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# Study on future decommissioning of nuclear facilities in Norway – Task 1 Waste Inventory

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## Abstract

This report is part of the KVU project regarding a concept selection study on future decommissioning of nuclear facilities in Norway.

The report presents an assessment of the waste arising during decommissioning of the Norwegian nuclear facilities. The assessment is based mainly on collected data complemented through existing decommissioning plans and other published information. The purpose with the inventory assessment is to serve as a basis for further studies regarding waste management alternatives and their associated costs.

The output of this task and report is an assessed inventory where all waste generated during the decommissioning projects is categorized depending on their material type and distribution over a set of radioactivity content categories.

| Reviewed by | | Approved by | |
|---|---|---|---|
| Arne Larsson | 2014-09-29<br>Date | Lars Johansson | 2014-09-29<br>Date |

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# 1 Introduction

This report was prepared as a part of the concept choice study (KVU) for future decommissioning of the nuclear facilities in Norway. The KVU is conducted by DNV GL with Studsvik, Westinghouse and Samfunns- og Næringslivsforskning (SNF) commissioned by the Ministry of Trade, Industry and Fisheries in Norway (NFD).

The KVU will provide a recommendation on the most optimal socio economic level for decommissioning when the facilities in Halden and Kjeller are shut down in the future. In addition the KVU will provide a recommendation on decommissioning strategies and provide input to the decision about how to allocate the total costs.

The Institute for Energy Technology (IFE) is the license holder for the operation of Norway's two research reactors at Kjeller and in Halden. It is not decided when decommissioning of the nuclear facilities is to take place.

During previous applications for operating licenses IFE has established decommissioning plans that vary somewhat from this study both in regards to scope – what buildings and areas are included - and the way the level of decommissioning is defined.

## 1.1 Purpose and aim of task 1 Waste Inventory

The purpose of this report is to present an assessment of the waste arising from decommissioning[1] of the Norwegian nuclear facilities (task 1). These data constitute the basis for further waste management cost studies in the project (task 3). Task 3 will evaluate the data in order to evaluate the costs associated with three main waste management strategies;

a. Direct disposal, which involves waste conditioning followed by direct transport to Himdalen.

b. Recycling off-site, which means waste treatment in a facility off-site with the purpose to achieve a high level of recycling.

c. Recycling on-site, which means waste treatment locally at Halden, and Kjeller respectively. This results in less recycling as compared to alternative b, but does not require external specialized facilities for the treatment.

[1] Note that decommissioning wastes do not include e.g. spent fuel, which is considered as operational waste. All operational waste are assumed to have been removed before decommissioning commences. Spent fuel is further studied e.g. in [Nordlinder, 2014].

In order to perform the studies, it is of importance to have an understanding of the waste properties, such as material, component types, sizes, weights, contamination levels etc., which this report aims to provide.

### 1.2 Methodology

The original approach that was intended to be used was to acquire detailed material and radioactivity information from the facility operators. This raw data would then be assessed to give a detailed understanding of the waste originating from each part of the various IFE facilities.

However, during the progress of the work it became increasingly clear that the level of detail on parts of the data either was not available, or not in a form that allowed for it to be compiled and used in the assessment within the resource constraints. Instead, much of the work was done using estimations and comparisons with other facilities. The methodology is further discusses in Chapter 3.

### 1.3 Scope, delimitations and assumptions

The report focuses mainly on describing the sources used, the waste mass inventory derived from these sources, and the corresponding radioactivity inventory assessment. Combining the mass and radioactivity inventories then leads to the full radioactive waste inventory assessment which can be further studied regarding waste management alternatives and their associated costs.

The focus when gathering the data has been to use basic and original data (i.e., data directly from each facility) as much as possible as compared to existing decommissioning plans. This is made partly in order for the study to serve as a (relatively) independent assessment, and partly since the data in the decommissioning studies are not reported with the amount of detail needed regarding specific parameters to serve as a basis for further studies e.g. regarding waste management alternatives.

As is discussed in this report, in certain areas there is a shortage of accessible data for this study. In such cases qualified assumptions based on similar facilities, project team experience etc. have been used. This does introduce some unavoidable additional uncertainty in the presented data, but this should still affect the studied alternatives roughly equal leading to less uncertainty in the relative costs.

### 1.4 Background

IFE is the license holder for operation of the research reactors at Kjeller and Halden as well as other facilities. IFE has in December 2010 and in June 2012 sent in updated decommissioning plans for the IFE nuclear facilities to the Competent Authority, including financing of these plans.

It has not yet been decided when decommissioning of the IFE nuclear facilities will take place.

Several decommissioning plans (DP) have been delivered from IFE to the competent authority, Strålevernet, in accordance with the regulatory requirements. These have been updated over time, with the latest updates from 2012. The DPs includes cost estimations and waste volumes to be sent for disposal.

These reports are, however, not reported with the necessary level of detail to be directly used in the assessment of waste management alternatives in the KVU project, as discussed further later in this report.

### 1.5 International experience and recommendations

IAEA provides international experience and recommendations in the field of decommissioning [D367], which also IFE refers to in its DPs. Generally, a decommissioning project need to choose a strategy, an end-states, and a RWM option, see Table 1-1.

**Table 1-1**
Commonly used decommissioning strategies, end-states and RWM options.

| Decommissioning strategy | End-state | RWM option |
|---|---|---|
| 1. Immediate | A. Un-restricted usage | a. Direct disposal |
| 2. Deferred | B. Industrial | b. Recycling off-site |
| 3. Entombment | C. Other nuclear activity | c. Recycling on-site |

## 2 Conclusions and recommendations

This report has given an inventory assessment where the mass of the expected decommissioning waste streams are distributed over activity inventory categories. This data serves as input to further waste management cost studies in the project (task 3).

It has become clear during the course of the work that there is a lack of detailed data both in the expected waste amounts as well as in the associated radioactivity inventory. This study, therefore, has made independent assessments based on databases, discussions with operators, and comparisons with other facilities.

In Tables 2-1 and 2-2 the result from the study are summarised for the two sites (Halden and Kjeller) respectively. Details of the activity classification can be found in Table 3-5.

**Table 2-1**
Waste distribution over activity class, Halden (tonne). Activity is based on Co-60 with the following limits in Bq/g;
(NC: 0, VLL: 0-1, LL: 1-20, LM: 20-100, LH: 100-1000, H: >1000)

| **Category** | **Unknown** | **NC** | **VLL** | **LL** | **LM** | **LH** | **H** | **Total** | **Total excl. NC** |
|---|---|---|---|---|---|---|---|---|---|
| Components | 26.7 | 14.2 | 35.6 | 62.1 | 0 | 0 | 144.7 | 283 | 269 |
| Pipes | 0 | 1.5 | 0.4 | 1.7 | 0 | 0 | 6.8 | 10 | 9 |
| Cabling. chutes | 0 | 0.4 | 30.3 | 0 | 0 | 0 | 0 | 31 | 30 |
| Ventilation | 0 | 0.1 | 0 | 30.4 | 0 | 0 | 0 | 31 | 30 |
| Structural steel | 0 | 0.3 | 20.5 | 0 | 0 | 0 | 0 | 21 | 21 |
| Concrete | 0 | 24 462 | 160 | 0 | 380 | 0 | 0 | 25 002 | 540 |
| Reinforcement | 0 | 525 | 0 | 0 | 0 | 8 | 0 | 533 | 8 |
| Incinerable | 0 | 0 | 50 | 0 | 0 | 0 | 0 | 50 | 50 |
| **Total Halden** | **27** | **25 003** | **297** | **94** | **380** | **8** | **152** | **25 960** | **957** |

**Table 2-2**
Waste distribution over activity class, Kjeller (tonne).

| Category | Unknown | NC | VLL | LL | LM | LH | H | Total | Total excl. NC |
|---|---|---|---|---|---|---|---|---|---|
| Components – Electrical | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 11 | 0 |
| Components – Electric cabinets | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 11 | 0 |
| Components – Overhead cranes | 0 | 0.3 | 43 | 0 | 0 | 0 | 0 | 43 | 43 |
| Components – Actuators and valves | 0 | 2.7 | 5.6 | 8.3 | 0 | 0 | 0 | 17 | 14 |
| Components – Heat exchangers | 0 | 1.3 | 3.2 | 5.5 | 0 | 0 | 0 | 10 | 8.7 |
| Components – Misc. | 0 | 8.5 | 70 | 6.8 | 30 | 9 | 10 | 134 | 126 |
| Components – Pumps | 0 | 0.6 | 1.1 | 1.7 | 0 | 0 | 0 | 3.4 | 2.8 |
| Components – Tanks and cisterns | 0 | 3.0 | 7.3 | 13 | 0 | 4.5 | 1.5 | 29 | 26 |
| Components – Internal components | 0 | 0 | 0 | 0 | 0 | 0 | 2.5 | 2.5 | 2.5 |
| Components – Reactor tank | 0 | 0 | 0 | 0 | 0 | 0 | 0.6 | 0.6 | 0.6 |
| Components – Thermal shield | 0 | 0 | 0 | 0 | 0 | 0 | 9.4 | 9.4 | 9.4 |
| Components – Insulation | 0 | 0 | 6.1 | 0 | 0 | 0 | 0 | 6.1 | 6.1 |
| Pipes | 0 | 1.0 | 2.5 | 5.2 | 0 | 0 | 0 | 8.7 | 7.7 |
| Cables, ladders, chutes | 0 | 0.6 | 21 | 0.2 | 0 | 0 | 0 | 22 | 21 |
| Structural steel | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 15 | 15 |
| Concrete/leca/tegel | 0 | 11 114 | 82 | 0 | 0 | 10 | 223 | 11 429 | 315 |
| Reinforcement | 0 | 1 234 | 0 | 0 | 0 | 5.1 | 0 | 1 239 | 5.1 |
| Components – Metal | 0 | 100 | 0.38 | 5.4 | 0 | 45 | 0 | 151 | 51 |
| Ventilation | 0 | 1.7 | 8.51 | 30 | 0 | 1 | 4.9 | 46 | 4 |
| Components – Handling equipment | 0 | 0 | 1 | 0 | 0 | 2.8 | 0 | 3.8 | 3.8 |
| Components – Heating and sanitation – pipes | 0 | 12 | 0 | 0 | 0 | 0 | 0 | 12 | 0 |
| Components – Heating and sanitation – components | 0 | 2.2 | 0 | 0 | 0 | 0 | 0 | 2.2 | 0 |
| Incinerable | 0 | 0 | 36 | 0 | 0 | 0 | 0 | 36 | 36 |
| NALFA | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 8 | 8 |
| **Total Kjeller** | **0** | **12 503** | **310** | **46** | **30** | **77** | **252** | **13 249** | **745** |

The data presented in Tables 2-1 and 2-2 serve as input for waste management studies in the KVU project.

The main recommendations for future studies in order to increase the resolution in the data, are to assess the waste arising further, e.g. through establishing a detailed database of piping and components including mass, as well as assessments of other material as discussed in this report. The majority of this data is expected to be available, although scattered through different sources, of which some are not electronic.

The data should then be complemented by an assessment of the radioactivity inventory in each system (or part thereof) or area of the respective facility. This includes measurements and sampling of surfaces, components, pipes, as well as e.g. assessment of the contamination depth in concrete through bore sampling. Since the facilities discussed in this report are currently in operation, the radioactivity inventory may not be easily established and may change over time. Such data may therefore also be acquired by modelling.

# 3 Approach

The source data that are needed in order to perform decommissioning waste inventory studies are mainly 1) the mass/volume of the decommissioning waste, and 2) the radionuclide inventory distribution in the waste. The latter is of significant importance in decommissioning projects as radioactively contaminated material requires much more from a management and disposal perspective than conventional, non-contaminated, waste. In order to fully acquire these two parameters, a good understanding of the facilities from a construction and engineering perspective is required, combined with a thorough understanding of the activities performed both in the present as well as throughout the entire history of the facility.

When these two parameters have been acquired, they can be used to assess how much of the waste (mass and/or volume) that may be subject for clearance (from radioactive waste categorization), the proper treatment and packaging methods, and finally the amount that requires disposal in a radioactive waste disposal facility.

In the early planning stages before final shutdown, it is often difficult to acquire a clear picture of the necessary data as this is both resource intensive to gather, as well as it being uncertain due to the potential for change due to continued operation of the facility. Instead, an assessment based on component lists, building drawings etc. is often used in order to estimate the future decommissioning waste arising. The waste is further categorized regarding its risk for, or level of, radioactive contamination depending on specific parameters, such as the system an item belongs to, proximity to the core or to coolant passing through the core, etc.

This study is based on a method where component databases, building drawings, assessments from operators, comparison with similar facilities etc. have been used and complemented with radiological data from published materials, assessments, discussions and experience. Together these parameters allow for a categorization of all waste on both their material type as well as their radioactivity content, leading to an inventory assessment which may serve as the basis for further studies regarding waste management and disposal volume.

### 3.1 Data collection and delivery schedule

The data collection and delivery schedule during the task have been as follows:

- Data input templates (common for Tasks 1, 3 and 4) sent to IFE 2013-11-12
- Data meetings at Halden 2013-12-03 and 2013-12-17
- Deadline for return of data input files extended to 2014-01-31
- Data freeze (no change in scope or data) for Halden 2014-02-26
- Data review meeting at Halden 2014-03-20
- Data freeze for Kjeller 2014-03-27
- Data review meeting at Kjeller 2014-04-25
- Data delivery for Halden to Task 3, rev. 0, 1, and 2, in May and June 2014
- Data delivery for Kjeller to Task 3, rev. 0 and 1, in June 2014.

### 3.2 Presumptions

The Halden and Kjeller sites consist of several buildings where different kinds of activities have been performed. This means that the various facilities have different properties which impact both the waste amount as well as the potential for clearance of such waste or the facilities themselves.

In order to draw the system boundaries of the KVU project, an assessment of each facility and/or building has been made regarding the activities which have been performed there [KVU-rapporten]. The purpose has been to determine the decommissioning strategy and endpoint for each building.

For this report, the assessed system boundaries have been kept, but with two exceptions;

- JEEP-1 is listed as a red facility, but has been partly decommissioned and decontaminated to a degree where it is not likely to lead to any further significant radioactive waste generation. It is therefore excluded in the inventory assessment.

- The NALFA-pipe is listed as yellow due to the difficulties in decommissioning based on the location of the pipe. The piping is, however, included in this assessment since it is likely to be contaminated.


**Figure 3-1**
System boundaries for the facilities and buildings at the Halden site.

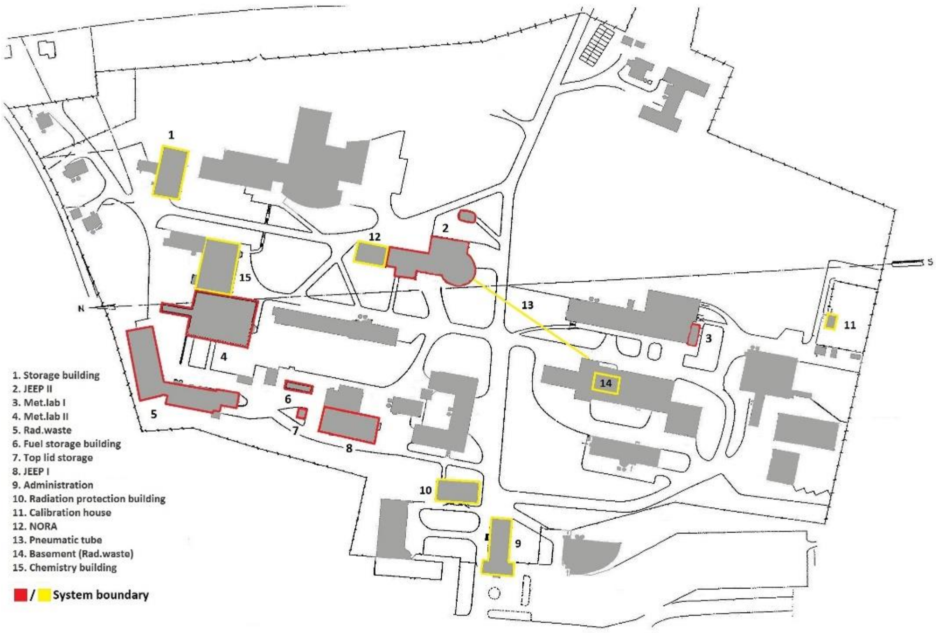


**Figure 3-2**
System boundaries for the facilities and buildings at the Kjeller site.

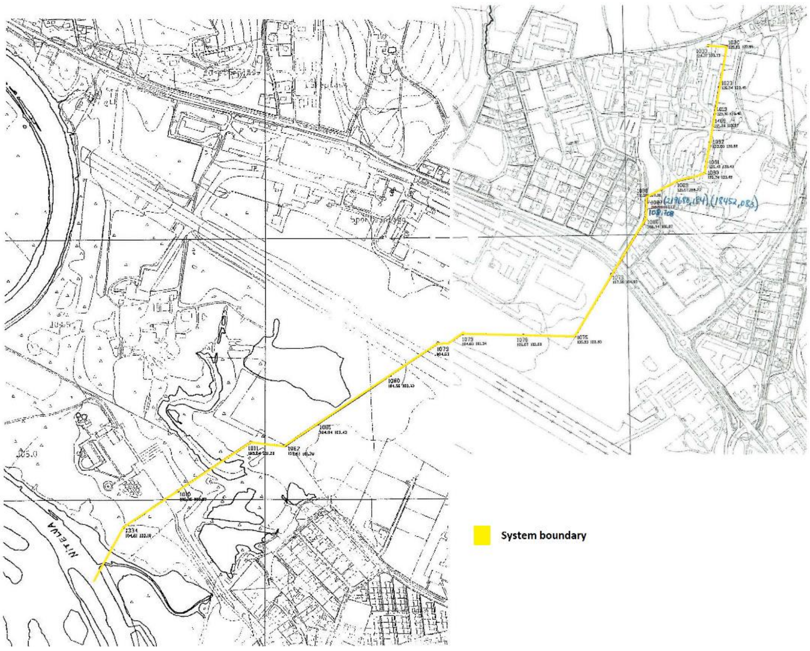


**Figure 3-3**
System boundaries for NALFA[2] piping at the Kjeller site.

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2 The NALFA piping transports water that fulfill the release criteria from the Kjeller site to Nitelva.

### 3.3 Data sources

This section gives an overview of the data that have been requested and acquired during the course of the inventory assessment. The purpose with the assessment has been to perform an independent assessment to the extent possible, which means that focus has been on gathering basic data rather than using previously produced documentation such as decommissioning plans.

In Table 3-1, a summary of the data that has been requested and received is presented.

**Table 3-1**
Overview of requested and acquired data.

| Facility | Data request | Data acquired |
|---|---|---|
| All | Pre-prepared templates for the various waste streams were sent to all facilities expected to generate waste. These templates allows the facility operator to list components/materials with parameters such as mass, volume, contamination level, etc. | Completed templates were received for Metlab 1 and Metlab 2. Some templates were also provided for the waste management building.<br><br>No templates were received for other facilities. |
| All | IFE decommissioning plans | IFE has provided the latest version of their various decommissioning plans. [D058, D059, D061, D062, D063, D064, D065] |
| HBWR, JEEP-2 | In absence of returned templates for components, Component database exports were requested from the two reactors | Database exports containing lists of component were received from HBWR and JEEP-2. The lists contain some mass information for certain components but is far from complete. The lists contain no contamination data. |
| HBWR, JEEP-2 | Piping and instrumentation diagrams (P&ID) | HBWR: P&ID has been provided.<br><br>JEEP-2: P&ID has been provided. |
| All | Building drawings | Building drawings have been received. |
| HBWR, JEEP-2 | Mass data for components | HBWR:<br>No complete list is available as this information is mainly in non-condensed paper form which is resource intensive to review. IFE has provided some available mass data for components and pipes in the primary circuit [D183].<br><br>JEEP-2: No complete list is available as this information is mainly in non-condensed paper form which is resource intensive to review. IFE has provided some data for components through correspondence and various documents. |

| Facility | Data request | Data acquired |
|---|---|---|
| HBWR, JEEP-2 | Contamination data for specific components | HBWR:<br>No component specific contamination data is available. IFE provided [D184] and [D065] which contains some general information regarding the decommissioning radioactivity inventory.<br><br>JEEP-2:<br>No system specific contamination data is available. IFE provided [D061] which contains some general information regarding the decommissioning radioactivity inventory. |
| HBWR | Review of a list of system specific contamination prepared by the project team based on experience from similar facilities. | IFE reviewed the list. |
| All | Photographs of facilities/areas have been requested when no other information has been available. | Some photographs have been provided. Opportunities to photograph areas during site visits have been provided. |

During the data gathering process it has become evident that there is a shortage of detailed data in several areas, both relating to material amounts as well as contamination levels. This has led to several assumptions having to be made for the inventory assessment, e.g. through comparison with other facilities, as well as evaluation of mass based e.g. on building drawings, P&ID charts, photographs etc. This results in a relatively coarse assessment with considerable uncertainty. Since a main purpose of the study is to evaluate different treatment options based on the same source material, this uncertainty is, however, less significant as the relative costs are of main interest.

The following two sections give an overview of the sources that have been used.

### 3.3.1 Waste material inventory

In Table 3-2, an overview of the main sources used for assessment of the waste material inventory is given.

**Table 3-2**
Overview of mass inventory sources and assessment approach for each facility.

| Site | Building | Source | Comment |
|---|---|---|---|
| Halden | HBWR | Component database | Reactor component database. Due to lack of data regarding mass of components, the mass of some components have been estimated, e.g. from a list of similar components from other similar facilities. |
| | | Piping and component listing for the primary circuit [D183] | Used for assessment of the piping inventory. Also provides some component mass information which complements the component database |
| | | Building drawings, P&ID:s and flow charts | Used for assessment of mainly construction material amounts. |
| | | Published decommissioning plan [D065] | Used for assessment of mainly construction material amounts. |
| | | Comparison with similar facilities | Comparisons are primarily done with Swedish research reactors and power plants. Used for assessment of ventilation, cabling etc. where no other information is available. |
| | Metlab, bunker building including waste treatment room, laundry building, storage tunnel | Building drawings and photographs | Used for assessment of mainly construction material amounts. |
| | | Estimations | Based on experience from similar facilities |
| | Other Halden buildings | Discussions with IFE | The other buildings at Halden have been assessed with the conclusion that there is no significant risk for radioactive waste generation during decommissioning. |
| Kjeller | JEEP-1 | Building drawings and photographs | Used for assessment of mainly construction material amounts. |
| | | Estimations | Based on experience from similar facilities |

| Site | Building | Source | Comment |
|---|---|---|---|
| | JEEP-2, Top cover storage building | Component database | Reactor component database. Due to lack of data regarding mass of components, the mass of some components have been estimated, e.g. from a list of similar components from other similar facilities. |
| | | SAR [D219 ], published decommissioning plan [D061] | Used for assessment of mainly construction material amounts. |
| | | Comparison with similar facilities | Comparisons are primarily done with Swedish research reactors and power plants. Used for assessment of ventilation, cabling etc. where no other information is available. |
| | | Building drawings and flow charts | Used for assessment of mainly construction material amounts. |
| | Metlab-1 | IFE provided inventory assessment | |
| | | Published decommissioning plan [D062] | |
| | Metlab-2, JEEP-1 fuel building | IFE provided inventory assessment | |
| | | Published decommissioning plan [D059] | |
| | Waste management building, NALFA | Published decommissioning plan [D064] | |
| | | Comparison with similar facilities | Based mainly on Metlab-2 due to lack of information |
| | | IFE provided inventory assessment | Data only available for a few waste streams |
| | | Estimations | Based on experience from similar facilities |
| | | Building drawings | Used for assessment of mainly construction material amounts. |
| | Other Kjeller buildings | Discussions with IFE | The other buildings at Kjeller have been assessed with the conclusion that there is no risk for significant radioactive waste generation during decommissioning. |

### 3.3.2 Radioactivity inventory

In Table 3-3, an overview of the sources used for assessment of the radioactivity inventory is given.

**Table 3-3**
Overview of radioactivity inventory sources and assessment approach for each facility.

| Site | Building | Source | Comment |
|---|---|---|---|
| Halden | HBWR | System specific Radioactivity category assessment | Based on comparison with similar facilities. Reviewed and complemented by IFE. |
| | | Published decommissioning plan [D065] | Used mainly for comparison with previously published data |
| | | Estimations | Based on cautios assumptions |
| | Metlab, bunker building including waste treatment room, laundry, storage tunnel | Estimations | Based on cautios assumptions |
| | Other Halden buildings | Discussions with IFE | The other buildings at Halden have been assessed with the conclusion that there is no risk for significant radioactive waste generation during decommissioning. |
| Kjeller | JEEP-1 | No specific information | JEEP-1 has been assessed with the conclusion that there is no risk for significant radioactive waste generation during decommissioning. |
| | JEEP-2, Top cover storage building | Published decommissioning plan [D061] | Used mainly for comparison with previously published data |
| | | Estimations | Based mainly on HBWR due to lack of information |
| | Metlab-1 | Estimations | Based on cautios assumptions |
| | Metlab-2, JEEP-1 fuel building | IFE provided data | |

| Site | Building | Source | Comment |
|---|---|---|---|
| | Radwaste, NALFA | Estimations | Based on cautios assumptions |
| | Other Kjeller buildings | Discussions with IFE | The other buildings at Kjeller have been assessed with the conclusion that there is no risk for significant radioactive waste generation during decommissioning. |

### 3.4 Categorization of waste

In order to assess the amount of waste generated during decommissioning of the facilities, the whole inventory of materials in them needs to be assessed. Furthermore, to be able to determine suitable treatment and packaging methods, the assessed waste has to be divided in categories, or waste streams.

The waste streams used for this assessment is given in Table 3-4 below.

All waste is further characterized based on the radioactivity level in the material. This is commonly expressed as a specific activity (Bq/g) based on a key nuclide. In this assessment the key nuclide chosen is Co-60. This choice is made since it is commonly the limiting nuclide (dose contribution) when assessing treatment alternatives as well as the possibility for clearance of material[3]. It should, however, be noted that from a disposal perspective other nuclides with longer decay times are of more interest due to their possibility of migration when the repository barriers have broken down. The inventory of such nuclides is not discussed further in this report.

3 While the full nuclide content needs to be taken into consideration, Co-60 has a relatively low clearance limit is many jurisdictions and therefore serves as a good nuclide to base preliminary assessments on.

**Table 3-4**
Waste streams used for the inventory assessment.

| Waste stream | Comment |
|---|---|
| Components | This is a broad category containing several types of objects and process components, such as heat exchangers, pumps, electrical equipment etc. While the material composition varies between these components, the majority is often assumed to be metallic.<br><br>For most facilities this category is divided into sub-streams based on the component type, while for others it is lumped into only one stream. |
| Pipes | Piping mainly from process systems. Unless otherwise stated process piping is assumed to consist of steel pipes. |
| Structural steel | Steel in e.g. walk ways, railing, beams, etc. |
| Cabling, chutes | Cabling and the associated pathways and chutes. Mainly metallic (steel and copper) but contains e.g. plastic sheets and rubber insulation as well. |
| Ventilation | Ventilation ducts. Metallic or plastic. May be galvanized. |
| Concrete | The vast majority of concrete consists of bulk concrete in the building structure. However, concrete is also used for radiation protection purposes, e.g. close to the reactor core. |
| Reinforcement | Steel reinforcement used to reinforce concrete. |
| Incinerable | Incinerable organic waste such as plastics, rags, scraps etc. This waste stream is also generated during actual decommissioning works. |

Based on the specific activity, the material is categorized into one of six radioactivity content categories as given in Table 3-5 below. In the table, an approximate risk category has been included as to illustrate the link between the assessment and the general decommissioning approach based on assessment of contamination risk, see e.g. [Lidar et.al., 2014]. It should be noted, however, that the categories are not fully equivalent.

**Table 3-5**
Categorization based on radioactivity content.

| Specific activity Co-60 (Bq/g) | Radio-activity content category | Approximate risk category | Comment |
|---|---|---|---|
| 0 | NC<br>(Not Contaminated) | Very low risk,<br>Low risk | Material that may reasonably be assumed to have a very low or low risk of contamination. |
| 0−1 | VLL<br>(Low: Very Low) | Risk, VLLW<br>(Very low level waste) | This category contains material with a very low radioactivity content. |
| 1−20 | LL<br>(Low: Low) | LLW<br>(Low level waste) | Material and components with a low radioactivity content.<br><br>Waste in this category will require decontamination and/or melting in order to be potentially subject for clearance. |
| 20−100 | LM<br>(Low: Medium) | LLW | Material and components that are contaminated at a moderate level.<br><br>Part of the waste in this category may be subject for clearance provided that decontamination and/or melting is performed. |
| 100−1 000 | LH<br>(Low: High) | LLW | Material and components that are contaminated at a moderate but relatively high level.<br><br>Waste in this category is unlikely to be subject for clearance except in special cases. Melting or other treatment may still reduce volume. |
| >1 000 | H<br>(High[4]) | ILW<br>(Intermediate level waste) | Material and components that are contaminated at a high level.<br><br>Waste in this class is not subject for clearance. Treatment for volume reduction may be possible if the material fulfils waste acceptance criteria at the treatment facility. |

4 Note: Not to be confused with the risk and waste category High Level Waste.

### 3.5 Method

This section gives a general description of the method that has been used in determining the mass of waste as well as the radioactivity categories for the wastes.

#### 3.5.1 Mass

**Components**
The assessment of component mass varies depending on the available information from the facility.

The main approach has been to use specified component masses whenever available. Such available information has further been used to assess the mass of similar component within the same system or facility, and if no other information exists also between facilities. This latter is mainly applied between HBWR and JEEP-2.

For some components, mainly regarding valves and similar objects, where no mass data has been found, a default mass based on similar components from external facilities has been used.

For tanks and cisterns with unspecified mass, a general formula of 165 kg/m$^3$ for objects with a volume less than 1 000 m$^3$, and 90 kg/m$^3$ for objects with a volume above, has been used.

As a last resort, for some facilities with few components estimations have been made by assessing the size and mass of components from photographs.

**Piping**
Piping specifications were received for the HBWR reactor, which also has been used to assess the JEEP-2 piping inventory by scaling.
For the waste management building, which has relatively thin pipes, an assumed weight of approximately 1 kg/m has been used.

For Metlab-1 and Metlab-2 specific information has been received. For other facilities assessments based on drawings, photographs or experience based estimations have been made.

**Structural steel**
The amount of structural steel has not been included in any of the received source material, and therefore has been assessed based on building area scaling from the Swedish Studsvik R2 reactor. This has been used for both HBWR and JEEP-2.

For other facilities assessments based on drawings, photographs or experience based estimations have been made.

**Cabling, chutes**
The amount of cabling and chutes has, unless specific information has been received, been assessed based on building area scaling from the Swedish Studsvik R2 reactor. This has been used for both HBWR and JEEP-2. For JEEP-2 assessments from operational personnel was also used.

For Metlab-1 and Metlab-2 specific information has been received. For the waste management building, scaling has been based on Metlab-2. For other facilities assessments based on drawings, photographs or experience based estimations have been made.

**Ventilation**
The amount of ventilation has been assessed based on building area scaling from the Swedish Studsvik R2 reactor complemented with some specific information from building drawings and reports when available.

For Metlab-1 and Metlab-2 specific information has been received. For the waste management building, scaling has been based on Metlab-2. For other facilities assessments based on drawings, photographs or experience based estimations have been made.

**Concrete**
The mass of concrete has mainly been assessed based on measurements from building drawing together with some specific wall thickness measurements when available. An assumed density of 2 400 kg/$m^3$ for regular concrete, and 4 100 kg/$m^3$ for heavy concrete has been used.

For concrete close to the core, e.g. in biological shields, specific information from decommissioning plans have been used.

**Reinforcement**
The mass of reinforcement has generally been set as 6 % of the concrete mass, based on containment building data from nuclear power plants.

**Incinerable**
The amount of incinerable waste generated during decommissioning is based on assessments for each facility.

### 3.5.2 Radioactivity

The approach in determining the radioactivity has been different for the various facilities and waste streams.

**Components**
For HBWR components, an assessment based on the corresponding system to which the component belongs has been used. In order to do this, the project team prepared a list of expected contamination category for each HBWR system which then was reviewed by IFE. This list is given in table 3-6 below.

**Table 3-6**
HBWR system list with assumed contamination category, used for assessment of component contamination.

| System ID | System name | Assumed contamination category |
|---|---|---|
| **A** | **Primary circuits** | |
| A1 | Main D2O steam circuit | H |
| A2 | Main D2O subcooler circuit | H |
| A3 | D2O purification circuit | H |
| A4 | Recombination circuit low and high pressure | H |
| A6 | Offgas and fission gas collection system | H |
| A7 | D2O drain tank circuit | H |
| **B** | **Secondary and tertiary circuit** | |
| B1 | Closed secondary circuit | LL |
| B2 | Feed water circuit | VLL |
| B3 | FWT-water supply and steam heating | NC |
| B4 | Main steam line | NC |
| B5 | Secondary circuit, purification system | VLL |
| **C** | **Light water circuits** | |
| C1 | Coolant circuit, outside RH | VLL |
| C2 | Coolant circuit, RH and Air lock | VLL |
| C3 | Coolant circuit, 1st, 2nd floor and sink | VLL |
| C4 | Water supply, office building | NC |
| C5 | Raw water filters | NC |
| C6 | Shield circuit | LL |
| C7 | Drainage and delay circuit | LL |
| C8 | Dosage circuit | NC |
| C9 | Fuel pit purification circuit | LL |

| System ID | System name | Assumed contamination category |
|---|---|---|
| C10 | Fuel storage and handling ponds purification circuit | LL |
| C11 | Main demineralizer unit | NC |
| C12 | RO-system | NC |
| C13 | Purification system, chemistry laboratory | VLL |
| **D** | **Experimental circuits** | |
| D5 | Loop 14 | H |
| D8 | Loop 7 | H |
| D11 | Loop 16 | H |
| D13 | Loop 6 | H |
| D18 | Loop 4 | H |
| D19 | Loop 8 | H |
| D20 | Loop 13 | H |
| D24 | Loop 9 | H |
| D31 | Loop 10 | H |
| D34 | Loop 11 | H |
| D35 | Loop 12 | H |
| D39 | Loop 15 | H |
| **E** | **Ventilation and air circuits** | |
| E1 | Reactor plant ventilation circuit | LL |
| E2 | Compressed air circuit | VLL |
| E3 | Off-gas to ventilation | LL |
| E4 | Air supply for pneumatic equipment | NC |
| E5 | Air supply for main ventilation systems | NC |
| E6 | Air supply for experimental systems | NC |
| E7 | Main air supply in compress room | NC |
| **F** | **Experimental systems, gas based** | |
| F1 | Material rig gas flow system-1 | LL |
| F2 | Ultra high gas pressurization system | LL |
| F3 | Fuel rod gas flow control system | LL |
| F4 | Material rig gas flow system-5 | LL |
| F5 | Helium 3 flux control system | LL |
| F6 | Gas supply for hydrogen | NC |
| F7 | H2 sensor calibration system | NC |
| F8 | Gas central 1 | NC |
| F9 | Material rig gas flow system-2 | LL |

| System ID | System name | Assumed contamination category |
|---|---|---|
| F10 | Material rig gas flow system-3 | LL |
| F11 | Incore contact pressurization system | LL |
| F12 | Fuel rod gas flow control system 2 | LL |
| F13 | Loop 16, bellow load system | NC |
| **G** | **Activity monitoring and purification system** | |
| G1 | Air monitoring circuit | VLL |
| G2 | Water monitoring systems | LL |
| G3 | Ventilation and air monitoring in bunker building/metlab | LL |
| G4 | Purification in waste processing room | LL |
| G5 | Purification circuits in FBB | LL |
| G6 | Purification circuits for washing machines | LL |
| **H** | **Electrical interlocks and alarm circuit** | |
| H3 | Electrical interlocks of D2O auxiliary circuits | NC |
| H6 | Program units HBWR | VLL |
| H9 | Radiation monitoring list | VLL |
| H10 | Air and water monitor location | VLL |
| **I** | **Process control** | |
| I1 | Process control principle diagram | VLL |
| **J** | **Power supply** | |
| J3 | Power supply, one line diagram | VLL |
| **K** | **Emergency circuits** | NC |
| K1 | Air cushion system | LL |
| K2 | Emergency spray and filter circuit | LL |
| K3 | Emergency purification plant | LL |
| K4 | HBWR emergency equipment | LL |
| K6 | Emergency core cooling system | LL |

Together with the component mass assessment this data allows for distribution of the waste mass per activity category as discussed in Chapter 4 below. The same radioactivity category distribution has also been used for the JEEP-2 reactor components due to lack of specific information.

Apart from contamination information received for Metlab-1, Metlab-2 and partly for the waste management building, the contamination category for components in other facilities have been estimated based on the activities performed in the facilities. This estimate has been made cautiously, generally assuming a risk for contamination.

**Piping**
The contamination level of piping for HBWR has been made based on the system group of the pipes according to Table 3-7 below.

**Table 3-7**
Assumed contamination category for HBWR piping.

| System group | Assumed contamination category |
|---|---|
| Primary circuit | H |
| Sub-cooler circuit | H |
| Purification circuit | H |
| Secondary circuit | LL |
| Tertiary circuit | NC |

Together with the piping mass assessment this data allows for distribution of the waste mass per radioactivity category as discussed in Chapter 4 below. This same radioactivity category distribution has also been used for the JEEP-2 reactor piping due to lack of specific information.

Apart from contamination information received for Metlab-2, piping in other facilities have been estimated based on the activities performed in the facilities. This estimate has been made cautiously, generally assuming a risk for contamination.

**Structural steel**
Structural steel has generally been assumed to have a low level of contamination. This has in general been set as VLL.

**Cabling, chutes**
Cables and chutes have generally been assumed to have a low level of contamination. This has in general been set as VLL, apart from Metlab-2 where specific information has been received.

**Ventilation**
Ventilation systems have generally been assumed to be contaminated. This has in general been set as LL, apart from Metlab-1, Metlab-2 and the waste management building where specific information has been received.

**Concrete**
Concrete in structures close to the core such as biological shields, reactor tank top-lids etc. have been assumed to be contaminated at a high level [D065, D061].

For other concrete, a cautious assumption has been made where the outermost 1 cm of concrete surfaces is assumed to have a low risk for contamination, i.e. set as VLL, while the deeper concrete is assumed non-contaminated.

**Reinforcement**
The reinforcement in concrete close to the core is set as LH. This is based on the potential for neutron induced activation in this region. Other reinforcement is assumed to be non-contaminated.

**Incinerable**
Incinerable waste generated during decommissioning will vary in contamination, but is likely mostly contaminated at a low level, and is set as VLL.

# 4 Waste and radioactivity inventory assessment

This chapter presents the data that is the result of the assessment based on the approach discussed in chapter 3.

## 4.1 Waste mass

This section discusses the assessment of waste mass. It should be noted that the entire inventory without consideration to radioactivity levels is listed, i.e. the data include material that is categorized as non-contaminated.

It should also be noted that the precision in data varies for the waste streams. The data presented are a snapshot of data from an algorithm and are presented with one decimal. This does not, however, mean that the overall certainty is at this level.

### 4.1.1 Halden

This section presents the mass assessment for the various facilities at the Halden site, as presented in Tables 4-1 to 4-5.

**Table 4-1**
Halden Boiling Water Reactor waste mass assessment.

| Waste stream | Mass (tonne) | Comment |
|---|---|---|
| Components | 260.1 | Based on HBWR component database, complemented with estimates of mass of components based on similar components or components from similar external facilities. |
| Pipes | 9.8 | Based on [D183] |
| Ventilation | 30 | Scaling based on the Swedish Studsvik R2 reactor |
| Cabling, chutes | 30 | Scaling based on the Swedish Studsvik R2 reactor |
| Structural steel | 20 | Scaling based on the Swedish Studsvik R2 reactor |
| Reinforcement | 492 | Based on concrete mass |
| Reinforcement, bioshield | 8 | Based on concrete mass |
| Concrete | 23 620 | Based on building drawings |
| Concrete, bioshield | 380 | Based on [D184] |
| Incinerable | 50 | Assessment of waste generated during decommissioning. This number includes that generated during decommissioning of the other Halden buildings. |

**Table 4-2**
Bunker building including waste treatment room waste assessment.

| Waste stream | Mass (tonne) | Comment |
|---|---|---|
| Components | 15.1 | Based on drawings, photographs and assessments based on experience |
| Pipes | 0.1 | Based on drawings, photographs and assessments based on experience |
| Ventilation | 0.3 | Based on drawings, photographs and assessments based on experience |
| Cabling, chutes | 0.2 | Based on drawings, photographs and assessments based on experience |
| Structural steel | 0.2 | Based on drawings, photographs and assessments based on experience |
| Reinforcement | 13 | Based on drawings, photographs and assessments based on experience |
| Concrete | 650 | Based on drawings, photographs and assessments based on experience |

**Table 4-3**
Storage tunnel waste assessment.

| Waste stream | Mass (tonne) | Comment |
|---|---|---|
| Cabling, chutes | 0.1 | Assessment based on experience |
| Concrete | 35 | Assessment based on experience |

**Table 4-4**
Laundry building waste assessment.

| Waste stream | Mass (tonne) | Comment |
|---|---|---|
| Components | 0.1 | Based on drawings, photographs and assessments based on experience |
| Pipes | 0.4 | Based on drawings, photographs and assessments based on experience |
| Ventilation | 0.1 | Based on drawings, photographs and assessments based on experience |
| Cabling, chutes | 0.1 | Based on drawings, photographs and assessments based on experience |
| Structural steel | 0.1 | Based on drawings, photographs and assessments based on experience |
| Reinforcement | 1 | Based on concrete mass |
| Concrete | 17 | Based on drawings, photographs and assessments based on experience |

**Table 4-5**
Metallurgical laboratory waste assessment.

| Waste stream | Mass (tonne) | Comment |
|---|---|---|
| Components | 8 | Based on drawings, photographs and assessments based on experience |
| Pipes | 0.1 | Based on drawings, photographs and assessments based on experience |
| Ventilation | 0.1 | Based on drawings, photographs and assessments based on experience |
| Cabling, chutes | 0.3 | Based on drawings, photographs and assessments based on experience |
| Structural steel | 0.5 | Based on drawings, photographs and assessments based on experience |
| Reinforcement | 18.5 | Based on concrete mass |
| Concrete | 300 | Based on drawings, photographs and assessments based on experience |

### 4.1.2 Kjeller

This section presents the mass assessment for the various facilities at the Kjeller site, as presented in Tables 4-6 to 4-9

**Table 4-6**
Jeep-2 reactor and top cover building decommissioning waste assessment.

| Waste stream | Mass (tonne) | Comment |
|---|---|---|
| Concrete | 5 327 | Based on drawings |
| Concrete − replaced top cover | 13 | IFE provided data |
| Reinforcement | 262.5 | Based on concrete mass |
| Structural steel | 15 | Scaling based on the Swedish Studsvik R2 reactor |
| Cable, chutes | 17.6 | Scaling based on the Swedish Studsvik R2 reactor, complemented using operator assessment |
| Components − Electrical components | 0.9 | Component database, similar components |
| Components − Electrical cabinets | 10.6 | Scaled from HBWR |
| Components − Overhead cranes | 31 | Based on HBWR and component database |
| Components − Actuators and valves | 15.1 | Scaled from HBWR |
| Components − Pumps | 2.9 | Component database, similar components |
| Components − Misc. | 4.1 | Component database, similar components |
| Components − Heat exchangers | 10 | Scaled from HBWR |
| Components − Tanks | 22.8 | Component database, similar components |
| Components − Insulation | 6.1 | Based on [D219 ] |
| Components − RPV | 0.6 | Component database, similar components |
| Components − Reactor internals | 2.5 | Component database, similar components |
| Components − Thermal shield | 9.4 | Based on [D061] |
| Ventilation | 30 | Scaling based on the Swedish Studsvik R2 reactor |
| Pipes | 7.7 | Scaled from HBWR |
| Incinerable | 20 | Estimate |

**Table 4-7**
Metlab 1 decommissioning waste assessment.

| Waste stream | Mass (tonne) | Comment |
|---|---|---|
| Components – Misc. | 0.03 | IFE provided data |
| Components − Other metallic | 0.2 | IFE provided data |
| Ventilation | 0.008 | IFE provided data |

**Table 4-8**
Metlab-2 and fuel storage building decommissioning waste assessment.

| Waste stream | Mass (tonne) | Comment |
|---|---|---|
| Concrete | 3 150 | IFE provided data |
| Reinforcement | 800 | IFE provided data |
| Cable, chutes | 2.4 | IFE provided data |
| Components – Electrical | 5.1 | IFE provided data |
| Components – Handling equipment | 3.8 | IFE provided data |
| Components – Actuators and valves | 1.1 | IFE provided data |
| Components – Pumps | 0.3 | IFE provided data |
| Components – Heating and sanitation | 1.2 | IFE provided data |
| Components – Tanks | 2 | IFE provided data |
| Components – Overhead cranes | 12.3 | IFE provided data |
| Components – Misc. | 85 | IFE provided data |
| Components – Other metallic | 150.7 | IFE provided data |
| Ventilation | 7.6 | IFE provided data |
| Pipes – Heating and sanitation pipes | 6 | IFE provided data |
| Incinerable | 11 | Estimate |

**Table 4-9**
Radwaste building and NALFA decommissioning waste assessment.

| Waste stream | Mass (tonne) | Comment |
|---|---|---|
| Concrete | 2938.8 | Based on drawings |
| Reinforcement | 176.3 | Scaled from concrete |
| Cable, chutes | 2 | Scaled from Metlab 2 |
| Components – Electrical | 5 | Scaled from Metlab 2 |
| Components – Actuators and valves | 0.4 | IFE provided data |
| Components – Pumps | 0.05 | Based on similar components at other facilities |
| Components – Heating and sanitation | 1 | Scaled from Metlab 2 |
| Components – Tanks | 4 | Calculated based on volume |
| Components – Misc. | 45 | Scaled from Metlab 2 |
| Ventilation | 8.5 | Scaled from Metlab 2 |
| Pipes | 1 | Assessment based on pipe length |
| Pipes – Heating and sanitation pipes | 6 | Scaled from Metlab 2 |
| Incinerable | 5 | Assessment |
| Incinerable (NALFA pipes) | 8 | Assessment |

## 4.2 Radioactivity

This section presents the assessment of radioactivity category for each waste stream based on the approach discussed in Chapter 3.

It should be noted that in [Huutoniemi, 2014] a parallel assessment has been done based on the data reported in IFE decommissioning plans. While this data is not given in such detail as would have been needed for the assessment below, it can be used to deduce the approximate full nuclide specific inventory if used together with the below.

### 4.2.1 Halden

In Tables 4-10 to 4-14 below, the assessed radioactivity category or range for the facilities at the Halden site is presented.

**Table 4-10**
Assumptions regarding contamination category for HBWR waste streams.

| Waste stream | Radioactivity category assessment |
|---|---|
| Components | NC-H |
| Pipes | NC-H |
| Structural steel | VLL |
| Cabling, chutes | VLL |
| Ventilation | LL |
| Concrete | LM close to the core. Outer 1 cm on other concrete surfaces are set as VLL. The remainder is assumed to be NC. |
| Reinforcement | Reinforcement in concrete close to the core is set as LH. The rest is considered as NC. |
| Incinerable | VLL |

**Table 4-11**
Assumptions regarding contamination category for Bunker building including waste treatment room waste streams.

| **Waste stream** | **Radioactivity category assessment** |
|---|---|
| Components | VLL-LL |
| Pipes | LL |
| Ventilation | LL |
| Cabling, chutes | NC |
| Structural steel | NC |
| Reinforcement | NC |
| Concrete | Outer 1 cm on other concrete surfaces are set as VLL. The remainder is assumed to be NC. |

Note that components, pipes and ventilation have been set to LL due to the handling and/or presence of spent fuel. It has been assumed, however, that cabling, structural steel and reinforcement which is not in contact with these systems are non-contaminated.

**Table 4-12**
Assumptions regarding contamination category for Storage tunnel waste streams.

| **Waste stream** | **Radioactivity category assessment** |
|---|---|
| Cabling, chutes | NC |
| Concrete | Outer 1 cm on other concrete surfaces are set as VLL. The remainder is assumed to be NC. |

The storage tunnel is likely only contaminated through contact with potentially contaminated objects. For this reason cabling and chutes is assumed to be non-contaminated while concrete is deemed to have a low risk of contamination.

**Table 4-13**
Assumptions regarding contamination category for Laundry building waste streams.

| Waste stream | Radioactivity category assessment |
|---|---|
| Components | VLL |
| Pipes | VLL |
| Ventilation | NC |
| Cabling, chutes | NC |
| Structural steel | NC |
| Reinforcement | NC |
| Concrete | NC |

The laundry building is only expected to be contaminated through the laundry process. For this reason only the components and pipes are assumed to have a risk for contamination.

**Table 4-14**
Assumptions regarding contamination category for Metallurgical laboratory waste streams.

| Waste stream | Radioactivity category assessment |
|---|---|
| Components | NC-VLL |
| Pipes | LL |
| Ventilation | LL |
| Cabling, chutes | VLL |
| Structural steel | VLL |
| Reinforcement | NC |
| Concrete | Outer 1 cm on other concrete surfaces are set as VLL. The remainder is assumed to be NC. |

### 4.2.2 Kjeller

In Tables 4-15 to 4-18 below, the assessed radioactivity category or range for the facilities at the Kjeller site is presented.

**Table 4-15**
Assumptions regarding contamination category for Jeep-2 reactor and top cover building waste streams.

| Waste stream | Radioactivity category assessment |
|---|---|
| Concrete | H close to the core. Outer 1 cm on other concrete surfaces are set as VLL. The remainder is assumed to be NC. |
| Concrete – replaced top cover | H |
| Reinforcement | LH close to the core. NC for other reinforcement. |
| Structural steel | VLL |
| Cable, chutes | VLL |
| Components – Electrical components | NC |
| Components – Electrical cabinets | NC |
| Components – Overhead cranes | VLL |
| Components – Actuators and valves | Same contamination level fractions as for HBWR components |
| Components – Pumps | Same contamination level fractions as for HBWR components |
| Components – Misc. | Same contamination level fractions as for HBWR components |
| Components – Heat exchangers | Same contamination level fractions as for HBWR components |
| Components – Tanks | Same contamination level fractions as for HBWR components |
| Components – Insulation | VLL |
| Components – RPV | H |
| Components – Reactor internals | H |
| Components – Thermal shield | H |
| Ventilation | LL |
| Pipes | Same contamination level fractions as for HBWR components |
| Incinerable | VLL |

**Table 4-16**
Assumptions regarding contamination category for Metlab 1 waste streams.

| Waste stream | Radioactivity category assessment |
|---|---|
| Components – Misc. | VLL |
| Components – Other metallic | VLL |
| Ventilation | VLL |

Metlab-1 is reportedly not contaminated to a significant degree. The assessment given here is cautious.

**Table 4-17**
Assumptions regarding contamination category for Metlab-2 and fuel storage building waste streams.

| Waste stream | Radioactivity category assessment |
|---|---|
| Concrete | NC-H |
| Reinforcement | NC |
| Cable, chutes | NC-LL |
| Components – Electrical | NC |
| Components – Handling equipment | VLL-H |
| Components – Actuators and valves | NC-VLL |
| Components – Pumps | NC-VLL |
| Components – Heating and sanitation | NC |
| Components – Tanks | LH-H |
| Components – Overhead cranes | NC-VLL |
| Components – Misc. | NC-H |
| Components – Other metallic | NC-LH |
| Ventilation | NC-H |
| Pipes – Heating and sanitation pipes | NC |
| Incinerable | VLL. |

Contamination estimates for Metlab-2 was provided by IFE.

**Table 4-18**
Assumptions regarding contamination category for Radwaste building and NALFA waste streams.

| Waste stream | Radioactivity category assessment |
|---|---|
| Concrete | 1 % has been assumed to have a low risk for contamination, i.e. set as VLL |
| Reinforcement | NC |
| Cable, chutes | VLL |
| Components – Electrical | NC |
| Components – Actuators and valves | VLL |
| Components – Pumps | LL |
| Components – Heating and sanitation | NC |
| Components – Tanks | LH |
| Components – Misc. | 10 % has been set as LL while the rest is set as VLL. |
| Ventilation | VLL |
| Pipes | LL |
| Pipes – Heating and sanitation pipes | NC |
| Incinerable | VLL |
| Plastic/Incinerable (NALFA pipes) | VLL |

## 4.3 Waste mass distributed on radioactivity category

This section presents the combined data from Sections 4.1 and 4.2, which serve as input data for further assessments on waste treatment.

### 4.3.1 Halden

In Tables 4-19 to 4-23 the waste mass distribution over radioactivity categories is given for the facilities at the Halden site.

**Table 4-19**
Waste distribution over radioactivity class, HBWR (tonne).

| **Category** | **Unknown** | **NC** | **VLL** | **LL** | **LM** | **LH** | **H** | **Total** | **Total excl. NC** |
|---|---|---|---|---|---|---|---|---|---|
| Components | 26.7 | 9.2 | 19.3 | 60.2 | | | 144.7 | 260.1 | 250.9 |
| Pipes | | 1.5 | | 1.5 | | | 6.8 | 9.8 | 8.3 |
| Ventilation | | | | 30.0 | | | | 30.0 | 30.0 |
| Cabling. chutes | | | 30.0 | | | | | 30.0 | 30.0 |
| Structural steel | | | 20.0 | | | | | 20.0 | 20.0 |
| Reinforcement | | 492.0 | | | | | | 492.0 | 0.0 |
| Reinforcement (bioshield) | | | | | | 8.0 | | 8.0 | 8.0 |
| Concrete | | 23 496.0 | 124.0 | 0.0 | 0.0 | 0.0 | 0.0 | 23 620.0 | 124.0 |
| Concrete (bioshield) | | | | | 380.0 | | | 380.0 | 380.0 |
| Incinerable | | | 50.0 | | | | | 50.0 | 50.0 |
| **Total** | **26.7** | **23 998.7** | **243.3** | **91.7** | **380.0** | **8.0** | **151.5** | **24 899.9** | **901.2** |

**Table 4-20**
Waste distribution over radioactivity class, Bunker building including waste treatment room (tonne).

| **Category** | **NC** | **VLL** | **LL** | **LM** | **LH** | **H** | **Total** | **Total excl. NC** |
|---|---|---|---|---|---|---|---|---|
| Components | | 13.2 | 1.9 | | | | 15.1 | 15.1 |
| Pipes | | | 0.1 | | | | 0.1 | 0.1 |
| Ventilation | | | 0.3 | | | | 0.3 | 0.3 |
| Cabling. chutes | 0.2 | | | | | | 0.2 | 0.0 |
| Structural steel | 0.2 | | | | | | 0.2 | 0.0 |
| Reinforcement | 13.0 | | | | | | 13.0 | 0.0 |
| Concrete | 635.0 | 15.0 | | | | | 650.0 | 15.0 |
| **Total** | **648.4** | **28.2** | **2.3** | **0.0** | **0.0** | **0.0** | **678.9** | **30.5** |

**Table 4-21**
Waste distribution over radioactivity class, Metlab (tonne).

| Category | NC | VLL | LL | LM | LH | H | Total | Total excl. NC |
|---|---|---|---|---|---|---|---|---|
| Components | 5.0 | 3.0 | | | | | 8.0 | 3.0 |
| Pipes | | | 0.1 | | | | 0.1 | 0.1 |
| Ventilation | | | 0.1 | | | | 0.1 | 0.1 |
| Cabling. chutes | | 0.3 | | | | | 0.3 | 0.3 |
| Structural steel | | 0.5 | | | | | 0.5 | 0.5 |
| Reinforcement | 18.5 | | | | | | 18.5 | 0.0 |
| Concrete | 286.0 | 14.0 | | | | | 300.0 | 14.0 |
| **Total** | **309.5** | **17.8** | **0.2** | **0** | **0** | **0** | **327.5** | **18** |

**Table 4-22**
Waste distribution over radioactivity class, Laundry (tonne)

| Category | NC | VLL | LL | LM | LH | H | Total | Total excl. NC |
|---|---|---|---|---|---|---|---|---|
| Components | | 0.1 | | | | | 0.1 | 0.1 |
| Pipes | | 0.4 | | | | | 0.4 | 0.4 |
| Ventilation | 0.1 | | | | | | 0.1 | 0.0 |
| Cabling. chutes | 0.1 | | | | | | 0.1 | 0.0 |
| Structural steel | 0.1 | | | | | | 0.1 | 0.0 |
| Reinforcement | 1.0 | | | | | | 1.0 | 0.0 |
| Concrete | 17.0 | | | | | | 17.0 | 0.0 |
| **Total** | **18.3** | **0.5** | **0.0** | **0.0** | **0.0** | **0.0** | **18.8** | **0.5** |

**Table 4-23**
Waste distribution over radioactivity class, Storage tunnel (tonne).

| Category | NC | VLL | LL | LM | LH | H | Total | Total excl. NC |
|---|---|---|---|---|---|---|---|---|
| Cabling. chutes | 0.1 | | | | | | 0.1 | 0.0 |
| Concrete | 28.0 | 7.0 | | | | | 35.0 | 7.0 |
| **Total** | **28.1** | **7.0** | **0.0** | **0.0** | **0.0** | **0.0** | **35.1** | **7.0** |

### 4.3.2 Kjeller

In Tables 4-24 to 4-27 the waste mass distribution over radioactivity categories is given for the facilities at the Kjeller site.

**Table 4-24**
Waste distribution over radioactivity class, JEEP-2 & top cover storage building (tonne)

| Category | NC | VLL | LL | LM | LH | H | Total | Total excl. NC |
|---|---|---|---|---|---|---|---|---|
| Concrete | 5124.7 | 52.3 | 0.0 | 0.0 | 0.0 | 150.0 | 5327.0 | 202.3 |
| Concrete – replaced top cover | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 13.0 | 13.0 | 13.0 |
| Reinforcement | 257.4 | 0.0 | 0.0 | 0.0 | 5.1 | 0.0 | 262.5 | 5.1 |
| Structural steel | 0.0 | 15.0 | 0.0 | 0.0 | 0.0 | 0.0 | 15.0 | 15.0 |
| Cables. chutes | 0.0 | 17.6 | 0.0 | 0.0 | 0.0 | 0.0 | 17.6 | 17.6 |
| Components – Electric components | 0.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 | 0.0 |
| Components – Electric cabinets | 10.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10.6 | 0.0 |
| Components – Overhead cranes | 0.0 | 31.0 | 0.0 | 0.0 | 0.0 | 0.0 | 31.0 | 31.0 |
| Components – Actuators and valves | 2.0 | 4.8 | 8.3 | 0.0 | 0.0 | 0.0 | 15.1 | 13.1 |
| Components – Pumps | 0.4 | 0.9 | 1.6 | 0.0 | 0.0 | 0.0 | 2.9 | 2.5 |
| Components – Misc. | 0.5 | 1.3 | 2.3 | 0.0 | 0.0 | 0.0 | 4.1 | 3.6 |
| Components – Heat exchangers | 1.3 | 3.2 | 5.5 | 0.0 | 0.0 | 0.0 | 10.0 | 8.7 |
| Components – Tanks | 3.0 | 7.3 | 12.5 | 0.0 | 0.0 | 0.0 | 22.8 | 19.8 |
| Components – Insulation | 0.0 | 6.1 | 0.0 | 0.0 | 0.0 | 0.0 | 6.1 | 6.1 |
| Components – RPV | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 0.6 | 0.6 |
| Components – Reactor internals | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.5 | 2.5 | 2.5 |
| Components – Thermal shield | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 9.4 | 9.4 | 9.4 |
| Ventilation | 0.0 | 0.0 | 30.0 | 0.0 | 0.0 | 0.0 | 30.0 | 30.0 |
| Pipes | 1.0 | 2.5 | 4.2 | 0.0 | 0.0 | 0.0 | 7.7 | 6.7 |
| Incinerable | 0.0 | 20.0 | 0.0 | 0.0 | 0.0 | 0.0 | 20.0 | 20.0 |
| **Total** | **5 401.8** | **162.0** | **64.4** | **0.0** | **5.1** | **175.5** | **5 808.8** | **407.0** |

**Table 4-25**
Waste distribution over radioactivity class, Metlab-1 (tonne).

| Category | NC | VLL | LL | LM | LH | H | Total | Total excl. NC |
|---|---|---|---|---|---|---|---|---|
| Components – Misc. | 0.0 | 0.027 | 0.0 | 0.0 | 0.0 | 0.0 | 0.027 | 0.027 |
| Components – Other metallic | 0.0 | 0.177 | 0.0 | 0.0 | 0.0 | 0.0 | 0.177 | 0.177 |
| Ventilation | 0.0 | 0.008 | 0.0 | 0.0 | 0.0 | 0.0 | 0.008 | 0.008 |
| **Total** | **0.0** | **0.212** | **0.0** | **0.0** | **0.0** | **0.0** | **0.212** | **0.212** |

**Table 4-26**
Waste distribution over radioactivity class, Metlab-2 (tonne).

| Category | NC | VLL | LL | LM | LH | H | Total | Total excl. NC |
|---|---|---|---|---|---|---|---|---|
| Concrete | 3 080.0 | 0.0 | 0.0 | 0.0 | 10.0 | 60.0 | 3 150.0 | 70.0 |
| Reinforcement | 800.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 800.0 | 0.0 |
| Cable. chutes | 0.6 | 1.6 | 0.2 | 0.0 | 0.0 | 0.0 | 2.4 | 1.8 |
| Components – Electric components | 5.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.1 | 0.0 |
| Components – Handling equipment | 0.0 | 1.0 | 0.0 | 0.0 | 2.8 | 0.0 | 3.8 | 3.8 |
| Components – Actuators and valves | 0.7 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 1.1 | 0.4 |
| Components – Pumps | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.2 |
| Components – Heating and sanitation | 1.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.2 | 0.0 |
| Components – Tanks | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 1.5 | 2.0 | 2.0 |
| Components – Overhead cranes | 0.3 | 12.0 | 0.0 | 0.0 | 0.0 | 0.0 | 12.3 | 12.0 |
| Components – Misc. | 8.0 | 28.0 | 0.0 | 30.0 | 9.0 | 10.0 | 85.0 | 77.0 |
| Components – Other metallic | 100.0 | 0.2 | 5.4 | 0.0 | 45.1 | 0.0 | 150.7 | 50.7 |
| Ventilation | 1.7 | 0.0 | 0.0 | 0.0 | 1.0 | 4.9 | 7.6 | 5.9 |
| Pipes – Heating and sanitation | 6.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.0 | 0.0 |
| Incinerable | 0.0 | 11.0 | 0.0 | 0.0 | 0.0 | 0.0 | 11.0 | 11.0 |
| **Total** | **4 003.8** | **54.3** | **5.6** | **30.0** | **68.4** | **76.4** | **4 238.4** | **234.7** |

**Table 4-27**
Waste distribution over radioactivity class, Radwaste building (tonne).

| Category | NC | VLL | LL | LM | LH | H | Total | Total excl. NC |
|---|---|---|---|---|---|---|---|---|
| Concrete | 2 909.4 | 29.4 | 0.0 | 0.0 | 0.0 | 0.0 | 2 938.8 | 29.4 |
| Reinforcement | 176.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 176.3 | 0.0 |
| Cable. chutes | 0.0 | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.0 | 2.0 |
| Components – Electric | 5.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.0 | 0.0 |
| Components – Actuators and valves | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.4 |
| Components – Pumps | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 |
| Components – Heating and sanitation | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.0 |
| Components – Tanks | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 0.0 | 4.0 | 4.0 |
| Components – Misc. | 0.0 | 40.5 | 4.5 | 0.0 | 0.0 | 0.0 | 45.0 | 45.0 |
| Ventilation | 0.0 | 8.5 | 0.0 | 0.0 | 0.0 | 0.0 | 8.5 | 8.5 |
| Pipes | 0.0 | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 | 1.0 | 1.0 |
| Pipes – Heating and sanitation | 6.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.0 | 0.0 |
| Incinerable | 0.0 | 5.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.0 | 5.0 |
| Plastic/Incinerable (NALFA pipes) | 0.0 | 8.0 | 0.0 | 0.0 | 0.0 | 0.0 | 8.0 | 8.0 |
| **Total** | **3 097.7** | **93.8** | **5.6** | **0.0** | **4.0** | **0.0** | **3 201.1** | **103.3** |

### 4.3.3 Summary

The summation of the data presented in section 4.3.1 and 4.3.2 are given in Tables 4-28 and 4-29 below.

**Table 4-28**
Waste distribution over activity class, Halden (tonne).

| Category | Unknown | NC | VLL | LL | LM | LH | H | Total | Total excl. NC |
|---|---|---|---|---|---|---|---|---|---|
| Components | 26.7 | 14.2 | 35.6 | 62.1 | 0 | 0 | 144.7 | 283 | 269 |
| Pipes | 0 | 1.5 | 0.4 | 1.7 | 0 | 0 | 6.8 | 10 | 9 |
| Cabling. chutes | 0 | 0.4 | 30.3 | 0 | 0 | 0 | 0 | 31 | 30 |
| Ventilation | 0 | 0.1 | 0 | 30.4 | 0 | 0 | 0 | 31 | 30 |
| Structural steel | 0 | 0.3 | 20.5 | 0 | 0 | 0 | 0 | 21 | 21 |
| Concrete | 0 | 24 462 | 160 | 0 | 380 | 0 | 0 | 25 002 | 540 |
| Reinforcement | 0 | 525 | 0 | 0 | 0 | 8 | 0 | 533 | 8 |
| Incinerable | 0 | 0 | 50 | 0 | 0 | 0 | 0 | 50 | 50 |
| **Total Halden** | **27** | **25 003** | **297** | **94** | **380** | **8** | **152** | **25 960** | **957** |

**Table 4-29**
Waste distribution over activity class, Kjeller (tonne).

| Category | Unknown | NC | VLL | LL | LM | LH | H | Total | Total excl. NC |
|---|---|---|---|---|---|---|---|---|---|
| Components – Electrical | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 11 | 0 |
| Components – Electric cabinets | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 11 | 0 |
| Components – Overhead cranes | 0 | 0.3 | 43 | 0 | 0 | 0 | 0 | 43 | 43 |
| Components – Actuators and valves | 0 | 2.7 | 5.6 | 8.3 | 0 | 0 | 0 | 17 | 14 |
| Components – Heat exchangers | 0 | 1.3 | 3.2 | 5.5 | 0 | 0 | 0 | 10 | 8.7 |
| Components – Misc. | 0 | 8.5 | 70 | 6.8 | 30 | 9 | 10 | 134 | 126 |
| Components – Pumps | 0 | 0.6 | 1.1 | 1.7 | 0 | 0 | 0 | 3.4 | 2.8 |
| Components – Tanks and cisterns | 0 | 3.0 | 7.3 | 13 | 0 | 4.5 | 1.5 | 29 | 26 |
| Components – Internal components | 0 | 0 | 0 | 0 | 0 | 0 | 2.5 | 2.5 | 2.5 |
| Components – Reactor tank | 0 | 0 | 0 | 0 | 0 | 0 | 0.6 | 0.6 | 0.6 |
| Components – Thermal shield | 0 | 0 | 0 | 0 | 0 | 0 | 9.4 | 9.4 | 9.4 |
| Components – Insulation | 0 | 0 | 6.1 | 0 | 0 | 0 | 0 | 6.1 | 6.1 |
| Pipes | 0 | 1.0 | 2.5 | 5.2 | 0 | 0 | 0 | 8.7 | 7.7 |
| Cables, ladders, chutes | 0 | 0.6 | 21 | 0.2 | 0 | 0 | 0 | 22 | 21 |
| Structural steel | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 15 | 15 |
| Concrete/leca/tegel | 0 | 11 114 | 82 | 0 | 0 | 10 | 223 | 11 429 | 315 |
| Reinforcement | 0 | 1 234 | 0 | 0 | 0 | 5.1 | 0 | 1 239 | 5.1 |
| Components – Metal | 0 | 100 | 0.38 | 5.4 | 0 | 45 | 0 | 151 | 51 |
| Ventilation | 0 | 1.7 | 8.51 | 30 | 0 | 1 | 4.9 | 46 | 4 |
| Components – Handling equipment | 0 | 0 | 1 | 0 | 0 | 2.8 | 0 | 3.8 | 3.8 |
| Components – Heating and sanitation – pipes | 0 | 12 | 0 | 0 | 0 | 0 | 0 | 12 | 0 |
| Components – Heating and sanitation – components | 0 | 2.2 | 0 | 0 | 0 | 0 | 0 | 2.2 | 0 |
| Incinerable | 0 | 0 | 36 | 0 | 0 | 0 | 0 | 36 | 36 |
| NALFA | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 8 | 8 |
| **Total Kjeller** | **0** | **12 503** | **310** | **46** | **30** | **77** | **252** | **13 249** | **745** |

# 5 Discussion

This report has presented an assessment of the waste that is generated during decommissioning of the Norwegian nuclear facilities. The amount of waste has further been categorized on the type of waste as well as its distribution over a set of radioactivity level categories. A summary of the results can be found in Section 4.3.3.

The purpose of this assessment is for the data to serve as input to further studies regarding its treatment and packaging before disposal, and hence for studies regarding final waste volume for disposal.

As has been discussed in this report, there has been a shortage of data in several parameters which have required assumptions to be made. This is not uncommon for facilities still in operation which have not yet commenced detailed decommissioning studies at the end of their operational life. This does, however, results in an uncertainty both in the estimation of mass and in estimations of contamination in the facilities, and hence in the results presented in this report. Since the purpose of the project is mainly to evaluate different waste management alternatives, this uncertainty is less significant as it has a similar effect on all alternatives. The data should therefore be able to serve as a first estimate of the waste data that are required in the KVU process.

## 6 References

| | |
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