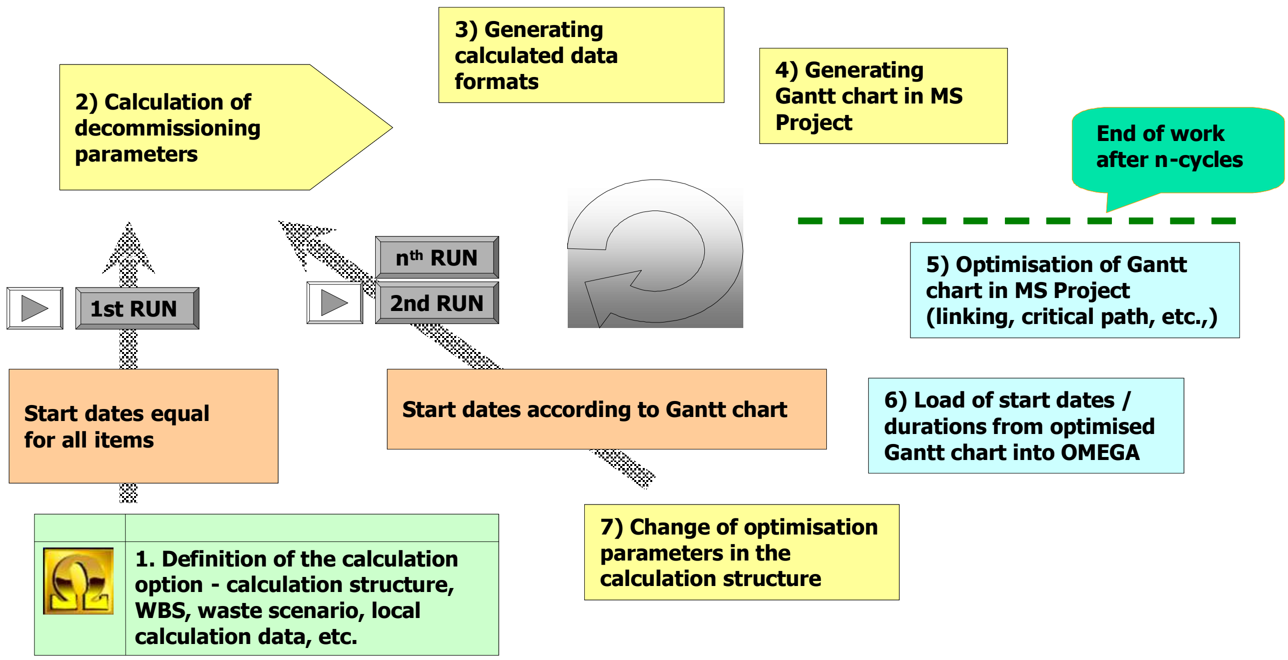
Figure 4-1 identifies input/output data, decommissioning process calculation and its time schedule planning. Displayed OMEGA input database applied in decommissioning calculations for Isotope Central Building are characterised in detail within Chapter 3.

The work with OMEGA for management of the decommissioning calculation option has an iterative character with following main steps displayed on Figure 4-2:

1) Definition of the calculation option in the scope of calculation structure, WBS, waste scenario, local calculation data, extent of calculation, etc.
2) Calculation of parameters in the first calculation runs with start dates equal each other.
3) Generating the calculated data formats.
4) Generating the Gantt chart in MS Project.
5) Optimisation of the Gantt chart in MS Project (linking, critical path, etc.,).

6) Load of start dates / durations from optimised Gantt chart into OMEGA, change of optimisation parameters in the calculation structure.
7) Calculation of decommissioning parameters with start dates derived from the Gantt chart, calculation of optimised decommissioning option. Repeated calculations with start dates derived from Gantt chart up to achieving the finally optimised decommissioning option ready for multi-attribute analysis of individually calculated / optimised / evaluated projects.

Figure 4-2 Graphical interpretation of main steps of the iterative work with Omega



Principles of algoritmisation of costs calculation in the Omega code can be summarised as follows:

1) What to do - management of the standardised calculation structure. Definition of decommissioning activities and extent of calculation,
2) How to do - management of calculation conditions. Definition of calculation procedures, definition of local calculation input data and correction factors,
3) In what sequence management of material/radioactivity flow in decommissioning by definition of calculation sequence and by data linking of calculation procedures (calculation modelling of decommissioning process),
4) At what time - management of time in decommissioning by on-line optimisation of decommissioning time schedule with feed-back to the calculation structure supported by dynamical recovery of radiological parameters.

5. CONDITIONS FOR TENTATIVE DECOMMISSIONING CALCULATIONS

The tentative decommissioning calculations using OMEGA code are performed for the Isotope Central Building in Studsvik.

For these calculations an inventory database of the Isotope Central Building is used based on relevant information obtained mainly by site visit. Another source of information was interviewing involved personnel from the Isotope Central Building. Unfortunately, technical documentation such as civil construction drawings, technological systems drawings, piece lists of equipment and materials and any other documentation on operation was not available at the time of preparation of test decommissioning calculations for the Isotope Central Building. Moreover, the only radiological data obtained were the personnel communications during the site visit. Therefore input radiological inventory was assumed based on similar research laboratory described in Chapter 2.3.

Since big efforts and works have been done in the field of preparation of input data for Isotope Central Building tentative decommissioning calculations, a separate Chapter 6 describes the development of input datasheets for Isotope Central Building in Studsvik. It has to be stressed out that except of inventory database, the most of technical and economical necessary calculation data are based on international and Slovak input parameters. These parameters characterize the decommissioning process and its individual activities from preparatory activities through dismantling up to waste treatment and disposal of radioactive waste. Moreover, the Slovak waste management scenarios as well as the end points - repositories or release into environment together with their radiological limits are applied.

The Swedish data were used in database of labour costs units factors – average wages of main personnel professions - see Annex 2-1. These parameters have crucial impact on costs of the decommissioning projects.

This approach of combination of the Isotope Central Building in Studsvik inventory database, Swedish labour costs (have major influence on overall costs) and the database of international cost unit factors and Slovak calculation parameters was applied to make first tentative calculations for demonstration of using the advanced decommissioning costing calculations for a small research/laboratory facility.

The decommissioning activities included in the presented calculations for the Isotope Central Building are divided into the following categories:

- preparatory activities,
- dismantling activities,
- decontamination of building surfaces,
- final building radiation survey,
- post-dismantling decontamination of technological equipment,
- waste management activities: Sorting of dismantled material, treatment and conditioning activities of dismantled material including packaging, transportation and disposal activities,
- demolition, site restoration and release of the site,
- management and support decommissioning activities.

The facility equipment is proposed to divide into four groups, considering their potential radioactivity contamination:

- non-contaminated equipment,
- potentially contaminated equipment,
- air-conditioning equipment,
- hot cell equipment.

As for the radiological inventory, a proposed nuclide vector consists of longer-life nuclides only. Predominant nuclide is Co-60, also small presence of Cs-137 is assumed as well as traces of some alpha nuclides. More details are presented in chapter 6. Mentioned radionuclides can occur in contamination as pollution originated from the reactor operation where the radiopharmaceuticals with very short half-lives (from tens of hours to tens of days) were prepared.

Three contamination levels of all the potentially contaminated equipment are supposed for the purpose of sensitivity calculations as follows:

- basic level according to assessed radiological data,
- level 10 times higher than basic level,
- level 10 times lower then basic level.

These margins should demonstrate an influence of radioactivity of decommissioned equipment to the overall decommissioning parameters.

The chosen waste treatment scenario evaluated in calculations for the Isotope Central Building by OMEGA code comprises availability of wet bath post-dismantling decontamination facility for iron/steel radwaste and melting facility for iron/steel radwaste at decommissioning site.

Demolition works of the Isotope Central Building civil constructions assumed in calculations is supposed to level -1m below surrounding level. All spaces below this depth will be filled up with recycled debris from demolition works and other filling material and the place will be landscaped.

For all performed decommissioning calculations the set of the following output parameters divided into two groups were evaluated and discussed:

1) **Main general decommissioning parameters** - these parameters characterize the decommissioning option from the overall management point of view. Costs, manpower and collective dose equivalent are included in this category.

- **Costs** - integral parameter, sensitive to any change of input decommissioning parameters. The parameter summarizes the subtotal costs items connected with decommissioning activities - labour costs, investment costs, expenses and contingency.
- **Manpower** – represents the sum of overall work carried out during the decommissioning process and it is influenced mainly by radiation situation and working conditions.

- **Collective dose equivalent** - represents the sum of all individual dose equivalents for all decommissioning personnel. It depends on individual dose rates at workplaces during the work execution and manpower needed of individual work processes.

2) **Distribution of materials arisen from decommissioning** - these parameters characterize the decommissioning option from the dismantled material distribution point of view. This category contains a mass distribution of given materials either destined to repositories or released into environment:

- **material released to environment after dismantling** – directly released material without application of post-dismantling decontamination,
- **material released to environment after decontamination** – dismantled material released after post-dismantling decontamination without melting,
- **material released to environment after melting** - dismantled material released after post-dismantling decontamination and consequent melting or direct melting without decontamination,
- **material destined to the near-surface repository** – non-releasable material, placed in fibre reinforced concrete (FRC) containers for near-surface repository disposal,
- **material destined to the deep geological repository** - non-releasable material, placed in containers for deep geological repository disposal.

Given calculated parameters are evaluated and compared numerically and graphically for the above mentioned three contamination levels of the Isotope Central Building equipment.

6. DEVELOPMENT OF DATABASE FOR THE INPUT DATA APPLIED IN CALCULATIONS

This chapter describes the concept of inventory and calculation database creation for Isotope Central building decommissioning tentative calculations.

Input database needed for calculations in OMEGA code is in principle created by two main types of input data:

- Inventory data – parameters characterizing decommissioned facility,
- Calculation data – parameters characterizing decommissioning process.

Extent of both types of data is large. In the case of inventory data it means to create a database of facility in buildings – floors – rooms – equipment structure with their tables. This database includes all together several hundreds of parameters describing physical and radiological parameters of facility e.g. dimensions, area of surfaces, weight, inner volume of equipment, contaminations, dose rates, nuclide vectors, categories of equipment etc.

Calculation database is even larger and consists of huge amount of tables with parameters characterizing decommissioning process with its individual activities. These parameters are heterogeneous; they include e.g. cost unit factors, consumption unit factors, parameters of working groups, time duration parameters, and a lot of other parameters needed for mathematical description of decommissioning process.

In this chapter only most significant and relevant parameters which are used for purposes of Isotope Central Building calculations are mentioned. Developed datasheets with inventory database data and selected calculation data are included as separate Annexes due to their large extent.

6.1 *FACILITY INVENTORY DATA*

For the purpose of decommissioning cost calculations using OMEGA code, an input database of the Isotope Central Building at Studsvik has been created. Creation of inventory database is one of the main and the most time-consuming preparatory activities for decommissioning calculations.

The inventory database encompasses all essential data which characterize the Isotope Central Building. This database is a baseline for performing any decommissioning calculation of the facility. It includes characterization of physical, material and radiological properties of individual equipment, building structures and rooms within facility. Whole inventory database is structured in logical hierarchical structure building – floors – rooms – equipment. It means that each equipment is assigned to given room, floor and building and is fully traceable within this inventory database structure.

In the following text, the concept of inventory database creation is described (including physical and radiological data generation) together with systematics and data arrangements within particular data tables.

6.1.1 Approach to inventory database creation – physical parameters

The database of material inventory was created on the basis of the visual inspection of the Isotope Central building in 2007, and further visual inspection repeated the year after. There was neither technical documentation, nor design documentation and nor lists of equipment or other technical documents available from the customer, which would have been suitable for generation of the database. Identification of material types and summarizing amount and weights of material was based on expert assessment and judgement taking into account estimation of size, dimensions, material composition and material densities of individual equipment. Part of the technical data was gained from interviewing the operational stuff, which accompanied authors during the above mentioned visual inspection. The visual inspection was performed in the whole building of the Isotope Central, for each individual floor. Empty rooms were considered to be offices. Four rooms equipped with hermetic doors were not accessible during the visual inspection. According to staff's information these rooms are empty; they contain only contaminated ventilation systems and tube post piping.

Basement

The basement consists of the main corridor and several rooms on both sides of the corridor. The corridor in the basement is equipped with duct under the surface of the floor. The duct houses two stainless steel pipes and two plastic pipes. According the staff's information the stainless steel piping was grouted by concrete due to their high contamination. For the both types of piping, their weight was calculated on the basis of estimated length and width of the walls. Figures of specific mass of the stainless steel and polyethylene were used for calculation.

- On the basis of survey of the corridor, the following material items were added to the database: power and data cables, lights and other electric equipment including cable ducts which were visible. Weights of these equipment were estimated by expert assessment on the basis of their sizes and construction materials. For cables, their weight was calculated separately for each diameter and cable type.
- The weights of the hot cells were also added to the database. The weights were estimated by expert judgement on the basis of information gained from accompanying stuff. The weights of the hot cells of both sizes, which are located in the building, were calculated on the basis of estimated outer sizes, thickness of stainless steel covering and thickness of lead shielding. The total weight of each hot cell contains also led-glass visor and supplementary handling tools in the cells.
- For lifting equipment located in the rooms of hot cells, approximate weights were calculated on the basis of the equipment sizes and their loads estimation.
- In the hot cells rooms, the ventilation systems were installed as well as pipes of the tube post, where the contamination is expected. Technical data on these equipment were estimated on the basis of survey as well as verbal information gained from the staff.
- Glow boxes and fume hoods were located in two rooms in the basement. As for these equipment, a contamination of technological surface is expected. Weights of these equipment were estimated on the basis of staff´s information and equipment sizes.

Ground floor

There are several rooms located on the ground floor without any technological equipment installed, except of ventilation pipes. However, there are also rooms containing contaminated equipment and one room contains the hot cells installed.

- The weight of non-contaminated ventilation piping was estimated on the basis of the pipe length and diameters.
- The hot cell located on this floor was added to the database. The weight of the hot cell was estimated by expert assessment as well as using the calculations, similarly to the hot cells located in the basement.
- Ventilation piping and tube post located in the room of the hot cell are contaminated. Weight of the pipes was estimated using the above mentioned means.
- The room of the hot cell is equipped with two lifting equipment, which weights were estimated by expert judgement on the basis of their sizes and load.
- In the corridor of the ground floor there are electric switch boards, supplementary electric equipment, power cables and lights. The weights of these equipment were estimated by expert judgement in the way mentioned in the following paragraph.
- As for electric cables, unit weight of one meter length for each type of cables was estimated. The estimation is based on the diameters and types of cables. Total weights of cables were calculated on the basis of total length and unit weight of relevant cables.
- As for supplementary electric equipment and electric switch boards, their weight was estimated on the basis of their sizes and structure of the switch boards, using expert judgement.
- The weight of the lights and other electric equipment was estimated by expert judgement.

First floor

A couple of empty rooms, without any equipment, are located on this floor. There is also a room containing two glow boxes.

- As for glow boxes, a contamination of inner surfaces is expected. Weight of equipment was estimated by expert judgement on the basis of equipment size.
- Weight of contaminated ventilation pipes was calculated on the basis of the sizes, length of pipes and specific weight of construction material (carbon steel).
- A room has been identified containing two contaminated fume hoods, contaminated ventilation pipes and the tube post. The weight of boxes was estimated on the basis of the sizes and specific weight of construction materials, using expert judgement.
- Weights of pipes were calculated on the basis their diameters, length and specific weights of construction materials.
- The last room with contaminated equipment located at this floor was equipped with a container and lead shielding box. The weight of individual equipment was estimated by expert judgement.

Attic

The attic represents the highest floor of the Isotope Central building. There are two ventilation machinery rooms, for non-contaminated and contaminated ventilation, in the attic.

- The rooms contain ventilation pipes of various diameters, heat exchangers, ventilation filters of various types and sizes. Their weights were estimated by expert judgement on the basis of their diameters, outer sizes and specific weight of construction materials.
- As for valves and the other control items located in the rooms, the weights were estimated and consequently summed to the total figures.
- Ventilators with electric motors and supplementary electric equipment including electric switchboards located on this floor were divided into two groups, i.e. contaminated and non-contaminated equipment. The weights of all above mentioned technological equipment were estimated on the basis of their sizes, types, construction materials and relevant specific weights.
- As for the lift shaft room, the weight of lift cabin was estimated as well as weight of steel construction, metal ropes, weight units (ballast) and machinery unit including electric engine and gear.

Civil construction part

During the generation of inventory database there was no information coming from design documents or any other supplementary information describing the civil construction. The inventory collated is based on the following information gained.

The Isotope Central Building is four-storey building with one underground storey, a ground level storey and two floors over the ground level. Based on the survey, the high of each floor was estimated to 4 meters. Estimated sizes of the floor plan are 15 m x 30 m.

- During the generation of the inventory, a massive foundation was assumed. On the basis of the assumption, the foundations were built from the lay of the plan concrete and a thick lay of reinforced concrete.
- Peripheral walls of the basement are made of reinforced concrete as well as the walls of rooms. Massive constructions of the floor in the basement and on ground floor are expected, due to significant load of floors, because of hot cells installed.
- A massive reinforced construction of walls is expected in the four rooms with hermetic doors located in the basement. Estimated thickness of the walls is 1 m.
- It is assumed that peripheral walls of the building on the floors over the ground (the first floor and the attic) are made of panels. Inner walls are assumed to be made of mason. The roof is made of blocks and panels.
- The roof is covered by insulation lay to avoid penetrating of rain water.

The weight of above mentioned civil construction materials was calculated. The calculations were based on physical dimensions of the civil construction structures and specific weights of individual types of materials.

There are fire protection doors installed on the individual floors. Their weight was calculated on the basis of their sizes. It is assumed that the fire protection doors contain asbestos. Weights of hermetic doors in the basement were estimated on the basis of the size of the doors and construction material used. In the corridors and in the offices the ceilings are lowered using decorative materials, i.e. aluminium and steel elements. Unit weights of these materials were also estimated. As for rooms with contaminated equipment, the floors were made of epoxide. As for the rest of rooms and offices, the floor was covered by vinyl. The weight of the floor covering was calculated on the basis of the total surface covered and specific weight of vinyl.

6.1.2 Approach to inventory database creation – radiological parameters

Radiological parameters of decommissioned facilities are important part of the input data for decommissioning parameters calculation. On the basis of radiological parameters a material flow as well as an amount of material arisen from decommissioning can be calculated. This encompasses contaminated materials as well as non-contaminated materials. It means that knowledge of the radiological data is necessary for performance of decommissioning parameters calculation from dismantling up to final landscaping of decommissioned facility.

As mentioned above, the input data calculation database of decommissioned facilities is based on the walk down of the Isotope Central building as well as on the information gained from the Isotope Central operational staff. Within this obtained information there were no such information concerning the radiological parameters as data on contamination of equipment and civil construction surfaces, data on dose rates from individual equipment and those in rooms and corridors of the Isotope Central or data on radionuclide content of contaminants and the dose rate sources. This is why we decided to make an expert judgement of these calculation vital data, based on similarities between the Isotope Central and other facilities of the similar type or purpose in the world, as they are mentioned in Chapter 2. The following radiological parameters have been estimated by an expert judgement:

- contamination of equipment surfaces,
- contamination of civil construction surfaces,
- dose rate from equipment,
- contamination nuclide vector,
- dose rate nuclide vector.

Contamination of equipment surfaces

- As mentioned at the beginning of this chapter, the following 4 contamination levels for technological equipment surfaces have been defined on the basis of known radiological parameters of similar radiological laboratories in the world as well as information on the Isotope Central operational history. Assigning of types of equipment to individual contamination levels have been used regarding to type, purpose and assumed possibility of contact with contaminated materials during former operation of equipment:
- 5 Bq.cm^{-2} - hot cells, vent systems/pipes for the hot cells and fume hoods, pipes housed in the duct in the basement,
- 0,5 Bq.cm^{-2} - pipes of the tube post, fume hoods, glow boxes,

- 0,05 $Bq.cm^{-2}$ - other vent pipes,
- 0 $Bq.cm^{-2}$ - other equipment as electric cables and equipment, electric motors, doors.

Database of the individual equipment according to rooms, including the contamination values, is listed in Annex 1.

Contamination of civil construction surfaces

On the basis of walk down and expert assessment, the conclusion has been made that it might be necessary to perform decontamination of specific civil minor isolated construction surfaces. These 'hot-spots' at the civil construction surfaces may be contaminated due to contact with contaminated medium (closed to contaminated vent piping, hot cells, contaminated liquid radioactive waste piping, etc.). Total area of these surfaces to be decontaminated as well as their surface contamination is roughly assumed as follows:

- 5% of surface of all walls within the Isotope Central (200 m^2) – contamination 0,5 $Bq.cm^{-2}$
- 10% of surface of all floors within the Isotope Central (160 m^2) – contamination 0,5 $Bq.cm^{-2}$.

Therefore for civil construction surfaces, 2 contamination levels have been considered: 0,5 $Bq.cm^{-2}$ and 0 $Bq.cm^{-2}$ it means that the rest of building surfaces (walls and floors) is considered to be clean with contamination not exceeding natural background.

Above mentioned surfaces as well as values of contamination were incorporated into the inventory database and allocated to so-called 'virtual room', located in the attic.

Preferred decontamination technique for the walls is chemical decontamination using decontamination foams, and for the floors it is mechanical decontamination using grinding.

Dose rate from equipment

The estimation of the dose rate is based on the surface contamination classes of equipment as mentioned above. The levels of the dose rates, taking in the account the Isotope Central building walk down, were estimated for individual equipment of the Isotope Central as follows:

- 5 $\mu Gy.h^{-1}$ - hot cells, vent systems/pipes for hot cells and fume hoods, pipes housed in the duct at the basement,
- 2 $\mu Gy.h^{-1}$ - pipes of the tube post, fume hoods, glow boxes,
- 1 $\mu Gy.h^{-1}$ - other vent pipes,
- 0 $\mu Gy.h^{-1}$ - other equipment as electric cable and equipment, electric motors, doors.

The database of individual equipment according to room as well as dose rate values is listed in Annex 1.

Average dose rate in rooms

Estimation of dose rates in rooms of the Isotope Central building was made as follows:

- 0,5 $\mu Gy.h^{-1}$ - technological rooms,
- 0,2 $\mu Gy.h^{-1}$ - other servicing rooms except technological and office rooms,
- 0 $\mu Gy.h^{-1}$ - offices.

The levels of the dose rates were estimated taking in the account the Isotope Central building walk down and types of rooms from the point of their purpose during the operation.

Contamination nuclide vector

Taking into account a purpose of the Isotope Central as well as the operational history, the for contamination of equipment and civil construction surfaces has been other facilities of the similar type or purpose in the world (some of them are well as Isotope Central personnel interviewing and also the expert judgement. only long live radionuclides. These nuclides are significant from the point of the point of waste treatment, releasing or disposal of waste. Contamination percentage level of individual nuclides within contamination of materials. The contamination is shown in the next

Table 6-1.

Table 6-1 Contamination nuclide vector of equipment and civil construction surfaces [%]

Ra-nuclide	^{3}H	^{14}C	^{60}Co	^{137}Cs	^{90}Sr	^{241}Am	^{239}Pu
Percentage [%]	1	1	90	5,9	2	0.05	0.05

Co-60 is assumed as a major contaminant of equipment surfaces. Abundance of Cs-137 is proposed to be around 1/20 of overall radioactivity. Radioactivity of Sr-90 is simulated to be around 1/50 of overall radioactivity and activity of H-3, C-14 and alpha contaminants is proposed to be 1/1000 of overall radioactivity for each. Am-241 and Pu-239 are proposed as typical representatives of alpha contaminants.

The above mentioned nuclide vector was used as general nuclide composition of contamination within the whole Isotope Central Building and was allocated to all the equipment and civil construction surfaces within the database.

Dose rate nuclide vector

Similarly to contamination nuclide vector, also a dose rate nuclide vector has been estimated. Taking into account the percentage level of individual contaminating nuclides in the contamination nuclide vector as well as radiological impact of individual nuclide (represented by kerma constant), the dose rate nuclide vector is represented by the only one radionuclide, 60Co (100 % presence).

This dose rate nuclide vector was allocated to all the equipment as well as civil construction surfaces within the database.

6.1.3 Inventory database structure

As it was previously mentioned, database structure consists of database tables of buildings, floors, rooms and equipment. For decommissioning calculation of Isotope Central Building, inventory database tables were created based on previous mentioned approaches.

Individual database tables with their content are described in the text below. Complete database is attached in Annexes 1.1 – 1.3.

6.1.3.1 Database of buildings

Only one building is used for purposes of the Isotope Central Building. This building contains all equipment (technological equipment and building structures) which is being a subject of decommissioning.

6.1.3.2 Database of floors

The Isotope Central Building is formed by main building with four floors: basement, ground floor, first floor and attic.

Floors have no significant description in inventory database. They are used only for accurate localization of rooms within calculation structure.

6.1.3.3 Database of rooms

In this table, all rooms within the Isotope Central Building are listed. Each room is characterized by several parameters, such as:

- Identification number of the room,
- Reference to the floor and building,
- Number of the room,
- Name of the room,
- Dimensions of the room,
- Average dose rate inside the room,
- Nuclide vector of dose rate,
- Reference date for dose rate [DD.MM.YYYY].

All of these parameters are required by OMEGA code during development of decommissioning calculation structure and calculation itself.

Rooms are assigned to individual floors.

Room dimensions were assessed on the basis of site visits (see Chapter 6.1.1).

Average dose rate in rooms was estimated by an expert judgement based on similarities between the Isotope Central and other facilities of the similar type or purpose in the world (see Chapter 6.1.2).

Dose rate nuclide vector is 100 Co-60 (see Chapter 6.1.2).

Reference date for dose rate. We have decided to use year 2009 as a date of dose rate evaluation. This date is used for calculation of dose rate decrease with time.

All rooms are assigned to controlled area. Completed database implemented into OMEGA code is listed in Annex 1.2.

6.1.3.4 Database of equipment

The main portion of input inventory database is created by database of equipment. It means technological equipment (pipes, valves, tanks, ventilation, motors etc.) and also building structure equipment (walls, building materials). Both of these types of equipment should be taken into inventory database for calculation of decommissioning parameters. In most cases, individual technological equipment located in the room corresponds to particular database items. Each database item within the Isotope Central Building in Studsvik is characterized by relevant parameters as follows:

- Identification number of technological equipment or building structure – identification of database item within the database,
- Name of technological equipment or building structure,
- Number of room to which technological equipment or building structure is assigned,
- Weight of technological equipment or building structure [kg],
- Inner surface of technological equipment [m^2],
- Outer surface of technological equipment or building structure [m^2],
- Inner surface contamination of technological equipment [Bq/m^2],
- Outer surface contamination of technological equipment or building structure [Bq/m^2],
- Nuclide vector of inner surface contamination – represents an average isotopic composition of inner surface contamination source [%],
- Reference date for inner contamination and nuclide vector of inner surface contamination [DD.MM.YYYY],
- Nuclide vector of outer surface contamination – represents an average isotopic composition of outer surface contamination source [%],
- Reference date for outer contamination and nuclide vector of outer surface contamination [DD.MM.YYYY],
- Dose rate nearby technological equipment or building structure – dose rate 0,5 m from the surface of the technological equipment or building structure [□Gy/h],

- Nuclide vector of dose rate – represent an average isotopic composition of dose rate source [%],
- Reference date for dose rate and nuclide vector of dose rate [DD.MM.YYYY],
- Inner volume of technological equipment – parameter used only for pre-dismantling decontamination by autonomous circuits (not necessary for all equipment),
- Category of technological equipment or building structure – characterizes type, shape, dimensions and material composition of technological or building equipment. This parameter is used for assignment of default dismantling and demolition procedures.

Inner and outer surface of equipment were assessed on the basis of site visits (see Chapter 6.1.1).

Nuclide vector of inner and outer surface contamination was estimated by an expert judgement based on similarities between the Isotope Central and other facilities of the similar type or purpose in the world (see Chapter 6.1.2).

- Co-60 90,0% half life – 5,27 y
- Cs-137 5,9% half life – 30,00 y
- Sr-90 2,0% half life – 28,78 y
- H-3 1,0% half life – 12,33 y
- C-14 1,0% half life – 5730,00 y
- Am-241 0,05% half life – 432,20 y
- Pu-239 0,05% half life – 24 110,00 y

Proposed nuclide vector is used both for inner and outer surfaces.

Nuclide vector of dose rate was used the same as for average dose rate in rooms, 100 % Co-60.

Contamination of inner or outer surfaces. were estimated by an expert judgement based on similarities between the Isotope Central and other facilities of the similar type or purpose in the world. Four levels of contamination have been used regarding to type, purpose and assumed possibility of contact with contaminated materials during former operation of equipment (see Chapter 6.1.2).

Reference dates for inner, outer contamination and dose rate. We used the same date as in the case of room dose rate, 2009.

Categories of equipment. The categorization of equipment implemented in OMEGA code was used. Based on this approach, 27 categories for technological equipment and 10 categories for building equipment were used. The list of used equipment categories is shown in the next tables:

Table 6-2 Table of technological equipment categories used for equipment in the inventory database

	Technological equipment	
	Category of equipment	**Number of database items**
Digestor	Digestors (CS)	6
Electric and control equipments	General electric equipment, (CS) mass <= 50 kg	10
	Electrical cables & conductors; (Cu), 1 kV power cables	10
Motors	Electric motors, mass > 50 kg	1
Ventilators	Ventilators (CS), mass <= 50 kg	2
	Ventilators (CS), mass > 50 kg, at least one dimension > 1m	2
Heat exchangers	Heat exchangers (CS) , diameter <= 1m, typical wall thickness 20 mm	1
Pipes	Piping (PE, PP ...), diameter <= 100 mm	24
Air condition equipments	Air conditioning systems, filter casings (CS), dimension <= 1m	5
	Air conditioning components - piping (CS), cross section < 0,16 m2	15
	Air conditioning components - piping (CS), 0,16 m2 =< cross section from <= 1 m2	1
General material categories	General category - colour metals equipment	27
	General category - stainless steel equipment	6
	General category - carbon steel equipment	16
Hoisting equipments	Hoisting equipment, (CS), small manual tackles	2
	Hoisting equipment (CS), crane rails	2
Firefighting door	Firefighting door, C steel cladding, asbestos plate	35
Hermetic and shielding doors	Hermetic and shielding doors (CS)	4
Steel constructions	Steel constructions, (CS), doors and manhole covers	1
	Steel constructions, (CS), hangings of piping, general hangings	3
	Steel constructions, (CS), platforms and stages	2
	Steel constructions, (CS), stairs, ladders, railings	1
	Steel constructions, (CS), shieldings	1
Embeded piping	Embedded piping - sewer piping, (SS), typical dimensions - D 100 mm/6 mm	2
Hot cells	Hot cell; C steel cladding, lead shielding, (typical dimensions 3 x 2,5 x 2 [m])	8
Sampling boxes	Sampling boxes (CS)	1
Other	Floor covering (flooring) PVC	17
Total		**205**

Table 6-3 Table of building structure categories used in the inventory database

	Building structure	
	Category of equipment	**Number of database items**
Building surfaces for decontamination	Building surfaces for mechanical decontamination	1
	Building surfaces for chemical decontamination	1
Bulding construction materials	Contaminated concrete	2
	Masonry	1
	Peripheral walls - panels	1
	Steel skeletons, (CS)	3
	Other building construction	2
	Prefabricates	1
	Reinforced concrete, thickness <= 400 mm	11
	Reinforced concrete, thickness => 700 mm	13
Total		**36**

There were also added some building structures for purposes of calculation of demolition and decontamination of building surfaces in OMEGA code, as follows:

- items characterizing weight of building materials for demolition of building structures,
- items characterizing surfaces of building materials for decontamination of building surfaces,
- contaminated surfaces of floors - expected mechanical decontamination,
- contaminated surfaces of walls - expected chemical decontamination.

These building structure items have been estimated for whole Isotope Central Building as total values. This is why, they were not allocated to existing rooms but to the "virtual room" having been created in the database for the this specific reason.

Using this hypothetical "virtual room", which does not exist physically, is necessary due to implementation OMEGA Code room oriented calculation approach. This approach means that each equipment (either technological equipment or building structure), which is subject to decommissioning, has to be allocated to individual room within the database.

The complete inventory database used for calculation including all databases (floors, rooms, equipment) and items within these databases is listed in Annexes1.1 – 1.3.

6.2 *CALCULATION DATA*

One part of input data is represented by inventory database mentioned in previous text. The second part of input data is calculation data. These data describe activities which are carried out during decommissioning process.

In OMEGA code, individual decommissioning activities are described by mathematical models. These models are represented by calculation procedures. Calculation procedures need for their run a set of calculation parameters which characterise and quantify input parameters of procedure. That includes a broad spectrum of parameters: Parameters describing features of activity such as capacity of decommissioning technology or technique, consumption of various media and materials used, working group composition (amount of workers and their professions), costs parameters (wages of workers, costs unit factors of consumed media and materials), and other parameters.

For the purposes of tentative decommissioning calculations for the Isotope Central Building, parameters already implemented in OMEGA code are used. Values of these parameters come out from international available data (capacities, consumptions, mostly cost unit factors), from Slovak data which were available (some cost unit factors) and Swedish data – labour cost unit factors - see Annex 2-1.

Main calculation parameters used within OMEGA code are described in this chapter. For better orientation, data are divided into three groups according to their character.

1) General calculation data - data concerning cost unit factors and other overall data.
2) Calculation data for technological procedures – these data include technological parameters of decommissioning procedures and parameters of working groups used for these procedures.
3) Specific calculation data – these data include parameters of preparatory, support and management activities which have time dependent character (duration of procedure, working group for procedure).

Due to large extent of input calculation parameters all data sheets containing individual data tables are attached in Annex 2.

6.2.1 General calculation data

This group of calculation data encompasses mainly cost unit factors. Database parameters are listed in Annex 2-1.

First portion of cost unit factors encompasses labour costs unit factors of individual professions used in working groups within calculation. Database table contains labour costs paid by company for employee. Labour costs include all payments connected with employee - social security contributions, insurance, social charges, pension scheme and other charges paid by the company is. For the purposes of calculation, values of labour costs are expressed in EUR per manhour. Labour cost unit factors used in calculations follow Swedish conditions for given professions, delivered by the Swedish partner based on [3].

Second portion of cost unit factors represents selected cost unit factors for media, substances and materials used by technological procedures within calculation. These cost unit factors are based on mainly international price levels and in some cases, where no international data was available, on Slovakian prices. They were collected from parameters of individual procedures to one common table. Values are expressed in EUR per unit of consumed material.

Other general parameters used in calculation are shown in the third table of Annex 2-1. This table includes common used parameters such as work days per year, work hours per shift, dose rate of background in facility and some others.

6.2.2 Calculation data for technological procedures

These input data represent a major portion of all calculation data, characterise and quantitatively describe individual technological decommissioning activities from pre-dismantling decontamination through dismantling, waste management up to disposal of waste packages. Extent of technological procedures included in decommissioning calculation for the Isotope Central Building is based on chapter 4 where individual activities are listed.

Calculation parameters of individual decommissioning procedures are used in combination with parameters from inventory database for calculation of output parameters. Calculation data for technological procedures include technical/economical parameters and working group parameters.

Technical and economical parameters characterise technological features of procedure. The main used parameters are:

- manpower unit factors (for hands on activities and techniques),
- capacities of equipment (for machines and technological lines),
- consumption unit factors – consumption of electricity, steam, fuel oil, air, chemical substances, working tools and equipment etc.,
- cost unit factors – prices for electricity, steam, fuel oil, air, chemical substances, working tools and equipment etc. – main cost unit factors are selected in general calculation data mentioned above.

Working group parameters includes assignment of working group to individual activities. Working groups consist of individual universal professions. Each profession in working group has assigned number of workers.

There are seven universal profession used for characterization of working groups:

- manager (average personnel on the management level),
- senior engineer (experienced graduated engineer, more than 10 years of experience in the field),
- engineer (standard graduated engineer),
- operator (qualified operator in relevant branch with secondary school education),
- administrative worker,
- skilled worker (qualified craftsman),
- auxiliary worker (semi skilled).

Individual working groups have also assigned a structure of non-effective working time fractions during carrying out work within individual working group. These non-effective working time fractions are by-products of effective time needed for decommissioning activity and these are time consuming, e.g.: entrance of workers to controlled area, breaks in work , moving of personnel during working time within controlled area, exit from controlled area, etc. In OMEGA code we used default values for non-productive time fractions for all workgroups.

Values of used parameters within this database were obtained from various sources. They were obtained from price catalogues for evaluation of costs in industrial sectors in Slovakia, from methodical work from operation of technological lines in A-1 NPP and maintenance of V-1 and V-2 NPP, international catalogues and prospects of producers of dismantling and demolition equipment. In addition, a lot of useful parameters were evaluated within cooperation with Japan specialists in the frame of cooperation on A-1 NPP decommissioning.

Data sheets of calculation data for technological procedures are divided into several parts according to the type of calculation technological procedures. In the beginning of each part there is a list of included procedures and also table of non-productive working time fractions for working groups. There is a table of parameters with values listed for each calculation technological procedure together with table for assigned work group.

Individual datasheets of calculation data for technological procedures with parameters are attached in Annex 2-2. Amount of parameters used for individual procedures is very extensive, owing to simplify parameters review, only main and most important parameters are listed in datasheets. Data listed in datasheets are mentioned within colour legend. Legend distinguishes most important or specialized parameters by individual colours.

6.2.3 Specific calculation data

These data are used for activities which have time dependent character. These activities have no technological character but they are a part of decommissioning process. They are connected with preparatory activities (decommissioning planning, preparation of documentation, etc.), management and decommissioning support activities (management unit, security and safety during decommissioning, etc.).

Main parameter for this type of procedures is time of duration, which determines how long is certain activity carried out during decommissioning process. Then a composition of working group is necessary – professions and numbers of workers in professions, which are involved in certain time dependent activity. Based on this data and parameters of professions wages data (included in general data), cost of workforce can be calculated.

Fixed costs are another type of parameter which can be used as specific data within the time dependent procedures. Fixed costs represent investment costs, for example in the case of procurement of some equipment or mechanisms etc.

Table with specific calculation data for individual selected time dependent procedures is attached in Annex 2-3.

7. DEFINITION OF DECOMMISSIONING ACTIVITIES

This chapter contains review of procedures representing individual decommissioning activities which are implemented within OMEGA code. Some of these procedures are not used within the Isotope Central Building calculation, (they can be used for other facilities with more various radiological and technological inventory), but they are mentioned owing to complexity of implemented procedures in OMEGA code.

7.1 *METHODS FOR DEFINITION OF DECOMMISSIONING ACTIVITIES*

One of the main features of the OMEGA code is the implementation of the standardised list of decommissioning activities [9]. The standardised list includes all activities that could be identified in any decommissioning project. From this point of view, the definition of extent of decommissioning activities involved in the given decommissioning project means the methods for selecting of decommissioning activities, relevant for the given project. The OMEGA code involves a set of standardised templates of decommissioning activities, which include segments for basic types of decommissioning activities:

- inventory-dependent activities, related to the extent of "hands-on" work like dismantling, decontamination , etc.,
- period-dependent activities, proportional to duration of individual decommissioning activities/phases,
- definition of fixed costs (costs special items which can neither be assigned to inventory-dependent activities nor to period-dependent activities.

For the first type of decommissioning activities, the segments in the template are available which corresponds to facility structure of buildings – floors – rooms/cells - inventory items in rooms/cells. For the second and the third type of decommissioning activity, the universal segments were developed, which can be applied in the given decommissioning project by implementing the procedure described below.

The user can configure the executive standardised calculation structure in three steps using the templates which facilitates significantly the work of the user. The base for this work is the general standardised template which covers the decommissioning activities as defined in [9]. In the first step the user can develop the master template which is specific for a type of a nuclear facility. In the second step the user can adapt the selected master template to the standardised structure specific to the decommissioning option to be calculated. In this step the user can define as much calculation options as required for the evaluation within the decommissioning project. The option specific standardised structure of decommissioning activities involves also the prescriptions for generation of lower levels of calculation items, for allocating the calculation procedures and definition of calculation sequence.

The third step is the automatic generation of the executive standardised calculation structure. The typical feature of this structure is that it has the hierarchical structure of the buildings – floors – rooms/cells – inventory items in the room/cell in selected sections of the standardised structure, as required in basic definition of decommissioning activities in [1]. The generated structure contains also input calculation data with default values. After the generation, the user can review/edit the generated calculated structure and the generated default values of the calculation data.

The generated calculation structure involves all decommissioning activities as defined in [9] and the definition of the extent of calculation is defined by the user by clicking in the individual calculation items. The procedure of generating the standardised calculation structure is presented in chapter 9.

The decommissioning activities presented in chapters 7.2 to 7.4 are the activities of the "inventory dependent type" and for these activities the relevant segments in executive calculation structure were generated based on the Isotope Central Building inventory database.

The decommissioning activities presented in the chapter 7.5 are activities planning activities for preparing the decommissioning project and general management and supporting activities during the execution of the project. These are activities of the "period dependent type" and "fixed cost". For calculation of parameters for these activities, the "static" segments of the executive calculation structure are used.

The full extent of calculated decommissioning activities for the Isotope Central Building is identified in the chapter 9, in the format of so-called "PSL" structure.

7.2 *DISMANTLING ACTIVITIES*

According to PSL numbering, dismantling activities cover a pre-dismantling decontamination of technological equipment, a dismantling technology itself including preparatory and finishing activities, a decontamination of building surfaces, a final building radiation survey and post- dismantling decontamination of technological equipment.

The following sections are involved to describe a set of decommissioning activities generated for the usual decommissioning calculation run by OMEGA code. Some of them are also used for Isotope Central Building tentative calculations.

7.2.1 Pre-dismantling decontamination

The pre-dismantling decontamination is considered in calculation due to decrease of dose rates from dismantled equipment or decrease of potential creation of aerosols during dismantling operations.

This procedure includes creation of autonomous circuit from existing piping and other equipment, connection of mobile tank with circulation pump for decontamination medium, filling the circuit with decontamination media and decontamination of inner surfaces by flowing of media through created circuit. The circuit is then flushed by water and decontamination ends with disconnecting of tank and pump from autonomous circuit.

However the pre-dismantling decontamination using by the autonomous circuit is not applied for the Isotope Central Building decommissioning calculations.

7.2.2 Dismantling procedures

Dismantling procedures involves the biggest portion of decommissioning calculation. These procedures describe activities of dismantling (removal) of technological equipment from rooms within facility. Dismantling is carried out in controlled area (active rooms) or outside the controlled area (inactive rooms). Dismantling in controlled area, in common, demands higher manpower than outside the controlled area.

There are three types of procedures during dismantling used in calculation:

- preparatory procedures prior dismantling,
- dismantling procedures,
- finishing procedures after dismantling.

Preparatory procedures prior dismantling

These procedures describe and calculate a set of activities carried out prior dismantling itself and they are carried out within individual rooms (room oriented). Insertion of individual preparatory procedures within particular room is optional.

- **Survey of radiological situation** – mapping of radiological situation in room directly prior dismantling.
- **Covering of floor by protective foil** – covering of contamination protective foil on the floor of the room.
- **Installation of scaffolding** – assembly of scaffolding needed for dismantling of equipment placed in heights. It is assumed that installation of static scaffolding will not be necessary in any room of the Isotope Central Building. Mobile lifting platform can be used in the case of dismantling activities in heights.
- **Installation of temporary air-conditioning** – installation and testing of local mobile air-conditioning with filters in the room which will be used during dismantling.
- **Installation of temporary electric and other media connections** –installation and testing of connections for electricity and other media (air, water, etc.) supply in the room.
- **Disconnection and revision of dismantled technological equipment** – securing of removal and closing of any connections of dismantled equipment to other systems (media, electricity) prior dismantling in room.
- **Marking of cuts and areas** – drawing of lines for cuts which determines segmented parts of equipment and guide personnel during dismantling.
- **Delivery of working tools and equipment** – transport of working tools and equipment into room prior dismantling.
- **Preparation of working tools and equipment** – activities connected with preparation, setting and adjusting of dismantling tools and equipment in room.
- **Preparation of transport containers** - delivery and placement of transport containers for dismantled material in room.
- **Installation of protective** tent – assembly of foil protective tent against spreading of potential aerosols during dismantling.

- **Working group instructions** – preparation and instruction of activities, cooperation and safety for working group personnel prior dismantling in room.

These preparation activities are carried out prior dismantling in active rooms (inside the controlled area). The set of preparation activities prior dismantling outside the controlled area (normal inactive rooms) is similar but activities relevant only for controlled area are missing (survey of radiological situation, covering of floor by protective foil, installation of temporary air-conditioning, installation of protective tent).

For the purpose of tentative decommissioning calculations by OMEGA code for the Isotope Central Building we assume using the reduced set of preparatory procedures for active rooms as well as for inactive rooms.

Dismantling procedures

These procedures represent dismantling itself. Dismantling procedures can be used both for active (inside the controlled area) or non-active equipment (outside the controlled are). The following techniques have been selected for the purpose of dismantling calculation (a description of techniques is taken from Ref. [10], [11]):

- dismantling by hydraulic shears,
- dismantling by oxygen-acetylene set,
- dismantling by plasma set,
- dismantling by circular saw,
- dismantling by hand tools (wrenches, etc.).

Dismantling by hydraulic shears is used especially for cutting of low diameter metal elements (pipelines, plates, air conditioning pipes, instrument panels, electric network installations, cables), which are made of steel, colour metals, (copper and its alloys, aluminium), plastics (PE pipes) and other materials.

Dismantling by oxygen-acetylene set is frequently used for cutting of non-active steel materials. This technique is applicable for cutting of steel tanks, structural and bearing parts of equipment, air-conditioning parts, cranes and other components, depending on the shape and thickness. Considerable amount of aerosols are produced during application of this technique and introduced into the air. That is why it is proposed just for non-active part of the equipment.

Dismantling by plasma set is applicable for cutting of any metallic materials using plasma burner. This technique is used especially for dismantling of various stainless steel equipment within the controlled area. Aerosol is produced in time of cutting, which has to be removed by air-conditioning. Dismantling by plasma set is used mainly for dismantling of heat exchangers, tanks, air conditioning pipes, ventilators, valves, steel linings and others.

Dismantling by circular saw is a cutting technique frequently used for dismantling of technology equipment of longitudinal shape, such as pipelines, rods, bearers and other parts made of steel, color metals, plastics. It is applicable especially for dismantling inside the controlled area due to low production of aerosols.

Dismantling by hand tools is a technique used for dismantling of technology equipment by means of hand instruments (screwdrivers, wrenches, various types of jigs). This manual method is the most frequently used especially in case of assumed re-using of dismantled components (electric motors, compressors, pumps, valves, electric equipment, diagnostic devices).

A number of technology categories were assigned to each of mentioned dismantling techniques. The combinations of material categories with dismantling techniques were elaborated for the purpose of the Isotope Central Building, as shown in the Table 7-1.

Particular combinations used within the calculation procedure are marked by blue point. This combinations are based on choosing of most suitable and applicable dismantling techniques for given categories of equipment regarding to radioactive conditions. For completeness, other alternative combinations possible in OMEGA are added marked by black circle. A complete list of the selected material categories is given in the chapter 6.1.3 of this report. A list of material categories given in the following table is reduced due to comprehensibility. Combinations mentioned below are valid for dismantling in the controlled area as well as for the non-controlled area.

Table 7-1 Table of combination of used technological equipment categories and available dismantling procedures

No	Name of technological equipment category	Dismantling (manual) by hydraulic shears in CA	Dismantling (manual) by oxygen-acetylene set in CA	Dismantling (manual) by plasma set in CA	Dismantling (manual) by circular saw in CA	Dismantling (manual) by hand tools (wrenches, etc.) in CA
1	Piping (C steel), various diameters	●	●	●	●	
2	Piping (S steel), various diameters	○		●	●	
3	Piping (PE, PP ..), various diameter	○			●	
4	Air conditioning components - piping (C steel), various cross sections [m^2]	●	●	●		●
5	Electrical cables & conductors; (Cu, Al)	●				●
6	General electric equipment, various mass		●	○		●
7	Heat exchangers (C steel) , various dimensions [m]		●	○		
8	Air conditioning components - filter casing (C steel), various dimensions		●			●
9	Steel constructions, (C steel), doors and manhole covers		○			●
10	Non-portable small equipment & instruments (C steel), various mass [kg]	○	●	○		●
11	Valves (C steel, S steel), various mass [kg]		●	●		●
12	Ventilators (C steel), various mass [kg]		●			○
13	Steel constructions, (C steel), stairs, ladders, railings		●			○
14	Glove boxes (S steel)			●		●
15	Digestors (S steel)			●		○
16	Steel constructions, (C steel), hangings of piping, cable grating etc.		●	●	●	●
17	Stainless steel (generaly)			●	○	
18	Carbon steel (generaly)		●		○	
19	Colour metals (generaly)			●	○	
20	Hoisting equipment (cranes and rails) C steel		●	●		●
21	Electric motors, various mass [kg]		○			●
22	Shieldings of lead			○		●
23	Contamined concrete					●
24	Hot cells				●	○
25	Hermetic doors (C steel)		●			●
26	Firefighting doors (C steel, azbestos)				●	●
27	Embeded contaminated pipe, various diameter				●	○
28	PVC flooring cover					●
29	Other common equipment		●	○		●
	C steel - carbon steel	●	used combination			
	S steel - stainless steel	○	alternative combination			

Finishing procedures after dismantling

Similarly to preparation activities prior dismantling, there is a set of finishing activities, represented by calculation procedures, used after dismantling of equipment in room. Insertion of individual finishing procedures within particular room is optional.

- **Removal of scaffolding** – de-installing and removal of scaffolding after dismantling. This activity is not supposed to be done, see paragraph "Preparatory procedures prior dismantling"
- **Removal of protective foil** – rolling and packing of protective foil from floor of the room.
- **Removal of temporary air - conditioning** – de-installation and removal of temporary mobile air-conditioning from room.
- **Removal of temporary electric and other media connections** – de-installation and removal of connections for electricity and other media (air, water, etc.) supply in the room.
- **Removal of working tools and equipment** - transport of working tools and equipment out of room prior dismantling to designated place.
- **Removal of protective tent** – de-installation of foil protective tent after dismantling.
- **Removal of transport containers** - transport of containers with dismantled material out of the room to designated place.
- **Cleaning of room** – final cleaning and removal of any remains after dismantling of equipment in the room.

These finishing activities are carried out after dismantling in active rooms (inside the controlled area). The set of finishing activities after dismantling outside the controlled area (normal inactive rooms) is similar but activities relevant only for controlled area are missing (removal of protective foil, removal of temporary air-conditioning, removal of protective tent).

Individual preparation and finishing activities were selected room by room with regards to radiological and technological properties of individual room and its equipment. Table of selected preparatory and finishing activities by rooms is showed in Annex 2-4. Criteria for using of given preparatory and finishing activity for individual room are as follows:

- Radiological survey prior dismantling
- Radiological survey has been used for all rooms. This is conservative approach by reason of old technological facility where possible unknown sources of contamination/dose rate can occur within rooms.
- Covering of floor by plastic foil. Covering of floor can be used for rooms with total mass of technological equipment more than 4 tons.
- Installation of temporary air-conditioning. These preparation activities prior dismantling are used for rooms with more than 4 tons of contaminated equipment.
- Installation of protective tent is used for rooms with temporary air conditioning
- Installation of scaffolding. This preparation activity prior dismantling is used if there are supposed some equipment which is inaccessible from the floor level. It is assumed that installation of static scaffolding will not be necessary in any room of the Isotope Central Building. Mobile lifting platform can be used in the case of dismantling activities in heights.

- Installation of temporary electric connection. These preparation activities prior dismantling are used for rooms with more than 4 tons of contaminated equipment.
- Marking of cuts and surfaces. These preparation activities prior dismantling are used for rooms with large contaminated equipment.
- Delivery of working tools and equipments.
- Disconnection and revision of decommissioned technological equipment.
- Preparation of working tools and equipments.
- Working group instructions.

Activities are used for all rooms with total mass of technological equipment more than 4 tons.

- Preparation of transport containers.

Activity are used for all rooms with total mass of technological equipment more than 0,5 tons.

- Finishing of dismantling.
- Removal of temporary air-conditioning.
- Dismantling and removal of scaffolding.
- Removal of temporary electric connection.
- Removal of protective tent.
- Removal of working tools and equipments.
- Removal of transport containers.

Activities have been used if corresponding preparation activities had been realized.

- Cleaning of room.

Activity is used for all rooms with total mass of technological equipment more than 0.5 tons.

7.2.3 Decontamination of building surfaces procedures

Decontamination of building surfaces is also taken into account in calculations for the Isotope Central Building. There are used decontamination procedures representing mechanical and chemical decontamination of building surfaces [10],[11]. Decontamination is supposed for rooms with presence of active components. Conservatively, there is calculated chemical decontamination for whole floors and for contaminated areas of walls (hot spots) in rooms with contains active equipments.

There are three types of procedures during decontamination of building surfaces used in calculation:

- preparatory procedures prior decontamination of building surfaces,
- decontamination of building surfaces procedures,
- finishing procedures after decontamination of building surfaces.

Preparatory procedures prior decontamination of building surfaces

System of procedures is the same as in the case of preparatory activities prior dismantling and includes the following procedures:

- survey of radiological situation,
- covering of floor by protective foil,
- installation of scaffolding. Only mobile lifting platform is intended to use,
- installation of temporary air-conditioning,
- installation of temporary electric and other media connections room,
- marking of decontaminated areas,
- delivery of working tools and equipment,
- preparation of working tools and equipment,
- preparation of transport containers,
- installation of protective tent,
- working group instructions.

Decontamination of building surfaces procedures

Chemical decontamination by foam application, vacuum cleaning and washing includes application of decontamination foam or reagent on decontaminated surfaces by application machine, action of applied foam on surface, vacuum cleaning of applied foam and final washing by water. This procedure is used in calculation for decontamination of contaminated wall surfaces (hot spots) within calculation.

Mechanical decontamination by grinding (shaving) represents decontamination by machine or hand tool equipped with grinding disk – shaver, which mechanically removes surface layer of building surfaces. Technique is suitable for building surfaces with suspicion of contamination penetrated into deeper layers of building material. This procedure is used for decontamination of contaminated floor surfaces within calculation.

Finishing procedures after decontamination of building surfaces

Set of these procedures is very similar as for the finishing of dismantling procedures. It includes procedures as follows:

- removal of working tools and equipments,
- removal of scaffolding - not intended to use (mobile lifting platform will be used),
- removal of protective foil,
- removal of temporary air-conditioning,
- removal of temporary electric and other media,
- removal of protective tent,
- removal of transport containers.

Preparation and finishing activities for building surfaces decontamination have been used for all rooms with contaminated equipment on floors and walls to height of 1 m from the floor.

7.2.4 Final building RA-survey procedures

The level of residual contamination will be monitored after completion of building surfaces decontamination and prior to release of building object from control [10],[11].

Final building surfaces RA-survey consists of three partial activities:

- preparation activities for radiation monitoring of building surfaces,
- radiation monitoring of building surfaces,
- finishing activities after decontamination of building surfaces.

Set of preparation activities comprises following procedures in calculation:

- installation of scaffolding. Only mobile lifting platform is intended to use
- marking of surfaces,
- preparation of working tools and equipments,
- preparation of RA-survey, calibration.

Radiation monitoring of building surfaces

This procedure represents radiation monitoring of building surfaces (walls, floors) prior releasing of building from regulatory control. Radiation monitoring is carried out by workers equipped with handheld monitors in rooms where active equipment are situated and contamination of surfaces is supposed to be. Monitoring is made for both wall and floor surfaces. Assumed capacity of monitoring capacity is 2 m^2/h per one worker (monitor).

Set of finishing activities after decontamination of building surfaces includes next procedures:

- removal of scaffolding - not intended to use (mobile lifting platform will be used),
- removal of equipment,
- release of the room.

Preparation and finishing activities of radiological survey have been used for all rooms in decommissioning calculations for the Isotope Central Building.

7.2.5 Post-dismantling decontamination of technological equipment

Post-dismantling decontamination is used to obtain larger amount of material for unconditional or conditional release or decreasing of material amount destined to deep geological repository disposal.

The chemical post-dismantling decontamination by means of ultrasound is considered in calculations. Dismantled material is immersed into the tank filled with chemical decontamination solution and its contaminated surface layer is removed by means of ultrasound action. Afterwards, material is transferred into rinsing tank where it is rinsed by detergent and dematerialized water. Assumed capacity of such post-dismantling decontamination is around 3 m^2/h.

For the Isotope Central Building decommissioning calculations, wet bath post-dismantling decontamination equipment for iron/steel radwaste is considered in radioactive waste treatment scenarios as stated in chapter 5.

7.3 *WASTE MANAGEMENT*

For the purpose of tentative decommissioning calculations for the Isotope Central Building in Studsvik a set of radioactive and non-radioactive waste management technologies were considered. Short characteristics of each waste management technology used in OMEGA decommissioning calculations are given below. Described technologies are either commonly used in Slovakia or considered to be used in future. For further decommissioning calculations for the Isotope Central Building it would be necessary to take into account waste management technologies available at Studsvik site together with their parameters as well as the final waste package forms and their disposal routes.

7.3.1 Radioactive waste management

Treatment and conditioning of radioactive waste (RAW) consists of a lot of technological procedures. The objective of these procedures is to reduce the volume of RAW, decrease the mobility of radionuclides and create a material matrix suitable to dispose of the waste in repository.

There is a variety of RAW generated during activities of dismantling and decontaminations. We considered the following technologies for material treatment and conditioning in OMEGA code calculations:

A) Technological methods for treatment of solid RAW:

- fragmentation of metals and cables,
- compaction (low and high pressure) of incombustible waste,
- incineration of combustible waste,
- melting of metals,
- cementation of fragmented RAW into drums.

B) Technological methods for treatment of liquid RAW:

- evaporation,
- bituminization,
- cementation,
- vitrification.

C) Conditioning of final products from treatment before disposal to the repository

Final conditioning of products from treatment will be inserted into the FRC containers. Products from treatment are grouted by cement mixture in FRC containers.

Following chapters (7.3.1.1, 7.3.1.2, 7.3.1.3) contain a short description of treatment activities using by OMEGA code for creation of waste management scenarios. However whole waste management scenarios for metal, non-metal and liquid RAW as well as RAW production in decommissioning process are described in chapter 8.

7.3.1.1 Technological methods for treatment of solid radwaste

Fragmentation of metals with radioactivity up to 3kBq/cm^2

This workplace includes fragmentation by air plasma cutting, hydraulic shears and circular saws. Dismantled material is transported to the fragmentation workplace in standardized ISO containers (1,6 x 1,2 x 1,4 m) with weight capacity 1,5 t. Material is fragmented to pieces with maximal dimensions up to 200 mm and filled into 200 l drums. Maximal allowed dose rate is 2 mGy/h at the surface of a drum. Capacity of fragmentation is considered about 2000 kg/shift.

Fragmentation of metals with radioactivity over 3kBq/cm2

This fragmentation workplace is remotely controlled due to higher radioactivity of dismantled material. The dismantled material is cut by hydraulic shears. Material is fragmented into 200 l drums. Capacity of fragmentation is considered about 200 kg/shift.

Low-pressure compaction

Low pressure compactor is hydraulic equipment designed for incombustible solid material compaction (PVC, glass, isolation glass wool, brash metal material). The RAW is compacted directly in 200 l drum. Drums with compacted RAW are intended for high-pressure compaction. Considered capacity of low-pressure compaction is 1,6 m^3/h.

High-pressure compaction

High-pressure compactor is designed for drums with low-pressure compacted materials, drums with small pieces of fragmented metals or debris. In this process the whole drum is compacted. Dimensions of output product depend on compressibility of compacted waste. That can be pellets or only partially compressed drums. These products are destined to final cementation into FRC containers for near surface repository. Capacity of low-pressure compaction is 3 drums/h with average weight of drum 330 kg.

Incineration

Combustible solid wastes packed in bags (3-10 kg) and transported in 200 l drums, processed in the incinerator. Incineration of a burnable liquid waste (oils, lubricant and grease) is also possible. Washing liquids for exhaust gases cleaning are generated as a secondary RAW. These can be used as active cement filler in cementation process. The same approach is used for ash treatment, it is mixed with cement filler. We suppose capacity 50 kg/h of input RAW with volume reduction factor around 15 and generation of 200 l of washing liquid per 1t of RAW.

Melting of metal RAW

Melting is used for, in combination with post-dismantling decontamination, increasing of amount of material for conditional and unconditional release. It means that melting is not intended for volume reduction for non releasable materials.

Individual radionuclides can have different behaviour in the process of melting. Some migrate from metal (or its surface) to exhaust gases or slag, some migrate only a little and mostly stay in metal volume. For example Cs-137 migrates to slag or evaporates and is caught by filters. On the other side major part of Co-60 remains in metal and only small part migrates to sludge or to exhaust gases as a dust. This behaviour of radionuclides is also taken into account in calculation. Supposed capacity of melting furnace is 125 kg/h.

Melting procedure for the Isotope Central Building decommissioning calculations is considered in selected waste treatment scenario.

Cementation of solid RAW into drums

This cementation line is designed for remotely fragmented solid materials which radioactivity level doesn’t allow high-pressure compaction. Fragmented material is grouted with cement mixture directly in drum. Capacity of drum cementation is 0,56 m^3/h.

7.3.1.2 Technological methods for treatment of liquid waste

Evaporation and bituminization

Bituminization line is intended for processing and fixation of liquid concentrates, sludge or used ion exchangers. Firstly, waste waters are concentrated by evaporator with natural circulation. Thicken liquid is consequently fixed into bitumen by rotary evaporator and filled into 200 l drums. Spent ion exchangers and condensate are generated as a secondary waste during the process of bituminization. Limit salinity of evaporated concentrates is intended to be about 180 kg/m^3. Capacity of bituminization line is 1drum of bitumen product per hour.

Secondary liquid RAW generated from decontamination activities within the Isotope Central Building is in calculations assumed either to be bituminised or used as for preparing an active cement grout in cementation process of final waste packages – FRC containers.

Vitrification

Liquid RAW with high level of overall radioactivity and especially with significant alpha radioactivity are treated by vitrification. Liquid RAW is concentrated in evaporator and generated concentrate is mixed with glass frit, dried and incorporated into glass matrix during melting of glass frit. Glass product is filled into metal shells with 7 liters volume and they are destined for cementing into containers for deep geological disposal. Assumed capacity of vitrification line is 0,002 m^3/h.

Vitrification is the very special procedure belonging to treatment of highly contaminated liquids however in case of the Isotope Central Building calculations it is not used for treatment of generated secondary radioactive liquids from decontamination activities.

7.3.1.3 Technological method for conditioning of RAW to the repository

Final cementation into FRC containers destined to near surface repository

Cementation into FRC containers is used for final disposal of RAW that can't be released and its radioactivity enables disposal at surface repository.

The FRC (fibre reinforced concrete) container is a cubic container designed for disposal of RAW at near surface repository. It is made of concrete reinforced by metal fibres (mixed together with concrete). Its inner volume is 3 m^3 and payload 10 t.

There are solid radioactive wastes placed into FRC containers such as high-pressure compaction products, drums filled with bitumen, cement product or pressured RAW, stand alone RAW (e.g. debris). These solid wastes are consequently fixed in the FRC container by cementation mixture grouting.

Capacity of cementation is 1 FRC container per day.

Final cementation into FRC containers destined to deep geological repository

Radioactive waste which can't be disposed at near surface repository has to be cemented into containers and destined to future deep geological repository. Disposal at deep geological repository is needed mainly for high alpha level contaminated materials or for high level activated reactor core materials.

Pieces of a high level irradiated or contaminated material and products of vitrification are put into containers and consequently grouted by cement mixture.

Payload of container is 4,5 t and capacity of cementation is 1 container per day.

7.3.2 Non-radioactive waste management

There is significant production of non-radioactive waste in process of decommissioning. These wastes are represented by two groups of materials:

1) Materials from decommissioning in controlled area of the Isotope Central Building that are after sorting, decontamination (if it is needed) and radioactivity measurement classified as materials releasable into environment:

- some metal or non-ferrous materials from dismantling or after subsequent decontamination process if necessary,
- building materials from demolition of buildings,
- ingots after melting process (if their radioactivity after melting is lower than the level of radioactive limits for release into environment).

2) Materials from decommissioning outside the controlled area of the Isotope Central Building. These materials had no contact with radioactive materials and are classified in advance as materials releasable into environment.

In order to obtain as much materials releasable into environment as possible, all the efforts are taken to decontaminate, sort as well melt contaminated materials. Part of this waste after treatment and recycling can be released into environment for unconditional usage as secondary raw materials (metals, ingots after melting and various building materials – concrete, waste on ceramic and mortar basis). Another part of the waste – scrap from demolition works or recycling activities can be used mainly for backfilling of underground volume after demolition of buildings. The rest of releasable materials not suitable for recycling and for unconditional usage are transported to waste dump (e.g.: floor coverings, thermal insulation, waterproof isolations, glass…) or specialised waste dump for hazardous materials (in case of e.g. asbestos materials)

Technological procedures used for non-radioactive waste material treatment in the Isotope Central Building decommissioning calculations are as follows:

1) Recycling of metals – collection of metals, sorting into containers and transport to the scrap yard (recycling facility).
2) Recycling of building materials - collection of materials, sorting and either using them for backfilling of underground volume after demolition of buildings or reuse of the building materials.
3) Treatment of non-recyclable materials - collection of materials and their transport to the conventional waste dump or specialised waste dumps for hazardous materials.

7.4 *DEMOLITION, SITE RESTORATION AND RELEASE OF SITE*

7.4.1 Demolition

Demolition of building structures includes preparation of equipment for demolition, breaking of building structures, sorting of materials, loading of debris and transport of debris within the site. These activities are included in parameters of demolition procedures.

Calculation procedures of demolition are assigned to appropriate categories of building equipment. Building equipment includes types of building materials which are supposed to occur within demolition of the Isotope Central Building – see Table 7-2.

Particular building equipment category can be combined with one or more demolition procedures, according to availability of demolition technique for category.

Chosen default procedures for individual category are marked by blue colour dot.

Table 7-2 Table of combination of used building equipment categories and available demolition procedures

Demolition procedures / **Building categories**	Demolition by excavator	Demolition with explosive	Demolition by hand tools	Demolition by demolition shears	Demolition by wiring saw and excavator	Demolition by oxygen-acetylene cutting set and crane	Demolition by hand tools and crane
masonry	○	○		●			
concrete	○			●			
prefabricates		○		●			
reinforced-concrete thickness <= 400 mm		○		●	○		
reinforced concrete, thickness => 700 mm		○			●		
steel skeletons						●	○
peripheral walls - panels		○		●			
other building materials	●		○				

● default combination
○ possible combination

Short description of selected procedures is presented in the text below.

Demolition by excavator

This demolition procedure is used for demolition of the following building equipment categories:

- masonry (walls from bricks or blocks with mortar),
- other building material (wood, plastics, glass, ceramics).

Demolition is carried out by mechanism (excavator equipped with shovel). Demolished material is loaded on lorry. Preparatory (transport of equipment to workplace) and finishing activities (terrain arrangements, transport of debris to local stock pile) are included to manpower unit factor (see Annex 2). Activity ends with rough arranged terrain.

Demolition by demolition shears

This demolition procedure is used for demolition of concrete or reinforced concrete up to thickness of 400 mm. Demolition is carried out by mechanism equipped with demolition shears. Demolished material is loaded on lorry. Preparatory (transport of equipment to workplace) and finishing activities (terrain arrangements, transport of debris to local stock pile) are included to manpower unit factor (see Annex 2). Activity ends with rough arranged terrain. Demolition of each building equipment category has assigned its own manpower unit factor.

Demolition of steel skeletons and roof skeletons by oxygen-acetylene cutting set and crane

Demolition procedure represents demolition of steel building constructions of various shapes and dimensions and demolition of steel roof constructions. Oxygen-acetylene set, electric grinder and mobile crane are used as demolition equipment. Demolished material is loaded on lorry. Preparatory (transport of equipment to workplace) and finishing activities (terrain arrangements, transport of steel scraps to local stock pile) are included to manpower unit factor (see Annex 2). Demolition of each building equipment category has assigned its own manpower unit factor.

7.4.2 Site restoration

Backfill of underground rooms

After demolition of the Isotope Central Building above ground floors and ground floor to the level -1m all underground rooms will be backfilled by debris. The aim is to fill all underground free spaces so that slumping could not happen. Within the OMEGA code software backfilling is divided into activities as follows:

- preparation of rooms for backfilling,
- transport of backfill material,
- backfilling of rooms by debris.

Preparation of rooms for backfilling consists of holes drilling through room ceiling. Jack hammers, drilling machines and other demolition tools will be used for the purpose of demolition.

Transportation of building waste procedure consists of lorry loading by jib-type loader or excavator, carriage and unloading of the waste at destined place.

Backfilling of rooms by debris comprises preparation and installation of backfilling equipment, implementation of backfilling and compaction of debris using building machinery. Unit parameters are given in the Annex. 2.

Final arrangement of landscape

After backfilling of underground rooms it is necessary to cover up the area by soil layer of 0,8 m and plough layer of 0,2 m thickness. Within the OMEGA software this procedure is considered to be time dependent. Labour content and costs are calculated on the basis of input parameters considering the area and volume of the soil. It is assumed to use lorries and building machinery (dozer, excavator, jib-type loader).

7.5 *MANAGEMENT AND SUPPORT ACTIVITIES*

In order to prepare the decommissioning project, a set of preparatory activities, management of the decommissioning project and supporting activities for the main decommissioning activities, as described in chapter 7.2 to 7.4, are needed. The standardised list of cost items defines the full list of decommissioning activities, for which the costs are to be calculated. The basic description of individual decommissioning activities is presented in the document [9]. For the given decommissioning project, the activities of this type are defined as selection from the full list of activities, presented in [9].

For the case of the Isotope Central Building, following period dependent activities and fixed cost items were preliminary selected for the preparation of the decommissioning project, for management of the project and for supporting of the inventory dependent activities presented in chapters 7.2 to 7.4:

01.0103 Preparation of final decommissioning plan

01.0104 Safety and environmental studies

01.0201 License applications and license approvals

01.0202 Public consultation and public inquiry

01.0301 Radiological surveys for planning and licensing

01.0401 Hazardous material surveys and analyses

01.0501 Prime contracting selection

02.0301 Drainage and drying or blow down of all systems not in operation

02.0401 Sampling for radiological inventory characterisation of equipment

02.0402 Sub grade soil sampling and monitoring wells to map contamination

02.0501 Removal of system fluids (water, oils, etc.)

02.1201 Isolation of systems out of operation

03.0101	Investment and maintenance for general site-dismantling equipment
03.0201	Investment and maintenance for personnel and tooling decontamination
03.0301	General radiation protection equipment such as portal monitoring system
04.1101	Arrangements in building objects for supporting D&D
04.2101	Characterization of radioactive materials for recycling and reuse
04.2300	Personnel training, training of new personnel
05.0101	Hazards analyses and risk analyses for handling, packing, storing
05.0201	Hazards analyses and risk analyses for waste transports
05.0301	Special permits, packing and transport requirements
06.0101	Site security operation and surveillance
06.0201	Inspection and maintenance of buildings and systems in operation
06.0301	Site upkeep
06.0401	Energy and water
07.0201	Final cleanup and landscaping
07.0301	Independent compliance verification with cleanup
08.0101	Mobilization of construction equipment and facilities
08.0102	Mobilisation of personnel
08.0104	Setup and construct temporary utilities
08.0201	Project manager and staff
08.0301	Public relations
08.0403	Decommissioning support including chemistry, decontamination
08.0501	Health physics
08.0601	Removal of temporary facilities

The parameters for these period dependent activities and for fixed cost items are presented in Annex 2-3.

The set of managing and supporting activities is tentative in order to document the method of managing of these activities in the calculation case. More accurate adjustment of these types of activities requires study of site specific features, like site management, site services, support activities, etc. applicable for the particular decommissioning project.

8. DEFINITION OF WASTE MANAGEMENT SCENARIOS FOR THE ISOTOPE CENTRAL BUILDING IN STUDSVIK

8.1 *WASTE MANAGEMENT SCENARIOS – GENERAL APPROACH*

Initial state for characterisation of waste arisen from decommissioning process in the Isotope Central Building is following:

- operation of facility was terminated in 2005,
- all radioactive waste from operation is removed from the rooms of facility.

Regarding waste production, decommissioning of facility such as the Isotope Central Building consists of the following activities:

- Dismantling of technological equipment in controlled area produces substantial part of decommissioning waste. All produced waste is treated as RAW. Non-contaminated waste arises from sorting procedures.
- Decontamination of building surfaces also generates RAW from contaminated building parts and materials.
- Dismantling of non-active technological equipment is performed out of the controlled area. All this waste is classified as non-radioactive as it did not come into contact with radioactivity.
- Demolition of building is performed after final radiological measurement, which assures that any radioactivity inside the building is below the limits for release into the environment. Therefore all waste is classified as non-radioactive.
- Final fieldworks of the area, e.g. backfilling of underground floors with releasable building material from demolition works, which does not produce additional waste.

Decommissioning process generates a radioactive waste which is necessary to treat, condition and transport either to repository or is destined into the environment if it meets all the limits and conditions for release of the materials. Following chapters describes waste scenarios for solid and liquid RAW accordingly. These scenarios are general schemes of RAW management applied in Slovakia and they fully cover produced decommissioning wastes arising from Isotope Central Building.

The system for management of material and radioactivity flow, as developed in the computer code OMEGA, implements the nuclear resolved limits for material release from decommissioning activities and also the nuclide resolved limits for final disposal at the LLW/ILW Mochovce repository (Slovak Republic), according the actual legislative in the Slovak Republic. The values of these limits are presented in the Annex 3.

The concept of material and radioactivity flow control in decommissioning developed at DECOM, a.s. represents an original generic methodology and tools implemented into the standardised OMEGA code for on-line optimisation of decommissioning and waste management processes. The modelling of the processes is based on mathematical material partitioning of inventory items into one-material elements which enter into the pre-defined sequence of calculation and sorting procedures linked each other by unambiguous material links. To each one-material calculation element are linked radiological parameters which are generated during the material partitioning. The generation is based on the calculation category of the inventory items and distribution coefficients relevant for the item category. The generation of secondary waste is considered. The linked radiological parameters are during the calculation dynamically recovered to the start dates of individual decommissioning activities. The decay of radioactivity of individual radio-nuclides is respected through the entire decommissioning process.

The sorting procedures implement the limits for releasing of materials, acceptance limits for disposal of materials, acceptance limits for individual process and parameters of individual processes which affect the material and radiological parameters of evaluated items. Multi-stream material calculation structures can be defined by appropriate sequence definition combined with selected sections of standardised calculation structure and by definition of dates for waste entry into individual material streams. The principles of material and radioactivity flow control in advanced decommissioning costing are presented in Annex 6.

8.2 *WASTE SCENARIOS FOR SOLID RADWASTE*

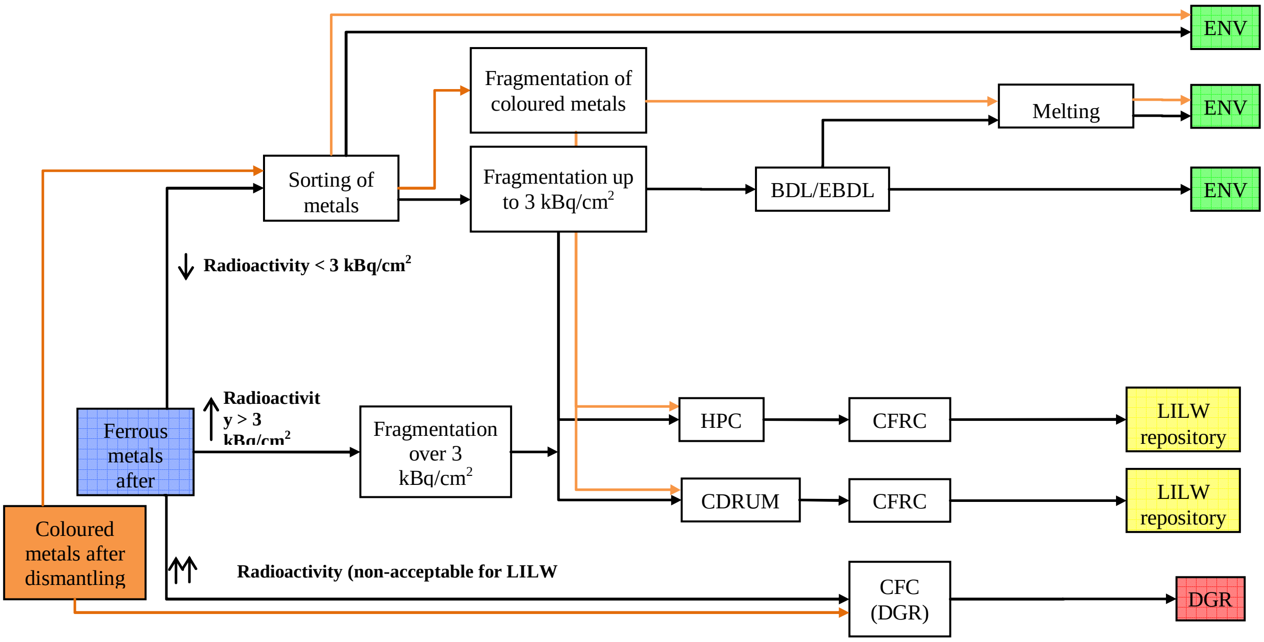
Solid RAW is represented mainly by primary waste from decommissioning such as materials from dismantled technological equipment (pipes, valves, pumps, motors, thermal isolation, cables etc.) as well as building equipment (concrete, masonry, steel skeletons etc.). In addition, solid RAW as secondary waste are produced during the whole decommissioning process (protective clothing, respirators, preservatives, protective coverings, various textiles, filters, used dismantling tools etc.). Solid RAW can be in general divided into the following categories:

1) metal RAW:
   - carbon steel,
   - stainless steel,
   - coloured metals (mainly lead, copper, aluminium, brass).
2) non-metal RAW:
   - combustible: textiles,
   - compressible: cable isolations, plastics, small building debris,
   - non-compressible: suitable only for cementation to drums and subsequently to FRC containers.

8.2.1 Waste scenario for metal RAW

Waste management scenario for metal RAW arisen from decommissioning and applied in tentative calculations for the Isotope Central Building has three basic endpoints, which are classified according to radioactivity of dismantled metals. Individual waste routes are displayed in Figure 8-1.

Figure 8-1 Waste management scenario for metal RAW



where:

BDL	*- wet bath post-dismantling decontamination*
Blasting	*- dry post-dismantling decontamination by metal abrasives*
EBDL	*- electrochemical bath post-dismantling decontamination of stainless steel*
HPC	*- high-pressure compaction*
CFRC	*- cementation into FRC containers*
CDRUM	*- cementation of metal RAW into drums*
ENV	*- environment*
LILW	*- near surface LILW repository*
DGR	*- deep geological repository*

Based on radioactivity criterion it is possible to divide the dismantled metal RAW from Figure 8-1 into groups:

1) A. Dismantled metal RAW with surface contamination below 3 kBq/cm^2 are sorted and later on segmented into pieces and decontaminated if necessary. Depending on the level of contamination, segmented and decontaminated metal RAW can be either released into the environment or is destined to melting process and subsequently released into the environment. In the case of higher contamination of segmented metal RAW (when meeting the limits for the release of materials neither by decontamination nor by melting is possible) such materials are compressed or cemented into drums, placed into FRC containers and disposed of in the near surface repository.

B. Coloured metals RAW are handled and treated similarly to the process described in previous paragraph A. After sorting, the coloured metals are either released into the environment or segmented for further treatment. That is either melting and consequent release of ingots into the environment (if it is possible to meet the release criteria for ingots), or such materials are compressed or cemented into drums, placed into FRC containers and disposed of in the near surface repository in, as in previous case A.

2) Dismantled metal RAW with surface contamination above 3 kBq/cm^2 are segmented by special remote controlled segmentation facility. These segments are treated by high-pressure compaction. In the case of higher radioactivity above technological limits for the compactor such metals are cemented into drums, subsequently into FRC containers and disposed of in the near surface repository.

3) In case of very high contamination or activation of metal RAW when the acceptance limits for the near surface repository cannot be met. Such dismantled metal RAW is directly conditioned (e.g. by cementation) into containers destined to deep geological disposal facility. For this metal RAW a remote controlled segmentation is performed to achieve requested dimensions for containers destined to DGR as well as to reduce storage volume.

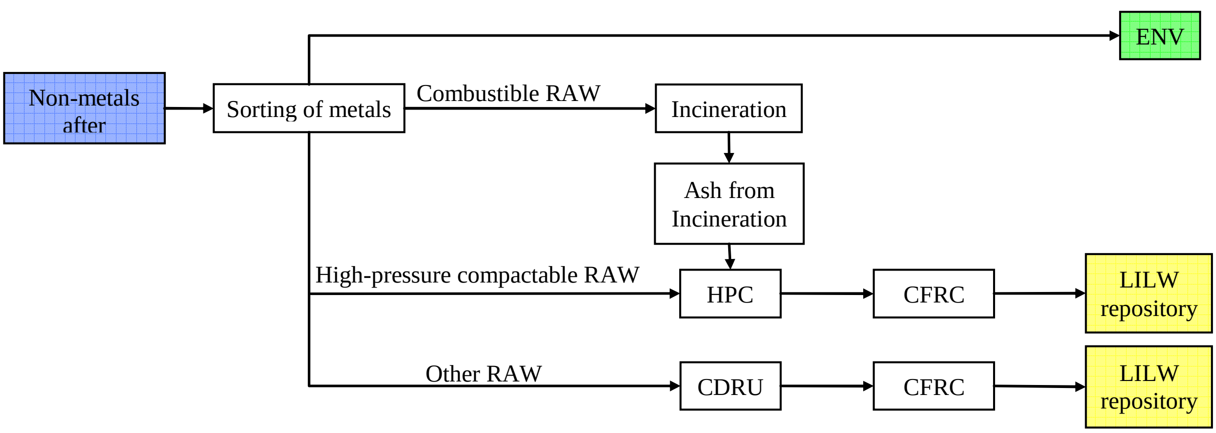
8.3 *WASTE SCENARIO FOR NON-METAL SOLID RAW*

Non-metal solid RAW after dismantling is sorted into 5 groups of materials:

- materials releasable into the environment directly without treatment,
- combustible RAW,
- low-pressure compactable RAW,
- high-pressure compactable RAW,
- other non-metal solid RAW.

The above listed groups of non-metal solid RAW are clearly displayed in Figure 8-2.

Figure 8-2 Waste management scenario for non-metal solid RAW



where: LPC - low-pressure compaction.

Figure 8-2 shows that in the case of non-metals breaching the limits for free release into the environment, the final waste packages are disposed of in the near surface repository. Ash as a product of incineration of combustible non-metals RAW is mixed with paraffin, compressed in high-pressure compactor and finally cemented into FRC containers. Water as secondary waste from incinerator is used for preparing of active cement grout for filling FRC containers.

Other non-metal solid RAW is non-compressible and non-combustible RAW, such as contaminated concrete, scrap from grinding of contaminated building surfaces, are cemented into drums, placed into FRC containers and destined to the near surface repository.

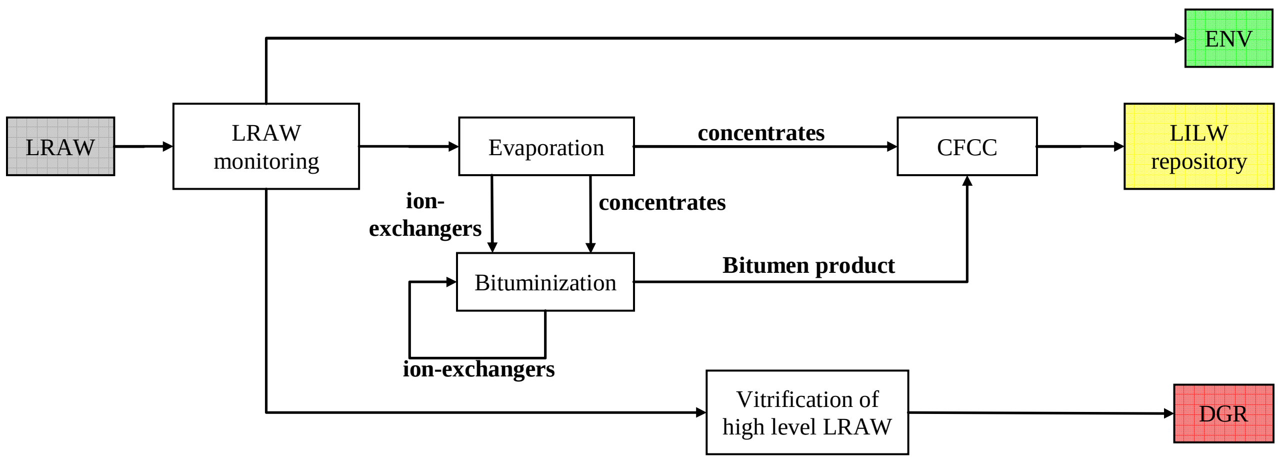
8.4 *WASTE SCENARIO FOR LIQUID RADWASTE*

Liquid RAW from decommissioning is exclusively generated as a secondary waste. Namely various used decontamination solutions from post-dismantling decontaminations of technological equipment and from decontamination of building surfaces. Moreover, they are condensates and water from incinerator and from other RAW treatment technologies as well as water from sanitary loops.

Liquid RAW (LRAW) after radioactivity monitoring can be divided to three waste groups (see Figure 8-3):

1) LRAW releasable into the environment,
2) LRAW advanced to evaporation procedure,
3) LRAW advanced to cleaning by ion-exchanger filters before any other treatment procedure.

Figure 8-3 Waste management scenario for liquid RAW



LRAW from the first group is discharged into the environment directly after monitoring or after cleaning by ion-exchanger filters.

Second group of LRAW are concentrated in evaporation unit, later on either treated in bituminization plant or are used as an active cement grout for cementation of filled FRC containers destined to the near surface repository. Condensates from bituminization plant are cleaned on ion-exchangers, monitored and discharged into the environment.

In order to reduce the radioactivity level of the third group of LRAW, which does not meet radioactivity limits for evaporation unit, this LRAW is cleaned by ion-exchangers, subsequently concentrated in evaporator and later on treated as the second group of LRAW.

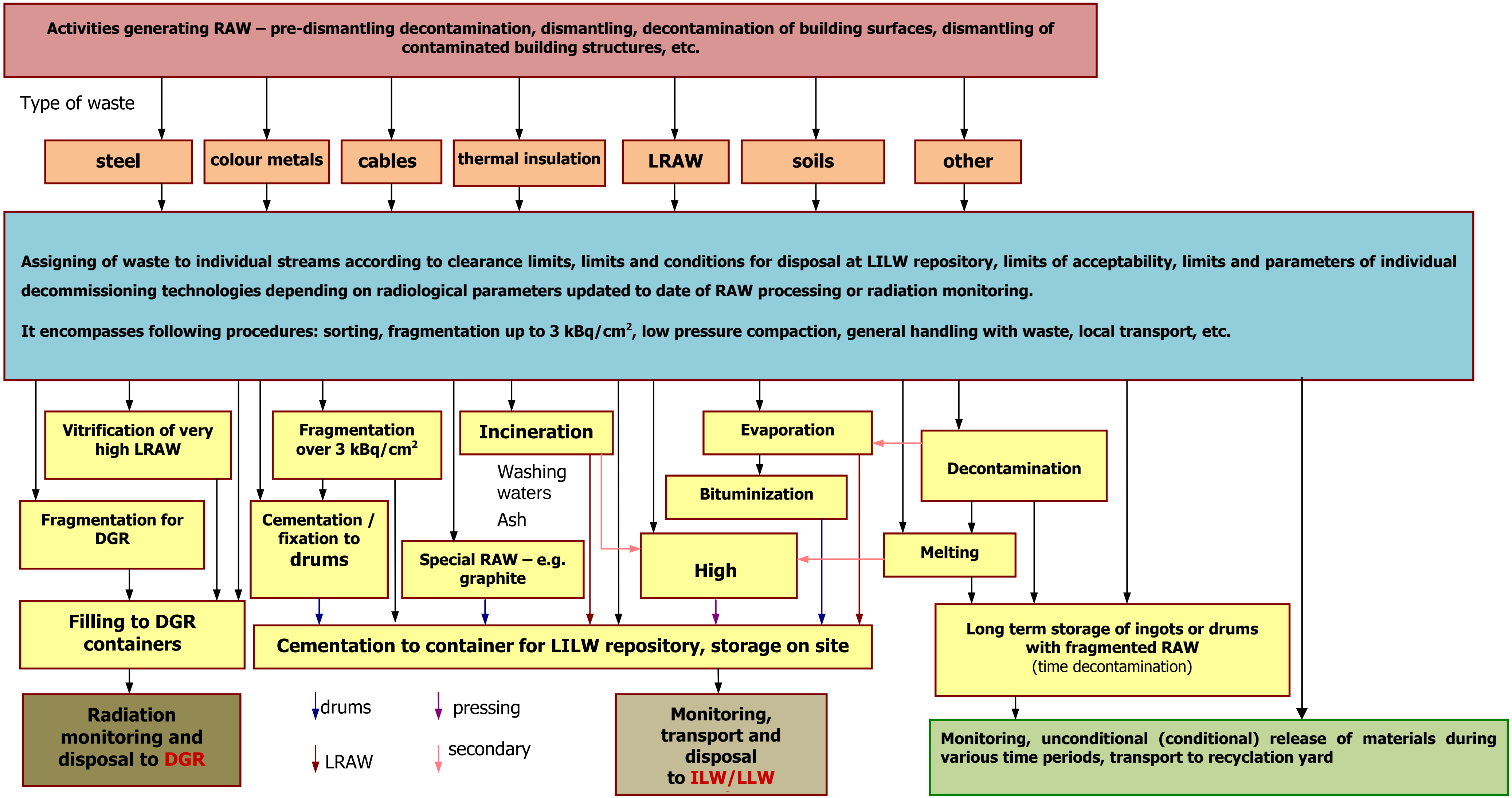
Clean-out of liquid media during operation, decommissioning or treatment on evaporation unit and bituminization plant, respectively, generates the spent ion resins as a secondary RAW which are usually bituminised in drums and cemented in FRC containers. FRC containers are disposed of in the near surface repository. Just in the case of very high radioactivity of spent ion resins, these are solidified in vitrification matrix. Vitrified cartridges are stored in special storage and are destined to a deep geological repository. However, this type of waste is produced only in the case of non-standard operation of nuclear facility. Given route is displayed in Figure 8-3 only to demonstrate an ability of treatment such waste within the waste scenario for liquid radioactive waste. For our OMEGA code calculations we do not suppose generation of given type of waste during the Isotope Central Building decommissioning.

Calculated quantities of liquid radioactive waste, such as contaminated waters, concentrates from the evaporation unit and spent ion resins from the Isotope Central Building decommissioning are presented in Chapter 10.

8.5 *GENERAL SCHEME FOR WASTE MANAGEMENT*

Based on data of individual waste treatment and conditioning technologies, related to real flow of radioactive materials within the system for management of waste from decommissioning and from operation of the NPP's in the Slovak Republic, a complete waste flow chart was developed and implemented in the computer code OMEGA. The scheme is presented in the Figure 8-4.

Figure 8-4 General scheme for waste management



9. DEVELOPMENT OF STANDARDIZED DECOMMISSIONING CALCULATION STRUCTURE

The chapter reviews the basic characteristics of the standardised cost structure for decommissioning purposes and the methods for its implementation into the real decommissioning projects.

9.1 *STANDARDIZED COST STRUCTURE – REVIEW*

The standardised structure for decommissioning purposes was issued by OECD/NEA, IAEA and EU in 1999 in the document "A Proposed Standardised List of Costs Items for Decommissioning Purposes" (PSL) [9]. The document defines the structure of decommissioning activities for which the costs are to be presented. The reason for issuing the document were inconsistencies in presented costs of various decommissioning projects caused by different extent of activities, technical / local / financial factors, waste management systems, etc. The main purpose of the document is:

- to facilitate communication,
- to promote uniformity,
- to encourage common usage,
- to avoid inconsistency or contradiction of results of costs evaluations,
- to be of worldwide interests to all decommissioners.

The basic chapters of standardised cost items are:

01 Pre-decommissioning actions

02 Facility shutdown activities

03 Procurement of general equipment and material

04 Dismantling activities

05 Waste processing and disposal

06 Site security, surveillance and maintenance

07 Site restoration, cleanup and landscaping

08 Project management, engineering and site support

09 Research and development

10 Fuel and nuclear material

11 Other costs

The standardised structure defines following cost groups:

12.0100	Labour costs
12.0200	Capital, equipment and material costs
12.0300	Expenses
12.0400	Contingency

It is recommended that implementation of the "Proposed Standardised List of Items for Costing Purposes in the Decommissioning of Nuclear Installations" should be respected in the early stage during the development of the decommissioning database.

The standardised cost structure represents in principle the system of decommissioning activities structured in above listed chapters. The main aim was to develop a structure for presenting the costs for decommissioning, but at the same time it can be used for presenting also other decommissioning parameters for presenting the decommissioning projects. From this point of view (systems of decommissioning activities) the standardised structure can be used as the base for the calculation structure for calculation of costs and other decommissioning parameters. Those issues of the individual decommissioning projects which are project specific, like the decommissioning work breakdown structure, can then be constructed using the items of the standardised calculation structure.

9.2 *METHODS OF IMPLEMENTATION OF STANDARDIZED COST STRUCTURE*

The calculation structure used for the calculation of costs and other decommissioning parameters is in general the result of the interaction of the list of decommissioning activities to be done within the decommissioning project and of the inventory database. It means that sets of room-oriented decommissioning activities are repeated according to the structure building – floor – room and set of decommissioning activities are generated for each inventory item within the room. Such a structure is repeated in various sections of the calculation structure for typical decommissioning activities like dismantling, decontamination of building surfaces, radiation monitoring of premises and other activities.

Other sections of the calculation structures are independent on the inventory database and they have their own conditions for generation of calculation items.

The standardised calculation structure for calculating of the decommissioning parameters is characterised by the fact that the whole published structure of decommissioning activities is implemented. This structure is the same for all the decommissioning options. Therefore, it is called a static structure. It does not necessary mean that all the items of the structure will be used for calculation.

Moreover, in relevant sections (for example for dismantling) the structure also uses the decommissioning inventory database for generating the individual calculation items. This part of the structure is called a dynamic structure, because it is different for each nuclear installation. The reason for difference is that the list of buildings, floors, rooms and equipment is different for each nuclear installation. The dynamic structure is connected in appropriate points to the static structure and both of them create an integral structure.

Therefore, the structure of the decommissioning inventory database should also reflect this requirement. It means the database should also contain the data needed for a proper generation of the standardised calculation structure.

The standardised calculation structure has also some special features which reflect the fact that the similar or the same decommissioning activities (for example the dismantling), applied to different rooms or equipment, are located in two or more independent parts of the structure. The decommissioning inventory database items should facilitate the generation of the standardised calculation structure also for these cases. An example is that the dismantling of equipment of non-contaminated buildings is located in the different part of the structure that the dismantling of equipment of contaminated ones.

9.3 *IMPLEMENTATION OF STANDARDIZED COST STRUCTURE IN OMEGA CODE*

The implementation of the standardised structure of decommissioning activities, in order to achieve the standardised costs structure, can then be characterized in three main steps:

- development of the detailed standardised structure of activities with numbered levels,
- development of the decommissioning database with data elements enabling the generation of the standardized calculation structure,
- generation of the standardized calculation structure,
- management of the standardized calculation structure.

Development of the detailed standardised structure of activities with numbered levels

The first step represents the developing the detailed standardised structure of decommissioning activities by extending the three numbered levels of the published standardised structure. The extending represents 3 to 5 additional numbered levels, depending on the section of the standardised structure. In this way, a set of templates of standardised structure can be developed which are then used for generating of the standardised calculation structure in interaction with the decommissioning inventory database.

Development of the decommissioning database with data elements enabling the generation of the standardized calculation structure

The second step is characterized by implementing additional database items related to premises (building/room) items and decommissioning inventory items:

- Type of the building. The parameter is used for generation of parts/sections of the standardised calculation structure relevant for nuclear buildings with reactor, without reactors or non-nuclear facilities especially in chapters 4 and 7 of the definition of the standardised structure.
- Type of the decommissioning inventory item. The parameter is used for the definition of the group of the equipment like types of the building surface or types of the technological equipment. The data are used for definition of the part/section of the standardised structure where the database items are to be implemented.

- Category of the decommissioning inventory item. The parameter is used for selection of the calculation procedure for the item of the calculation structure and for selection of calculation data dependent on the category.
- Number of the item of the standardised structure (PSL number) – a number from the detailed standardized structure used for generation of the calculation structure of the decommissioning option. The parameter is used for definition of the calculation item within the detailed numbered standardisation structure. The data are used for definition of the calculation structure only for special items defined in standardised calculation structure like reactor structure, refuelling machines, etc. Therefore, it does not necessary mean that each inventory item has to contain a PSL number.

For generation of the standardized calculation structure in the third step it is needed to develop also additional data which enable to generate the room oriented calculation structure according to the definition of individual sections of the standardized structure.

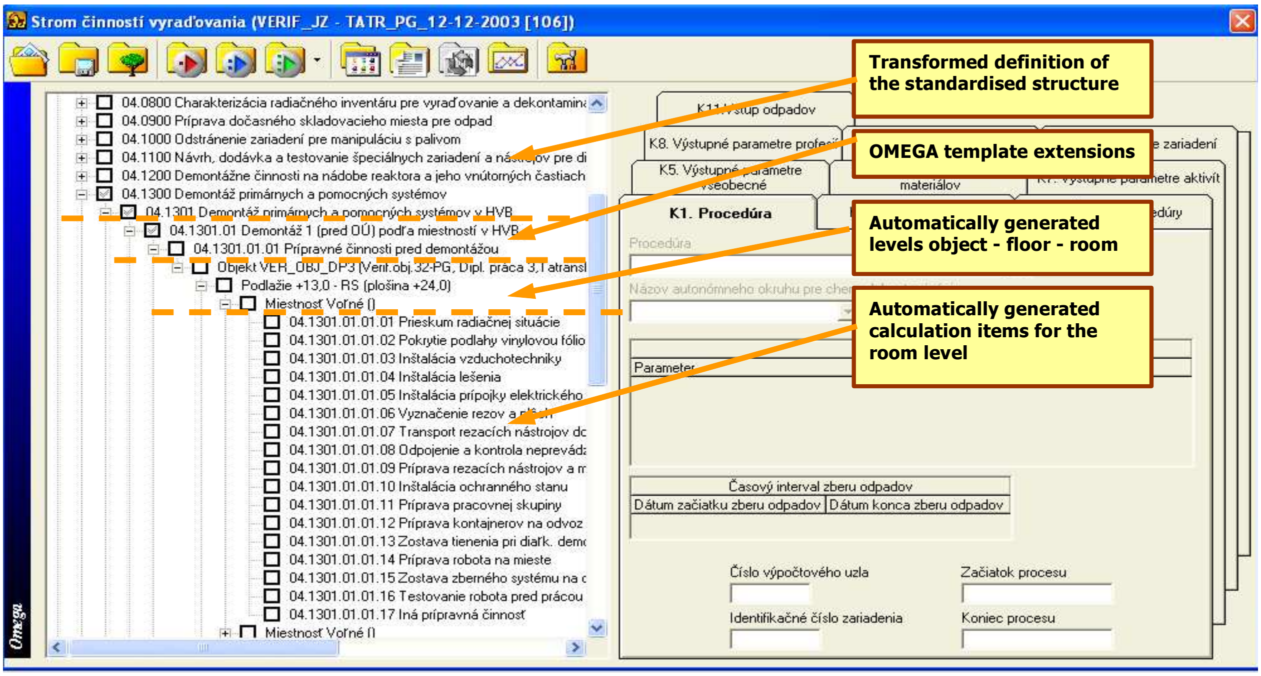
Summary of the steps

The simplified procedure for the implementation of the standardised structure of decommissioning activities is following (an example of the generated standardised cost calculation structure is presented in the Figure 9-1):

1) To use the standardised PSL structure as the input data,
   - the original structure is categorized up to the third numbered level,
   - list of decommissioning activities is defined for the lowest levels,
2) Developing the standardised template structures,
   - extended standardised structure with lower numbered levels,
3) Developing the standardised structure of the calculation option (static structure),
   - user defined specific structure based on a selected template structure at lowest levels, where applicable, modes for generating of lower calculation levels are defined, e.g. building / floor /room / equipment structure,
4) Generation of the executive standardised calculation structure,
   - generation based on the static standardised structure and facility inventory data,
   - extent of calculation is defined by the user by switching an appropriate decommissioning activities on in generated executive calculation structure.

This working in the stages enables flexibility in developing the standardised calculation structures for any nuclear facility/installation. The precondition is that the inventory database for the nuclear facility/installation with relevant structure is available, and this database also contains the data needed for application of the standardised structure. The methods for development of the inventory database with these properties were developed and applied for developing the calculation structure for model calculations for the Isotope Central Building.

Figure 9-1 Example of an executive standardised cost calculation structure within OMEGA code



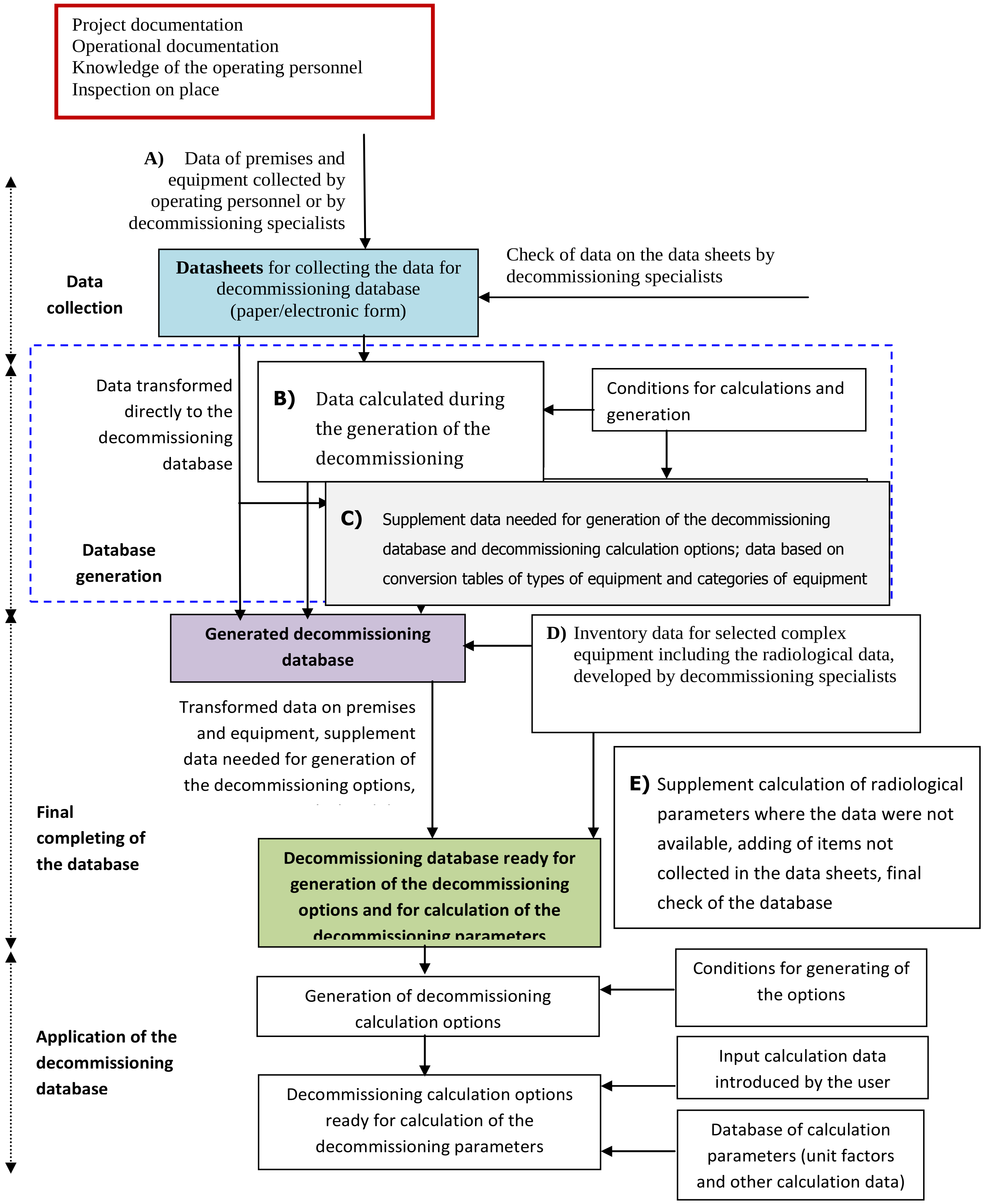
9.4 *EXECUTIVE CALCULATION STRUCTURE OF ISOTOPE CENTRAL BUILDING*

The executive calculation structure for the Isotope Central Building was developed on the basis of the procedure described in the chapter 9.3 The structure contains all the decommissioning activities as described in the chapter 7. The calculation structure was generated on the basis of the developed inventory database of the Isotope Central Building and on the basis of a template of the standardised decommissioning structure in the OMEGA code.

Before the generation of the standardised calculation structure for the Isotope Central Building, the inventory database was completed, as it is described in the chapter 6.

The complex procedure spanning from developing the inventory database to generating of the executive calculation structure is presented in the Figure 9-2. This complex procedure should be follow up during preparation of database for final decommissioning plan.

Figure 9-2 Principal phases of development of the inventory database and generating of the calculation structure



Data of "A" type are the primary data to be collected from facility technical documentation and based on physical inspection in individual premises of the facility.

Data of "B" type are the secondary date derived from the primary data by calculation by decommissioning experts.

Data of "C" type are the data used in the generation of the calculation database and in generation (or definition) of the decommissioning calculation options.

Data of "D" type are the complete inventory data for complex reactor structures, developed in separate tasks. Preparation of this kind of data requires additional complex calculations like the neutron flux calculations, calculation of activation of reactor construction of materials, development of a hierarchical inventory database structure which corresponds to a proposed dismantling procedure. Similar approach is also used for other complex equipment like the steam generators, volume compensators, primary piping and other equipment. This kind of data should be prepared by decommissioning specialists. These examples are generic ones, applicable for the nuclear power plants or research reactors, just to highlight the complexity of "D" Data. Naturally, this is not the general case for the Isotope Central Building.

Data of "E" type are in general the radiological data, mostly the contamination levels and the nuclide composition of contamination or dose rate. It is expected that the main radiological parameter – the dose rate in the defined distance (0,5 m) from the equipment - is collected in the frame of collecting the primary data by the operational personnel. The contamination data can be then calculated, based on calculation models of categories of equipment, if they are not available as the primary data. The nuclide composition can be derived from the radiological analysis of relevant samples.

10. PERFORMING OF TENTATIVE CALCULATIONS

Decommissioning cost calculations for the Isotope Central Building were performed for 3 options. These options differ by level of contamination of equipment and building surfaces. The options are marked as S1-S3 and represent following levels of contamination:

- Scenario S1: it presents a basic contamination level assumed by expert assessment. Values of contamination for individual types of equipment are described in Chapter 6.1.2.
- Scenario S2: level of contamination is 10 times higher than basic level,
- Scenario S3: level of contamination is 10 times lower then basic level.

For each option, following set of parameters was calculated:

- main decommissioning parameters, such as costs, manpower and collective dose equivalent characterizing each decommissioning option,
- parameters characterizing distribution of materials arisen from decommissioning, such as mass distribution of steel destined to repositories or released into the environment and number of disposed radioactive waste containers.
- These parameters were calculated for individual activities within calculation structure for each option, based on the PSL structure. Parameters are presented in the following forms:
- Results presented within PSL structure. Main parameters costs, manpower and exposure of personnel for given PSL items are listed in individual tables. Tables are presented in Annex 4, due to large extent PSL items. This type of results allows browsing decommissioning option on detailed level.
- Summarized results for whole calculation option. Costs, manpower, exposure and distribution of material released into environment and distribution of material disposed in LILW repository are presented within these results. These results are presented in table and graph form and allow analyzing decommissioning an option on overall level and comparing individual options.
- Work breakdown structure – time schedule for option with scenario. This time schedule allows viewing a time distribution of individual decommissioning activities during decommissioning process. Scenario S1 was selected as a basic scenario with basic assessed level of contaminations.

Summarized results and graphs with commentaries are presented in the following text within this chapter. Total values of costs, manpower and exposure for individual decommissioning options are listed in Table 10-1. Graphs related to this table are shown in Figure 10-1, Figure 10-2, Figure 10-3. More detailed comparison of costs, manpower and exposure for all main 11 PSL categories is given in Annex 4-5.

Summary distribution of all materials arising from decommissioning of the Isotope Central Building is shown in Table 10-2. Summary distribution of material released into the environment from decommissioning of Isotope Central Building is presented in Tab. 10 3 with associated graph in Figure 10-4. Distribution of material disposed in LILW repository from decommissioning of Isotope Central Building is listed in Table 10-4 with associated graph in Figure 10-5.

Table 10-1 Values of costs, manpower, exposure for individual decommissioning options

Parameter	Unit	Scenario S1	Scenario S2	Scenario S3
Costs	[Euro]	29 302 429	30 279 796	29 287 688
Manpower	[manhours]	197 068	203 167	196 991
Exposure	[manmicroSv]	37 711	119 131	27 622

Figure 10-1 Costs for individual decommissioning options

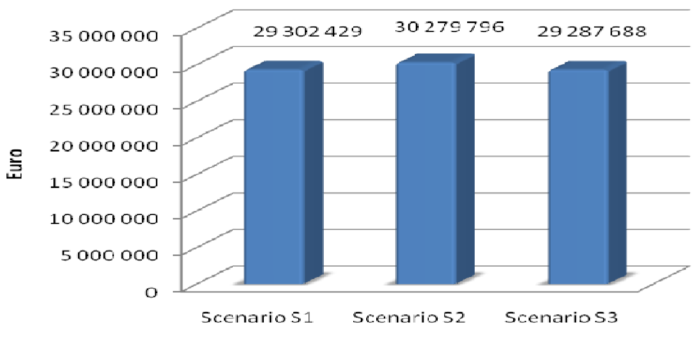


Figure 10-2 Manpower for individual decommissioning options

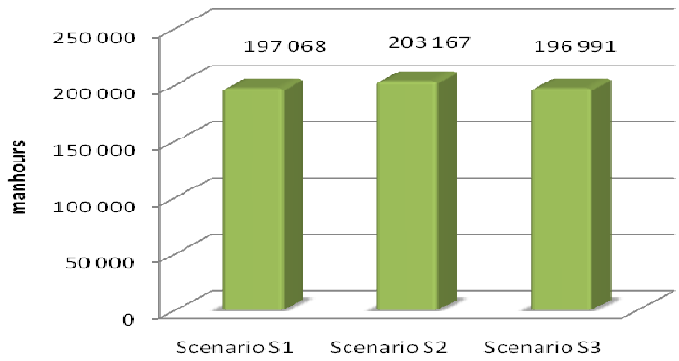


Figure 10-3 Exposure for individual decommissioning options

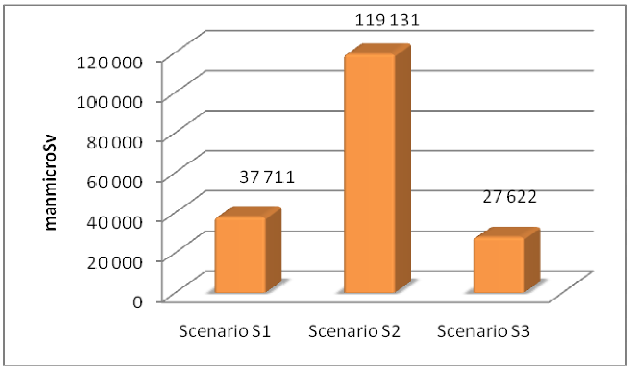


Table 10-2 Summary distribution of all materials for individual decommissioning options

Material	Unit	Scenario S1	Scenario S2	Scenario S3
Total mass of material released to environment	kg	3 179 596	3 145 188	3 180 151
Total mass of material disposed in repository (excluding secondary RAW)	kg	590	34 998	35
Total mass of material from decommissioning	**kg**	**3 180 186**	**3 180 186**	**3 180 186**

Table 10-3 Summary distribution of material released to environment for individual decommissioning options

Material	Unit	Scenario S1	Scenario S2	Scenario S3
Iron metals released to environment	kg	434 110	431 988	434 110
Colour metals released to environment	kg	4 341	4 341	4 341
Lead released to environment	kg	220 751	215 983	220 751
Non - metal materials released to environment - municipal dump	kg	43 222	42 673	43 777
Non - metal materials released to environment - special dump	kg	5 819	5 819	5 819
Non - metal materials released to environment - backfilling	kg	2 471 353	2 444 384	2 471 353
Total mass of materials released to environment	**kg**	**3 179 596**	**3 145 188**	**3 180 151**

Figure 10-4 Distribution of materials released to environment

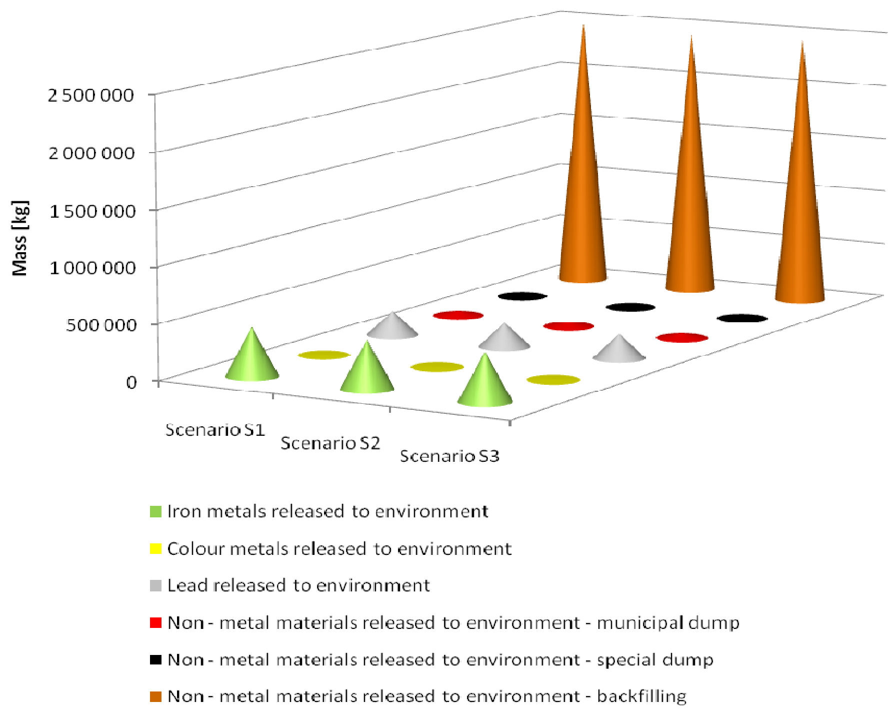
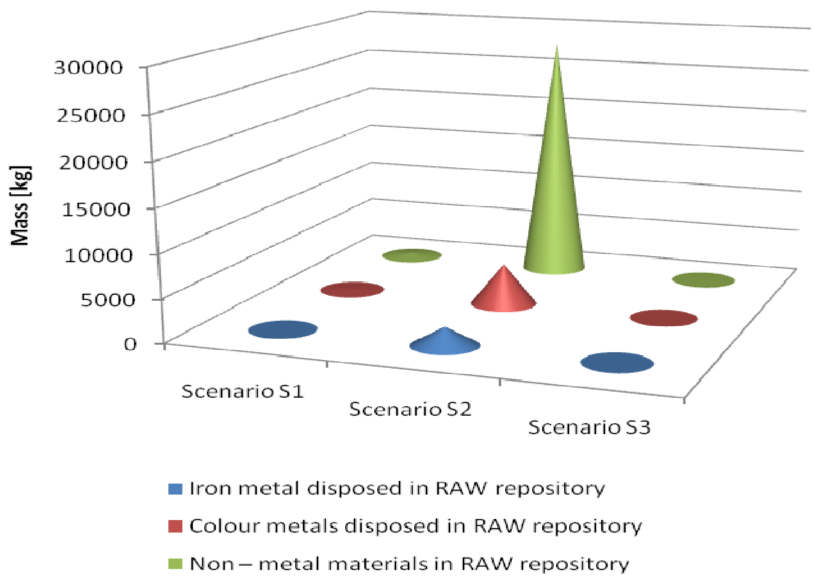


Table 10-4 Summary distribution of RAW disposed in repositories for individual decommissioning options

Material	Unit	Scenario S1	Scenario S2	Scenario S3
Iron metal disposed in RAW repository	kg	0	2 122	0
Colour metals disposed in RAW repository	kg	178	4 768	0
Non – metal materials in RAW repository	kg	412	28 108	35
Total mass of materials disposed in repository	**kg**	**590**	**34 998**	**35**
Contaminated abrasives (building surface decontamination)	m3	3,2	3,2	3,2
Number of containers disposed in repository	**pc**	**5,1**	**19,4**	**4,9**

Figure 10-5 Distribution of RAW disposed in repositories



The set of activities used in calculations covers whole decommissioning process from pre-decommissioning activities up to final restoration of the site. These activities include dismantling, building surface decontamination, building surface radiation monitoring, demolition, waste management activities and also the set of period depended activities including management, engineer support, security service, maintenance, etc., as they are described in Chapter 7.

Main decommissioning output parameters for all calculated scenarios are discussed below:

Costs

Values of costs for individual options are quite similar. The amount of costs is around 30 000 000 EUR with small variations for individual options (see Table 10-1, Figure 10-1). The reason of this is the fact that the Isotope Central Building is a small, radio-isotopes preparation, non-nuclear facility where the mass ratio of contaminated materials (from contaminated equipment) to non-contaminated materials (from non-contaminated equipment and building structure materials) is low. Also the contamination levels are not so high to use remote dismantling techniques or extensive decontamination techniques (pre-dismantling or building surface decontaminations). Also the amount of radwaste destined to repository is negligible portion of overall waste generation (see also Table 10-2). From this point of view the influence of contamination on total costs in all activities is not very significant.

The main cost driver determining overall costs are labour costs which encompass almost two thirds of overall costs. Comparison of individual cost groups for given scenarios is available in Annex 4-6.

Manpower

In the case of manpower, the situation is similar to cost. All options show very similar values in the range of around 196 000 up to 203 000 manhours (see Table 10-1, Figure 10-2).

Exposure

In the case of exposure, the situation is different comparing to costs and manpower. Exposure of scenario

S2 (119,1 man mSv) is approximately three times higher than the other two scenarios S1 (37,7 man mSv) and S3 (27,6 man mSv), see Table 10-1, Figure 10-3. This can be explained by fact that dose rates from equipment and in rooms in scenarios S1, and S3 are low (levels similar to general background of facility) according to contamination levels. In the case of scenario S2, these dose rates are ten times higher, but only part of activities is carried out in these dose rate fields. That is why this exposure level within the calculations is approximately three times higher comparing to S1 and S3 scenarios.

Material distribution

Concerning distribution of materials arising from decommissioning (see Table 10-2), the great majority of materials is releasable into environment for all three scenarios. These releasable materials are created especially by demolition of building construction materials that can be used for onsite backfilling (see Table 10-3, Figure 10-4). Other releasable materials consist of iron and non iron metals from dismantling of technological equipment (including treating by melting of coloured metals) and also from recycling of building materials (iron reinforcement bars in reinforced concrete).

Amount of material destined to disposal in LILW repository is very low comparing to amount of materials releasable to environment. Only in the case of scenario S2 this value is higher comparing to S1 and S3, but it is still very low comparing to amount of releasable material.

The assortment of materials for disposal is shown in Table 10-4 and Figure 10-5. It is obvious that the main portion of these materials is represented by non-metal materials. These materials are mainly created by contaminated concrete (originated from the space of channel duct in basement). In the case of scenario S2 there is also an increase of amount of coloured metals (lead from hot cells) destined to repository due to exceeding of release limit even if melting of these metals is available.

It has to be stressed that these tentative calculations are strongly dependent on input data from the Isotope Central Building inventory (technological and radiological). Other important parameters are input technological and economical data used for individual decommissioning activities (mainly labour cost unit factors, manpower unit factors, capacities of decommissioning equipment and processing lines, of workers, prices of consumption materials and media etc.).

11. IDENTIFICATION OF DIFFERENCES IN CALCULATION CONDITIONS RESULTING FROM SWEDISH AND SLOVAK DECOMMISSIONING INFRASTRUCTURE

The chapter identifies possible differences in calculation conditions resulting from Swedish and Slovak decommissioning infrastructure used within these decommissioning calculations.

Infrastructure of decommissioning represents whole system and structure of decommissioning process. It includes D&D techniques, waste management technologies including final disposal and releasing of materials arising from decommissioning process, relevant radiological limits and conditions and links among them characterizing a flow of material and radioactivity and also the support, administrative and management activities carried out during decommissioning process.

This infrastructure is common in its general features and can be used worldwide (see PSL structure document [9]. It enables to use a general methodology for decommissioning process evaluation in any country, but there can be differences which are resulting from legal and technical approach to decommissioning in individual country and thus they are country specific.

In calculation of the Isotope Central decommissioning, Slovak infrastructure of decommissioning was used together with relevant calculation data due to their actual availability. Although we expect similar character of decommissioning infrastructure in Sweden (Studsvik) conditions, there can be some differences identified. Typical identified areas of differences can be following:

1) Characterization of endpoints for waste arisen from the decommissioning process, unconditional, possible conditional releasing of materials and disposal at available (or planned) repositories (HLW, LLW, ILW, VLLW).

This characterization includes the legal stipulated radiological limits and conditions for releasing of waste to environment and for disposal of RAW and also characterization of final packages authorized for disposal at available types of repositories including physical characteristics (dimensions, useful volumes and weights, availability for certain types of RAW, etc.). Slovak release limits used within calculations are fully nuclide resolved and they are derived from EURATOM Direction 96/29 [15] limits.

Characterization of endpoints used in Omega code according to Slovak conditions is mentioned in Annex 3.

2) Implementation of comparable dismantling, decontamination techniques and waste management technologies including their technological parameters.

There are not expected significant differences in dismantling techniques, because basic types of dismantling techniques within the decommissioning are commonly used worldwide (hands on dismantling by general tools, dismantling by grinders, circular saws, plasma set or oxygen-acetylene set, etc.). Differences can occur in capacities of these techniques (man-hours per kg of dismantled material) arising mostly from definition of involved activities.

Similarly, basic practices and types of waste management technologies are also used in general, but for individual technologies some differences can occur concerning their availability on the site or according to the country policy, also technological parameters and characteristics of individual technologies (capacities, used chemical substances or media and their consumptions, workforce requirements) can be different. These differences are related to such waste management technologies as sorting of metals (carbon, stainless steel and colour metals) and other materials according to its type and level of radioactivity, fragmentation of sorted materials, post-dismantling decontamination of steel, low and high pressure compaction, melting of metals, decontamination of building surfaces, packaging of waste into authorized packages, radiation monitoring of packages and building surfaces, transports and disposal at individual types of repositories.

Main parameters of techniques and technologies used within OMEGA calculation code are listed in Annex 2-2. Data listed in these datasheets are mentioned within colour legend, which distinguishes parameters of particular types by individual colours. There are coloured most significant parameters (mainly cost unit factor parameters, wages), parameters with significant impact of technological procedures (capacities of technologies and techniques, characteristics of processes) and also parameters depending on package type (drums, transport containers or disposal containers). Also amounts of workers within professions of the working groups assigned to individual procedures, together with the time structure of their working time during performing the decommissioning activity.

3) Characterization of project management, engineering and various support activities.

These types of activities are considered as period dependent activities, which are needed to be performed during individual phases or during whole duration of decommissioning project. Although, these activities are common for all projects of decommissioning, their necessity and extent can vary from project to project depending on national policy, facility characteristics (type and size) and for selected decommissioning option (immediate, deferred decommissioning or entombment). Characterization of these activities includes identification of their need, assigning of appropriate amount workers of individual professions and potential fixed costs.

Period depending activities considered in calculations of Isotope Central Building and their parameters are listed in Annex 2-3.

4) Determination of proper values of labour costs and cost unit factors.

Parameters of labour costs have the highest impact on calculated costs. Costs of workforce can significantly vary depending on country economics and other conditions and they have significant impact to overall costs arisen from decommissioning process. These costs also depend on individual types of professions used in decommissioning process evaluation. From the long-time period, there is an assumption that differences in the labour costs among the European Union member states will decrease. The presence of efficient European common market will reduce these differences. The Swedish labour cost unit factors based on Ref. [3] were used within the calculation.

Cost unit factors (prices) for individual commodities used in decommissioning process can vary depending on country and even site. It includes unit prices of spent media, chemical substances, energy, commonly used tools and working instruments. Cost unit factors of individual commodities in the calculation were used on the basis of international (e.g. German, UK) price levels and where no relevant international data was available Slovakian data was used.

Labour costs of main types of professions and the most significant cost unit factors used in calculations are listed in Annex 2-1.

12. CONCLUSIONS

This research project report is the continuation of cooperation having been commenced between the Swedish Nuclear Power Inspectorate (SKI) and the Slovak team of decommissioning experts from the company DECOM, a.s., since 2004. This research project freely continues on findings and suggestions that were presented in previous research projects [1], [2], [14].

The main goal of this project was to present the tentative usage of advanced cost calculation methodology including other decommissioning parameters such as manpower, exposure, generated waste, for older, radiopharmaceutical preparation facility represented by the Isotope Central Building in Studsvik. Advanced calculation methodology for decommissioning parameters evaluation is fully implemented in calculation code OMEGA based upon standardized cost calculation structure so called "PSL" [9]. This structure is recommended for application in decommissioning costing by EC, IAEA, and OECD/NEA.

The report itself presents a description of approach and results of the tentative calculations of main decommissioning parameters within the standardized cost structure for the Isotope Central Building. The report also includes a developed Isotope Central Building inventory database and calculation parameters database. The individual steps of implementation starting from developing the decommissioning facility inventory database, through defining the standardized calculation option, developing the executive standardized calculation structure, and finishes with calculating the data for three options depending on simulated levels of contamination and discussion on the results.

The inventory database of the Isotope Central Building was created only on the basis of visual inspections and brief information of facility staff, since no further relevant information and documents were available within the research project. Labour cost unit factors used in calculation are based on Swedish data [3]. Parameters of commonly used decommissioning techniques (dismantling, decontamination, demolition) are based on international data and experience. Other calculation parameters such as an infrastructure of waste management and its technologies are based on Slovak data.

It is necessary to highlight that due to lack of inventory data, expert assessment of these data has been used and therefore the results calculated have only tentative character.

This is why further steps should be done in the future:

1) Survey of material and radiological data of the Isotope Central Building, for both equipment and civil construction, and then development of inventory database
2) Review and update existing decommissioning waste management infrastructure unit data to let them reflect common Swedish conditions.

13. ANNEXES

Annex 1 Inventory database of the Isotope Central Building

Annex 1-1 List of the floors

Annex 1-2 List of the rooms

Annex 1-3 List of the technological equipment and building structures

Annex 2 Calculation parameters (most important selected parameters)

Annex 2-1 General parameters

Annex 2-2 Parameters of technological procedures

Annex 2-2-1 Set of calculation procedures for dismantling of technological equipment

Annex 2-2-2 Set of calculation procedures for decontamination of building surfaces

Annex 2-2-3 Set of calculation procedures for demolition of building

Annex 2-2-4 Set of calculation procedures for treatment technologies

Annex 2-2-5 Set of calculation procedures for radiation monitoring

Annex 2-2-6 Set of calculation procedures for transports

Annex 2-3 Parameters of specific procedures (Time depended activities)

Annex 2-4 Extend of preparation and finishing activities for dismantling

Annex 3 Limits for unconditional release of materials to environment and limits for disposal of RAW of LILW repository in Mochovce Slovak Republic

Annex 4 Lists of calculated decommissioning activities and results of calculation, according the PSL structure, Comparison of costs, manpower and exposure for individual scenarios

Annex 4-4-1 PSL structure of calculated decommissioning activities - Summary - Scenario S1

Annex 4-4-2 PSL structure of calculated decommissioning activities - Summary - Scenario S2

Annex 4-4-3 PSL structure of calculated decommissioning activities - Summary - Scenario S3

Annex 4-5 Comparison of individual scenarios

Annex 4-6 Cost structure of calculated decommissioning activities

Annex 5 Tentative work breakdown structure for Isotope Central Building decommissioning

Annex 6 Principles of material / radioactivity flow control in advanced decommissioning costing

ANNEXES

Annex 1- 1 List of the floors

ID	Name of building	Name of floor	Underground floor
1	Isotope Central	Basement	1
2	Isotope Central	Ground floor	0
3	Isotope Central	First floor	0
4	Isotope Central	Attic	0
5	Isotope Central	Virtual floor_demolition	0

Annex 1-2 List of the rooms

ID	Name of Building	Name of floor	Number of room	Name of room	Room width (m)	Room length (m)	Room high (m)	Average dose rate (µGy/h)
001	Isotope Central	Basement	1	Stairs	2	2	4	0
002	Isotope Central	Basement	2	NA 01 - cell	3,5	3,5	4	0
003	Isotope Central	Basement	3	NA 02 - cell	3,5	3,5	4	0
004	Isotope Central	Basement	4	NA 03 - cell	3,5	3,5	4	0
005	Isotope Central	Basement	5	E012 - cell	3,5	3,5	4	0
006	Isotope Central	Basement	6	NA 04 - corridor 2	2	4	4	0
007	Isotope Central	Basement	7	Corridor	2,5	30	4	0
008	Isotope Central	Basement	8	Elevator shaft	4	2	4	0
009	Isotope Central	Basement	9	E002 - Hot cell laboratory	8	6	4	0
010	Isotope Central	Basement	10	E013 - Small hot cell laboratory	6	6	4	0
011	Isotope Central	Basement	11	E003 - Digestor laboratory	3	6	4	0
012	Isotope Central	Basement	12	Neutron laboratory	8	6	4	0
013	Isotope Central	Ground floor	101	Stairs	2	2	4	0
014	Isotope Central	Ground floor	102	Office	5	6	4	0
015	Isotope Central	Ground floor	103	Office	5	6	4	0
016	Isotope Central	Ground floor	104	Office	5	6	4	0
017	Isotope Central	Ground floor	105	116A, 116B - Hot cell laboratory	10	6	4	0
018	Isotope Central	Ground floor	106	Transit corridor	3	14,5	4	0
019	Isotope Central	Ground floor	107	Corridor	2,5	27	4	0
020	Isotope Central	Ground floor	108	Elevator shaft	4	2	4	0
021	Isotope Central	Ground floor	109	Office	5	6	4	0
022	Isotope Central	Ground floor	110	Office	5	6	4	0

ID	Name of Building	Name of floor	Number of room	Name of room	Room width (m)	Room length (m)	Room high (m)	Average dose rate (µGy/h)
023	Isotope Central	Ground floor	111	Office	5	6	4	0
024	Isotope Central	Ground floor	112	Office	5	6	4	0
025	Isotope Central	Ground floor	113	Office	5	6	4	0
026	Isotope Central	First floor	201	Stairs	2	2	4	0
027	Isotope Central	First floor	202	Office	5	6	4	0
028	Isotope Central	First floor	203	Office	5	6	4	0
029	Isotope Central	First floor	204	Office	5	6	4	0
030	Isotope Central	First floor	205	Office	5	6	4	0
031	Isotope Central	First floor	206	Office	5	6	4	0
032	Isotope Central	First floor	207	Corridor	2,5	30	4	0
033	Isotope Central	First floor	208	Elevator shaft	4	2	4	0
034	Isotope Central	First floor	209	E203 - empty laboratory	5	6	4	0
035	Isotope Central	First floor	210	E204 - Digestors & PM Control panel	10	6	4	0
036	Isotope Central	First floor	211	E206 - empty laboratory	5	6	4	0
037	Isotope Central	First floor	212	E205 - Glow boxes	5	6	4	0
038	Isotope Central	Attic	301	Stairs	2	2	2,5	0
039	Isotope Central	Attic	302	NA 04	9	6	2,5	0
040	Isotope Central	Attic	303	NA 05	9	6	2,5	0
041	Isotope Central	Attic	304	E308	2	6	2,5	0
042	Isotope Central	Attic	305	E309A - filter room	2	6	2,5	0
043	Isotope Central	Attic	306	E309 - heater room	2	6	2,5	0
044	Isotope Central	Attic	307	Corridor 1	2,5	20	2,5	0
045	Isotope Central	Attic	308	Corridor 2	2,5	6	2,5	0
046	Isotope Central	Attic	309	Elevator machinery	6	6	2,5	0
047	Isotope Central	Attic	310	E306 - High contaminated airconditionary	10	6	2,5	0
048	Isotope Central	Attic	311	E305 - Low contaminaed airconditionary	10	6	2,5	0
049	Isotope Central	Attic	312	Empty store	4	8,5	2,5	0
050	Isotope Central	Attic	313	I129 store	4	6	2,5	0
051	Isotope Central	Attic	401	Virtual room	1	1	1	0

Annex 1-3 List of the technological and building equipments

ID	Name of technological or building equipment	Name of floor and room	Weight [kg]	Inner surface [m^2]	Inner surface contam. [Bq/m^2]	Outer surface [m^2]	Outer surface contam. [Bq/m^2]	Dose rate [μGy/h]	Inner volume [m^3]	Category of technological or building equipment
1	Pumps, various diameter, S steel	Basement - 001 - Stairs	760	0		0	0	0	0	General category for study level - stainless steel equipment
2	S steel - reserve item	Basement - 001 - Stairs	0	0		0	0	0		General category for study level - carbon steel equipment
3	Firefighting door, C steel & azbestos	Basement - 001 - Stairs	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
4	Pipe mail, plastic pipe, O < 100 mm	Basement - 002 - NA 01 - cell	8	1,8	5000	0	0	2	0	Piping (PE, PP ...), diameter <= 100 mm
5	Air condition system, C steel pipe	Basement - 002 - NA 01 - cell	55	4,8	50000	0	0	5	0	Air conditioning components - piping (CS), cross section < 0,16 m2
6	Reiforced concrete; walls	Basement - 002 - NA 01 - cell	105000	0		0	0	0	0	Reinforced concrete, thickness => 700 mm
7	Reiforced concrete, ceiling	Basement - 002 - NA 01 - cell	22960	0		0	0	0	0	Reinforced concrete, thickness => 700 mm
8	Reiforced concrete, floor	Basement - 002 - NA 01 - cell	27560	0		0	0	0	0	Reinforced concrete, thickness => 700 mm
9	Hermetic door, C steel	Basement - 002 - NA 01 - cell	3850	0		0	0	0	0	Hermetic and shielding doors (CS)
10	Pipe mail, plastic pipe, O < 100 mm	Basement - 003 - NA 02 - cell	8	1,8	5000	0	0	2	0	Piping (PE, PP ...), diameter <= 100 mm
11	Air condition system, C steel pipe	Basement - 003 - NA 02 - cell	55	4,8	50000	0	0	5	0	Air conditioning components - piping (CS), cross section < 0,16 m2
12	Reiforced concrete; walls	Basement - 003 - NA 02 - cell	105000	0		0	0	0	0	Reinforced concrete, thickness => 700 mm
13	Reiforced concrete, ceiling	Basement - 003 - NA 02 - cell	22960	0		0	0	0	0	Reinforced concrete, thickness => 700 mm
14	Reiforced concrete, floor	Basement - 003 - NA 02 - cell	27560	0		0	0	0	0	Reinforced concrete, thickness => 700 mm
15	Hermetic door, C steel	Basement - 003 - NA 02 - cell	3850	0		0	0	0	0	Hermetic and shielding doors (CS)
16	Pipe mail, plastic pipe, O < 100 mm	Basement - 004 - NA 03 - cell	8	1,8	5000	0	0	2	0	Piping (PE, PP ...), diameter <= 100 mm
17	Air condition system, C steel pipe	Basement - 004 - NA 03 - cell	55	4,8	50000	0	0	5	0	Air conditioning components - piping (CS), cross section < 0,16 m2
18	Reiforced concrete; walls	Basement - 004 - NA 03 - cell	105000	0		0	0	0	0	Reinforced concrete, thickness => 700 mm
19	Reiforced concrete, ceiling	Basement - 004 - NA 03 - cell	22960	0		0	0	0	0	Reinforced concrete, thickness => 700 mm
20	Reiforced concrete, floor	Basement - 004 - NA 03 - cell	27560	0		0	0	0	0	Reinforced concrete, thickness => 700 mm
21	Hermetic door, C steel	Basement - 004 - NA 03 - cell	3850	0		0	0	0	0	Hermetic and shielding doors (CS)
22	Pipe mail, plastic pipe, O < 100 mm	Basement - 005 - E012 - cell	8	1,8	5000	0	0	2	0	Piping (PE, PP ...), diameter <= 100 mm
23	Air condition system, C steel pipe	Basement - 005 - E012 - cell	55	4,8	50000	0	0	5	0	Air conditioning components - piping (CS), cross section < 0,16 m^2
24	Reiforced concrete; walls	Basement - 005 - E012 - cell	105000	0		0	0	0	0	Reinforced concrete, thickness => 700 mm

ID	Name of technological or building equipment	Name of floor and room	Weight [kg]	Inner surface [m^2]	Inner surface contam. [Bq/m^2]	Outer surface [m^2]	Outer surface contam. [Bq/m^2]	Dose rate [µGy/h]	Inner volume [m^3]	Category of technological or building equipment
25	Reiforced concrete, ceiling	Basement - 005 - E012 - cell	22960	0		0	0	0	0	Reinforced concrete, thickness => 700 mm
26	Reiforced concrete, floor	Basement - 005 - E012 - cell	27560	0		0	0	0	0	Reinforced concrete, thickness => 700 mm
27	Hermetic door, C steel	Basement - 005 - E012 - cell	3850	0		0	0	0	0	Hermetic and shielding doors (CS)
28	Plastic pipe, O = 100 mm,Channel	Basement - 006 - NA 04 - corridor 2	21	1,9	5000	0	0	2	0	Piping (PE, PP ...), diameter <= 100 mm
29	Plastic pipe, O = 160 mm,Channel	Basement - 006 - NA 04 - corridor 2	31	3	5000	0	0	2	0	Piping (PE, PP ...), diameter > 100 mm
30	Embeded pipe, O = 80 mm, C steel, Channel	Basement - 006 - NA 04 - corridor 2	110	1,5	50000	0	0	5	0	Embeded piping - sewer piping, (SS), typical dimensions - D 100 mm/6 mm
31	Contaminated concrete, Channel	Basement - 006 - NA 04 - corridor 2	3760	0	0	4	50000	5	0	
32	Decorative sheet ceiling, colour metal	Basement - 006 - NA 04 - corridor 2	39,5	0	0	0	0	0	0	General category for study level - colour metals equipment
33	Firefighting door, C steel & azbestos	Basement - 006 - NA 04 - corridor 2	80	0	0	0	0	0	0	Firefighting door, C steel cladding, azbestos plate
34	Plastic pipe, O = 100 mm,Channel	Basement - 007 - Corridor	107	9,42	5000	0	0	2	0	Piping (PE, PP ...), diameter <= 100 mm
35	Plastic pipe, O = 160 mm,Channel	Basement - 007 - Corridor	156	15	5000	0	0	2	0	Piping (PE, PP ...), diameter > 100 mm
36	Embeded pipe, O = 80 mm, S steel	Basement - 007 - Corridor	515	7,54	50000	0	0	5	0	Embeded piping - sewer piping, (SS), typical dimensions - D 100 mm/6 mm
37	Contaminated concrete, Channel	Basement - 007 - Corridor	23760	0	0	20	50000	5	0	
38	Steel plate of channel, C steel	Basement - 007 - Corridor	1130	0	0	15	5000	2	0	Steel constructions, (CS), doors and manhole covers
39	Air condition system, 400 x 500 mm, C steel	Basement - 007 - Corridor	595	15	50000	0	0	5	0	Air conditioning components - piping (CS), 0,16 m^2 =< cross section from <= 1 m^2
40	Air condition system, O = 160 mm, PP pipe	Basement - 007 - Corridor	156	15	500	0	0	1	0	Piping (PE, PP ...), diameter > 100 mm
41	Air condition system, O = 220 mm, PP pipe	Basement - 007 - Corridor	309	21	500	0	0	1	0	Piping (PE, PP ...), diameter > 100 mm
42	Electrical cable, Cu, colour metal	Basement - 007 - Corridor	5605	0	0	0	0	0	0	Electrical cables & conductors; (Cu), 1 kV power cables
43	Electric equipment, switches	Basement - 007 - Corridor	1,5	0	0	0	0	0	0	General electric equipment, (CS) mass <= 50 kg
44	Electric equipment, light bodies	Basement - 007 - Corridor	140	0	0	0	0	0	0	General electric equipment, (CS) mass <= 50 kg
45	Cable grating	Basement - 007 - Corridor	890	0	0	0	0	0	0	Steel constructions, (CS), plattforms and stages

ID	Name of technological or building equipment	Name of floor and room	Weight [kg]	Inner surface [m^2]	Inner surface contam. [Bq/m^2]	Outer surface [m^2]	Outer surface contam. [Bq/m^2]	Dose rate [µGy/h]	Inner volume [m^3]	Category of technological or building equipment
46	Decorative sheet ceiling, colour metal	Basement - 007 - Corridor	256	0	0	0	0	0	0	General category for study level - colour metals equipment
47	Elevator	Basement - 008 - Elevator shaft	560	0		0	0	0	0	General electric equipment, (CS) mass > 50 kg
48	Elevator, steel konstruction, metals, rope, C steel	Basement - 008 - Elevator shaft	2550	0		0	0	0	0	Steel constructions, (CS), hangings of piping, general hangings
49	Elevator, cables	Basement - 008 - Elevator shaft	260	0		0	0	0	0	Electrical cables & conductors; (Cu), 1 kV power cables
50	Hot cell, C steel & lead	Basement - 009 - E002 - Hot cell laboratory	82940	8	50000	0	0	5	0	Hot cell; C steel cladding, lead shielding, (typical dimesions 3 x 2,5 x 2 [m])
51	Air condition system, D < 0,16 m2, C steel	Basement - 009 - E002 - Hot cell laboratory	264	4,8	50000	0	0	5	0	Air conditioning components - piping (CS), cross section < 0,16 m2
52	Air condition system, D < 0,16 m2, C steel	Basement - 009 - E002 - Hot cell laboratory	98	1,8	50000	0	0	5	0	Air conditioning components - piping (CS), cross section < 0,16 m2
53	Hoisting equipment, C steel	Basement - 009 - E002 - Hot cell laboratory	1250	0		0	0	0	0	Hoisting equipment, (CS), small manual tackles
54	Hoisting equipment rails, C steel	Basement - 009 - E002 - Hot cell laboratory	860	0		0	0	0	0	Hoisting equipment (CS), crane rails
55	Electrical cable, Cu, colour metal	Basement - 009 - E002 - Hot cell laboratory	250	0		0	0	0	0	Electrical cables & conductors; (Cu), 1 kV power cables
56	Distribution box, electrical equipment	Basement - 009 - E002 - Hot cell laboratory	300	0		0	0	0	0	General electric equipment, (CS) mass > 50 kg
57	Pipe mail, plastic pipe, O < 100 mm,	Basement - 009 - E002 - Hot cell laboratory	10	1,3	5000	0	0	2	0	Piping (PE, PP ...), diameter <= 100 mm
58	Hot cell, C steel & lead	Basement - 009 - E002 - Hot cell laboratory	5530	6	50000	0	0	5	0	Hot cell; C steel cladding, lead shielding, (typical dimesions 3 x 2,5 x 2 [m])
59	Firefighting door, C steel & azbestos	Basement - 009 - E002 - Hot cell laboratory	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
60	Decorative sheet ceiling, colour metal	Basement - 010 - E013 - Small hot cell laboratory	156	0		0	0	0	0	General category for study level - colour metals equipment
61	Air condition system, D < 0,16 m2, C steel	Basement - 010 - E013 - Small hot cell laboratory	130	3,2	50000	0	0	5	0	Air conditioning components - piping (CS), cross section < 0,16 m^2
62	Electrical cable, Cu, colour metal	Basement - 010 - E013 - Small hot cell laboratory	20	0		0	0	0	0	Electrical cables & conductors; (Cu), 1 kV power cables
63	Hot cell, C steel & lead	Basement - 010 - E013 - Small hot cell laboratory	41470	6	50000	0	0	5	0	Hot cell; C steel cladding, lead shielding, (typical dimesions 3 x 2,5 x 2 [m])

ID	Name of technological or building equipment	Name of floor and room	Weight [kg]	Inner surface [m^2]	Inner surface contam. [Bq/m^2]	Outer surface [m^2]	Outer surface contam. [Bq/m^2]	Dose rate [μGy/h]	Inner volume [m^3]	Category of technological or building equipment
64	Hot cell, C steel & lead	Basement - 010 - E013 - Small hot cell laboratory	41470	6	50000	0	0	5	0	Hot cell; C steel cladding, lead shielding, (typical dimesions 3 x 2,5 x 2 [m])
65	Firefighting door, C steel & azbestos	Basement - 010 - E013 - Small hot cell laboratory	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
66	Air condition system, D < 0,16 m2, C steel	Basement - 011 - E003 - Digestor laboratory	85	1,9	50000	0	0	5	0	Air conditioning components - piping (CS), cross section < 0,16 m^2
67	Digestor	Basement - 011 - E003 - Digestor laboratory	160	1	5000	0	0	2	0	Digestors (CS)
68	Glove box	Basement - 011 - E003 - Digestor laboratory	130	2	5000	0	0	2	0	Sampling boxes (CS)
69	Valves, various dimensions, C steel	Basement - 011 - E003 - Digestor laboratory	420	0		0	0	0	0	General category for study level - carbon steel equipment
70	Reserve item	Basement - 011 - E003 - Digestor laboratory	0	0		0	0	0	0	General category for study level - carbon steel equipment
71	Decorative sheet ceiling, colour metal	Basement - 011 - E003 - Digestor laboratory	78	0		0	0	0	0	General category for study level - colour metals equipment
72	Firefighting door, C steel & azbestos	Basement - 011 - E003 - Digestor laboratory	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
73	Pipe mail, plastic pipe, O < 100 mm,	Basement - 012 - Neutron laboratory	10	1,5	5000	0	0	2	0	Piping (PE, PP ...), diameter <= 100 mm
74	Air condition system, D < 0,16 m2, C steel	Basement - 012 - Neutron laboratory	80	2	50000	0	0	5	0	Air conditioning components - piping (CS), cross section < 0,16 m^2
75	Steel construction. C steel	Basement - 012 - Neutron laboratory	250	0		1,7	50000	5	0	Steel constructions, (CS), shieldings
76	Electrical cable, Cu, colour metal	Basement - 012 - Neutron laboratory	12	0		0	0	0	0	Electrical cables & conductors; (Cu), 1 kV power cables
77	Decorative sheet ceiling, colour metal	Basement - 012 - Neutron laboratory	156	0		0	0	0	0	General category for study level - colour metals equipment
78	Firefighting door, C steel & azbestos	Basement - 012 - Neutron laboratory	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
79	Valves, various dimensions, S steel	Ground floor - 101 - Stairs	380	0		0	0	0	0	General category for study level - stainless steel equipment
80	S steel - reserve item	Ground floor - 101 - Stairs	0	0		0	0	0		General category for study level - carbon steel equipment
81	Firefighting door, C steel & azbestos	Ground floor - 101 - Stairs	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
82	Air condition system, D < 0,16 m2, PE	Ground floor - 102 - Office	20	0		0	0	0	0	Piping (PE, PP ...), diameter > 100 mm

ID	Name of technological or building equipment	Name of floor and room	Weight [kg]	Inner surface [m^2]	Inner surface contam. [Bq/m^2]	Outer surface [m^2]	Outer surface contam. [Bq/m^2]	Dose rate [µGy/h]	Inner volume [m^3]	Category of technological or building equipment
83	Decorative sheet ceiling, colour metal	Ground floor - 102 - Office	100	0		0	0	0	0	General category for study level - colour metals equipment
84	PVC flooring	Ground floor - 102 - Office	95	0		0	0	0	0	Floor covering (flooring) PVC
85	Firefighting door, C steel & azbestos	Ground floor - 102 - Office	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
86	Air condition system, D < 0,16 m2, PE	Ground floor - 103 - Office	20	0		0	0	0	0	Piping (PE, PP ...), diameter > 100 mm
87	Decorative sheet ceiling, colour metal	Ground floor - 103 - Office	100	0		0	0	0	0	General category for study level - colour metals equipment
88	PVC flooring	Ground floor - 103 - Office	95	0		0	0	0	0	Floor covering (flooring) PVC
89	Firefighting door, C steel & azbestos	Ground floor - 103 - Office	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
90	Air condition system, D < 0,16 m2, PE	Ground floor - 104 - Office	20	0		0	0	0	0	Piping (PE, PP ...), diameter > 100 mm
91	Decorative sheet ceiling, colour metal	Ground floor - 104 - Office	100	0		0	0	0	0	General category for study level - colour metals equipment
92	PVC flooring	Ground floor - 104 - Office	95	0		0	0	0	0	Floor covering (flooring) PVC
93	Firefighting door, C steel & azbestos	Ground floor - 104 - Office	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
94	Air condition system, D < 0,16 m2, C steel	Ground floor - 105 - 116A, 116B - Hot cell laboratory	120	3	50000	0	0	5	0	Air conditioning components - piping (CS), cross section < 0,16 m^2
95	Decorative sheet ceiling, colour metal	Ground floor - 105 - 116A, 116B - Hot cell laboratory	100	0		0	0	0	0	General category for study level - colour metals equipment
96	Pipe mail, plastic pipe, O < 100 mm,	Ground floor - 105 - 116A, 116B - Hot cell laboratory	20	0,8	5000	0	0	2	0	Piping (PE, PP ...), diameter <= 100 mm
97	Hot cell, C steel & lead	Ground floor - 105 - 116A, 116B - Hot cell laboratory	82940	8	50000	0	0	5	0	Hot cell; C steel cladding, lead shielding, (typical dimesions 3 x 2,5 x 2 [m])
98	Box, C steel	Ground floor - 105 - 116A, 116B - Hot cell laboratory	120	0	0	4	5000	2	0	General category for study level - carbon steel equipment
99	Electrical cable, Cu, colour metal	Ground floor - 105 - 116A, 116B - Hot cell laboratory	130	0		0	0	0	0	Electrical cables & conductors; (Cu), 1 kV power cables
100	Cable grating	Ground floor - 105 - 116A, 116B - Hot cell laboratory	50	0		0	0	0	0	Steel constructions, (CS), plattforms and stages
101	Hoisting equipment, C steel	Ground floor - 105 - 116A, 116B - Hot cell laboratory	1100	0		0	0	0	0	Hoisting equipment, (CS), small manual tackles
102	Hoisting equipment rails, C steel	Ground floor - 105 - 116A, 116B - Hot cell laboratory	550	0		0	0	0	0	Hoisting equipment (CS), crane rails

ID	Name of technological or building equipment	Name of floor and room	Weight [kg]	Inner surface [m^2]	Inner surface contam. [Bq/m^2]	Outer surface [m^2]	Outer surface contam. [Bq/m^2]	Dose rate [μGy/h]	Inner volume [m^3]	Category of technological or building equipment
103	Decorative sheet ceiling, colour metal	Ground floor - 105 - 116A, 116B - Hot cell laboratory	297	0		0	0	0	0	General category for study level - colour metals equipment
104	Firefighting door, C steel & azbestos	Ground floor - 105 - 116A, 116B - Hot cell laboratory	160	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
105	Rest material item, C steel	Ground floor - 106 - Transit corridor	0	0		0	0	0	0	General category for study level - carbon steel equipment
106	Electrical cable, Cu, colour metal	Ground floor - 106 - Transit corridor	50	0		0	0	0	0	Electrical cables & conductors; (Cu), 1 kV power cables
107	Electric equipment, light bodies	Ground floor - 106 - Transit corridor	80	0		0	0	0	0	General electric equipment, (CS) mass <= 50 kg
108	Decorative sheet ceiling, colour metal	Ground floor - 106 - Transit corridor	144	0		0	0	0	0	General category for study level - colour metals equipment
109	Firefighting doors, C steel & azbestos	Ground floor - 106 - Transit corridor	440	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
110	Decorative sheet ceiling, colour metal	Ground floor - 107 - Corridor	223	0		0	0	0	0	General category for study level - colour metals equipment
111	Suppling steel construction, C steel	Ground floor - 107 - Corridor	190	0		0	0	0	0	Steel constructions, (CS), hangings of piping, general hangings
112	Distribution box, electrical equipment	Ground floor - 107 - Corridor	800	0		0	0	0	0	General electric equipment, (CS) mass > 50 kg
113	Electrical cable, Cu, colour metal	Ground floor - 107 - Corridor	300	0		0	0	0	0	Electrical cables & conductors; (Cu), 1 kV power cables
114	Electric equipment, light bodies	Ground floor - 106 - Transit corridor	120	0		0	0	0	0	General electric equipment, (CS) mass <= 50 kg
115	Elevator shaft, reserve item	Ground floor - 108 - Elevator shaft	0	0		0	0	0	0	General category for study level - carbon steel equipment
116	Air condition system, D < 0,16 m2, PE	Ground floor - 109 - Office	20	0		0	0	0	0	Piping (PE, PP ...), diameter > 100 mm
117	Decorative sheet ceiling, colour metal	Ground floor - 109 - Office	100	0		0	0	0	0	General category for study level - colour metals equipment
118	Firefighting door, C steel & azbestos	Ground floor - 109 - Office	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
119	PVC flooring	Ground floor - 109 - Office	95	0		0	0	0	0	Floor covering (flooring) PVC
120	Air condition system, D < 0,16 m2, PE	Ground floor - 110 - Office	20	0		0	0	0	0	Piping (PE, PP ...), diameter > 100 mm
121	Decorative sheet ceiling, colour metal	Ground floor - 110 - Office	100	0		0	0	0	0	General category for study level - colour metals equipment

ID	Name of technological or building equipment	Name of floor and room	Weight [kg]	Inner surface [m^2]	Inner surface contam. [Bq/m^2]	Outer surface [m^2]	Outer surface contam. [Bq/m^2]	Dose rate [μGy/h]	Inner volume [m^3]	Category of technological or building equipment
122	PVC flooring	Ground floor - 110 - Office	95	0		0	0	0	0	Floor covering (flooring) PVC
123	Firefighting door, C steel & azbestos	Ground floor - 110 - Office	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
124	Air condition system, D < 0,16 m2, PE	Ground floor - 111 - Office	20	0		0	0	0	0	Piping (PE, PP ...), diameter > 100 mm
125	Decorative sheet ceiling, colour metal	Ground floor - 111 - Office	100	0		0	0	0	0	General category for study level - colour metals equipment
126	PVC flooring	Ground floor - 111 - Office	95	0		0	0	0	0	Floor covering (flooring) PVC
127	Firefighting door, C steel & azbestos	Ground floor - 111 - Office	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
128	Air condition system, D < 0,16 m2, PE	Ground floor - 112 - Office	20	0		0	0	0	0	Piping (PE, PP ...), diameter > 100 mm
129	Decorative sheet ceiling, colour metal	Ground floor - 112 - Office	100	0		0	0	0	0	General category for study level - colour metals equipment
130	PVC flooring	Ground floor - 112 - Office	95	0		0	0	0	0	Floor covering (flooring) PVC
131	Firefighting door, C steel & azbestos	Ground floor - 112 - Office	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
132	Air condition system, D < 0,16 m2, PE	Ground floor - 113 - Office	20	0		0	0	0	0	Piping (PE, PP ...), diameter > 100 mm
133	Decorative sheet ceiling, colour metal	Ground floor - 113 - Office	100	0		0	0	0	0	General category for study level - colour metals equipment
134	PVC flooring	Ground floor - 113 - Office	95	0		0	0	0	0	Floor covering (flooring) PVC
135	Firefighting door, C steel & azbestos	Ground floor - 113 - Office	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
136	Rest material, reserve item	First floor - 201 - Stairs	0	0		0	0	0	0	General category for study level - carbon steel equipment
137	Firefighting door, C steel & azbestos	First floor - 201 - Stairs	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
138	Decorative sheet ceiling, colour metal	First floor - 202 - Office	100	0		0	0	0	0	General category for study level - colour metals equipment
139	PVC flooring	First floor - 202 - Office	95	0		0	0	0	0	Floor covering (flooring) PVC
140	Firefighting door, C steel & azbestos	First floor - 202 - Office	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
141	Decorative sheet ceiling, colour metal	First floor - 203 - Office	100	0		0	0	0	0	General category for study level - colour metals equipment
142	PVC flooring	First floor - 203 - Office	95	0		0	0	0	0	Floor covering (flooring) PVC

ID	Name of technological or building equipment	Name of floor and room	Weight [kg]	Inner surface [m^2]	Inner surface contam. [Bq/m^2]	Outer surface [m^2]	Outer surface contam. [Bq/m^2]	Dose rate [μGy/h]	Inner volume [m^3]	Category of technological or building equipment
143	Firefighting door, C steel & azbestos	First floor - 203 - Office	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
144	Decorative sheet ceiling, colour metal	First floor - 204 - Office	100	0		0	0	0	0	General category for study level - colour metals equipment
145	PVC flooring	First floor - 204 - Office	95	0		0	0	0	0	Floor covering (flooring) PVC
146	Firefighting door, C steel & azbestos	First floor - 204 - Office	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
147	Decorative sheet ceiling, colour metal	First floor - 205 - Office	100	0		0	0	0	0	General category for study level - colour metals equipment
148	PVC flooring	First floor - 205 - Office	95	0		0	0	0	0	Floor covering (flooring) PVC
149	Firefighting door, C steel & azbestos	First floor - 205 - Office	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
150	Decorative sheet ceiling, colour metal	First floor - 206 - Office	100	0		0	0	0	0	General category for study level - colour metals equipment
151	PVC flooring	First floor - 206 - Office	95	0		0	0	0	0	Floor covering (flooring) PVC
152	Firefighting door, C steel & azbestos	First floor - 206 - Office	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
153	Decorative sheet ceiling, colour metal	First floor - 207 - Corridor	248	0		0	0	0	0	General category for study level - colour metals equipment
154	Electric equipment, light bodies	First floor - 207 - Corridor	140	0		0	0	0	0	General electric equipment, (CS) mass <= 50 kg
155	Air condition system, D < 0,16 m2, C steel	First floor - 210 - E204 - Digestors & PM Control panel	120	3	50000	0	0	5	0	Air conditioning components - piping (CS), cross section < 0,16 m^2
156	Elevator shaft, reserve item	First floor - 208 - Elevator shaft	0	0		0	0	0	0	General category for study level - carbon steel equipment
157	Decorative sheet ceiling, colour metal	First floor - 209 - E203 - empty laboratory	100	0		0	0	0	0	General category for study level - colour metals equipment
158	PVC flooring	First floor - 209 - E203 - empty laboratory	95	0		0	0	0	0	Floor covering (flooring) PVC
159	Firefighting door, C steel & azbestos	First floor - 209 - E203 - empty laboratory	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
160	Decorative sheet ceiling, colour metal	First floor - 210 - E204 - Digestors & PM Control panel	100	0		0	0	0	0	General category for study level - colour metals equipment
161	Shield lead box	First floor - 210 - E204 - Digestors & PM Control panel	9100	0		0	0	0	0	Hot cell; C steel cladding, lead shielding, (typical dimesions 3 x 2,5 x 2 [m])
162	Sink, C steel	First floor - 210 - E204 - Digestors & PM Control panel	50	0		0,3	500	1	0	General category for study level - carbon steel equipment

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163	Distribution box, electrical equipment	First floor - 210 - E204 - Digestors & PM Control panel	180	0		0	0	0	0	General electric equipment, (CS) mass > 50 kg
164	Firefighting door, C steel & azbestos	First floor - 210 - E204 - Digestors & PM Control panel	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
165	Decorative sheet ceiling, colour metal	First floor - 211 - E206 - empty laboratory	100	0		0	0	0	0	General category for study level - colour metals equipment
166	Lead panel for pipe mail	First floor - 210 - E204 - Digestors & PM Control panel	2300	0		0	0	0	0	Hot cell; C steel cladding, lead shielding, (typical dimesions 3 x 2,5 x 2 [m])
167	Digestor 1, C steel	First floor - 210 - E204 - Digestors & PM Control panel	150	2	5000	0	0	2	0	Digestors (CS)
168	Digestor 2, C steel	First floor - 210 - E204 - Digestors & PM Control panel	150	2	5000	0	0	2	0	Digestors (CS)
169	Electrical cable, Cu, colour metal	First floor - 211 - E206 - empty laboratory	20	0		0	0	0	0	Electrical cables & conductors; (Cu), 1 kV power cables
170	PVC flooring	First floor - 211 - E206 - empty laboratory	95	0		0	0	0	0	Floor covering (flooring) PVC
171	Firefighting door, C steel & azbestos	First floor - 211 - E206 - empty laboratory	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
172	Decorative sheet ceiling, colour metal	First floor - 212 - E205 - Glow boxes	100	0		0	0	0	0	General category for study level - colour metals equipment
173	Air condition system, D < 0,16 m2, C steel	First floor - 212 - E205 - Glow boxes	90	3	50000	0	0	5	0	Air conditioning components - piping (CS), cross section < 0,16 m^2
174	Digestor, C steel	First floor - 212 - E205 - Glow boxes	450	1	5000	0	0	2	0	Digestors (CS)
175	Firefighting door, C steel & azbestos	First floor - 212 - E205 - Glow boxes	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
176	C steel - reserve item	Attic - 301 - Stairs	0	0		0	0	0	0	General category for study level - carbon steel equipment
177	S steel - reserve item	Attic - 301 - Stairs	0	0		0	0	0	0	General category for study level - stainless steel equipment
178	Firefighting door, C steel & azbestos	Attic - 301 - Stairs	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
179	C steel - reserve item	Attic - 302 - NA 04	0	0		0	0	0	0	General category for study level - carbon steel equipment
180	S steel - reserve item	Attic - 302 - NA 04	0	0		0	0	0	0	General category for study level - stainless steel equipment
181	Firefighting door, C steel & azbestos	Attic - 302 - NA 04	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate

ID	Name of technological or building equipment	Name of floor and room	Weight [kg]	Inner surface [m^2]	Inner surface contam. [Bq/m^2]	Outer surface [m^2]	Outer surface contam. [Bq/m^2]	Dose rate [μGy/h]	Inner volume [m^3]	Category of technological or building equipment
182	C steel - reserve item	Attic - 303 - NA 05	0	0		0	0	0	0	General category for study level - carbon steel equipment
183	S steel - reserve item	Attic - 303 - NA 05	0	0		0	0	0	0	General category for study level - stainless steel equipment
184	Firefighting door, C steel & azbestos	Attic - 303 - NA 05	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
185	C steel - reserve item	Attic - 304 - E308	0	0		0	0	0	0	General category for study level - carbon steel equipment
186	S steel - reserve item	Attic - 304 - E308	0	0		0	0	0	0	General category for study level - stainless steel equipment
187	Air condition filters	Attic - 305 - E309A - filter room	420	0		0	0	0	0	Air conditioning systems, filter casings (CS), dimension > 1m
188	Heater, C steel	Attic - 306 - E309 - heater room	1200	0		0	0	0	0	Heat exchangers (CS) , diameter <= 1m, typical wall thickness 20 mm
189	Air condition system, O = 200 mm, PP pipe	Attic - 306 - E309 - heater room	10	0		0	0	0	0	Piping (PE, PP ...), diameter <= 100 mm
190	C steel - reserve item	Attic - 307 - Corridor 1	0	0		0	0	0	0	General category for study level - carbon steel equipment
191	Firefighting door, C steel & azbestos	Attic - 307 - Corridor 1	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
192	C steel - reserve item	Attic - 308 - Corridor 2	0	0		0	0	0	0	General category for study level - carbon steel equipment
193	Electric equipment, light bodies	Attic - 308 - Corridor 2	80	0		0	0	0	0	General electric equipment, (CS) mass <= 50 kg
194	Electrical cable, Cu, colour metal	Attic - 308 - Corridor 2	20	0		0	0	0	0	Electrical cables & conductors; (Cu), 1 kV power cables
195	Elevator engine, C steel	Attic - 309 - Elevator machinery	250	0		0	0	0	0	Electric motors, mass > 50 kg
196	Supporting construction, C steel	Attic - 309 - Elevator machinery	800	0		0	0	0	0	Steel constructions, (CS), hangings of piping, general hangings
197	Firefighting door, C steel & azbestos	Attic - 310 - E306 - High contaminated airconditionary	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
198	Air condition system, D < 0,16 m2, C steel	Attic - 310 - E306 - High contaminated airconditionary	320	25	50000	0	0	5	0	Air conditioning components - piping (CS), cross section < 0,16 m^2
199	Air condition system, D < 0,16 m2, PE	Attic - 310 - E306 - High contaminated airconditionary	35	15	50000	0	0	5	0	Piping (PE, PP ...), diameter > 100 mm
200	Air condition filter box	Attic - 310 - E306 - High contaminated airconditionary	220	0		6	5000	2	0	Air conditioning systems, filter casings (CS), dimension > 1m

ID	Name of technological or building equipment	Name of floor and room	Weight [kg]	Inner surface [m^2]	Inner surface contam. [Bq/m^2]	Outer surface [m^2]	Outer surface contam. [Bq/m^2]	Dose rate [μGy/h]	Inner volume [m^3]	Category of technological or building equipment
201	Air condition fan, 10 kW	Attic - 310 - E306 - High contaminated airconditionary	60	0		0	0	0	0	Ventilators (CS), mass > 50 kg, at least one dimension > 1m
202	Air condition fan, 5 kW	Attic - 310 - E306 - High contaminated airconditionary	40	0		0	0	0	0	Ventilators (CS), mass <= 50 kg
203	Air condition filter box	Attic - 310 - E306 - High contaminated airconditionary	70	0		6	5000	2	0	Air conditioning systems, filter casings (CS), dimension <= 1m
204	Firefighting door, C steel & azbestos	Attic - 311 - E305 - Low contaminaed airconditionary	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
205	Air condition system, D < 0,16 m2, C steel	Attic - 311 - E305 - Low contaminaed airconditionary	170	20	5000	0	0	2	0	Air conditioning components - piping (CS), cross section < 0,16 m^2
206	Air condition system, D < 0,16 m2, PE	Attic - 311 - E305 - Low contaminaed airconditionary	215	15	5000	0	0	2	0	Hot cell; C steel cladding, lead shielding, (typical dimesions 3 x 2,5 x 2 [m])
207	Air condition fan, 10 kW	Attic - 311 - E305 - Low contaminaed airconditionary	120	0		0	0	0	0	Ventilators (CS), mass > 50 kg, at least one dimension > 1m
208	Air condition fan, 5 kW	Attic - 311 - E305 - Low contaminaed airconditionary	40	0		0	0	0	0	Ventilators (CS), mass <= 50 kg
209	Air condition filter box	Attic - 311 - E305 - Low contaminaed airconditionary	200	0		6	500	1	0	Air conditioning systems, filter casings (CS), dimension > 1m
210	Air condition filter box	Attic - 311 - E305 - Low contaminaed airconditionary	700	0		6	500	1	0	Air conditioning systems, filter casings (CS), dimension <= 1m
211	Firefighting door, C steel & azbestos	Attic - 312 - Empty store	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
212	Air condition system, D < 0,16 m2, C steel	Attic - 312 - Empty store	380	4	50000	0	0	5	0	Air conditioning components - piping (CS), cross section < 0,16 m^2
213	PVC flooring	Attic - 312 - Empty store	107	0		0	0	0	0	Floor covering (flooring) PVC
214	Firefighting door, C steel & azbestos	Attic - 313 - I129 store	80	0		0	0	0	0	Firefighting door, C steel cladding, azbestos plate
215	PVC flooring	Attic - 313 - I129 store	57	0		0	0	0	0	Floor covering (flooring) PVC
216	Building surfaces for mechanical decontamination, floors	Attic - 401 - Virtual room	0	0		160	5000	0	0	
217	Building surfaces for chemical decontamination, walls	Attic - 401 - Virtual room	0	0		200	5000	0	0	
218	Concrete under -1m	Attic - 401 - Virtual room	287100	0		0	0	0	0	Masonry
219	Reinforced concrete, under -1m	Attic - 401 - Virtual room	435000	0		0	0	0	0	Reinforced concrete, thickness => 700 mm
220	External cladding, reinforced concrete under -1m	Attic - 401 - Virtual room	333750	0		0	0	0	0	Reinforced concrete, thickness <= 400 mm

ID	Name of technological or building equipment	Name of floor and room	Weight [kg]	Inner surface [m^2]	Inner surface contam. [Bq/m^2]	Outer surface [m^2]	Outer surface contam. [Bq/m^2]	Dose rate [µGy/h]	Inner volume [m^3]	Category of technological or building equipment
221	External cladding, reinforced concrete above -1m	Attic - 401 - Virtual room	11125	0		0	0	0	0	Reinforced concrete, thickness <= 400 mm
222	Dividing walls, reinforced concrete wall under -1m	Attic - 401 - Virtual room	75240	0		0	0	0	0	Reinforced concrete, thickness <= 400 mm
223	Dividing walls, reinforced concrete wall above -1m	Attic - 401 - Virtual room	25080	0		0	0	0	0	Reinforced concrete, thickness <= 400 mm
224	Steel construction, basement C steel under -1m	Attic - 401 - Virtual room	13170	0		0	0	0	0	Steel skeletons, (CS)
225	External cladding, reinforced concrete	Attic - 401 - Virtual room	670500	0		0	0	0	0	Reinforced concrete, thickness <= 400 mm
226	Dividing walls, ground floor, reinforced concrete	Attic - 401 - Virtual room	257000	0		0	0	0	0	Reinforced concrete, thickness <= 400 mm
227	Floor plate, ground floor, reinforced concrete	Attic - 401 - Virtual room	315000	0		0	0	0	0	Reinforced concrete, thickness <= 400 mm
228	Steel construction, ground floor, C steel	Attic - 401 - Virtual room	11310	0		0	0	0	0	Steel skeletons, (CS)
229	Dividing walls, 1st floor, reinforced concrete	Attic - 401 - Virtual room	252000	0		0	0	0	0	Reinforced concrete, thickness <= 400 mm
230	Floor plate, 1st floor, reinforced concrete	Attic - 401 - Virtual room	315000	0		0	0	0	0	Reinforced concrete, thickness <= 400 mm
231	Steel construction, 1st floor. C steel	Attic - 401 - Virtual room	28000	0		0	0	0	0	Steel skeletons, (CS)
232	Dividing walls, attic, reinforced concrete	Attic - 401 - Virtual room	190000	0		0	0	0	0	Reinforced concrete, thickness <= 400 mm
233	Floor plate, attic, reinforced concrete	Attic - 401 - Virtual room	315000	0		0	0	0	0	Reinforced concrete, thickness <= 400 mm
234	Stair construction, steel	Attic - 401 - Virtual room	15000	0		0	0	0	0	Steel constructions, (CS), stairs, ladders, railings
235	Roof construction, girders	Attic - 401 - Virtual room	51000	0		0	0	0	0	Prefabricates
236	Roof construction, Siporex panels	Attic - 401 - Virtual room	132600	0		0	0	0	0	Peripheral walls - panels
237	Roof insulation, other material	Attic - 401 - Virtual room	3200	0		0	0	0	0	Other building construction
238	Windows of building	Attic - 401 - Virtual room	27000	0		0	0	0	0	Other building construction
239	Digestor, C steel	First floor - 212 - E205 - Glow boxes	450	1	5000	0	0	2	0	Digestors (CS)
240	Digestor, C steel	First floor - 212 - E205 - Glow boxes	450	1	5000	0	0	2	0	Digestors (CS)
241	Pipe mail, plastic pipe, O < 100 mm,	First floor - 210 - E204 - Digestors & PM Control panel	10	1,4	5000	0	0	2	0	Piping (PE, PP ...), diameter <= 100 mm

Annex 2- 1

General data for all questionnaires

Labour cost unit factors (social security contributions, insurance, social charges and other charges paid by the company are included)

Profession	Labour cost	Unit
manager (average personel on the management level)	135,45	€/manhour
senior engineer (experienced engineer, more then 10 years of experience in the field)	92,11	€/manhour
engineer (standard engineer)	86,69	€/manhour
operator (qualified operator in relevant branch)	83,44	€/manhour
administrative worker	83,44	€/manhour
worker (skilled, qualified craftsman)	59,60	€/manhour
auxiliary worker (only basic training)	49,85	€/manhour

Selected cost unit factors for general use in calculation

Cost unit factor	Value	Unit
Cost unit factor of demineralised water	70	€/m^3
Cost unit factor of cooling water	0,7	€/m^3
Cost unit factor of electrolyte for decontamination of metals	120	€/m^3
Cost unit factor of decontamination solvents - HNO_3 + $KMnO_4$	153,13	€/m^3
Cost unit factor of decontamination solvents - $C_6H_8O_7$ + $C_2H_2O_4$ + $EDTANa_4$	918,75	€/m^3
Cost unit factor of detergent	2000	€/m^3
Cost unit factor of aceton	750	€/m^3
Cost unit factor of neutralising reagent	725	€/m^3
Cost unit factor of ionex exchanger	9958,18	€/m^3
Cost unit factor of bitumen	350	€/m^3
Cost unit factor of steam	92,94	€/t
Cost unit factor of cement powder	0,11	€/kg
Cost unit factor of acetylene	5,98	€/Nm^3
Cost unit factor of oxygen	1,66	€/Nm^3
Cost unit factor of compressed air	0,04	€/Nm^3
Cost unit factor of plastic foil	6	€/kg
Cost unit factor of filters for ventilation systems	282,15	€/pc
Cost unit factor of disposal container	4979,1	€/container
Cost unit factor of standard drum (200 l volume)	33,19	€/drum
Cost unit factor of electricity	0,078	€/kWh
Cost unit factor of fuel oil	1,1	€/kg

Other costs unit factors (several hundreds) have minor impact on calculation of decmmissioning parameters and will be checked in next reviews

Other general data

Parameter	Value	Unit
Work days per year	206	-
Work hours per shift	8	-
Inner volume of drum for waste	0,2	m3
Inner volume of fibre-rainforced container (FRC) for waste (final disposal package, dimensions 1,7 x 1,7 x 1,7m)	3,1	m3
Dose rate of background in facility	0,2	mikroGy/h
Period of air change through airconditioning systems	2	changes/h

Use of colors for review of parameters

Color	Meaning of the color
no color	informative value for the first review, will be reviewed in next in-depth reviews
	parameter with most significant impact on cost, should be udapted for Swedish conditions
	parameter based on volume of 200L drum, should be updated for Swedish conditions if different package is used
	parameter based on volume of fibre-rainforced container (FRC), should be updated for Swedish conditions if different package is used
	parameter with significant impact on cost, could be updated in next reviews

Annex 2-2-1

Set of calculation procedures for dismantling of technological equipment

Preparatory activities in individual rooms before starting the dismantling:

P1 - Survey of radiological situation
P2 - Covering of floor by protective foil
P3 - Installation of scaffolding
P4 - Installation of temporary air-conditioning
P5 - Instalation of temporary electric and other media conections
P6 - Disconnection and revision of decommissioned technological equipment
P7 - Marking of cuts and areas
P8 - Delivery of working tools and equipments
P9 - Preparation of working tools and equipments
P10 - Preparation of transport containers
P11 - Installation of protective tent
P12 - Working grup instructions

Dismantling ig technological equipment-realization

D1 - Dismantling (manual) by hydraulic shears in CA
D2 - Dismantling (manual) by hydraulic shears out of CA
D3 - Dismantling (manual) by oxygen-acetylene set in CA
D4 - Dismantling (manual) by oxygen-acetylene set out of CA
D5 - Dismantling (manual) by plasma set in CA
D6 - Dismantling (manual) by plasma set out of CA
D7 - Dismantling (manual) by circular saw in CA
D8 - Dismantling (manual) by circular saw out of CA
D9 - Dismantling (manual) by hand tools (wrenches, etc.) in CA
D10 - Dismantling (manual) by hand tools (wrenches, etc.) out of CA

Finishing activities in individual rooms after decommissioning:

F1 - Removal of scaffolding
F2 - Removal of protective foil
F3 - Removal of temporary air-conditioning
F4 - Removal of temporary electric and other media conections
F5 - Removal of working tools and equipments
F6 - Removal of protective tent
F7 - Removal of transport containers
F8 - Cleaning of room

Preparation activities for dismantling of technological equipment - mechanical

Survey of radiological situation

Input technological parameters

Parameter	Value	Dimension
Manpower unit factor	0,21	man.hour/m^2

Work group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0,05
operator	2
clerk	0
worker	0
auxilliary worker	0

Covering of floor by protective foil

Input technological parameters

Parameter	Value	Dimension
Manpower unit factor	0,3	man.hour/m^2
Constant unit factor	8,75	man.hour

Work group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	1,3
clerk	0
worker	4
auxilliary worker	0

Installation of scaffolding

Input technological parameters

Parameter	Value	Dimension
Manpower unit factor	1	man.hour/scaffolding square
Constant unit factor	7	man.hour

Work group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	1,3
clerk	0
worker	4
auxilliary worker	0

Installation of temporary air-conditioning

Input technological parameters

Parameter	Value	Dimension
Manpower unit factor	12	man.hour/room

Work group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	3,1
clerk	0
worker	2
auxilliary worker	0

Installation of temporary electric and other media connections

Input technological parameters

Parameter	Value	Dimension
Manpower unit factor	5	man.hour/room

Work group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	1,5
clerk	0
worker	2
auxilliary worker	1

Disconnection and revision of decommissioned technological equipment

Input technological parameters

Parameter	Value	Dimension
Manpower unit factor	0,11	man.hour/m^2
Constant unit factor	3	man.hour

Work group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	2,6
clerk	0
worker	2
auxilliary worker	0

Marking of cuts and areas

Input technological parameters

Parameter	Value	Dimension
Manpower unit factor	0,15	man.hour/m^2
Constant unit factor	3,5	man.hour

Work group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	2,6
clerk	0
worker	2
auxilliary worker	0

Delivery of working tools and equipments

Input technological parameters

Parameter	Value	Dimension
Manpower unit factor	0,12	man.hour/m^2
Constant unit factor	3	man.hour

Work group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	2,6
clerk	0
worker	2
auxilliary worker	0

Preparation of working tools and equipments

Input technological parameters

Parameter	Value	Dimension
Manpower unit factor	0,23	man.hour/m^2
Constant unit factor	3,5	man.hour

Work group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	2,6
clerk	0
worker	2
auxilliary worker	0

Preparation of transport containers

Input technological parameters

Parameter	Value	Dimension
Internal volume of transport container	1,5	m^3
Manpower unit factor	0,28	man.hour/container

Work group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	2,1
clerk	0
worker	3
auxilliary worker	2

Installation of protective tent

Input technological parameters

Parameter	Value	Dimension
Manpower unit factor	0,18	man.hour/m^2
Constant unit factor	4,2	man.hour

Work group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	1,3
clerk	0
worker	4
auxilliary worker	0

Working grup instructions

Input technological parameters

Parameter	Value	Dimension
Manpower unit factor	0,15	man.hour/m^2
Constant unit factor	3,5	man.hour

Work group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	2,1
clerk	0
worker	3
auxilliary worker	2

Dismantling procedure

Dismantling (manual) by hydraulic shears in CA

Input technological parameters for Piping (CS), diameter <= Ø25 mm

Parameter	Value	Dimension
Manpower unit factor	30,41	man.hour/t

Input technological parameters for Air conditioning components - piping (CS), cross section < 0,16 m^2

Parameter	Value	Dimension
Manpower unit factor	31,92	man.hour/t

Input technological parameters for Controll & low-voltage cables (Cu)

Parameter	Value	Dimension
Manpower unit factor	110	man.hour/t

Input technological parameters for Electrical cables & conductors; (Cu), 1 kV power cables

Parameter	Value	Dimension
Manpower unit factor	36	man.hour/t

Input technological parameters for Thermal insulations, non-metal covering

Parameter	Value	Dimension
Manpower unit factor	39,6	man.hour/t

Work group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	2,5
clerk	0
worker	2
auxilliary worker	1

Dismantling (manual) by hydraulic shears out of CA

Input technological parameters for Piping (CS), diameter <= Ø25 mm

Parameter	Value	Dimension
Manpower unit factor	30,41	man.hour/t

Input technological parameters for Air conditioning components - piping (CS), cross section < 0,16 m^2

Parameter	Value	Dimension
Manpower unit factor	31,92	man.hour/t

Input technological parameters for Controll & low-voltage cables (Cu)

Parameter	Value	Dimension
Manpower unit factor	110	man.hour/t

Input technological parameters for Electrical cables & conductors; (Cu), 1 kV power cables

Parameter	Value	Dimension
Manpower unit factor	36	man.hour/t

Work group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	1
clerk	0
worker	3,5
auxilliary worker	0,5

Input technological parameters for Thermal insulations, non-metal covering

Parameter	Value	Dimension
Manpower unit factor	39,6	man.hour/t

Dismantling (manual) by oxygen-acetylene set in CA

Input technological parameters for Air conditioning systems, filter casings (CS), dimension <= 1 m

Parameter	Value	Dimension
Manpower unit factor	23,82	man.hour/t

Work group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	2,5
clerk	0
worker	3
auxilliary worker	1

Input technological parameters for General electric equipment, mass > 50 kg

Parameter	Value	Dimension
Manpower unit factor	10,17	man.hour/t

Input technological parameters for Heat exchangers (CS) , each dimension <= 1m

Parameter	Value	Dimension
Manpower unit factor	13,75	man.hour/t

Input technological parameters for Hoisting equipment (CS), cranes

Parameter	Value	Dimension
Manpower unit factor	21	man.hour/t

Input technological parameters for Hoisting equipment (CS), electrical tackles

Parameter	Value	Dimension
Manpower unit factor	11,25	man.hour/t

Input technological parameters for Non-portable small equipment & instruments (CS), mass > 50kg

Parameter	Value	Dimension
Manpower unit factor	22,5	man.hour/t

Input technological parameters for Other general equipment

Parameter	Value	Dimension
Manpower unit factor	37,5	man.hour/t

Input technological parameters for Piece components (CS), mass ≤ 200 kg)

Parameter	Value	Dimension
Manpower unit factor	18,75	man.hour/t

Input technological parameters for Piping (CS), Ø25 < diameter <= Ø100 mm

Parameter	Value	Dimension
Manpower unit factor	10,56	man.hour/t

Input technological parameters for Pumps (CS), mass > 50 kg, at least one dimension > 1m

Parameter	Value	Dimension
Manpower unit factor	6,38	man.hour/t

Input technological parameters for Sampling boxes (CS)

Parameter	Value	Dimension
Manpower unit factor	16,67	man.hour/t

Input technological parameters for Steel constructions, (CS), hangings of piping, general hangings

Parameter	Value	Dimension
Manpower unit factor	5,79	man.hour/t

Input technological parameters for Steel constructions, (CS), platforms and stages

Parameter	Value	Dimension
Manpower unit factor	6,3	man.hour/t

Input technological parameters for Steel constructions, (CS), stairs, ladders, railings

Parameter	Value	Dimension
Manpower unit factor	9	man.hour/t

Input technological parameters for Tanks and containers (CS), diameter < Ø 1 m, thickness of wall <= 20 mm

Parameter	Value	Dimension
Manpower unit factor	9,56	man.hour/t

Input technological parameters for Tanks and containers (CS), diameter >= Ø 1 m, typical wall thickness 12 mm

Parameter	Value	Dimension
Manpower unit factor	9,5	man.hour/t

Input technological parameters for Valves (CS), mass <= 50 kg

Parameter	Value	Dimension
Manpower unit factor	75	man.hour/t

Input technological parameters for Ventilators (CS), mass > 50 kg, at least one dimension > 1m

Parameter	Value	Dimension
Manpower unit factor	9,6	man.hour/t

Dismantling (manual) by oxygen-acetylene set out of CA

Input technological parameters for Air conditioning systems, filter casings (CS), dimension <= 1 m

Parameter	Value	Dimension
Manpower unit factor	23,82	man.hour/t

Work group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	2
clerk	0
worker	2,25
auxilliary worker	2

Input technological parameters for General electric equipment, mass > 50 kg

Parameter	Value	Dimension
Manpower unit factor	10,17	man.hour/t

Input technological parameters for Heat exchangers (CS) , each dimension <= 1m

Parameter	Value	Dimension
Manpower unit factor	13,75	man.hour/t

Input technological parameters for Hoisting equipment (CS), cranes

Parameter	Value	Dimension
Manpower unit factor	11,25	man.hour/t

Input technological parameters for Hoisting equipment (CS), electrical tackles

Parameter	Value	Dimension
Manpower unit factor	13,5	man.hour/t

Input technological parameters for Non-portable small equipment & instruments (CS), mass > 50kg

Parameter	Value	Dimension
Manpower unit factor	22,5	man.hour/t

Input technological parameters for Other general equipment

Parameter	Value	Dimension
Manpower unit factor	37,5	man.hour/t

Input technological parameters for Piping (CS), Ø25 < diameter <= Ø100 mm

Parameter	Value	Dimension
Manpower unit factor	10,56	man.hour/t

Input technological parameters for Pumps (CS), mass > 50 kg, at least one dimension > 1m

Parameter	Value	Dimension
Manpower unit factor	6,38	man.hour/t

Input technological parameters for Steel constructions, (CS), hangings of piping, general hangings

Parameter	Value	Dimension
Manpower unit factor	5,79	man.hour/t

Input technological parameters for Steel constructions, (CS), platforms and stages

Parameter	Value	Dimension
Manpower unit factor	6,3	man.hour/t

Input technological parameters for Steel constructions, (CS), stairs, ladders, railings

Parameter	Value	Dimension
Manpower unit factor	9	man.hour/t

Input technological parameters for Tanks and containers (CS), diameter < Ø 1 m, thickness of wall <= 20 mm

Parameter	Value	Dimension
Manpower unit factor	9,56	man.hour/t

Input technological parameters for Tanks and containers (CS), diameter >= Ø 1 m, typical wall thickness 12 mm

Parameter	Value	Dimension
Manpower unit factor	9,5	man.hour/t

Input technological parameters for Valves (CS), mass <= 50 kg

Parameter	Value	Dimension
Manpower unit factor	75	man.hour/t

Input technological parameters for Ventilators (CS), mass > 50 kg, at least one dimension > 1m

Parameter	Value	Dimension
Manpower unit factor	9,6	man.hour/t

Dismantling (manual) by plasma set in CA

Input technological parameters for Casing of technological euipment (CS), thickness < 100 mm)

Parameter	Value	Dimension
Consumption unit factor of electric power	14,4	kWh/t
Manpower unit factor	18	man.hour/t

Work group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	2,5
clerk	0
worker	3
auxilliary worker	1

Input technological parameters for Hoisting equipment (CS), cranes

Parameter	Value	Dimension
Consumption unit factor of electric power	9,96	kWh/t
Manpower unit factor	11,25	man.hour/t

Input technological parameters for Piece components (CS), mass ≤ 200 kg)

Parameter	Value	Dimension
Consumption unit factor of electric power	8,71	kWh/t
Manpower unit factor	17,5	man.hour/t

Input technological parameters for Piping (CS), Ø25 < diameter <= Ø100 mm

Parameter	Value	Dimension
Consumption unit factor of electric power	5,71	kWh/t
Manpower unit factor	9,18	man.hour/t

Input technological parameters for Stainless steel linings (SS)

Parameter	Value	Dimension
Consumption unit factor of electric power	17,05	kWh/t
Manpower unit factor	25,8	man.hour/t

Input technological parameters for Steel constructions, (CS), hangings of piping, general hangings

Parameter	Value	Dimension
Consumption unit factor of electric power	4,5	kWh/t
Manpower unit factor	4,82	man.hour/t

Input technological parameters for Steel constructions, (CS), platforms and stages

Parameter	Value	Dimension
Consumption unit factor of electric power	4,95	kWh/t
Manpower unit factor	5,3	man.hour/t

Input technological parameters for Tanks and containers (CS), diameter >= Ø 1 m, typical wall thickness 12 mm

Parameter	Value	Dimension
Consumption unit factor of electric power	7,65	kWh/t
Manpower unit factor	9	man.hour/t

Dismantling (manual) by plasma set out of CA

Input technological parameters for Casing of technological euipment (CS), thickness < 100 mm)

Parameter	Value	Dimension
Consumption unit factor of electric power	14,4	kWh/t
Manpower unit factor	18	man.hour/t

Work group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	2
clerk	0
worker	2,25
auxilliary worker	2

Input technological parameters for Hoisting equipment (CS), cranes

Parameter	Value	Dimension
Consumption unit factor of electric power	9,96	kWh/t
Manpower unit factor	11,25	man.hour/t

Input technological parameters for Piece components (CS), mass ≤ 200 kg)

Parameter	Value	Dimension
Consumption unit factor of electric power	8,71	kWh/t
Manpower unit factor	17,5	man.hour/t

Input technological parameters for Piping (CS), Ø25 < diameter <= Ø100 mm

Parameter	Value	Dimension
Consumption unit factor of electric power	5,71	kWh/t
Manpower unit factor	9,18	man.hour/t

Input technological parameters for Stainless steel linings (SS)

Parameter	Value	Dimension
Consumption unit factor of electric power	17,05	kWh/t
Manpower unit factor	25,8	man.hour/t

Input technological parameters for Steel constructions, (CS), hangings of piping, general hangings

Parameter	Value	Dimension
Consumption unit factor of electric power	4,5	kWh/t
Manpower unit factor	4,82	man.hour/t

Input technological parameters for Steel constructions, (CS), plattforms and stages

Parameter	Value	Dimension
Consumption unit factor of electric power	4,95	kWh/t
Manpower unit factor	5,3	man.hour/t

Input technological parameters for Tanks and containers (CS), diameter >= Ø 1 m, typical wall thickness 12 mm

Parameter	Value	Dimension
Consumption unit factor of electric power	7,65	kWh/t
Manpower unit factor	9	man.hour/t

Dismantling (manual) by circular saw in CA

Input technological parameters for Piece components (CS), mass ≤ 200 kg)

Parameter	Value	Dimension
Consumption unit factor of electric power	20,78	kWh/t
Manpower unit factor	20	man.hour/t

Input technological parameters for Piping (CS), Ø25 < diameter <= Ø100 mm

Parameter	Value	Dimension
Consumption unit factor of electric power	10,33	kWh/t
Manpower unit factor	10,56	man.hour/t

Input technological parameters for Steel constructions, (CS), hangings of piping, general hangings

Parameter	Value	Dimension
Consumption unit factor of electric power	5,03	kWh/t
Manpower unit factor	5,14	man.hour/t

Input technological parameters for Steel constructions, (CS), plattforms and stages

Parameter	Value	Dimension
Consumption unit factor of electric power	5,5	kWh/t
Manpower unit factor	5,63	man.hour/t

Work group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	2,5
clerk	0
worker	2
auxilliary worker	1

Dismantling (manual) by circular saw out of CA

Input technological parameters for Piece components (CS), mass ≤ 200 kg)

Parameter	Value	Dimension
Consumption unit factor of electric power	20,78	kWh/t
Manpower unit factor	20	man.hour/t

Input technological parameters for Piping (CS), Ø25 < diameter <= Ø100 mm

Parameter	Value	Dimension
Consumption unit factor of electric power	10,33	kWh/t
Manpower unit factor	10,56	man.hour/t

Input technological parameters for Steel constructions, (CS), hangings of piping, general hangings

Parameter	Value	Dimension
Consumption unit factor of electric power	5,03	kWh/t
Manpower unit factor	5,14	man.hour/t

Input technological parameters for Steel constructions, (CS), plattforms and stages

Parameter	Value	Dimension
Consumption unit factor of electric power	5,5	kWh/t
Manpower unit factor	5,63	man.hour/t

Work group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	1
clerk	0
worker	3,5
auxilliary worker	0,5

Dismantling (manual) by hand tools (wrenches, etc.) in CA

Input technological parameters for Air conditioning systems, filter casings (CS), dimension <= 1 m

Parameter	Value	Dimension
Manpower unit factor	23,82	man.hour/t

Input technological parameters for Electric motors, mass <= 50 kg

Parameter	Value	Dimension
Manpower unit factor	31,5	man.hour/t

Input technological parameters for Electrical cables & conductors; (Cu), 1 kV power cables

Parameter	Value	Dimension
Manpower unit factor	42	man.hour/t

Input technological parameters for General electric equipment, mass <= 50 kg

Parameter	Value	Dimension
Manpower unit factor	22,5	man.hour/t

Input technological parameters for General electric equipment, mass > 50 kg

Parameter	Value	Dimension
Manpower unit factor	10,5	man.hour/t

Input technological parameters for Hoisting equipment (CS), cranes

Parameter	Value	Dimension
Manpower unit factor	15	man.hour/t

Input technological parameters for Hoisting equipment (CS), electrical tackles

Parameter	Value	Dimension
Manpower unit factor	10,8	man.hour/t

Input technological parameters for Non-portable small equipment & instruments (CS), mass <= 50kg

Parameter	Value	Dimension
Manpower unit factor	33,75	man.hour/t

Input technological parameters for Non-portable small equipment & instruments (CS), mass > 50kg

Parameter	Value	Dimension
Manpower unit factor	25,88	man.hour/t

Input technological parameters for Other general equipment

Parameter	Value	Dimension
Manpower unit factor	40,5	man.hour/t

Work group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	2,5
clerk	0
worker	2
auxilliary worker	1

Input technological parameters for Piece components (CS), mass ≤ 200 kg)

Parameter	Value	Dimension
Manpower unit factor	20	man.hour/t

Input technological parameters for Pumps (CS), mass <= 50 kg

Parameter	Value	Dimension
Manpower unit factor	24,08	man.hour/t

Input technological parameters for Pumps (CS), mass > 50 kg, at least one dimension > 1m

Parameter	Value	Dimension
Manpower unit factor	6,75	man.hour/t

Input technological parameters for Sampling boxes (CS)

Parameter	Value	Dimension
Manpower unit factor	17,5	man.hour/t

Input technological parameters for Steel constructions, (CS), dismantling appliances

Parameter	Value	Dimension
Manpower unit factor	12,6	man.hour/t

Input technological parameters for Steel constructions, (CS), plattforms and stages

Parameter	Value	Dimension
Manpower unit factor	7,11	man.hour/t

Input technological parameters for Thermal insulations, non-metal covering

Parameter	Value	Dimension
Manpower unit factor	41,4	man.hour/t

Input technological parameters for Valves (CS), mass <= 50 kg

Parameter	Value	Dimension
Manpower unit factor	82,5	man.hour/t

Input technological parameters for Ventilators (CS), mass > 50 kg, at least one dimension > 1m

Parameter	Value	Dimension
Manpower unit factor	11,1	man.hour/t

Dismantling (manual) by hand tools (wrenches, etc.) out of CA

Input technological parameters for Air conditioning systems, filter casings (CS), dimension <= 1 m

Parameter	Value	Dimension
Manpower unit factor	23,82	man.hour/t

Work group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	1
clerk	0
worker	3,5
auxilliary worker	0,5

Input technological parameters for Electric motors, mass <= 50 kg

Parameter	Value	Dimension
Manpower unit factor	31,5	man.hour/t

Input technological parameters for Electrical cables & conductors; (Cu), 1 kV power cables

Parameter	Value	Dimension
Manpower unit factor	42	man.hour/t

Input technological parameters for General electric equipment, mass <= 50 kg

Parameter	Value	Dimension
Manpower unit factor	22,5	man.hour/t

Input technological parameters for General electric equipment, mass > 50 kg

Parameter	Value	Dimension
Manpower unit factor	10,5	man.hour/t

Input technological parameters for Hoisting equipment (CS), cranes

Parameter	Value	Dimension
Manpower unit factor	15	man.hour/t

Input technological parameters for Hoisting equipment (CS), electrical tackles

Parameter	Value	Dimension
Manpower unit factor	10,8	man.hour/t

Input technological parameters for Non-portable small equipment & instruments (CS), mass <= 50kg

Parameter	Value	Dimension
Manpower unit factor	33,75	man.hour/t

Input technological parameters for Non-portable small equipment & instruments (CS), mass > 50kg

Parameter	Value	Dimension
Manpower unit factor	25,88	man.hour/t

Input technological parameters for Other general equipment

Parameter	Value	Dimension
Manpower unit factor	40,5	man.hour/t

Input technological parameters for Piece components (CS), mass ≤ 200 kg)

Parameter	Value	Dimension
Manpower unit factor	20	man.hour/t

Input technological parameters for Pumps (CS), mass <= 50 kg

Parameter	Value	Dimension
Manpower unit factor	24,08	man.hour/t

Input technological parameters for Pumps (CS), mass > 50 kg, at least one dimension > 1m

Parameter	Value	Dimension
Manpower unit factor	6,75	man.hour/t

Input technological parameters for Sampling boxes (CS)

Parameter	Value	Dimension
Manpower unit factor	17,5	man.hour/t

Input technological parameters for Steel constructions, (CS), dismantling appliances

Parameter	Value	Dimension
Manpower unit factor	12,6	man.hour/t

Input technological parameters for Steel constructions, (CS), plattforms and stages

Parameter	Value	Dimension
Manpower unit factor	7,11	man.hour/t

Input technological parameters for Thermal insulations, non-metal covering

Parameter	Value	Dimension
Manpower unit factor	41,4	man.hour/t

Input technological parameters for Valves (CS), mass <= 50 kg

Parameter	Value	Dimension
Manpower unit factor	82,5	man.hour/t

Input technological parameters for Ventilators (CS), mass > 50 kg, at least one dimension > 1m

Parameter	Value	Dimension
Manpower unit factor	11,1	man.hour/t

Finishing of dismantling

Removal of scaffolding

Input technological parameters

Parameter	Value	Dimension
Manpower unit factor	0,8	man.hour/scaffolding square
Constant unit factor	3,5	man.hour

Work group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	2
clerk	0
worker	2
auxilliary worker	1

Removal of protective foil

Input technological parameters

Parameter	Value	Dimension
Manpower unit factor	0,12	man.hour/m^2
Constant unit factor	6,5	man.hour

Work group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	2
clerk	0
worker	2
auxilliary worker	1

Removal of temporary air-conditioning

Input technological parameters

Parameter	Value	Dimension
Manpower unit factor	8,5	man.hour/room

Work group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	2
clerk	0
worker	2
auxilliary worker	1

Removal of temporary electricand other media connections

Input technological parameters

Parameter	Value	Dimension
Manpower unit factor	3,5	man.hour/room

Work group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	2
clerk	0
worker	2
auxilliary worker	1

Removal of working tools and equipments

Input technological parameters

Parameter	Value	Dimension
Manpower unit factor	0,1	man.hour/m^2
Constant unit factor	3	man.hour

Work group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	2
clerk	0
worker	2
auxilliary worker	1

Removal of protective tent

Input technological parameters

Parameter	Value	Dimension
Manpower unit factor	8,7	man.hour/room
Constant unit factor	4,9	man.hour

Work group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	2
clerk	0
worker	2
auxilliary worker	1

Removal of transport containers

Input technological parameters

Parameter	Value	Dimension
Manpower unit factor	1,4	man.hour/container

Work group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	2
clerk	0
worker	2
auxilliary worker	1

Cleaning of room

Input technological parameters

Parameter	Value	Dimension
Manpower unit factor	0,11	man.hour/m^2
Constant unit factor	5	man.hour

Work group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	2
clerk	0
worker	2
auxilliary worker	1

Time ratio of related non-productive parts to productive part of operation (whole work group)

Non-productive time part	Ratio to productive time part
Entry to Uncontrolled Area	3,00%
Work preparation in Uncontrolled Area	2,00%
Work breaks in Uncontrolled Area	6,00%
Moving within Uncontrolled Area	2,00%
Entry to Controlled Area	3,00%
Work preparation in Controlled Area	3,00%
ALARA breaks	6,00%
Work breaks in Controlled Area	4,00%
Moving within Controlled Area	4,00%
Work finishing in Controlled Area	3,00%
Exit from Controlled Area	5,00%
Exit from Uncontrolled Area	3,00%

Annex 2-2-2

Set of calculation procedures for decontamination of building surfaces

Preparatory activities in individual rooms prior decontamination:

P1 - Covering of floor surface by protective foils
P2 - Installation of scaffolding
P3 - Marking and delineating of surfaces
P4 - Installation of temporal air-conditioning
P5 - Installation of temporal electric and others media connections
P6 - Delivery of working tools and equipments to the working place
P7 - Preparation of working tools and equipments for the work
P8 - Installation of protective tents
P9 - Preparation of transport containers
P10 - Instructions for the decontamination working group

Decontamination of building surfaces - selected technologies

D1 - Hands-on mechanical decontamination
D2 - Hands-on detergent foam application

Finishing activities in individual rooms after decontamination:

F1 - Removal of scaffolding
F2 - Removal of protective foils from floor surface
F3 - Removal of temporary air-conditioning
F4 - Removal of temporary electric and other media connections
F5 - Removal of working tools and equipments
F6 - Removal of protective tents
F7 - Removal of transport containers

Preparation activities for decontamination of building surfaces

Covering of floor surface by protective foils

Hands on covering of floor by plastic foil. Transport of foil to room is included.

Input technological parameters

Parameter	Value	Unit
Consumption unit factor of plastic foil	0,025	kg/ m^2
Manpower unit factor	0,32	man.hour/ m^2
Constant unit factor for preparatory and finishing activities	9,75	man.hour

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0
operator	2
clerk	0
worker	2
auxilliary worker	1

Installation of scaffolding

Hands on installation of scaffolding.Transport of materials to room is included.

Input technological parameters

Parameter	Value	Unit
Manpower unit factor	0,5	man.hour/room
Constant unit factor for preparatory and finishing activities	4	man.hour

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0
operator	2
clerk	0
worker	2
auxilliary worker	1

Marking and delineating of surfaces

Hands on marking of surface contaminated areas.

Input technological parameters

Parameter	Value	Unit
Manpower unit factor	0,1	man.hour/m^2
Constant unit factor for preparatory and finishing activities	3,5	man.hour

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0
operator	2
clerk	0
worker	2
auxilliary worker	1

Installation of temporary air-conditioning

Hands on installation of temporary air-conditioning. Transport of equipment to room is included.

Calculation parameters

Parameter	Value	Unit
Manpower unit factor	12	man.hour/room

Work group structure

Profession	Number of personel for each profesion
manager	0
senior engineer	0
engineer	0,3
operator	6
clerk	0
worker	0
auxilliary worker	0,5

Installation of temporary electric and other media connections

Hands on installation of temporal electric connection.Transport of materials to room is included.

Input technological parameters

Parameter	Value	Unit
Manpower unit factor	5	man.hour/room

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0,3
operator	6
clerk	0
worker	0
auxilliary worker	0,5

Delivery of working tools and equipments to the working place

Transport of tools and equipments to room.

Input technological parameters

Parameter	Value	Unit
Manpower unit factor	0,1	man.hour/m^2
Constant unit factor for preparatory and finishing activities	4	man.hour

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0
operator	2
clerk	0
worker	2
auxilliary worker	1

Preparation of working tools and equipments for the work

Hands on preparation working tools and equipments.

Input technological parameters

Parameter	Value	Unit
Manpower unit factor	0,22	man.hour/m^2
Constant unit factor for preparatory and finishing activities	3,5	man.hour

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0
operator	2
clerk	0
worker	2
auxilliary worker	1

Installation of protective tents

Hands on installation of protective tent.Transport of materials to room is included.

Input technological parameters

Parameter	Value	Unit
Manpower unit factor	0,18	man.hour/m^2
Constant unit factor for preparatory and finishing activities	4,2	man.hour

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0
operator	2
clerk	0
worker	2
auxilliary worker	1

Preparation of transport containers

Preparation of containers for waste (transport of containers into the room is included).

Input technological parameters

Parameter	Value	Unit
Internal volume of transport container	0,2	m^3
Manpower unit factor	0,28	man.hour/container

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0
operator	2
clerk	0
worker	2
auxilliary worker	1

Instructions for the decontamination working group

Instucting of decontamination crew, tasks assignment.

Input technological parameters

Parameter	Value	Unit
Manpower unit factor	0,15	man.hour/m^2
Constant unit factor for preparatory and finishing activities	3,5	man.hour

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0
operator	2
clerk	0
worker	2
auxilliary worker	1

Realization the decontamination

Decontamination of building surfaces - mechanical

Hands on mechanical decontamination of building surfaces by manual grinding equipment.

Input technological parameters

Parameter	Value	Unit
Thickness of shaved layer	0,02	m
Shaving capacity of equipment	0,08	m^3/h
Input power	5	kW

Work group structure

Profession	Number of staff
manager	0
senior engineer	0,125
engineer	0
operator	2
clerk	0
worker	0
auxilliary worker	2

Decontamination of building surfaces - detergent foam application + vacuum cleanning + washing

Hands on mechanical decontamination of building surfaces by foam application and vacuum cleaning equipments.

Input technological parameters

Parameter	Value	Unit
Consumption unit factor of demineralised water (foam application)	0,00025	m^3/m^2
Consumption unit factor of demineralised water (foam washing)	0,001	m^3/m^2
Input power for foam application equipment	1	kW
Input power for vacuum cleaning equipment	2	kW
Consumption unit factor of detergent (used in demineralised water volu	0,1	m^3/m^3
Volume salinity of generated liquid radioactive waste	1	kg/m^3
Time of foam action	0,25	h/equipment/room
Capacity of eqipment (foam application)	5	m^2/h
Capacity of eqipment (vacuum cleaning)	10	m^2/h

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0,125
operator	4
clerk	0
worker	0
auxilliary worker	2

Completion activities after decontamination of building surfaces

Removal of scaffolding

Hands on removal of scaffolding.Transport of materials from room is included.

Parameter	Value	Unit
Manpower unit factor	0,4	man.hour/room
Constant unit factor for preparatory and finishing activities	3,5	man.hour

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0
operator	2
clerk	0
worker	2
auxilliary worker	1

Removal of protective foils from floor surface

Hands on removal of plastic foil.Transport of material from room is included.

Parameter	Value	Unit
Manpower unit factor	0,14	man.hour/ m^2
Constant unit factor for preparatory and finishing activities	8,5	man.hour

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0
operator	2
clerk	0
worker	2
auxilliary worker	1

Removal of temporary air-conditioning

Hands on removal of temporal air-conditioning.Transport of equipment from room is included.

Parameter	Value	Unit
Manpower unit factor	3,5	man.hour/room

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0
operator	2
clerk	0
worker	2
auxilliary worker	1

Removal of temporary electricand other media connections

Hands on removal temporal electric connection.Transport of material from room is included.

Parameter	Value	Unit
Manpower unit factor	3,5	man.hour/room

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0
operator	2
clerk	0
worker	2
auxilliary worker	1

Removal of working tools and equipments

Hands on removal of working tools and equipments.Transport of equipment from room is included.

Parameter	Value	Unit
Manpower unit factor	0,1	man.hour/ m^2
Constant unit factor for preparatory and finishing activities	3	man.hour

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0
operator	2
clerk	0
worker	2
auxilliary worker	1

Removal of protective tents

Hands on removal ofprotective tent.Transport ofmaterials from room is included.

Parameter	Value	Unit
Manpower unit factor	0,14	man.hour/ m^2
Constant unit factor for preparatory and finishing activities	4,9	man.hour

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0
operator	2
clerk	0
worker	2
auxilliary worker	1

Removal of transport containers

Hands on removal of transport containers.Transport of transport containers from room is included.

Parameter	Value	Unit
Manpower unit factor	1,4	man.hour/ container

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0
operator	2
clerk	0
worker	2
auxilliary worker	1

Time ratio of related non-productive parts to productive part of operation (whole work group)

Non-productive time part	Ratio to productive time part
Entry to Uncontrolled Area	3,00%
Work preparation in Uncontrolled Area	2,00%
Work breaks in Uncontrolled Area	6,00%
Moving within Uncontrolled Area	2,00%
Entry to Controlled Area	3,00%
Work preparation in Controlled Area	3,00%
ALARA breaks	6,00%
Work breaks in Controlled Area	4,00%
Moving within Controlled Area	4,00%
Work finishing in Controlled Area	3,00%
Exit from Controlled Area	5,00%
Exit from Uncontrolled Area	3,00%

A 2-2-3 **Demolition technologies**

Set of calculation procedures for demolition of building

1 Demolition of walling by excavator
2 Demolition of other building material by excavator
3 Demolition of concrete by demolition sheers
4 Demolition of reinforced-concrete (to 400mm) by demolition shears
5 Demolition of steel skeletons by oxygen-acetylene cutting set
6 Demolition of roof skeletons by oxygen-acetylene cutting set
7 Transport of backfill material
8 Preparation of rooms for backfilling
9 Backfilling of rooms by debris
10 Final landscape

Demolition of walling by excavator

Complete demolition of masonry walling by excavator
Transport of demolished material to recycling workplace

Calculation parameters of the technology

Parameter	Quantity	Dimension
Consumption unit factor of fuel-oil	1,5	kg/t
Manpower unit factor	1,85	man.hour/t

Working group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	
operator	0,5
clerk	0
worker	3,5
auxilliary worker	1

Demolition of other building material by excavator

Complete demolition of other building material by excavator
Transport of demolished material to recycling workplace

Calculation parameters of the technology

Parameter	Value	Dimension
Consumption unit factor of fuel-oil	4,2	kg/t
Manpower unit factor	10	man.hour/t

Working group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	0,5
clerk	0
worker	3,5
auxilliary worker	2

Demolition of concrete by demolition shears

Complete demolition of usual concrete by shears
Transport of demolished material to recycling workplace

Calculation parameters of the technology

Parameter	Value	Dimension
Consumption unit factor of fuel-oil	2,5	kg/t
Manpower unit factor	2,6	man.hour/t

Working group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	0,5
clerk	0
worker	3,5
auxilliary worker	1

Demolition of reinforced-concrete (to 400mm) by demolition shears

Complete demolition of renforced-concrete by shears, excavator and oxygen cutting set
Transport of demolished material to recycling workplace

Calculation parameters of the technology

Parameter	Value	Dimension
Consumption unit factor of fuel-oil	4,5	kg/t
Manpower unit factor	4,2	man.hour/t

Working group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	0,5
clerk	0
worker	3,5
auxilliary worker	2

Demolition of steel skeletons by oxygen-acetylene cutting set

Complete demolition of steel skeletons by oxygen cutting set and crane
Transport of demolished material to recycling workplace

Calculation parameters of the technology

Parameter	Value	Dimension
Consumption unit factor of fuel-oil	1,5	kg/t
Consumption unit factor of acetylen	0,7	Nm^3/t
Consumption unit factor of oxygen	7	Nm^3/t
Manpower unit factor	9,6	man.hour/t

Working group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	0,5
clerk	0
worker	3,5
auxilliary worker	2

Demolition of roof skeletons by oxygen-acetylene cutting set

Complete demolition of roofs by oxygen cutting set and crane
Transport of demolished material to recycling workplace

Calculation parameters of the technology

Parameter	Value	Dimension
Consumption unit factor of fuel-oil	1,5	kg/t
Consumption unit factor of acetylen	0,7	Nm^3/t
Consumption unit factor of oxygen	7	Nm^3/t
Manpower unit factor	12	man.hour/t

Working group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	0,5
clerk	0
worker	3,5
auxilliary worker	2

Transport of backfill material

Transport of demolished material and debris to backfilling of rooms

Calculation parameters of the technology

Parameter	Value	Dimension
Consumption unit factor of fuel-oil	0,1	kg/t
Manpower unit factor	1,9	man.hour/t

Working group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	
operator	0,5
clerk	0
worker	3,5
auxilliary worker	1

Preparation of rooms for backfilling

Preparation of room for backfilling, demolition of room floors

Calculation parameters of the technology

Working group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0

Parameter	Value	Dimension
Consumption unit factor of fuel-oil	1,5	kg/t
Consumption factor of electric energy	2,2	kWh/t
Manpower unit factor	19	man.hour/t

operator	0,5
clerk	0
worker	3,5
auxilliary worker	1

Backfilling of rooms by debris

Backfilling of rooms by debris

Calculation parameters of the technology

Parameter	Value	Dimension
Manpower unit factor	1,2	man.hour/t

Working group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	0,5
clerk	0
worker	3,5
auxilliary worker	1

Final landscape

Complete demolition, definite layout of surface by bulldozer and excavator
Transport of demolished material to recycling workplace

Calculation parameters of the technology

Parameter	Value	Dimension
Consumption unit factor of fuel-oil	0,25	kg/t
Manpower unit factor	0,151	man.hour/t

Working group structure

Profession	Number of staff
manger	0
senior engineer	0
engineer	0
operator	0,5
clerk	0
worker	3,5
auxilliary worker	1

Structure of non-productive working time of working groups for demolition technologies

Item of non-productive working time	Ratio to productive working time
Entry to Uncontrolled Area	3,00%
Work preparation in Uncontrolled Area	2,00%
Work breaks in Uncontrolled Area	6,00%
Moving within Uncontrolled Area	2,00%
Entry to Controlled Area	0,00%
Work preparation in Controlled Area	0,00%
ALARA breaks	0,00%
Work breaks in Controlled Area	0,00%
Moving within Controlled Area	0,00%
Work finishing in Controlled Area	0,00%
Exit from Controlled Area	0,00%
Exit from Uncontrolled Area	3,00%

Annex 2-2-4

Set of calculation procedures for treatment technologies

1 Post-dismantling decontamination of dismantled materials - rinsing bath
2 Post-dismantling decontamination of equipments - chemical bath
3 Post-dismantling decontamination of equipments - electrochemical bath
4 Sorting of metal materials before fragmentation (according to surface contamination)
5 Sorting of non-metal solid materials before fragmentation (according to surface contamination)
6 Fragmentation of iron materials (up to 3000 Bq/m2 contamination)
7 Fragmentation of iron metals (over 3000 Bq/m2 contamination)
8 Fragmentation of non-iron metals
9 Treatment of filters from ventilation systems
10 Low pressure compaction
11 High pressure compaction
12 Melting of iron and non-iron metals
13 Incineration
14 Evaporation
15 Bituminization of concentrates
16 Bituminization of ionexchangers
18 Grouting of disposal containers
19 Disposal of container in surface repository
20 Recyclation of cables
21 Recyclation of building materials from demolition
22 Recyclation of non-radioactive metal materials from dismantling

Treatment / conditioning technologies

Post-dismantling decontamination of dismantled materials - rinsing bath

Bath decontamination of dismantled carbon / stainless steel in rinsing bath, including the transport before and after decontamination

Selected calculation parameters of the technology

Parameter	Value	Unit
Capacity of eqipment (area)	2	m^2/h
Consumption unit factor of demineralised water	0,02	m^3/m^2
Consumption unit factor of detergent (used in demineralised water volume unit)	0,001	m^3/m^3
Average dose rate at the working place	5	microGy/h
Time unit factor of detergent renewal and decontamination line maitainance	0,075	h/m^2
Operational unit costs (depreciation + other non-specific cost)	11,85	€/m^2
Volume salinity of generated liquid radioactive waste	5	kg/m^3

Working group structure

Profession	Number of personel per profession
manager	0
senior engineer	0
engineer	0,25
operator	1,7
clerk	0
worker	0,5
auxilliary worker	0

Post-dismantling decontamination of equipments - chemical bath

Bath decontamination of dismantled carbon / stainless steel in chemical bath (use of decontamination solution), including the

Input technological parameters

Parameter	Value	Unit
Capacity of eqipment (area)	8,3	m^2/h
Dose rate from technological line (0,5 m distance from line)	5	microGy/h
Consumption unit factor of decontamination solution	0,0026	m^3/m^2
Consumption unit factor of demineralised water	0,02	m^3/m^2
Operational unit costs (depreciation + other non-specific cost)	23,07	€/m^2
Consumption unit factor of detergent (used in demineralised water volume unit)	0,001	m^3/m^3

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0,25
operator	1,7
clerk	0
worker	0,5
auxilliary worker	0

Post-dismantling decontamination of equipments - electrochemical bath

Bath decontamination of dismantled carbon / stainless steel in electrochemical bath (use of electrolyte), including the transport

Input technological parameters

Parameter	Value	Unit
Capacity of eqipment (area)	2	m^2/h
Consumption unit factor of demineralised water	0,05	m^3/m^2
Consumption unit factor of electrolyte	0,06	m^3/m^2
Consumption unit factor of detergent (used in demineralised water volume unit)	0,001	m^3/m^3
Input power	20	kW
Dose rate from decontamination line (0,5 m distance from line)	5	mikroGy/h
Operational unit costs (depreciation + other non-specific cost)	34,12	€/m^2

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0,25
operator	1,7
clerk	0
worker	0,5
auxilliary worker	0

Sorting of metal materials before fragmentation (according to surface contamination)

Hands on monitoring and sorting of individual pieces of metal material and placing into drums, including transport before and after

Input technological parameters

Parameter	Value	Unit
Dose rate from technological line (0,5 m distance from line)	5	microGy/h
Weight of steel (metal) in monitoring batch	350	kg/container, batch respectively
Time of one batch monitoring	1	h
Operational unit costs (depreciation + other non-specific cost)	8,85	€/batch

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0
operator	0,666
clerk	0
worker	0
auxilliary worker	3

Sorting of non-metal solid materials before fragmentation (according to surface contamination)

Hands on monitoring and sorting of individual pieces of non-metal solid material and placing into drums, including transport before

Input technological parameters

Parameter	Value	Unit
Dose rate from technological line (0,5 m distance from line)	5	microGy/h
Weight of azbestos in one monitoring batch	350	kg/container, batch respectively
Weight of concrete in one monitoring batch	350	kg/container, batch respectively
Weight of brash waste in one monitoring batch	100	kg/container, batch respectively
Weight of graphite in one monitoring batch	100	kg/container, batch respectively
Weight of plastic insulation in one monitoring batch	150	kg/container, batch respectively
Weight of glass wool in one monitoring batch	100	kg/container, batch respectively
Weight of azbestos in drum	350	kg/drum
Weight of graphite in drum	100	kg/drum
Operational unit costs (depreciation + other non-specific cost)	8,85	€/batch
Time of one batch monitoring	0,25	h

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0
operator	0,25
clerk	0
worker	0
auxilliary worker	2

Fragmentation of iron materials (up to 3000 Bq/m2 contamination)

Hands on picking out of sorted iron material from drum, fixing of material in jaws. Remote fragmentation of iron material with hack

Input technological parameters

Parameter	Value	Unit
Input power	5	kW
Weigh of carbon steel in the drum	350	kg
Weigh of stainless steel in the drum	350	kg
Capacity of equipment (drums)	0,222	drum/h
Operational unit costs (depreciation + other non-specific cost)	0,51	€/kg
Dose rate from technological line (0.5 m distance from line)	5	mikroGy/h

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0,125
operator	0,5
clerk	0
worker	2,5
auxilliary worker	2

Fragmentation of iron metals (over 3000 Bq/m2 contamination)

Remote picking out of sorted iron material from drum, fixing of material in jaws. Remote fragmentation of iron material with guillotine

Input technological parameters

Parameter	Value	Unit
Input power	20	kW
Weigh of carbon steel in the drum	350	kg
Weigh of stainless steel in the drum	350	kg
Capacity of equipment (drums)	2	drum/h
Operational unit costs (depreciation + other non-specific cost)	1,98	€/kg
Dose rate from technological line (0.5 m distance from line)	5	mikroGy/h

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0
operator	6
clerk	0
worker	7
auxilliary worker	0

Fragmentation of non-iron metals

Hands on picking out of sorted non-iron material from drum, fixing of material in jaws. Remote fragmentation of iron material with

Input technological parameters

Parameter	Value	Unit
Input power	2	kW
Weigh of copper in the drum	350	kg
Weigh of aluminium in the drum	350	kg
Weigh of lead in the drum	350	kg
Weigh of coloured material (except of Cu, Al a Pb) in the drum	350	kg
Capacity of equipment (drums)	0,75	drum/h
Operational unit costs (depreciation + other non-specific cost)	0,51	€/kg
Dose rate from technological line (0.5 m distance from line)	5	mikroGy/h

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0,125
operator	0,5
clerk	0
worker	2,5
auxilliary worker	2

Treatment of filters from ventilation systems

Treatment of air conditioning filters with aceton and placing into drums. Transport of materials and products before and after

Input technological parameters

Parameter	Value	Unit
Specific mass of filters	150	kg/m^3
Number of filters in drum	6	pc/drum
Number of filters in treatment batch	6	pc/batch
Filter batch treatment duration	240	h/batch
Operational unit costs (depreciation + other non-specific cost)	27,55	€/batch
Dose rate from technological line (0.5 m distance from line)	5	mikroGy/h

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0,125
operator	2,5
clerk	0
worker	0,5
auxilliary worker	0

Low pressure compaction

Compaction of low pressure compactible solid waste, directly in drum. Hands on handling with drums. Transport of materials and

Input technological parameters

Parameter	Value	Unit
Dose rate from technological line (0,5 m distance from line)	5	microGy/h
Specific mass of brash waste	100	kg/m^3
Specific mass of low-pressure compactible waste	100	kg/m^3
Specific mass of plastic insulation	150	kg/m^3
Specific mass of glass wool	80	kg/m^3
Input power	4	kW
Operational unit costs (depreciation + other non-specific cost)	0,96	€/m^3
Capacity of eqipment (volume)	1,6	m^3/h

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0,125
operator	2,5
clerk	0
worker	0,5
auxilliary worker	0

High pressure compaction

Compaction of drums with fragmented solid materials and drums with low pressure compacted solid materials. Remote handling

Input technological parameters

Parameter	Value	Unit
Dose rate from technological line (0,5 m distance from line)	5	microGy/h
Input power	48	kW
Capacity of eqipment (volume)	1,5	m^3/h
Operational unit costs (depreciation + other non-specific cost)	162,92	€/drum
Capacity of eqipment (drums)	3	drum/h

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0,125
operator	1,375
clerk	0
worker	1
auxilliary worker	0

Melting of iron and non-iron metals

Melting of iron materials in inductive furnace and casting of ingots. Transport of materials and products before and after melting is

Input technological parameters

Parameter	Value	Unit
Dose rate from technological line (0,5 m distance from line)	5	microGy/h
Weight of carbon steel ingot	1000	kg/container, batch respectively
Weight of stainless steel ingot	1000	kg/container, batch respectively
Weight of slag in drum	350	kg/drum
Input power	250	kW
Operational unit costs (depreciation + other non-specific cost)	1,61	€/kg
Capacity of eqipment (mass)	125	kg/h

Work group structure

Profession	Number of staff
manager	0
senior engineer	0,5
engineer	1
operator	4
clerk	0
worker	3
auxilliary worker	0

Incineration

Incineration of solid combustible waste in shaft kiln with conveyor filling system. Transport of materials and products before and

Input technological parameters

Parameter	Value	Unit
Dose rate from technological line (0,5 m distance from line)	5	microGy/h
Specific mass of white protective clothing	100	kg/m^3
Specific mass of combustible waste	100	kg/m^3
Input power	124	kW
Consumption unit factor of fuel oil (for one mass unit of combustible waste)	0,01	kg/kg
Operational unit costs (depreciation + other non-specific cost)	5,21	€/kg
Capacity of eqipment (mass)	50	kg/h

Work group structure

Profession	Number of staff
manager	0
senior engineer	0,5
engineer	2
operator	4,25
clerk	0
worker	1
auxilliary worker	0

Evaporation

Evaporation of liquid waste into concentrate and condensate in rotary film evaporator. Transport of materials and products before

Input technological parameters

Parameter	Value	Unit
Input power	2	kW
Limit salinity of concentrates	180	kg/m^3
Capacity of equipment (volume of produced condensate)	1	m^3/h
Consumption unit factor of steam	2,5	t/h
Operational unit costs (depreciation + other non-specific cost)	33,69	€/m^3
Dose rate from technological line (0.5 m distance from line)	5	mikroGy/h

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0,125
operator	3
clerk	0
worker	0,5
auxilliary worker	0

Bitumінization of concentrates

Mixing of concentrate and bitumen, evaporating of mixture and filling of drums with bitumen product. Transport of materials and

Input technological parameters

Parameter	Value	Unit
Input power	10	kW
Capacity of equipment (volume of produced condensate)	0,1	m^3/h
Limit salinity of bitumen	400	kg/m^3
Consumption unit factor of steam	0,3	t/h
Operational unit costs (depreciation + other non-specific cost)	252,74	€/m^3
Dose rate from technological line (0.5 m distance from line)	5	mikroGy/h

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0
operator	2,5
clerk	0
worker	3
auxilliary worker	1

Bituminization of ionexchangers

Mixing of spent ionexchangers and bitumen, evaporating of mixture and filling of drums with bitumen product. Transport of materials

Input technological parameters

Parameter	Value	Unit
Input power	10	kW
Capacity of equipment (volume of produced condensate)	0,12	m^3/h
Consumption unit factor of steam	2,5	t/h
Operational unit costs (depreciation + other non-specific cost)	252,74	€/m^3
Dose rate from technological line (0.5 m distance from line)	1	mikroGy/h

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0
operator	2,5
clerk	0
worker	3
auxilliary worker	1

Cementation of ash

Mixing of cement compound and ash. Filling of drums with cement mixture. Transport of materials and products before and after

Input technological parameters

Parameter	Value	Unit
Input power	5,5	kW
Capacity of equipment (volume)	0,2	m^3/h
Inner useful volume of drum	0,2	m^3
Weight of cement product per mass unit of ash	3	kg/kg
Dose rate from technological line (0.5 m distance from line)	5	mikroGy/h
Operational unit costs (depreciation + other non-specific cost)	5,54	€/m^3
Specific weigh of ash	750	kg/m^3

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0,125
operator	2,25
clerk	0
worker	1
auxilliary worker	0

Grouting of disposal containers

Placing of drums, pellets from high pressure compaction, large pieces of metal materials into disposal container. Preparation of

Input technological parameters

Parameter	Value	Unit
Input power	3,5	kW
Capacity of equipment (volume)	0,56	m^3/h
Operational unit costs (depreciation + other non-specific cost)	1075,42	€/container
Number of concetrate bituminisation product drums in container	6	pc/container
Number of ash cementation product drums in container	6	pc/container
Number of ionex changers bituminisation product drums in container	6	pc/container
Number of D23 kl air conditioning filters product drums in container	6	pc/container
Number of carbon steel product drums in container	6	pc/container
Number of stailness steel product drums in container	6	pc/container
Number of carbon ingots in container	1	pc/container
Number of stailness steel ingots in container	1	pc/container
Number of slag drums in container	6	pc/container
Number of stainless steel pellets in container	18	pc/container
Number of carbon steel pellets in container	18	pc/container
Number of copper pellets in container	30	pc/container
Number of aluminium pellets in container	30	pc/container
Number of lead pellets in container	15	pc/container
Number of coloured metal pellets in container	30	pc/container
Number of low pressure compactible pellets after supercompaction in container	15	pc/container
Number of glass wool pellets in container	15	pc/container
Carbon ingot volume	0,5	m^3
Stailness steel ingot volume	0,5	m^3
Carbon steel pellet volume	0,07	m^3
Stainless steel pellet volume	0,07	m^3
Copper pellet volume	0,05	m^3
Aliminium pellet volume	0,05	m^3
Lead pellet volume	0,1	m^3
Coloured metal pellet volume	0,05	m^3
Low pressure compactible pellet volume after supercompaction	0,05	m^3
Glass wool pellet volume	0,05	m^3
Powder cement volume per unit volume of cement mixture	0,72	m^3/m^3
Specific weigh of cement powder	1600	kg/m^3
Time of arrangement of product (drum, pellet, cartrige) in container	0,15	h
Closing time of container	0,5	h/container
Dose rate from technological line (0.5 m distance from line)	5	mikroGy/h
Number of soil product drums in container	6	pc/container
Number of azbestos pellets in container	28	pc/container
Number of plastic insulation pellets in container	28	pc/container
Number of brash pellets in container	28	pc/container
Number of graphite pellets in container	20	pc/container
Number of concrete product drums in container	6	pc/container
Azbestos pellet volume	0,05	pc/container
Plastic insulation pellet volume	0,05	pc/container
Brash pellet volume	0,05	pc/container
Number of abrasion product drums in container	6	pc/container
Number of graphite pellets in container	0,06	pc/container
Consumption unit factor of water for cementation per cement powder volume	0,64	m^3/m^3
Number of 6 kV aluminium cable pellets in container	30	pc/container
Number of 1 kV aluminium cable pellets in container	30	pc/container
Number of 1 kV copper cable pellets in container	30	pc/container
Number of 1 kV copper cable pellets in container	30	pc/container
Number of signal copper cable pellets in container	30	pc/container

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0,125
operator	1,2
clerk	0
worker	2
auxilliary worker	0

Disposal of container in surface repository

Recieving, radiation check, visual control and disposal of container at surface repository. Transport within locality is included.

Input technological parameters

Parameter	Value	Unit
Dose rate from technological line (0,5 m distance from line)	1	microGy/h
Cost unit factor of container disposal at repository	3292,84	€/container
Operational unit costs (depreciation + other non-specific cost)	11926,74	€/container
Time from recieving to placement of container at repository	5	h/equipment/room

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0
operator	0,875
clerk	0
worker	3
auxilliary worker	1

Recyclation of cables

Removing of PVC cable insulation and placing of metal material of cables into drums. Transport of materials and products before and after recyclation is included.

Input technological parameters

Parameter	Value	Unit
Input power	2	kW
Capacity of equipment (mass)	30	kg/h
Operational unit costs (depreciation + other non-specific cost)	0,37	€/kg
Dose rate from technological line (0.5 m distance from line)	2	mikroGy/h

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0,125
operator	0,5
clerk	0
worker	2,5
auxilliary worker	2

Recyclation of building materials from demolition

Transport of materials and products before and after recyclation is included.

Input technological parameters

Parameter	Value	Unit
Cost unit factor of iron scrap repurchasing	66,39	€/t
Cost unit factor of usable building material repurchasing	3,32	€/t
Cost unit factor of concrete recycling	8,3	€/t
Cost unit factor of masonry recycling	6,64	€/t
Cost unit factor of reinforced concrete recycling	9,96	€/t
Cost unit factor of prefabricated elements recycling	9,96	€/t
Cost unit factor of building boards recycling	9,96	€/t
Cost unit factor of stoneware recycling	8,3	€/t
Cost unit factor of porous concrete	8,3	€/t
Input power	100	kW
Capacity of equipment	18000	kg/hour

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0,125
operator	1
clerk	0
worker	6
auxilliary worker	3

Recyclation of non-radioactive metal materials from dismantling

Transport of materials and products before and after recyclation is included.

Input technological parameters

Parameter	Value	Unit
Input power	2	kW
Capacity of equipment	500	kg/hour
Cost unit factor of metal scrap repurchase	66,3	€/t
Cost unit factor of colour metals scrap repurchase	1493,7	€/t

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0,125
operator	0,25
clerk	0
worker	1
auxilliary worker	3

Structure of non-productive working time of working groups for stabile treatment/conditioning technologies

Item of non-productive working time	Ratio to productive working time
Entry to uncontrolled area	3,00%
Preparation for work in uncontrolled area	2,00%
Working breaks in uncontrolled area - total	6,00%
Moving of personel within uncontrolled area	2,00%
Entry to controlled area	3,00%
Preparation for work preparation in controlled area	3,00%
ALARA breaks	6,00%
Working breaks in controlled area	4,00%
Moving of personel within the controlled area	4,00%
Finishing of work in controlled area	3,00%
Exit from controlled area	5,00%
Exit from uncontrolled area	3,00%
Total	44,00%

Annex 2-2-5

Set of calculation procedures for radiation monitoring

R1 - Radiation monitoring of iron metals in drums before release into environment
R2 - Radiation monitoring of ingots before release into environment
R3 - Radiation monitoring of non-iron metals in drums before release into environment
R4 - Radiation monitoring of non-metal materials in drums before release into environment
R6 - Radiation monitoring of containers before transportation to repository

Preparatory activities in individual rooms before starting the radiation monitoring of building surfaces:

P5_1 - Installation of scaffolding
P5_2 - Marking and delineating of surfaces
P5_3 - Delivery of working tools and equipments to the working place
P5_4 - Instructions for the radiation monitoring working group

Radiation monitoring - realization

R5 - Radiation monitoring of building surfaces

Finishing activities in individual rooms after the radiation monitoring of building surfaces:

F5_1 - Removal of scaffolding
F5_2 - Removal of working tools and equipments
F5_3 - Cleaning of room

Radiation monitoring

Radiation monitoring of iron metals in drums before release into environment

Radiation monitoring of drums by gamma scaner, including the transport before and after monitoring.

Input technological parameters

Parameter	Value	Unit
Cost unit factor of one batch monitoring (depreciations + operatic	9,13	€/batch
Time of one batch monitoring	0,75	h
Weight of carbon steel in monitored batch	350	kg/container, batch respectively
Weight of stainless steel in monitored batch	350	kg/container, batch respectively

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	1,125
operator	1
clerk	0
worker	0
auxilliary worker	0

Radiation monitoring of ingots before release into environment

Radiation monitoring of ingots by gamma scaner, including the transport before and after monitoring.

Input technological parameters

Parameter	Value	Dimension
Cost unit factor of one batch monitoring (depreciations + operatic	9,13	€/batch
Number of carbon steel ingots in monitored batch	1	pc/batch
Number of stainless steel ingots in monitored batch	1	pc/batch
Time of one batch monitoring	2	h

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	1,125
operator	1
clerk	0
worker	0
auxilliary worker	0

Radiation monitoring of non-iron metals in drums before release into environment

transport before and after monitoring.

Input technological parameters

Parameter	Value	Dimension
Cost unit factor of one batch monitoring (depreciations + operatic	9,13	€/batch
Time of one batch monitoring	0,25	h
Weight of alluminium cables in monitored batch	200	kg/container, batch respectively
Weight of alluminium in monitored batch	200	kg/container, batch respectively
Weight of copper cables in monitored batch	200	kg/container, batch respectively
Weight of copper in monitored batch	200	kg/container, batch respectively
Weight of lead in monitored batch	450	kg/container, batch respectively
Weight of other metals in monitored batch	350	kg/container, batch respectively

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	1,125
operator	1
clerk	0
worker	0
auxilliary worker	0

Radiation monitoring of non-metal materials in drums before release into environment

Radiation monitoring of drums by gamma scaner, including the transport before and after monitoring.

Input technological parameters

Parameter	Value	Dimension
Cost unit factor of one batch monitoring (depreciations + operatic	9,13	€/batch
Time of one batch monitoring	0,75	h
Weight of azbestos in monitored batch	100	kg/container, batch respectively
Weight of brash waste in monitored batch	100	kg/container, batch respectively
Weight of concrete in monitored batch	350	kg/container, batch respectively
Weight of glass wool in monitored batch	100	kg/container, batch respectively
Weight of graphite in monitored batch	100	kg/container, batch respectively
Weight of plastic insulation in monitored batch	150	kg/container, batch respectively

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	1,125
operator	1
clerk	0
worker	0
auxilliary worker	0

Radiation monitoring of containers before transportation to repository

Radiation monitoring of containers by dose measurement equipment.

Input technological parameters

Parameter	Value	Dimension
Consumption unit factor of one container monitoring	3,32	€/container
Time of one container monitoring	0,25	h/container

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	1,125
operator	1
clerk	0
worker	0
auxilliary worker	0

Preparatory activities in individual rooms before starting the radiation monitoring of building surfaces

Installation of scaffolding

Hands on installation of scaffolding.Transport of materials to room is included.

Input technological parameters

Parameter	Value	Unit
Manpower unit factor	0,5	man.hour/room
Constant unit factor for preparatory and finishing activities	4	man.hour

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0,125
operator	3
clerk	0
worker	0
auxilliary worker	0,5

Marking and delineating of surfaces

Hands on marking of radiation monitored areas.

Input technological parameters

Parameter	Value	Unit
Manpower unit factor	0,05	man.hour/m^2
Constant unit factor for preparatory and finishing activities	2	man.hour

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0,125
operator	3
clerk	0
worker	0
auxilliary worker	0,5

Delivery of working tools and equipments to the working place

Transport of tools and equipments to room.

Input technological parameters

Parameter	Value	Unit
Manpower unit factor	0,05	man.hour/m^2
Constant unit factor for preparatory and finishing activities	2,5	man.hour

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0,125
operator	3
clerk	0
worker	0
auxilliary worker	0,5

Instructions for the radiation monitoring working group

Instucting of radiation monitoring crew, tasks assignment.

Input technological parameters

Parameter	Value	Unit
Manpower unit factor	0,08	man.hour/m^2
Constant unit factor for preparatory and finishing activities	3,5	man.hour

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0,125
operator	3
clerk	0
worker	0
auxilliary worker	0,5

Radiation monitoring

Radiation monitoring of building surfaces

Radiation monitoring of building surfaces by dose measurement equipment.

Input technological parameters

Parameter	Value	Dimension
Consumption unit factor of labour content	2	m^2/man hour
Cost unit factor of monitoring	0,07	€/m^2

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0,2
operator	4
clerk	0
worker	0
auxilliary worker	0

Finishing activities in individual rooms after the radiation monitoring of building surfaces

Removal of scaffolding

Hands on removal of scaffolding.Transport of materials from room is included.

Parameter	Value	Unit
Manpower unit factor	0,4	man.hour/room
Constant unit factor for preparatory and finishing activities	3,5	man.hour

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0,125
operator	3
clerk	0
worker	0
auxilliary worker	0,5

Removal of working tools and equipments

Hands on removal of working tools and equipments.Transport of equipment from room is included.

Input technological parameters

Parameter	Value	Unit
Manpower unit factor	0,1	man.hour/m^2
Constant unit factor	3	man.hour

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0,125
operator	3
clerk	0
worker	0
auxilliary worker	0,5

Cleaning of room

Hands on removal of working tools and equipments.Transport of equipment from room is included.

Input technological parameters

Parameter	Value	Unit
Manpower unit factor	0,1	man.hour/m^2
Constant unit factor	5	man.hour

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0,125
operator	3
clerk	0
worker	0
auxilliary worker	0,5

Time ratio of related non-productive parts to productive part of operation (whole work group)

Non-productive time part	Ratio to productive time part
Entry to Uncontrolled Area	3,00%
Work preparation in Uncontrolled Area	2,00%
Work breaks in Uncontrolled Area	6,00%
Moving within Uncontrolled Area	2,00%
Entry to Controlled Area	3,00%
Work preparation in Controlled Area	3,00%
ALARA breaks	6,00%
Work breaks in Controlled Area	4,00%
Moving within Controlled Area	4,00%
Work finishing in Controlled Area	3,00%
Exit from Controlled Area	5,00%
Exit from Uncontrolled Area	3,00%

Annex 2-2-6

Set of calculation procedures for transports

T1 - Transport of materials by containers to recyclation plant

T2 - Transport of materials by containers to dumping ground

T3 - Transport of ingots to recyclation plant

T4 - Transport of containers to surface repository

Transports

Transport of materials by containers to recyclation plant

Input technological parameters

Parameter	Value	Unit
Time of one container (batch) transportation	8	h
Cost unit factor of container transport	400	€/container
Weight of alluminium cables in transport container	3500	kg/container, batch respectively
Weight of alluminium in transport container	10000	kg/container, batch respectively
Weight of carbon steel in transport container	10000	kg/container, batch respectively
Weight of copper cables in transport container	10000	kg/container, batch respectively
Weight of copper in transport container	10000	kg/container, batch respectively
Weight of lead in transport container	10000	kg/container, batch respectively
Weight of other metals in transport container	10000	kg/container, batch respectively
Weight of stainless steel in transport container	10000	kg/container, batch respectively

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0
operator	0,125
clerk	0
worker	1,25
auxilliary worker	1,5

Transport of materials by containers to dumping ground

Input technological parameters

Parameter	Value	Unit
Time of one container (batch) transportation	2	h
Cost unit factor of container transport	300	€/container
Weight of brash waste in transport batch	3500	kg/container, batch respectively
Weight of concrete in transport batch	3500	kg/container, batch respectively
Weight of glass wool in transport batch	1000	kg/container, batch respectively
Weight of graphite in transport batch	1500	kg/container, batch respectively
Weight of plastic insulation in transport batch	3500	kg/container, batch respectively

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0
operator	0,125
clerk	0
worker	1,25
auxilliary worker	1,5

Transport of ingots to recyclation plant

Input technological parameters

Parameter	Value	Unit
Time of one container (batch) transportation	8	h
Cost unit factor of container transport	400	€/container
Weight of carbon steel ingots in transport container	10000	kg
Weight of stainless steel ingots in transport container	10000	kg

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	0
operator	0,125
clerk	0
worker	1,25
auxilliary worker	1,5

Transport of containers to surface repository

Input technological parameters

Parameter	Value	Unit
Dose rate from technological link (0.5 m distance from link)	1	mikroGy/h
Cost unit factor of container transport to repository	232,36	€/container
Time of one container (batch) transportation	6	h

Work group structure

Profession	Number of staff
manager	0
senior engineer	0
engineer	1,5
operator	5,5
clerk	0
worker	0,5
auxilliary worker	0

Time ratio of related non-productive parts to productive part of operation (whole work group)

Non-productive time part	Ratio to productive time part
Entry to Uncontrolled Area	3,00%
Work preparation in Uncontrolled Area	2,00%
Work breaks in Uncontrolled Area	6,00%
Moving within Uncontrolled Area	2,00%
Entry to Controlled Area	3,00%
Work preparation in Controlled Area	3,00%
ALARA breaks	6,00%
Work breaks in Controlled Area	4,00%
Moving within Controlled Area	4,00%
Work finishing in Controlled Area	3,00%
Exit from Controlled Area	5,00%
Exit from Uncontrolled Area	3,00%

Time depended activities

Annex 2- 3

Activity according PSL structure	Name of activity	Duration [hours]	Duration [months]	Manpower [man hours]	Working grup: auxiliary worker [man]	worker [man]	operator [man]	administrative worker [man]	engineer [man]	senior engineer [man]	manager [man]
01.0103	Preparation of final decommissioning plan	1500	9,0	9 000	0	0	1	1	3	1	0
01.0104	Safety and environmental studies, nuclear safety analysis, involving	1200	7,2	7 200	0	0	1	1	3	1	0
01.0201	License applications and license approvals	1000	6,0	3 000	0	0	0	1	1	1	0
01.0202	Public consultation and public inquiry	300	1,8	450	0	0	0	1	0,5	0	0
01.0301	Radiological surveys for planning and licensing	500	3,0	1 250	0	0	2	0	0,5	0	0
01.0401	Hazardous material surveys and analyses	160	1,0	400	0	1	1	0	0,5	0	0
01.0501	Prime contranting selection	500	3,0	625	0	0	0	0,5	0,5	0,25	0
02.0301	Drainage and drying or blowdown of all systems not in operation	80	0,5	280	1	1	1	0	0,5	0	0
02.0401	After shutdown sampling for characterisation of equipment	320	1,9	1 120	0	1	2	0	0,5	0	0
02.0402	Subgrade soil sampling and monitorong wells to map contamination	160	1,0	720	0	2	2	0	0,5	0	0
02.0501	Removal of system fluids (water, oils, etc.)	80	0,5	280	1	1	1	0	0,5	0	0
02.1201	Isolation of systems out of operation	160	1,0	560	0	1	2	0	0,5	0	0
03.0101	Investments and maintenance for general site-dismantling equipment	160	1,0	360	0	0	0,5	1	0,5	0,25	0
03.0201	Investments and maintenance for personel and tooling decontaminatio	160	1,0	360	0	0	0,5	1	0,5	0,25	0
03.0301	General radiation protection equipment	160	1,0	360	0	0	0,5	1	0,5	0,25	0
04.1101	Arrangenments in buildings for supporting D&D	80	0,5	360	1	2	1	0	0,5	0	0
04.2101	Characterization of radioactive materials for recycling and reuse	160	1,0	240	0	0	1	0	0,5	0	0
04.2301	Personnel training, training of new personnel	80	0,5	200	0	0	2	0	0,5	0	0
05.0101	Analyses for handling, packing, storing of waste	80	0,5	120	0	0	1	0	0,5	0	0
05.0201	Analyses for waste transports	80	0,5	120	0	0	1	0	0,5	0	0
05.0301	Special permits, packing and transport requirements	80	0,5	200	0	0	0	1	1	0,5	0
06.0101	Site security operation and surveillance	6220	37,3	18 660	0	2	1	0	0	0	0
06.0201	Inspection and maintenance of buildings and systems in operation	3340	20,0	3 340	0	0	1	0	0	0	0
06.0301	Site upkeep	6220	37,3	6 220	1	0	0	0	0	0	0
06.0401	Energy and water	3340	20,0	3 340	0	0	1	0	0	0	0
07.0201	Final cleanup and landscaping	160	1,0	720	3	1	0,5	0	0	0	0
08.0101	Mobilization of construction equipment and facilities	40	0,2	60	0	0	1	0	0,5	0	0
08.0102	Mobilisation of personnel	40	0,2	60	0	0	1	0	0,5	0	0
08.0104	Set-up and construct temporary utilities	80	0,5	280	0	2	1	0	0,5	0	0
08.0201	Project manager and staff	6220	37,3	18 660	0	0	0	1	0,5	1	0,5
08.0301	Public relations	6220	37,3	3 110	0	0	0	0,25	0,25	0	0
08.0403	Decommissioning support including chemistry, decontamination	3340	20,0	5 010	0	0	1	0	0,5	0	0
08.0501	Health physics	3340	20,0	4 175	0	0	1	0	0,25	0	0
08.0601	Removal of temporary facilities	40	0,2	120	0	2	1	0	0	0	0

Floor	Room	Preparation activities for dismantling												Finishing of dismantling								Total mass of equipment [t]	Dimension of rooms [wxlxh]
		ra - survey	covering of floor	air-condition	scaffolding	electric connection	marking of cuts	delivery of tools	disconnection	preparation of tools	protective tent	instructions	containers	covering of floor	air-condition	scaffolding	electric connection	protective tent	removal of tools	containers	cleaning		
Basement	001	X																				0,08	2x2x4
	002	X						X		X			X						X	X	X	3,91	3,5x3,5x4
	003	X						X		X			X						X	X	X	3,91	3,5x3,5x4
	004	X						X		X			X						X	X	X	3,91	3,5x3,5x4
	005	X						X		X			X						X	X	X	3,91	3,5x3,5x4
	006	X	X	X		X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	4,04	2x4x4
	007	X	X	X		X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	33,62	2,5x30x4
	008	X				X		X	X	X			X				X		X	X	X	3,37	4x2x4
	009	X	X	X		X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	91,58	8x6x4
	010	X	X	X		X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	83,3	6x6x4
	011	X						X		X			X						X	X	X	0,5	3x6x4
	012	X						X		X			X						X	X	X	0,5	8x6x4
Ground floor	101	X						X		X			X						X	X	X	0,8	2x2x4
	102	X								X									X			0,3	5x6x4
	103	X								X									X			0,3	5x6x4
	104	X								X									X			0,3	5x6x4
	105	X	X	X		X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	85,6	10x6x4
	106	X						X		X			X						X	X	X	0,8	3x14,5x4
	107	X								X									X			0,45	2,5x27x4
	108	X																				0	4x2x4
	109	X								X									X			0,3	5x6x4
	110	X								X									X			0,3	5x6x4
	111	X								X									X			0,3	5x6x4
	112	X								X									X			0,3	5x6x4
	113	X								X									X			0,3	5x6x4
First floor	201	X																				0,08	2x2x4
	202	X																				0,28	5x6x4
	203	X																				0,28	5x6x4
	204	X																				0,28	5x6x4
	205	X																				0,28	5x6x4
	206	X																				0,28	5x6x4
	207	X								X									X			0,38	2,5x30x4
	208	X																				0	4x2x4
	209	X																				0,28	5x6x4
	210	X	X	X		X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	12,24	10x6x4
	211	X								X									X			0,3	5x6x4
	212	X						X		X			X						X	X	X	1,62	5x6x4
Attic	301	X																				0,08	2x2x2,5
	302	X																				0,08	9x6x2,5
	303	X																				0,08	9x6x2,5
	304	X																				0	2x6x2,5
	305	X						X		X									X			0,45	2x6x2,5
	306	X						X		X			X						X	X	X	1,2	2x6x2,5
	307	X																				0,08	2,5x20x2,5
	308	X								X									X			0,1	2,5x6x2,5
	309	X						X		X			X						X	X	X	1,05	6x6x2,5
	310	X						X		X			X						X	X	X	0,82	10x6x2,5
	311	X						X		X			X						X	X	X	1,52	10x6x2,5
	312	X						X		X			X						X	X	X	0,5	4x8,5x2,5
	313	X																				0,18	4x6x2,5

LEGEND:

Preparation activities for dismantling

ra - survey	Radiological survey prior dismantling
covering of floor	Covering of floor by plastic foil
air-condition	Installation of temporary air-conditioning
scaffolding	Installation of scaffolding
electric connection	Installation of temporary electric connection
marking of cuts	Marking of cuts and surfaces
delivery of tools	Delivery of working tools and equipments
disconnection	Disconnection and revision of decommissioned technological equipment
preparation of tools	Preparation of working tools and equipments
protective tent	Installation of protective tent
instructions	Working group instructions
containers	Preparation of transport containers

Finishing of dismantling

covering of floor	Removal of plastic foil
air-condition	Removal of temporary air-conditioning
scaffolding	Dismatling and removal of scaffolding
electric connection	Removal of temporary electric connection
protective tent	Removal of protective tent
removal of tools	Removal of working tools and equipments
containers	Removal of transport containers
cleaning	Cleaning of room

Contaminated equipment

Annex 3 Radiological limits for unconditional release of materials to environment implemented in OMEGA code

Radioactive contaminated materials can be released into environment if average effective dose of individuals in critical group of population, caused by their releasing into environment, does not exceed in any year 10 µSv and also collective effective dose does not exceed 1 manSv.

The limit values are defined for release of radioactive materials into environment for individual classes of radio-toxicity of nuclides. If activity of released contaminated materials is lower as the values for releasing defined in the Table A3-1, than above presented individual and collective dose criteria are met.

Tab. A3-1 Limit values for unconditional release of materials and radio-toxicity categories for individual radio-nuclides

Location of radioactive contamination	Radio-toxicity category				
	1	2	3	4	5
Materials, solid materials released into environment	Releasing levels of mass activity of radioactive contamination [kBq.kgP^{-1P}]				
	0,3	3	30	300	3000
Surfaces of materials and objects removed into ENV	Releasing levels of surface activity of surface radioactive contamination [kBq.mP^{-2P}]				
	3	30	300	3000	3.10P^{4P}

Categories of radio-toxicity and assigned radio nuclides

Category	Radionuclide
1	Na-22, Na-24, Mn-54, Co-60, Zn-65, Nb-94, Ag-110, Sb-124, Cs-134, Cs-137, Eu-152, Pb-210, Ra-226, Ra-228, Th-228, Th-232, U-234, U-235, U-238, Np-237, Pu-239, Pu-240, Am-241, Cm-244
2	Co-58, Fe-59, Sr-90, Ru-106, In-111, I-131, Ir-192, Au-198, Po-210
3	Cr-51, Co-57, Tc-99, I-123, I-125, I-129, Ce-144, Tl-201, Pu-241
4	C-14, P-32, Cl-36, Fe-55, Sr-89,Y-90, Tc-99, Cd-109
5	H-3, S-35, Ca-45, Ni-63, Pm-147

Mass activity of materials released into environment is determined as an average value in the volume, which weight is not larger than 1000 kg, if activity is distributed evenly and which weight is not larger than 300 kg if activity is not distributed evenly.

Similarly surface activity of materials is determined as the average value at the area not larger than 10 000 cmP^{2P} (evenly distributed activity) or better on the surface less than 1 000 cmP^{2P} (not evenly distributed activity).

If the released material is mass contaminated and surface contaminated as well, it is necessary that both limits for unconditional release be met.

Radiological limits for disposal of RAW at LILW Mochovce repository, as implemented in OMEGA code

Limits are stipulated for authorized disposal package, which is the fibre reinforced concrete container (FRC). This container is made of concrete reinforced by strips of stainless steel homogenously incorporated within the container walls. It has cubical shape with side of 1,7 m, inner useful volume 3,1 m^3 and useful load of 10 tones (it includes treated radioactive waste and cement grout for fixing and immobilization of waste in FRC). Radiological limits are defined for volume activity of individual monitored nuclide in homogenous volume of disposal container. Based on this volume limits, weight limits are derived within OMEGA code taking into account type of waste, its maximal amount in container and its specific mass. These limits are shown on the Table A3-2. Besides these limits, another limit condition must be met, which define that the sum of ratios of individual disposed activity per nuclide to their limits must be lower maximally equal to 1:

$$\sum_i \frac{A_{i\,disposed}}{A_{i\,\lim it}} \le 1$$

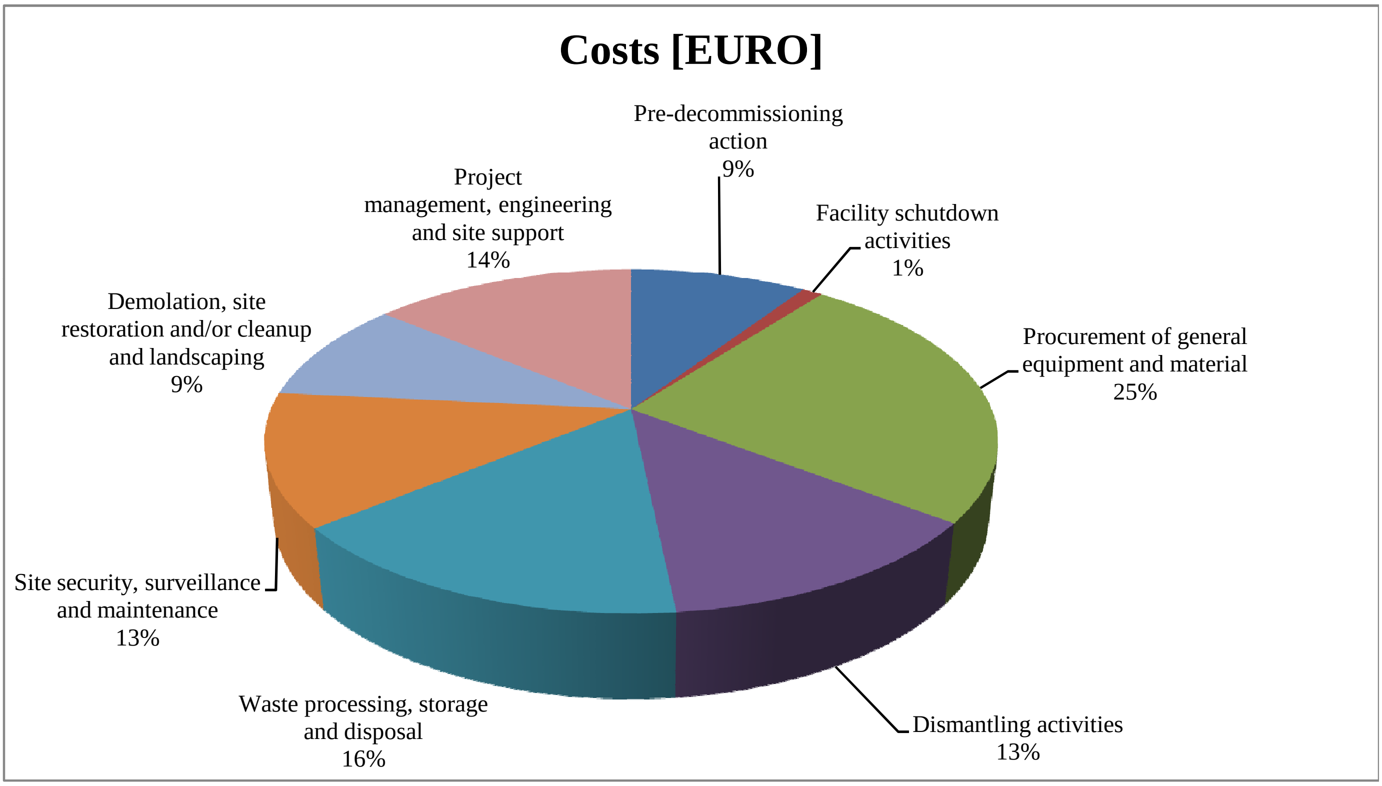
Where: $A_{i\ disposed}$ - activity of ith - nuclide placed in disposal container (volume or mass activity)
$A_{i\ limit}$ - limit activity of ith - nuclide (volume or mass activity)

Tab. A3-2 LILW disposal limits

nuclides	Limit values of volume material activity for disposal in surface repository in Bq/m^3	Limit values of weight material activity for disposal in surface repository in Bq/kg derived from volume limits										
		material										
		asbestos	concrete	small scrap	graphite	aluminium	else non-ferrous metals	metal	copper	lead	plastic	glass wool
Am-241	2,24E+08	1,29E+05	1,18E+05	2,57E+06	1,16E+05	9,51E+04	1,56E+05	1,48E+05	1,56E+05	1,54E+05	1,74E+06	1,05E+06
C-14	1,35E+10	7,76E+06	7,10E+06	1,55E+08	6,98E+06	5,74E+06	9,40E+06	8,90E+06	9,40E+06	9,26E+06	1,05E+08	6,33E+07
Ca-41	1,70E+10	9,76E+06	8,93E+06	1,95E+08	8,78E+06	7,22E+06	1,18E+07	1,12E+07	1,18E+07	1,17E+07	1,32E+08	7,96E+07
Cs-135	1,43E+10	8,20E+06	7,51E+06	1,64E+08	7,38E+06	6,07E+06	9,96E+06	9,43E+06	9,96E+06	9,81E+06	1,11E+08	6,69E+07
Cs-137	1,01E+13	5,80E+09	5,31E+09	1,16E+11	5,22E+09	4,29E+09	7,04E+09	6,66E+09	7,04E+09	6,93E+09	7,83E+10	4,73E+10
I-129	1,91E+07	1,10E+04	1,00E+04	2,19E+05	9,87E+03	8,11E+03	1,33E+04	1,26E+04	1,33E+04	1,31E+04	1,48E+05	8,94E+04
Mo-93	1,70E+10	9,76E+06	8,93E+06	1,95E+08	8,78E+06	7,22E+06	1,18E+07	1,12E+07	1,18E+07	1,17E+07	1,32E+08	7,96E+07
Nb-94	4,57E+07	2,63E+04	2,41E+04	5,26E+05	2,37E+04	1,95E+04	3,18E+04	3,01E+04	3,18E+04	3,13E+04	3,55E+05	2,15E+05
Ni-59	7,35E+11	4,22E+06	3,86E+06	8,44E+07	3,80E+06	3,12E+06	5,12E+08	4,85E+08	5,12E+08	5,04E+08	5,70E+07	3,44E+07
Ni-63	1,14E+13	6,54E+09	5,98E+09	1,31E+11	5,88E+09	4,84E+09	7,94E+09	7,52E+09	7,94E+09	7,82E+09	8,83E+10	5,33E+10
Pd-107	1,84E+12	1,06E+09	9,66E+08	2,11E+10	9,50E+08	7,81E+08	1,28E+09	1,21E+09	1,28E+09	1,26E+09	1,43E+10	8,61E+09
Pu-238	4,57E+09	2,63E+06	2,41E+06	5,26E+07	2,37E+06	1,95E+06	3,18E+06	3,01E+06	3,18E+06	3,13E+06	3,55E+07	2,15E+07
Pu-239	8,24E+07	4,72E+04	4,32E+04	9,44E+05	4,25E+04	3,49E+04	5,74E+04	5,43E+04	5,74E+04	5,65E+04	6,38E+05	3,85E+05
Se-79	3,44E+10	1,98E+07	1,81E+07	3,96E+08	1,78E+07	1,47E+07	2,40E+07	2,27E+07	2,40E+07	2,36E+07	2,68E+08	1,62E+08
Sm-151	1,14E+14	6,54E+10	5,98E+10	1,31E+12	5,88E+10	4,84E+10	7,94E+10	7,52E+10	7,94E+10	7,82E+10	8,83E+11	5,33E+11
Sn-126	2,93E+07	1,68E+04	1,54E+04	3,36E+05	1,51E+04	1,24E+04	2,04E+04	1,93E+04	2,04E+04	2,01E+04	2,27E+05	1,37E+05
Sr-90	1,90E+13	1,09E+10	9,98E+09	2,18E+11	9,82E+09	8,07E+09	1,32E+10	1,25E+10	1,32E+10	1,30E+10	1,47E+11	8,90E+10
Tc-99	4,48E+09	2,57E+06	2,36E+06	5,15E+07	2,32E+06	1,90E+06	3,12E+06	2,95E+06	3,12E+06	3,07E+06	3,48E+07	2,10E+07
Zr-93	2,28E+11	1,31E+08	1,20E+08	2,62E+09	1,18E+08	9,68E+07	1,59E+08	1,50E+08	1,59E+08	1,56E+08	1,77E+09	1,07E+09

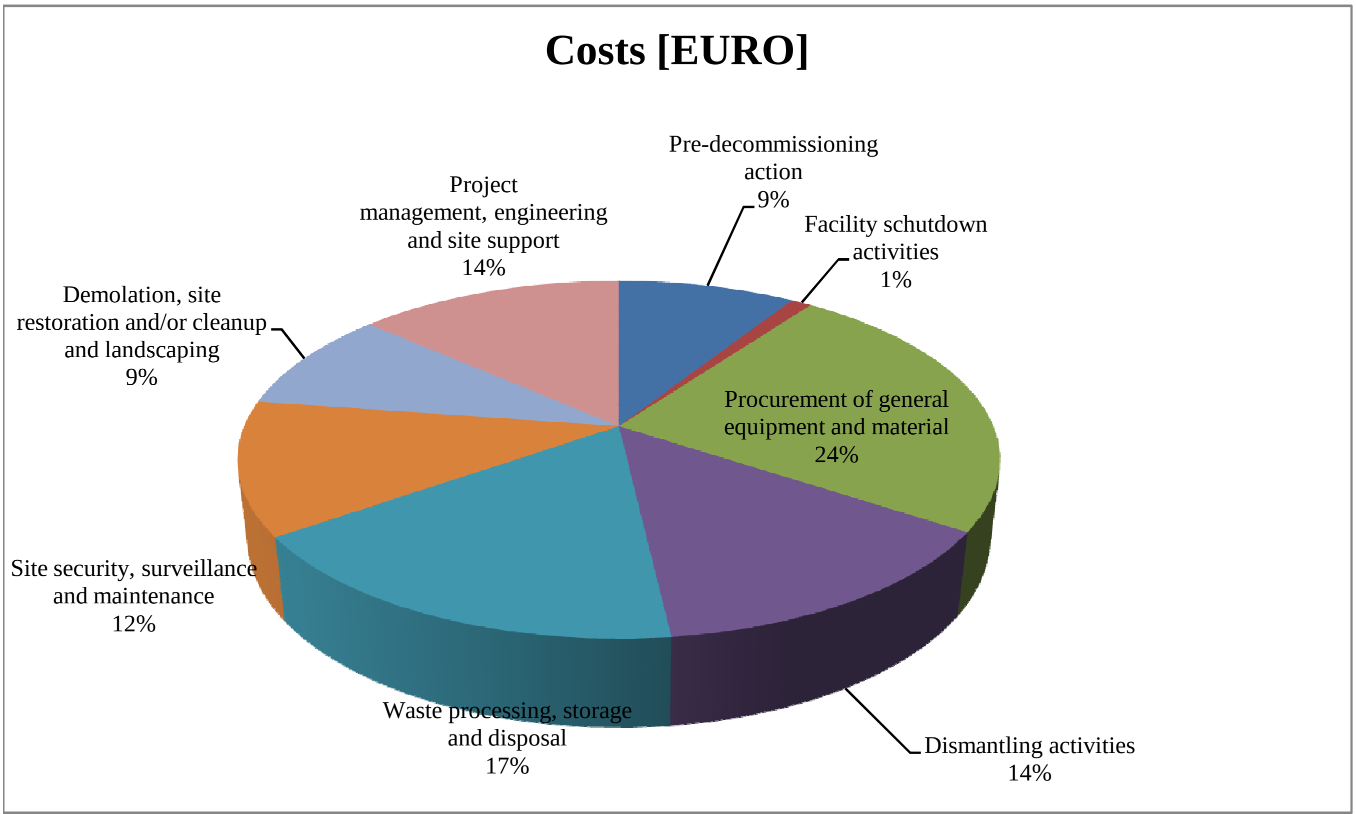
Annex 4-4-1 PSL structure of calculated decommissioning activities - Summary - Scenario S1

	PSL number	Costs [EUR]	Manpower [manhours]	Exposure [manmicroSv]
		29 302 429	**197 068**	**37 711**
Pre-decommissioning action	01	2 722 634	21 925	0
Facility schutdown activities	02	316 831	2 960	0
Procurement of general equipment and material	03	7 343 787	1 080	0
Dismantling activities	04	3 792 057	35 812	18 224
Waste processing, storage and disposal	05	4 602 865	38 683	19 487
Site security, surveillance and maintenance	06	3 664 087	33 160	0
Demolation, site restoration and/or cleanup and landscaping	07	2 784 884	30 573	0
Project management, engineering and site support	08	4 075 285	32 875	0
Research and development	09	0	0	0
Fuel and nuclear material	10	0	0	0
Other costs	11	0	0	0



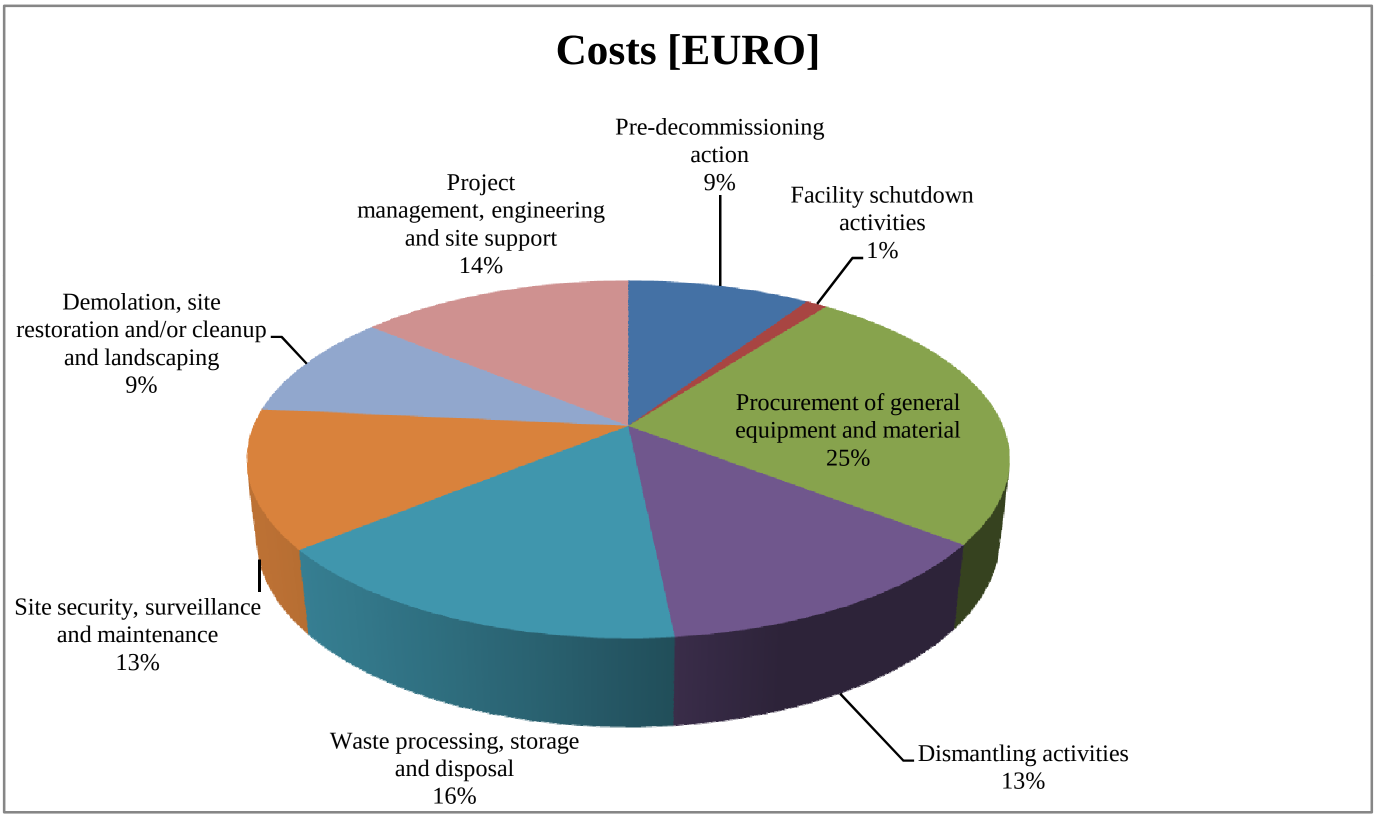
Annex 4-4-2 PSL structure of calculated decommissioning activities - Summary - Scenario S2

	PSL number	Costs [EUR]	Manpower [manhours]	Exposure [manmicroSv]
		30 279 796	**203 169**	**119 067**
Pre-decommissioning action	01	2 722 634	21 925	0
Facility schutdown activities	02	316 831	2 960	0
Procurement of general equipment and material	03	7 343 787	1 080	0
Dismantling activities	04	4 204 459	40 078	98 879
Waste processing, storage and disposal	05	5 167 830	40 517	20 188
Site security, surveillance and maintenance	06	3 664 087	33 160	0
Demolation, site restoration and/or cleanup and landscaping	07	2 784 884	30 573	0
Project management, engineering and site support	08	4 075 285	32 875	0
Research and development	09	0	0	0
Fuel and nuclear material	10	0	0	0
Other costs	11	0	0	0



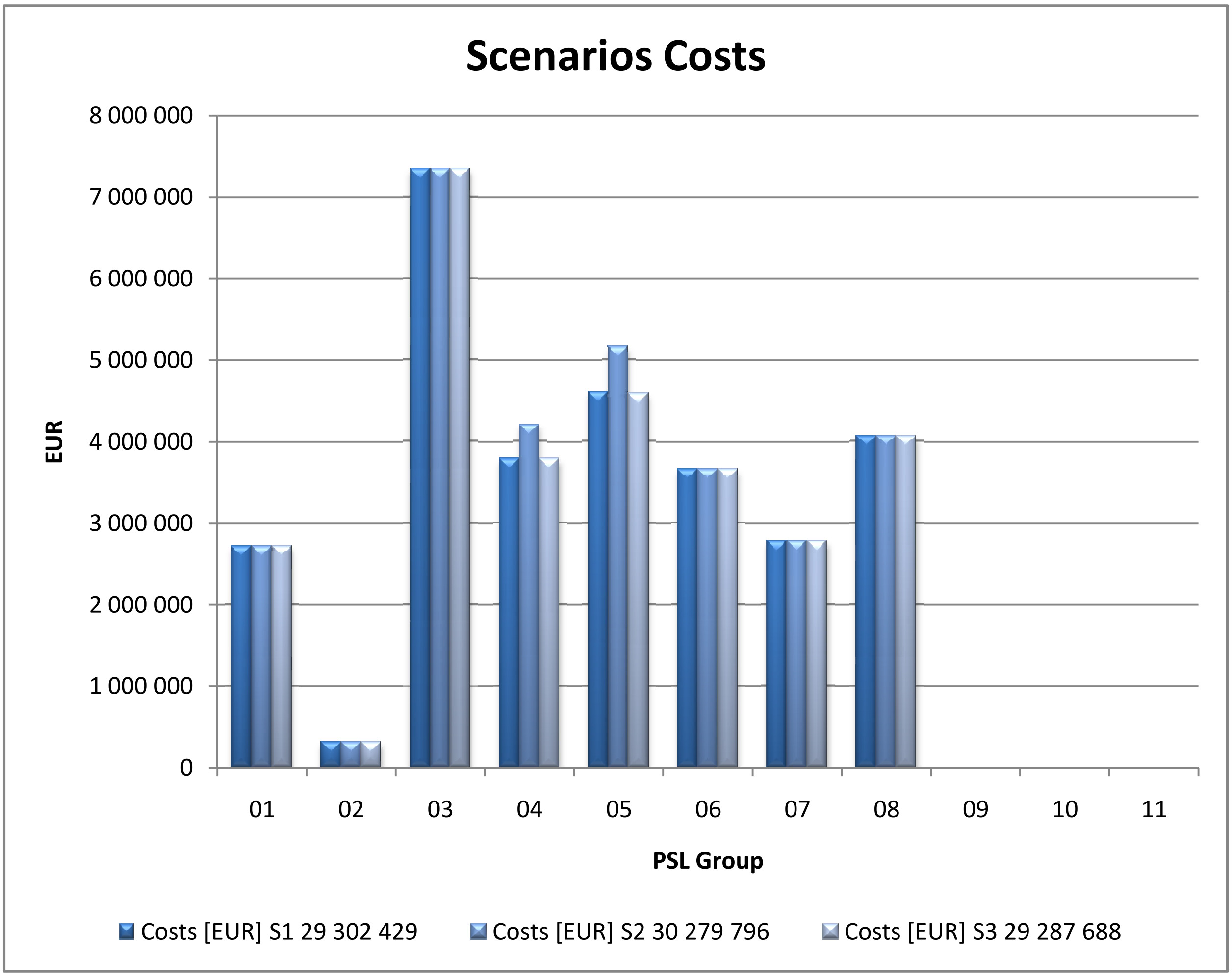
Annex 4-4-3 PSL structure of calculated decommissioning activities - Summary - Scenario S3

	PSL number	Costs [EUR]	Manpower [manhours]	Exposure [manmicroSv]
		29 287 688	**196 991**	**27 622**
Pre-decommissioning action	01	2 722 634	21 925	0
Facility schutdown activities	02	316 831	2 960	0
Procurement of general equipment and material	03	7 343 787	1 080	0
Dismantling activities	04	3 788 395	35 793	8 159
Waste processing, storage and disposal	05	4 591 786	38 625	19 463
Site security, surveillance and maintenance	06	3 664 087	33 160	0
Demolation, site restoration and/or cleanup and landscaping	07	2 784 884	30 573	0
Project management, engineering and site support	08	4 075 285	32 875	0
Research and development	09	0	0	0
Fuel and nuclear material	10	0	0	0
Other costs	11	0	0	0

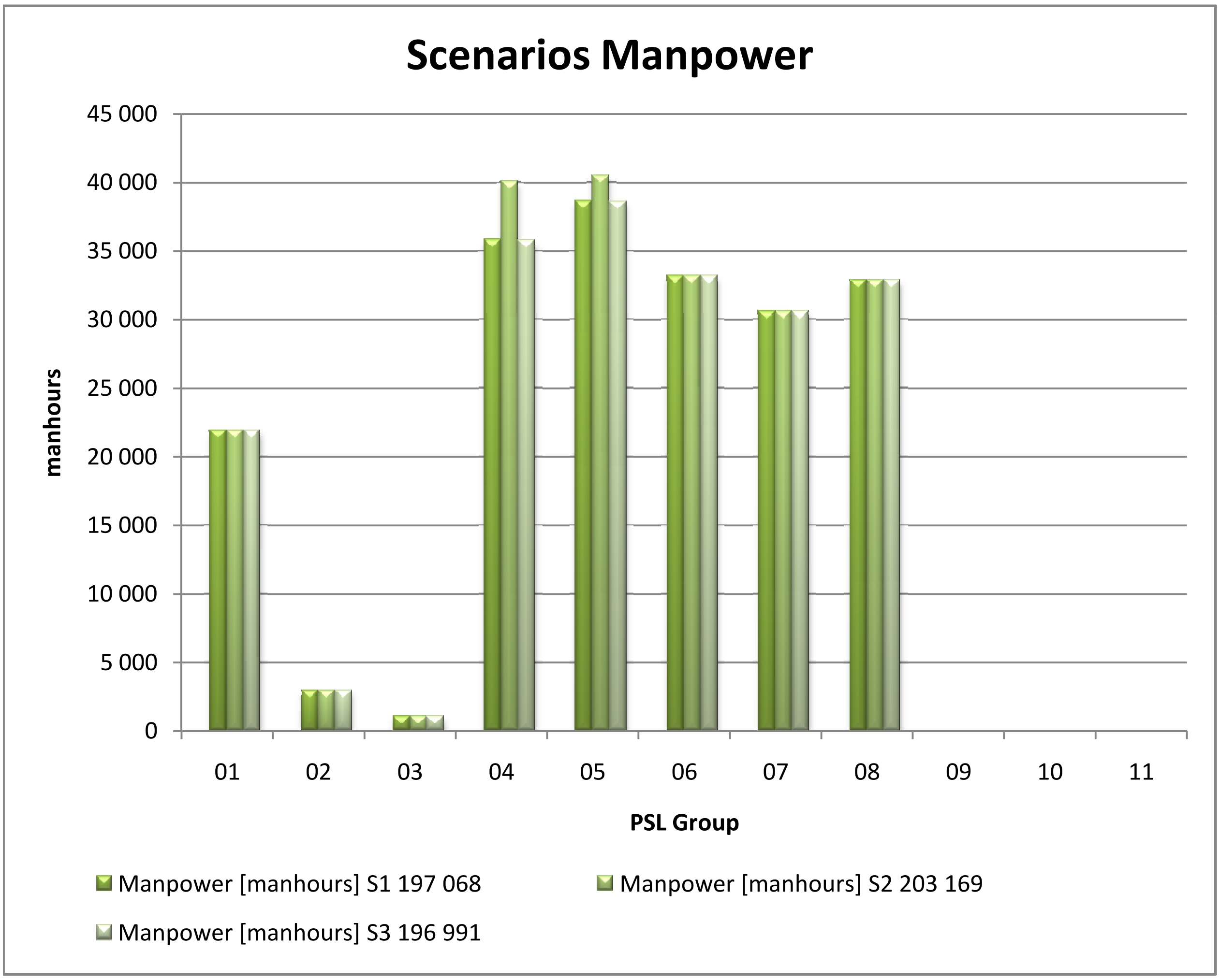


Annex 4-5 Comparison of individual scenarios

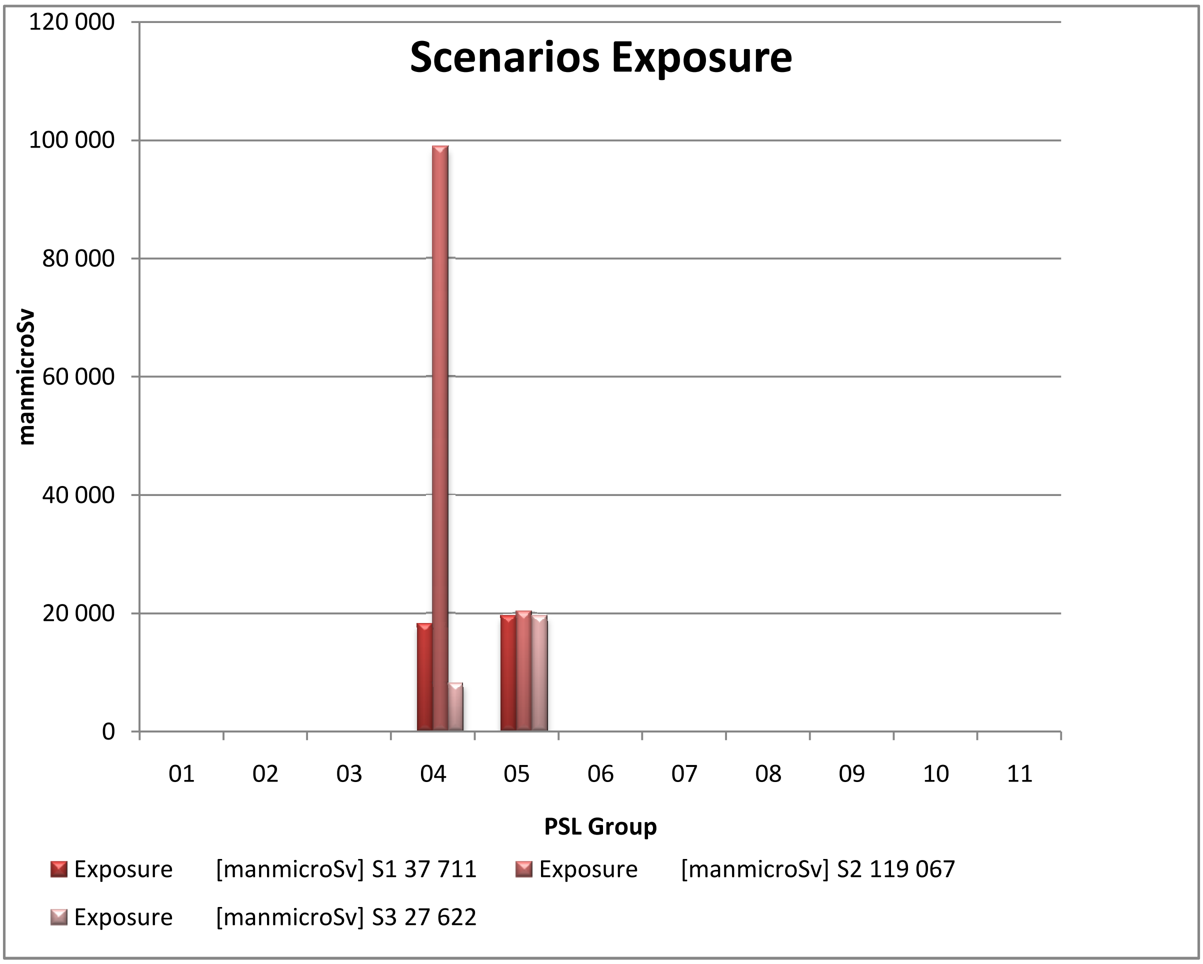
	PSL number	Costs [EUR]	Costs [EUR]	Costs [EUR]
		S1	S2	S3
		######	30 279 796	29 287 688
Pre-decommissioning action	01	2 722 634	2 722 634	2 722 634
Facility schutdown activities	02	316 831	316 831	316 831
Procurement of general equipment and material	03	7 343 787	7 343 787	7 343 787
Dismantling activities	04	3 792 057	4 204 459	3 788 395
Waste processing, storage and disposal	05	4 602 865	5 167 830	4 591 786
Site security, surveillance and maintenance	06	3 664 087	3 664 087	3 664 087
Demolation, site restoration and/or cleanup and landscaping	07	2 784 884	2 784 884	2 784 884
Project management, engineering and site support	08	4 075 285	4 075 285	4 075 285
Research and development	09	0	0	0
Fuel and nuclear material	10	0	0	0
Other costs	11	0	0	0



	PSL number	Manpower [manhours]	Manpower [manhours]	Manpower [manhours]
		S1	S2	S3
		197 068	203 169	196 991
Pre-decommissioning action	01	21 925	21 925	21 925
Facility schutdown activities	02	2 960	2 960	2 960
Procurement of general equipment and material	03	1 080	1 080	1 080
Dismantling activities	04	35 812	40 078	35 793
Waste processing, storage and disposal	05	38 683	40 517	38 625
Site security, surveillance and maintenance	06	33 160	33 160	33 160
Demolation, site restoration and/or cleanup and lands	07	30 573	30 573	30 573
Project management, engineering and site support	08	32 875	32 875	32 875
Research and development	09	0	0	0
Fuel and nuclear material	10	0	0	0
Other costs	11	0	0	0

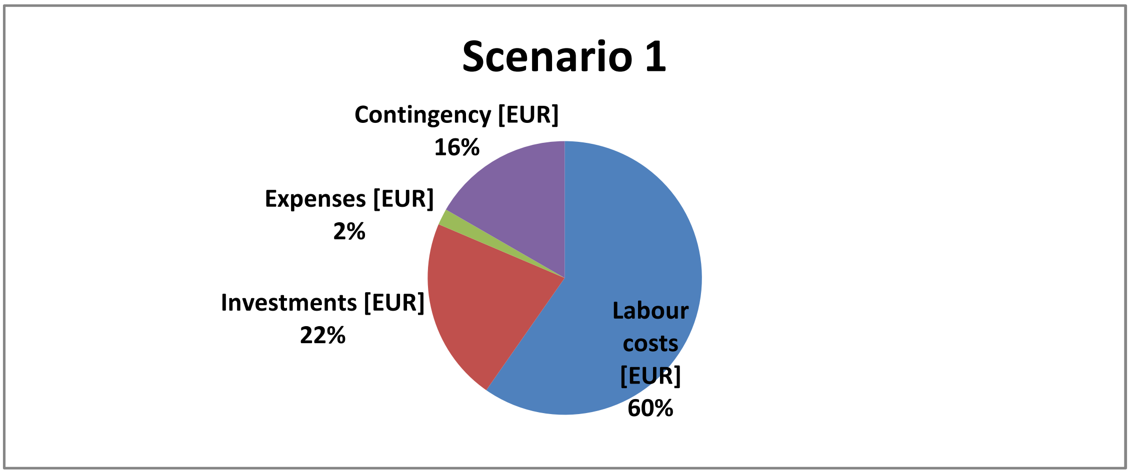


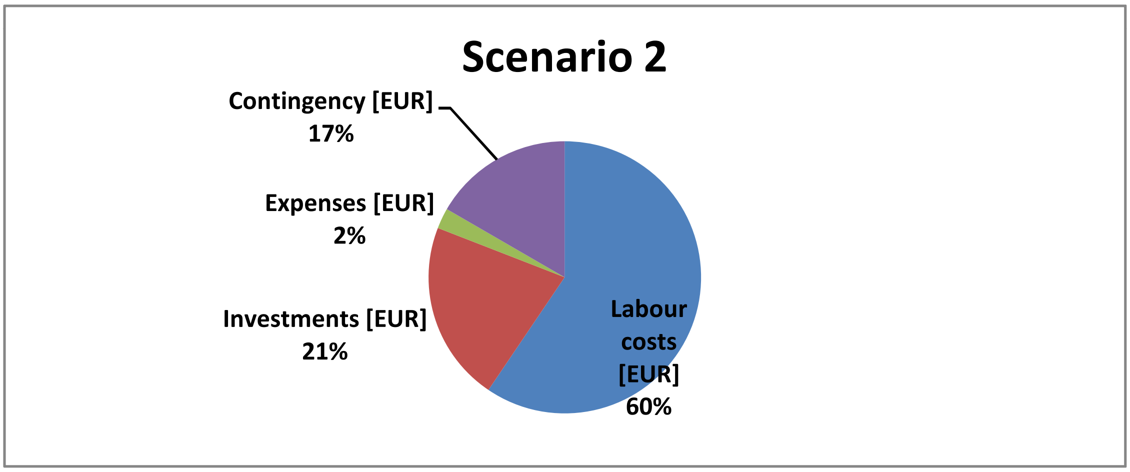
	PSL number	Exposure [manmicroSv]	Exposure [manmicroSv]	Exposure [manmicroSv]
		S1	S2	S3
		37 711	119 067	27 622
Pre-decommissioning action	01	0	0	0
Facility schutdown activities	02	0	0	0
Procurement of general equipment and material	03	0	0	0
Dismantling activities	04	18 224	98 879	8 159
Waste processing, storage and disposal	05	19 487	20 188	19 463
Site security, surveillance and maintenance	06	0	0	0
Demolation, site restoration and/or cleanup and lands	07	0	0	0
Project management, engineering and site support	08	0	0	0
Research and development	09	0	0	0
Fuel and nuclear material	10	0	0	0
Other costs	11	0	0	0

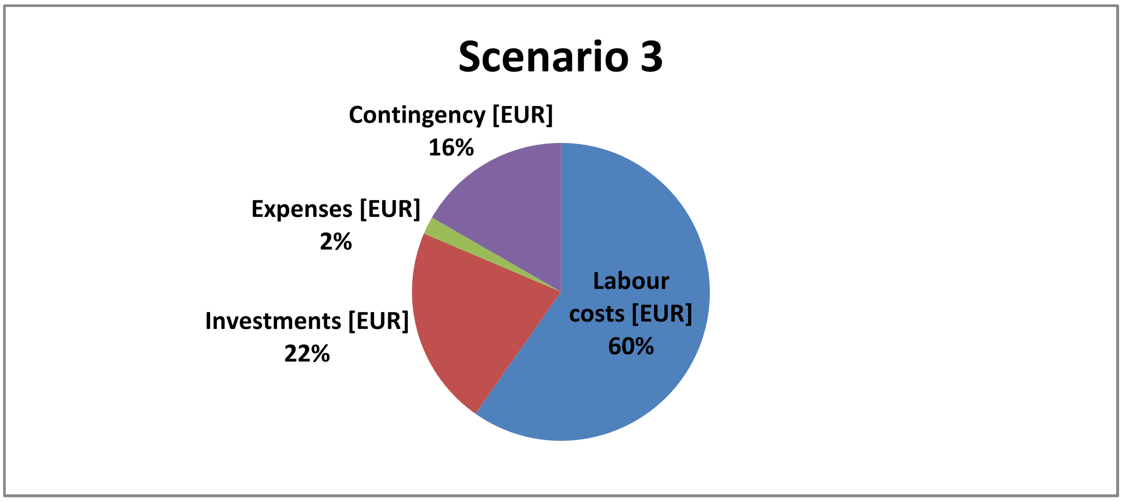


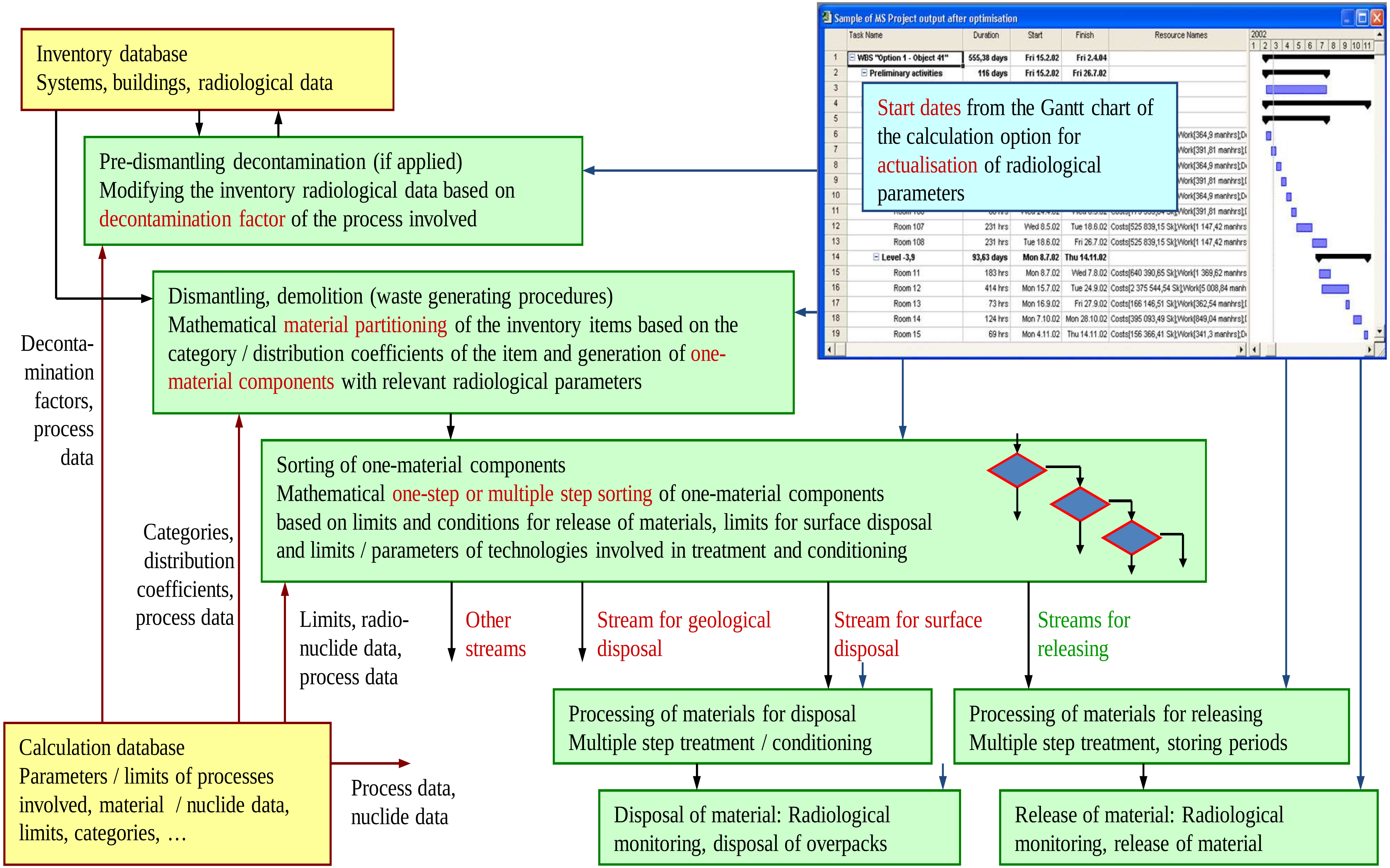
Annex 4-6 Cost structure of calculated decommissioning activities

	Scenario 1	Scenario 2	Scenario 3
Labour costs [EUR]	**17 502 252**	**18 009 023**	**17 495 058**
Investments [EUR]	**6 350 129**	**6 491 254**	**6 347 177**
Expenses [EUR]	**566 424**	**732 887**	**564 171**
Contingency [EUR]	**4 883 623**	**5 046 633**	**4 881 281**
Total [EUR]	**29 302 429**	**30 279 796**	**29 287 688**








Inventory database
Systems, buildings, radiological data
Pre-dismantling decontamination (if applied)
Modifying the inventory radiological data based on decontamination factor of the process involved
Sample of MS Project output after optimisation
Start dates from the Gantt chart of the calculation option for actualisation of radiological parameters
Dismantling, demolition (waste generating procedures)
Mathematical material partitioning of the inventory items based on the category / distribution coefficients of the item and generation of one-material components with relevant radiological parameters
Deconta-mination factors, process data
Sorting of one-material components
Mathematical one-step or multiple step sorting of one-material components based on limits and conditions for release of materials, limits for surface disposal and limits / parameters of technologies involved in treatment and conditioning
Categories, distribution coefficients, process data
Limits, radio-nuclide data, process data
Other streams
Stream for geological disposal
Stream for surface disposal
Streams for releasing
Processing of materials for disposal
Multiple step treatment / conditioning
Processing of materials for releasing
Multiple step treatment, storing periods
Calculation database
Parameters / limits of processes involved, material / nuclide data, limits, categories, …
Process data, nuclide data
Disposal of material: Radiological monitoring, disposal of overpacks
Release of material: Radiological monitoring, release of material

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