Determination of the inventory
Part B: Matrix composition

OPERA-PU-NRG1112B

Radioactive substances and ionizing radiation are used in medicine, industry, agriculture, research, education and electricity production. This generates radioactive waste. In the Netherlands, this waste is collected, treated and stored by COVRA (Centrale Organisatie Voor Radioactief Afval). After interim storage for a period of at least 100 years radioactive waste is intended for disposal. There is a world-wide scientific and technical consensus that geological disposal represents the safest long-term option for radioactive waste.

Geological disposal is emplacement of radioactive waste in deep underground formations. The goal of geological disposal is long-term isolation of radioactive waste from our living environment in order to avoid exposure of future generations to ionising radiation from the waste. OPERA (OnderzoeksProgramma Eindberging Radioactief Afval) is the Dutch research programme on geological disposal of radioactive waste.

Within OPERA, researchers of different organisations in different areas of expertise will cooperate on the initial, conditional Safety Cases for the host rocks Boom Clay and Zechstein rock salt. As the radioactive waste disposal process in the Netherlands is at an early, conceptual phase and the previous research programme has ended more than a decade ago, in OPERA a first preliminary or initial safety case will be developed to structure the research necessary for the eventual development of a repository in the Netherlands. The safety case is conditional since only the long-term safety of a generic repository will be assessed. OPERA is financed by the Dutch Ministry of Economic Affairs, and the public limited liability company Electriciteits-Produktiemaatschappij Zuid-Nederland (EPZ) and coordinated by COVRA. Further details on OPERA and its outcomes can be accessed at www.covra.nl.

This report concerns a study conducted in the framework of OPERA. The conclusions and viewpoints presented in the report are those of the author(s). COVRA may draw modified conclusions, based on additional literature sources and expert opinions. A .pdf version of this document can be downloaded from www.covra.nl.

OPERA-PU-NRG1112B
Title: Determination of the inventory: part B matrix composition
Authors: J.C.L. Meeussen, E. Rosca-Bocancea
Date of publication: 15 December 2014
Keywords: Radioactive waste disposal, chemical matrix composition

NRG

Summary

This report gives a description of the estimated chemical composition of the radioactive waste matrix as projected to be available for disposal in 2130, and accompanies the *Reference list of waste inventory Part B: Matrix composition* that contains more detailed information (OPERA-IR-NRG1111B). The average composition of different types of waste containers is largely based on the information currently available at COVRA or in public literature. The estimated total number of different types of containers was taken from the "Outline of a Disposal Concept in Clay" [Verhoef et al., 2014A].

Samenvatting

Dit rapport geeft een beschrijving van de geschatte chemische samenstelling van de matrix van het radioactieve afval dat wordt verwacht beschikbaar te zijn voor eindberging in 2130. Het vormt de begeleidende tekst voor de bijbehorende *Reference list of waste inventory Part B: Matrix composition* (OPERA-IR-NRG1111B). Voor het bepalen van de gemiddelde chemische samenstelling van de verschillende soorten afval containers is voornamelijk gebruik gemaakt van de huidige afvalinventaris aanwezig bij COVRA en van beschikbare literatuurgegevens. De totale aantallen containers zijn overgenomen uit het "Outline of a Disposal Concept in Clay" [Verhoef et al., 2014A].

1. Introduction

1.1. Background

The five-year research programme for the geological disposal of radioactive waste – OPERA - started on 7 July 2011 with an open invitation for research proposals for the tasks described in the OPERA Research Plan.

The work in the OPCHAR project directly supports the OPERA Research Plan Task 1.1.1: *Definition of radionuclide inventory and matrix composition*.

This task has four final deliverables:

1. OPERA-PU-NRG1111A Reference list of waste inventory - Part A: radionuclides
2. OPERA-PU-NRG1112A Determination of the inventory - Part A: radionuclides
3. OPERA-PU-NRG1111B Reference list of waste inventory - Part B: matrix composition
4. OPERA-PU-NRG1112B Determination of the inventory - Part B: matrix composition

This report represents the final version of deliverable 4 (OPERA-PU-NRG1112B) and is released together with the accompanying final deliverable 3 (OPERA-PU-NRG1111B *Reference list of waste inventory - Part B: matrix composition*). Although the final versions of these deliverables were originally scheduled for release in 2016, COVRA has suggested to r elease these final deliverables in 2014.

The macro chemical composition of the waste matrix is assessed in the OPERA programme because it is an important factor in the degradation process of a waste disposal facility and in its interaction with the surrounding host rock material. Degradation of the waste matrix determines the development of chemical conditions over time and in that way affects radionuclide dissolution rates. Information on matrix composition, especially on its rate of dissolution is therefore required as input for the estimation of source terms in Performance assessment models.

The current report and the accompanying Reference database of matrix composition will serve as input for performance assessment calculations in OPERA WP7. The results of that work are also necessary input for OPERA Task 5.1.1 in which the future evolution of the repository and interactions with the host rock are evaluated.

1.2. Objectives

The aim of this report is to provide an estimation of the chemical composition and amount of matrix material that is likely to be present as part of the radioactive waste intended for disposal in a radioactive waste repository by the year 2130. This information is stored in an interim database that is available for use by other OPERA participants as input for their work.

1.3. Realization

The data presented in this report originate from the current inventory data provided by COVRA, internal information, calculations by NRG, and extrapolations to 2130 based on the generic OPERA disposal concept. The methods used and a summary of the resulting data are given in this report, while the detailed numerical description is available in the accompanying OPERA-PU -NRG1111B *Reference list of waste inventory Part B: Matrix composition*.

1.4. Explanation of contents

Chapter 2 describes the different waste categories and the followed approach and the selected chemical parameters of the matrix.

Chapter 3 gives an overview of the matrix composition of the radioactive waste currently (2013) stored at COVRA. From this overview the average chemical composition of the different types of waste containers is estimated. The average chemical composition of the different waste type containers is then combined with the total number of containers as given in the "Outline of a disposal concept in clay" [Verhoef et al., 2014A] to estimate total waste matrix composition that will be available for disposal in 2130.

Chapter 4 combines the information on chemical composition of the different waste types derived in Chapter 3 to estimate the overall waste matrix composition that will be available for disposal in 2130.

2. Method

Firstly, the current information on the amounts of waste and their composition will be used to establish the representative composition of each waste container type. Secondly, based on the representative composition and the expected total number of containers of each type of waste to be disposed in geological formation [Verhoef et al., 2014A; Appendix, Table A-1 to A-3]) the OPERA matrix inventory for each waste section specified in [Verhoef et al., 2014A] will be calculated.

2.1. Selection of matrix parameters

The set of parameters that is necessary for describing chemical evolution of the waste over time is to a large extent dictated by the conceptual model for waste degradation over time, and the chemical processes involved.

Based on process understanding and experience in other (radioactive) waste disposal programmes [Alder et al., 1994], several potentially important degradation processes have been identified under the conditions expected in a geological disposal in Boom Clay:

- Degradation of cementitious materials, which form a significant fraction of the waste. This degradation will produce a large amount of alkalinity, which will affect pH, react with CO_2, and is likely to dominate the overall chemistry of the waste matrix for a long time.
- Oxidation of metals, especially of steel, which forms another significant fraction of total amount waste. This oxidation may lead to the formation of hydrogen gas, and lead to reducing conditions.
- Biodegradation of a wide range of organic materials (wood, fabrics, paper, plastics etc.) which may result in formation of CO_2, methane, reducing capacity, organic acids, and H_2S. These formed organic acids may mobilize radionuclides by forming dissolved reactive colloids. The formed sulphides may affect the solubility and leaching potential of radionuclides and also may accelerate metal corrosion and gas production.

Based on these processes, available information and on experience in other (radioactive) waste disposal programmes [Alder et al., 1994; p. 50], the following main chemical matrix parameters were selected for this inventory:

- Cementitious materials (concrete, mortars and grout)
- Steel
- Stainless steel
- Organic components (including cement plasticizer)
- Zinc
- Aluminium
- Paint
- Glass (vitrifying glass type 1 [NRG, 2014A])
- Zircaloy
- Inconel
- U_3O_8-concrete

2.2. Waste categories

The main sources of radioactive waste in the Netherlands are: the operation of nuclear power plants, the use of radioactive materials in medical applications, and the use of radioactive materials in research and industrial applications. In the "Outline of a Disposal Concept in Clay", [Verhoef et al., 2014A], the outline of the projected waste inventory and its general features are described. The classification of different waste types given here is also followed in this report. Note that this classification is not fully consistent with the IAEA definition.

In the projected disposal layout [Verhoef et al., 2014A; Fig. 5-2], the following waste categories are distinguished:

- Low and Intermediate Level Waste (LILW)
- Technically Enhanced Naturally Occurring Radioactive Materials (TE)NORM
- High Level Waste (HLW)
    - Heat generating HLW
        - Spent fuel (SF)
        - Vitrified waste
    - Non-heat-generating HLW
        - Compacted hulls and ends from the Nuclear power plants (NPPs) Dodewaard and Borssele, and other fractions.
        - Other non-heat-generating HLW. May consist of decommissioning waste of nuclear facilities.

LILW
The waste in the LILW section is composed of two fractions: the LILW itself, originating from a wide range of sources such as operation of nuclear power plants, use of radionuclides in medical and industrial applications.

Within the LILW waste fraction the following waste categories are distinguished:

- A: containing alpha emitting nuclides
- B: containing waste originating from nuclear power plants
- C: containing beta and gamma emitters with half-lives >15 years
- D: containing only beta and gamma emitters with half-lives <15 years

The LILW waste category represents the main fraction by volume of the projected total waste inventory.

(TE) NORM
The only (TE) NORM '*Technically Enhanced Naturally Occurring Radioactive Material'* fraction that is intended for geological disposal consists of depleted uranium from the enrichment facility URENCO.

Heat-generating HLW, spent fuel
The spent fuel waste fraction consists of used fuel elements from the High Flux Reactor (HFR) in Petten and the Hoger Onderwijs Reactor (HOR) in Delft.

Heat-generating HLW, vitrified waste
In the vitrified HLW fraction consists of reprocessed vitrified waste from the Dutch nuclear power plants.

Non-heat-generating HLW compacted hulls and ends
This waste fraction mainly contains compacted hulls and ends from the Nuclear Power Plants (NPPs) Dodewaard and Borssele.

Non-heat-generating HLW other
This waste fraction includes waste originating from decommissioning of nuclear facilities.

3. Determination of the representative inventory

The representative composition of each waste fraction was determined using the current inventory of radioactive waste. The current inventory of LILW waste fractions, as obtained from COVRA per 19 February 2013, consists of 189,584 entries in an Excel spread sheet and comprises all radionuclides stored in five different container types, distinguished by volume [COVRA, 2013C]. The information on current amount of depleted uranium has been obtained from [COVRA 2013A; p. 17]. The average composition of the HLW vitrified waste, spent fuel, uranium filters, compacted hulls and ends was provided by COVRA in [COVRA, 2013B].

3.1. LILW section

The inventory of LILW waste fractions [COVRA, 2013C], comprises all radionuclides stored in five different container types, distinguished by volume. An overview of the number of containers with LILW waste stored at COVRA per February 2013 is given in Table 3-1.

Table 3-1 Number and weight of current LILW inventory

Container type	Number	Total Volume [m^3]	Total weight [Ton]
200-liter	35431	7086	16139
400-liter	2	0.8	3
600-liter	43	26	87
1000-liter	3200	3200	7791
1500-liter	69	104	322
Total	**38745**	**10420**	**24342**

From this overview follows that the 200-liter and 1000-liter containers together make up 98.7 % of the total volume and 98.3 % of the total weight of the LILW waste stored at COVRA. Under the assumption that these container types and content are indicative for future waste, we therefore focus on the chemical matrix composition of these two container categories and the main reactive chemical components of the packaging material - cementitious materials and steel.

3.1.1. LILW

Composition of 200-liter containers

The most significant fraction of LILW waste is stored in the 200-liter and 1000-liter containers. From the data in Table 3-1 follows that the average total weight of a currently stored 200-liter container is 16139/35431 = 456 kg [NRG, 2014A].

A 200-liter container consists of a (galvanized) steel 200-liter barrel in which a number (3 - 9) of compressed canisters is placed on a centering iron. The pressed canisters contain the actual solid waste. The remaining outer void between pressed canisters and outer barrel is filled with cementitious material.

Table 3-2 Characteristics of 200-liter containers (Information COVRA)

200-liter container content	Comment	min [kg]	max [kg]
Steel: total per container	(barrel, compressed canisters, centering iron)	58	118
Concrete: total per container		210	240
Superplasticizer: total per container	0.74-1.16% of cement weight*	0.27	0.51
Zinc: total per (galvanised) container	50-100 µm, 4.4 m^2	1.57	6.71
Paint: total per container	50-100 µm, 2.2 m^2	0.11	0.72
Total tare mass (all packaging materials)	combined tare weights	270	366
Total average mass (waste plus packaging)	Based on current COVRA inventory [COVRA, 2013C]	456	
Remaining net waste (without packaging materials)	Based on current COVRA inventory [COVRA, 2013C]	90.1	186.1

*Based on the composition of containment of LILW waste processed at COVRA given in Table 5-2 in [Verhoef et al., 2014B; p.13]

The net weight fraction of the LILW waste within a 200-liter container is estimated by subtracting the masses of steel and concrete from the total average mass of the containers.

Based on the present average composition of the LILW waste (see Table 3-2) and the expected inventory of LILW intended for disposal [Verhoef et al., 2014A; Appendix; Table A-1], the amount of concrete, superplasticizer and waste corresponding to 200-liter LILW containers has been determined (See **Table 3-3**).

Table 3-3 Matrix composition for 200-liter containers intended for disposal (140,000 containers)

	Total per 200 l container		Total for disposal (x 140,000)	
Material	**min [kg]**	**max [kg]**	**min [kg]**	**max [kg]**
concrete	2.10E+02	2.40E+02	2.94E+07	3.36E+07
steel	5.80E+01	1.18E+02	8.12E+06	1.65E+07
superplasticizer	2.75E-01	5.10E-01	3.84E+04	7.13E+04
zinc	1.57E+00	6.71E+00	2.20E+05	9.40E+05
paint	1.10E-01	7.20E-01	1.54E+04	1.01E+05
net waste	9.01E+01	1.86E+02	1.26E+07	2.60E+07

No direct information on exact matrix composition of LILW waste fraction is available. However, COVRA has provided a detailed list with weights and Eural codes of waste colli accepted for storage at COVRA between 2009 and 2012 (see Appendix, Table A-1). Although the categories are not very precisely defined we can draw the following conclusions from this list:

- A significant fraction (>30 %) of waste mass falls in a category indicated as “containing dangerous (in chemical sense, not radioactivity) substances” in some form.
- Another large fraction (8.4 %) consists of “Unsorted Municipal waste”, which suggests that this fraction is likely to contain some form of organic matter.
- More than 4% of the waste mass is indicated to consist of NaOH and/or KOH.

In summary the waste matrix fraction upon delivery to COVRA:

- Composition is not precisely known.
- Is likely to contain a significant fraction of dangerous substances.
- Is likely to contain a significant fraction of organic / degradable material.
- May contain a significant fraction of NaOH / KOH.

Composition of 1000-liter containers

The second largest fraction of LILW is made up of 1000-liter containers.

The of 1000-liter containers are used for three types of waste material:

- Waste originating from the Borssele and Dodewaard nuclear power plants, a.o. liquid waste, cement stabilized at location (container ID in COVRA inventory starting with K: Kerncentrale Borssele or G: Gemeenschappelijke Kernenergiecentrale Nederland GKN). The amounts of cement are not precisely known to COVRA but these will contain at least 50% grout.
- Molybdenum waste (container ID in COVRA inventory starting with M). The liquid wastes are solidified and placed in 200-litre (galvanized) steel barrels (ca. 180 l solidified waste per container) and casted afterwards in 1000-litre concrete containers with magnetite aggregates.
- Waste conditioned by COVRA (container ID in COVRA inventory starting with S), predominantly containing radiation sources and conditioned with grout. This type of waste forms only a small fraction of the total number of 1000-liter containers and therefore will not be considered in the calculations. It will be assumed that all 1000-liter containers contain solidified wastes.

Two types of container material are used:

- Concrete container (ca. 1,600 kg reinforced concrete)
- New type of magnetite container (ca. 2,100 kg concrete/magnetite). Used for molybdenum waste.

Table 3-4 Matrix composition for 1000-liter containers intended for disposal (12,000 containers)

Material	Total per 1000-liter container		Total for disposal (x 12,000)	
	min [kg]	max [kg]	min [kg]	max [kg]
Grout	2.88E+02	3.24E+02	3.46E+06	3.89E+06
Concrete	1.60E+03	2.10E+03	1.92E+07	2.52E+07
Steel*	7.20E+01	2.22E+02	8.64E+05	2.66E+06
Superplasticizer	5.19E+00	7.56E+00	6.23E+04	9.07E+04
Zinc**	1.57E+00	3.14+00	1.88E+04	3.77E+04
Paint**	1.10E-01	2.20E-01	1.32E+03	2.64E+03

*total of reinforcing steel and 200-liter (galvanized) steel barrels (one 200-liter barrel per 1000-liter container).

** corresponding to the 200-liter (galvanized) steel barrels.

Composition of 600 and 1500-liter containers

Based on information from COVRA it can be assumed that the composition of the 600 and 1500-liter containers will not be significantly different from the average composition of the 200-liter containers. Furthermore, the total LILW mass fraction of the combined 600 and 1500-liter containers is small (< 2%), therefore the uncertainty in the composition of these container types contributes only slightly to the overall uncertainty of the LILW composition [Verhoef et al. 2014A; Table A-1]. The matrix inventory of these fractions has been established and summarized in Table 3-5.

Table 3-5 Total LILW matrix inventory for 600- and 1500-liter containers

Material	Total for disposal	
	min [kg]	max [kg]
Concrete	5.54E+05	6.34E+05
Steel	1.53E+05	3.12E+05
Superplasticizer	7.25E+02	1.35E+03
Zinc	4.15E+03	1.77E+04
Paint	2.90E+02	1.90E+03
Net waste	2.38E+05	4.91E+05

3.1.2. (TE)NORM

Depleted uranium from the Urenco uranium enrichment plant, in the form of uranium oxide (U_3O_8), is stored at COVRA in DV-70 containers. There also is a small number of 200-liter containers, but because these are not intended for disposal, and also because their total volume is negligible in comparison with that of the 1000-liter containers, these 200-liter containers are not further taken into account.

According to the description given in the Disposal Concept [Verhoef et al., 2014A] the content of the DV-70 containers will be mixed with cement and stored in 7700 KONRAD type II containers with given external dimensions of 1.6 x 1.7 x 1.7 m.

The selected structural material chosen for these containers is sheet steel of at least 3 mm. To calculate the total chemical composition of the Konrad II container we have assumed a minimum thickness of 3 mm and a maximum thickness of 5 mm. We have assumed a minimum net volume of 4.2 m^3 and a maximum net volume of 4.5 m^3.

The resulting estimated corresponding weight fractions are given in Table 3-6.

Table 3-6 Matrix composition of (TE)NORM intended for disposal (7,700 containers)

Material	Per (Konrad II) container		Total for disposal (x 7,700)	
	min [kg]	max [kg]	min [kg]	max [kg]
U_3O_8	1.12E+04	1.20E+04	8.62E+07	9.23E+07
Steel	3.90E+02	6.50E+02	3.00E+06	5.00E+06
Concrete*	6.11E+03	6.54E+03	4.70E+07	5.04E+07
Superplasticizer	1.39E+01	1.49E+01	1.07E+05	1.14E+05

*excluding the mass of the U_3O_8 aggregate, see [Verhoef et al., 2014B; p. 15] for the U_3O_8-concrete recipe

3.2. *Spent fuel, uranium filters section*

The composition of the spent fuel containers is dominated by the single stainless steel basket (type 32) per container. The weight of this basket is 530 kg (information NRG). The mass of the stainless steel container itself is 105 kg, which results in a total stainless steel content per container of 635 kg.

Table 3-7 Matrix composition of spent fuel containers intended for disposal

Material	Per ECN container		Total for disposal (x 150)	
	min [kg]	max [kg]	min [kg]	max [kg]
Stainless steel [kg]	635	635	9.35E+04	9.53E+04
Spent fuel (fuel assembly material, including U) [kg]	226	302	3.39E+04	4.53E+04
Spent fuel (U) [kg]	5.3	81.2	7.95E+02	1.22E+04
Aluminium (metal) [kg]	50	70	7.50E+03	1.05E+04

The minimum and maximum weights of the assembly material and Uranium were taken from the canister types HFR-HEU and HFR-LEU, which together represent 75% of the total number of expected canisters (NRG, 2014B). The spread in the Uranium masses per container is related to the different compositions of HEU and LEU spent fuel, where each contains about the same amount of U-235.

3.3. *Vitrified waste section*

The average composition of the HLW vitrified waste containers was provided by COVRA [COVRA, 2013B] and it is presented in Table 3-9. The total amount of glass and stainless steel corresponding to the vitrified waste intended for disposal is given in Table 3-8.

Table 3-8 Matrix composition of vitrified waste intended for disposal

Material	Per CSD-V container [kg]	Total for disposal [kg] (x 625)
COGEMA glass (Glass type 1)	380	237500
Container (stainless steel)	80	50000

Table 3-9 Chemical composition of COGEMA glass (Glass type 1)

Chemical composition	Min (wt%)	Max (wt%)
SiO_2	42.4	51.7
B_2O_3	12.4	16.5
Al_2O_3	3.6	6.6
Na_2O	8.1	11
Fe_2O_3	0	4.5
NiO	0	0.5
Cr_2O_3	0	0.6
P_2O_5	0	1
Li_2O	1.6	2.4
ZnO	2.2	2.8
CaO	3.5	4.8
RuO_2+Rh+Pd	0	3
oxides(fission products +Zr+actinides)	4.2	18.5

3.4. Non-heat-generating HLW section

3.4.1. Compacted hulls and ends

The average composition of compacted hulls and ends was provided by [COVRA, 2013B] and in Table 3-10.

Table 3-10 Matrix composition of compacted hulls and ends intended for disposal

Material	Per CSD-C container[kg]	Total for disposal [kg] (x 1250)
Steel	116	1.45E+05
Zircaloy	393	4.91E+05
Inconel	19	2.38E+04
Container (stainless steel type 316)	80	1.00E+05

3.4.2. Other non-heat-generating HLW

Other non-heat generating high level waste includes waste from dismantling and decommissioning nuclear facilities or historical wastes (this type of waste is categorised as ILW in the IAEA classification scheme).

The amount of this waste is available in 2130 is currently estimated to be 600 m^3 [Verhoef et al., 2014A]. It is assumed that this waste is packed in the same type of containers as spent fuel, and that it will also be conditioned with concrete. The exact composition of the waste matrix is not known, it can be assumed that a significant fraction will consist of concrete and steel.

Based on the estimated maximum total weight of a waste container of 1000 kg and a volume of 408 litre [Verhoef et al., 2014A] we can deduce that the total steel volume fraction is expected to be less than ca. 10 %. We estimate here 5 % minimum and 10 % maximum. This percentage of 10 % will already result in a container weight of ca. 1200 kg. Higher (volumetric) steel fractions will further exceed the maximum container weight. (e.g. of 30 % steel volume would result in a container weight of ca. 1640 kg).

We estimate here 5 % minimum and 10 % maximum volume fraction of steel.

Table 3-11 Matrix composition of Other non-heat-generating HLW containers intended for disposal

Material	Per container		Total for disposal (x 2000)	
	min [kg]	max [kg]	min [kg]	max [kg]
Concrete [kg]	880	930	1.76E+06	1.86E+06
Steel [kg]	160	320	3.20E+05	6.40E+05
Stainless steel [kg]	105	105	2.10E+05	2.10E+05
Superplasticizer	1.6	1.7	3.29E+03	3.48E+03

3.5. Composition of the supercontainers

The high level waste containers will be overpacked for geological disposal in so called "supercontainers". The projected composition of these supercontainer structures consists of a carbon steel overpack of 30 mm, a concrete mantle, and around this mantle, a stainless steel envelope with a thickness of 4 mm [Verhoef et al., 2014A].

Currently there are two sizes/types of supercontainers considered [Verhoef et al., 2014A]:

1) A 250 cm long supercontainer containing a single inner container with vitrified waste or compacted hulls and ends (Table 3-12);
2) A 300 cm long supercontainer containing two inner containers with either "other non-heat generating waste" or (heat generating) spent fuel (Table 3-13).

Both containers types will have a diameter of 190 cm.

Table 3-12 Matrix composition of 2.5 m long Supercontainer

Diameter [cm]		length [cm]	volume [l]	surface area [m^2]	volume [l]	concrete [kg]	Stainless steel* [kg]	Carbon steel ** [kg]	total mass [kg]
Outer	190	250	7.09E+03	2.06E+01	6.89E+03	1.65E+04	6.43E+02	4.92E+02	1.77E+04
Inner	43	134	1.95E+02	2.10E+00					

* 4mm envelope
** 30mm overpack

Table 3-13 Matrix composition of 3.0 m long Supercontainer

Diameter [cm]		length [cm]	volume [l]	surface area [m^2]	volume [l]	concrete [kg]	Stainless steel [kg]	Carbon steel [kg]	total mass [kg]
Outer	190	300	8.51E+03	2.36E+01	7.69E+03	1.85E+04	7.36E+02	1.23E+03	2.04E+04
Inner	74	190	8.17E+02	5.28E+00					

* 4mm envelope
** 30mm overpack

The resulting estimated corresponding weight fractions intended for disposal are given in Table 3-14 below:

Table 3-14 Matrix composition of the supercontainers intended for disposal

Material	***Per Supercontainer***		**Total for disposal (x2950)***	
	min [kg]	max [kg]	min [kg]	max [kg]
concrete	1.65E+04	1.85E+04	4.88E+07	5.44E+07
steel	4.92E+02	1.23E+03	1.45E+06	3.64E+06
stainless steel	6.43E+02	7.36E+02	1.90E+06	2.17E+06
superplasticizer	3.10E+01	3.45E+01	9.13E+04	1.02E+05

*1875 supercontainers holding one CSD-C or CSD-V container and 1075 supercontainers holding two ECN containers with either spent fuel, uranium filters or other non-heat producing HLW.

Detailed calculations are given in the accompanying database [NRG, 2014].

4. The OPERA reference inventory

The waste matrix inventory for the LILW, (TE)NORM and HLW waste fractions as well as their totals have been summarized in Table 4-1.

Table 4-1 Total estimated waste matrix composition in the OPERA disposal facility

Material	*LILW*		*(TE) NORM*		*HLW Spent fuel*		*HLW Vitrified waste*		*HLW Compacted hulls and ends*		*Other non-heat-generating HLW*		*Supercontainer material*		*Total*	
	min [kg]	max [kg]	min [kg]	max [kg]	min [kg]	max [kg]	min [kg]	max [kg]	min [kg]	max [kg]	min [kg]	max [kg]	min [kg]	max [kg]	min [kg]	max [kg]
concrete	4.92E+07	5.94E+07	4.70E+07	5.04E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.76E+06	1.86E+06	4.88E+07	5.44E+07	1.47E+08	1.66E+08
grout	3.46E+06	3.89E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.46E+06	3.89E+06
superplasticizer	1.01E+05	1.64E+05	1.07E+05	1.14E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.29E+03	3.48E+03	9.13E+04	1.02E+05	3.02E+05	3.84E+05
steel	9.14E+06	1.95E+07	3.00E+06	5.00E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.45E+05	1.45E+05	3.20E+05	6.40E+05	1.45E+06	3.64E+06	1.41E+07	2.89E+07
glass type 1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.38E+05	2.38E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.38E+05	2.38E+05
stainless steel	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.53E+04	9.53E+04	5.00E+04	5.00E+04	1.00E+05	1.00E+05	2.10E+05	2.10E+05	1.90E+06	2.17E+06	2.35E+06	2.63E+06
U_3O_8	0.00E+00	0.00E+00	8.62E+07	9.23E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.62E+07	9.23E+07
zircaloy	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.91E+05	4.91E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.91E+05	4.91E+05
inconel	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.38E+04	2.38E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.38E+04	2.38E+04
net LILWaste	1.28E+07	2.65E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.28E+07	2.65E+07
zinc	2.43E+05	9.95+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.43E+05	9.95E+05
paint	1.70E+04	1.05E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.70E+04	1.05E+05
aluminium	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.50E+03	1.05E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.50E+03	1.05E+04
spent fuel & fuel assembly material	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.39E+04	4.53E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.39E+04	4.53E+04

5. References

[Alder et al., 1994] Alder J C, McGinnes D F, *Model Radioactive Waste Inventory for Swiss Waste Disposal Projects*, , NAGRA, Technical Report 93-21, Wettingen 1994, 1-111.

[NEA, 2006] Nuclear Energy Agency (NEA), *Radioactive waste management programmes in OECD/NEA member countries, Netherlands national nuclear energy context* , Country profile on http://www.oecd-nea.org/rwm/profiles/Netherlands_profile_web.pdf, 2008, 1-11.

[JCR, 2008] *National report on the joint convention on the safety of spent fuel management and on the safety of radioactive waste management*, 3rd National report of the Netherlands, October 2008, 1-132.

[Brennecke, 2011] Brenneke, P. *Anforderungen an endzulagernde radioaktive Abfälle* (Endlagerungsbedingungen, Stand: September 1995) – Schachtanlage KONRAD.

[BfS, 1995] *Radioactive waste disposal requirements – KONRAD mine* , Bericht ET-3/90-REV-3, Bundesamt für Strahlenschutz (BfS), Salzgitter 1995.

[COVRA, 2013A] COVRA, *Kwartaalrapport Nr 103*, COVRA rapport 13203, 30 September 2013.

[COVRA, 2013B] *"HLW-NRG.xlsx"*, Annex to e-mail, 3 October 2013. [COVRA, 2013C] E-mail annex: Excel file "Voorraad LOG per 19-02-2012.zip"[1], COVRA, K. Huizen, 2013, 19 February 2013.

[NRG, 2014A] Meeussen JCL, Rosca-Bocancea E, *Reference list of waste inventory - Part B: matrix composition,* (spread sheet) OPERA-IR-NRG1111B, October 2014.

[NRG, 2014B] Hart J, *Determination of the inventory - Part A: Radionuclides*, OPERA-PU-NRG1111A, October 2014, 1-58.

[Verhoef et al., 2014A] Verhoef E, Neeft E, Grupa J, Poley A., *Outline of a disposal concept in clay*, (Revised version), OPERA-PG-COV008, October 2014, 1-24.

[Verhoef et al., 2014B] Verhoef E V, de Bruin A M G , Wiegers R B , Neeft E A C, Deissmann G, *Cementitious materials in OPERA disposal concept in Boom Clay,* OPERA-PG-COV020, 30 April 2014, 1-24.

[Duerksen 2000] Duerksen W K et al *"Selection of optimum storage forms for depleted Uranium"*, appendix B in Hightower JR and Trabalka J R, Depleted Uranium Storage and Disposal Trade Study Summary Report, ORNL/TM-2000/10, January 2000 http://web.ornl.gov/~webworks/cpr/rpt/105913.pdf, p B21.

[1] The designation "Voorraad LOG per 19-02-2012.zip" was erroneously indicated by the year 2012. The actual data were provided as per 19-02-2013.

Appendix 1 Matrix composition of collected LLW/ILW waste.

Table A-1: Distribution of ILW/LLW waste mass over different Eural code categories as collected by COVRA over the years 2009-2012. Classification of waste is carried out by waste producers. The percentage indicates the fraction of each category of the total ILW/LLW mass

Eural code	Description (according to Eural code classification)	Weight%
19 02 05	* sludges from physico/chemical treatment containing dangerous substances	15.17%
20 03 01	mixed municipal waste	8.19%
19 12 12	wastes (including mixtures of materials) from the mechanical treatment of wastes not containing dangerous substances	7.87%
06 05 02	* sludges from on-site effluent treatment containing dangerous solutions	6.42%
07 05 13	* solid wastes containing dangerous substances	5.21%
06 02 04	* sodium and potassium hydroxide	4.30%
19 02 11	* other wastes containing dangerous substances	4.23%
15 02 03	absorbents, filter materials, wiping cloths and protective clothing not contaminated with dangerous substances	4.19%
02	unspecified wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing	4.15%
19 02 99	Wastes from physico chemical treatments (including dechromatation, decyanidation) not otherwise specified	4.11%
01 04 09	waste sand and clays	2.72%
15 01 10	* packaging containing residues of or contaminated by dangerous substances	2.41%
06 11 99	wastes from the manufacture of inorganic pigments and opacificiers, not otherwise specified	1.85%
01 04 99	wastes from phycial and chemical processing of non-metalliferous minerals not otherwise specified	1.76%
19 01 07	* solid wastes from gas treatment	1.75%
16 05 07	* discarded inorganic chemicals consisting of or containing dangerous substances	1.73%
19 02 03	premixed wastes composed only of non-hazardous wastes	1.71%
10 03 08	* salt slags from secondary production	1.62%
10 09 03	furnace slag	1.53%
16 03 04	inorganic wastes off-specification batches and unused products	1.35%
19 01 05	* filter cake from gas treatment	1.08%
16 02 16	components removed from discarded equipment	1.06%
16 11 05	* linings and refractories from non-metallurgical processes containing dangerous substances	1.03%
17 04 07	mixed metals	1.00%
10 09 99	wastes from casting of ferrous pieces, not otherwise specified	1.00%
15 02 02	* absorbents, filter materials (including oil filters not otherwise specified), wiping cloths,protective clothing contaminated by dangerous substances	1.00%

*containing dangerous substances

OPERA

Meer informatie:

Postadres
Postbus 202
4380 AE Vlissingen

T 0113-616 666
F 0113-616 650
E info@covra.nl

www.covra.nl