

| | | |
|---------------------|---------------|--|
| WASTE STREAM | 2D02/C | Vitrified High Level Waste - Magnox |
|---------------------|---------------|--|

SITE Sellafield

SITE OWNER Nuclear Decommissioning Authority

WASTE CUSTODIAN Sellafield Limited

WASTE TYPE HLW

Is the waste subject to Scottish Policy: No

WASTE VOLUMES

| | | Conditioned | Packaged |
|------------------------------------|---------------------------|----------------------|----------------------|
| Stocks: | At 1.4.2022..... | 455.3 m ³ | 594.9 m ³ |
| Future arisings - | 1.4.2022 - 31.3.2030..... | 0 m ³ | 0 m ³ |
| Total future arisings: | | 0 m ³ | 0 m ³ |
| Total waste volume: | | 455.3 m ³ | 594.9 m ³ |
| Number of waste packages in stock: | At 1.4.2022..... | 3035 package(s) | |

Comment on volumes: Current plan is to only create blend containers from now on. Conditioned waste volumes are based on an average container capacity of 0.15m³.

Uncertainty factors on volumes:

| | | | |
|----------------|-------|------------------|---|
| Stock (upper): | x 1.1 | Arisings (upper) | x |
| Stock (lower): | x 0.9 | Arisings (lower) | x |

WASTE SOURCE Reprocessing of spent fuel gives rise to acidic aqueous raffinate which is concentrated, then vitrified by thermally denitrating and mixing with glass formers.

PHYSICAL CHARACTERISTICS

General description: Vitrified waste is the oxide form of the fission products from spent fuel incorporated in a borosilicate lithia glass matrix. The glass blocks are cast in stainless steel product containers. Each container holds approximately 400 kg of glass. No large items are present, individual containers are approximately 430 mm diameter and 1,340 mm high. Due to process improvements the waste loading has increased from an initial typical waste oxide incorporation rate of 25% with 98% Magnox HLW containers have a waste oxide incorporation rate of up to 30% and 2% of containers having a waste oxide incorporation rate of 30-34%.

Physical components (%vol): Glass blocks in stainless steel containers (100%).

Sealed sources: The waste does not contain sealed sources.

Bulk density (t/m³): 2.65

Comment on density: -

CHEMICAL COMPOSITION

General description and components (%wt): SiO₂ (47.2%), Na₂O (8.6%), B₂O₃ (17.3%), Li₂O (2.0%), waste oxides (25%).

Chemical state: Neutral

Chemical form of radionuclides:

- H-3: Not present
- C-14: Not present
- Cl-36: Present as oxide in trace quantities
- Se-79: Present as oxide
- Tc-99: Present as oxide
- I-129: Present as oxide
- Ra: Likely to be present as oxide
- Th: Likely to be present as oxide
- U: Present as oxide
- Np: Present as oxide
- Pu: Present as oxide

Metals and alloys (%wt): -

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| | (%wt) | Type(s) / Grade(s) with proportions | % of total C14 activity |
|---------------------------|-------|-------------------------------------|-------------------------|
| Stainless steel..... | | | |
| Other ferrous metals..... | | | |
| Iron..... | | | |
| Aluminium..... | | | |
| Beryllium..... | | | |
| Cobalt..... | | | |
| Copper..... | | | |
| Lead..... | | | |
| Magnox/Magnesium..... | | | |
| Nickel..... | | | |
| Titanium..... | | | |
| Uranium..... | | | |
| Zinc..... | | | |
| Zircaloy/Zirconium..... | | | |
| Other metals..... | | | |

Organics (%wt): No organic materials are present.

| | (%wt) | Type(s) and comment | % of total C14 activity |
|-------------------------------------|-------|---------------------|-------------------------|
| Total cellulose..... | | | |
| Paper, cotton..... | | | |
| Wood..... | | | |
| Halogenated plastics | | | |
| Total non-halogenated plastics..... | | | |
| Condensation polymers..... | | | |
| Others..... | | | |
| Organic ion exchange materials.... | | | |
| Total rubber..... | | | |
| Halogenated rubber | | | |
| Non-halogenated rubber..... | | | |
| Hydrocarbons..... | | | |
| Oil or grease | | | |
| Fuel..... | | | |
| Asphalt/Tarmac (cont.coal tar)... | | | |
| Asphalt/Tarmac (no coal tar).... | | | |
| Bitumen..... | | | |
| Others..... | | | |
| Other organics..... | | | |

Other materials (%wt): -

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| | (%wt) | Type(s) and comment | % of total C14 activity |
|------------------------------------|-------|---------------------|-------------------------|
| Inorganic ion exchange materials.. | 0 | | |
| Inorganic sludges and flocs..... | 0 | | |
| Soil..... | 0 | | |
| Brick/Stone/Rubble..... | 0 | | |
| Cementitious material..... | 0 | | |
| Sand..... | NE | | |
| Glass/Ceramics..... | 100.0 | | |
| Graphite..... | 0 | | |
| Desiccants/Catalysts..... | NE | | |
| Asbestos..... | 0 | | |
| Non/low friable..... | 0 | | |
| Moderately friable..... | 0 | | |
| Highly friable..... | 0 | | |
| Free aqueous liquids..... | 0 | | |
| Free non-aqueous liquids..... | 0 | | |
| Powder/Ash..... | 0 | | |

Inorganic anions (%wt): Oxides are present

| | (%wt) | Type(s) and comment |
|----------------|-------|---------------------|
| Fluoride..... | | |
| Chloride..... | | |
| Iodide..... | | |
| Cyanide..... | | |
| Carbonate..... | | |
| Nitrate..... | | |
| Nitrite..... | | |
| Phosphate..... | | |
| Sulphate..... | | |
| Sulphide..... | | |

Materials of interest for waste acceptance criteria: There are no hazardous materials in the waste.

| | (%wt) | Type(s) and comment |
|--------------------------------|-------|---------------------|
| Combustible metals..... | | |
| Low flash point liquids..... | | |
| Explosive materials..... | | |
| Phosphorus..... | | |
| Hydrides..... | | |
| Biological etc. materials..... | | |
| Biodegradable materials..... | | |
| Putrescible wastes..... | | |
| Non-putrescible wastes..... | | |

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Corrosive materials.....
 Pyrophoric materials.....
 Generating toxic gases.....
 Reacting with water.....
 Higher activity particles.....
 Soluble solids as bulk chemical
 compounds.....

Hazardous substances /
 non hazardous pollutants: -

| | (%wt) | Type(s) and comment |
|---------------------------------------|-------|---|
| Acrylamide..... | | |
| Benzene..... | | |
| Chlorinated solvents..... | | |
| Formaldehyde..... | | |
| Organometallics..... | | |
| Phenol..... | | |
| Styrene..... | | |
| Tri-butyl phosphate..... | | |
| Other organophosphates..... | | |
| Vinyl chloride..... | | |
| Arsenic..... | | |
| Barium..... | | |
| Boron..... | | |
| Boron (in Boral)..... | | |
| Boron (non-Boral)..... | P | Boron Trioxide content within both types of glass is within range 21-31 wt% |
| Cadmium..... | | |
| Caesium..... | | |
| Selenium..... | | |
| Chromium..... | | |
| Molybdenum..... | | |
| Thallium..... | | |
| Tin..... | | |
| Vanadium..... | | |
| Mercury compounds..... | | |
| Others..... | | |
| Electronic Electrical Equipment (EEE) | | |
| EEE Type 1..... | | |
| EEE Type 2..... | | |
| EEE Type 3..... | | |
| EEE Type 4..... | | |
| EEE Type 5..... | | |

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Complexing agents (%wt): No

| | (%wt) | Type(s) and comment |
|--------------------------------|-------|---------------------|
| EDTA..... | 0 | |
| DPTA..... | 0 | |
| NTA..... | 0 | |
| Polycarboxylic acids..... | | |
| Other organic complexants..... | | |
| Total complexing agents..... | | |

Potential for the waste to contain discrete items: Yes. Waste stream is made up entirely of discrete waste containers.

PACKAGING AND CONDITIONING

| Container type: | Container | Waste packaged (%vol) | Waste loading (m ³) | Payload (m ³) | Number of packages |
|-----------------|--------------|-----------------------|---------------------------------|---------------------------|--------------------|
| | HLW canister | 100.0 | 0.15 | 0.15 | 3035 |

Container type comment: -

Range in container waste volume: -

Other information on containers: Stainless steel grade 309.

Conditioned density (t/m³): 2.65

Conditioned density comment: -

Other information on conditioning: This waste is already conditioned.

RADIOACTIVITY

Source: The main sources of activity in the waste are mixed fission products and actinides resulting from the reprocessing of irradiated Magnox fuel.

Uncertainty: -

Definition of total alpha and total beta/gamma: The total alpha and total beta/gamma activities are the sums of the reported nuclide activities only.

Measurement of radioactivities: The specific activity has been derived from plant records and predictions of feedstocks to the conditioning plant and a target waste incorporation of 25-35% in the conditioning matrix.

Other information: Short-lived daughters are not included. Other radionuclides not listed represent less than 0.01% of the total activity.

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| Nuclide | Mean radioactivity, TBq/m ³ | | | | Nuclide | Mean radioactivity, TBq/m ³ | | | |
|---------|--|----------------|-----------------|----------------|------------------|--|----------------|-----------------|----------------|
| | Waste at 1.4.2022 | Bands and Code | Future arisings | Bands and Code | | Waste at 1.4.2022 | Bands and Code | Future arisings | Bands and Code |
| H 3 | | 8 | | 4 | Gd 153 | 3.38E-13 | AA 2 | | 4 |
| Be 10 | 9.42E-05 | AA 2 | | 4 | Ho 163 | 2.43E-08 | AA 2 | | 4 |
| C 14 | | 8 | | 4 | Ho 166m | 2.21E-04 | AA 2 | | 4 |
| Na 22 | NE | | | 4 | Tm 170 | 4.72E-23 | AA 2 | | 4 |
| Al 26 | NE | | | 4 | Tm 171 | 7.85E-07 | AA 2 | | 4 |
| Cl 36 | | 8 | | 4 | Lu 174 | 5.93E-11 | AA 2 | | 4 |
| Ar 39 | | 8 | | 4 | Lu 176 | 3.63E-14 | AA 2 | | 4 |
| Ar 42 | | 8 | | 4 | Hf 178n | | 8 | | 4 |
| K 40 | 4.19E-10 | AA 2 | | 4 | Hf 182 | 5.58E-13 | AA 2 | | 4 |
| Ca 41 | 1.05E-05 | AA 2 | | 4 | Pt 193 | 1.29E-09 | AA 2 | | 4 |
| Mn 53 | 4.79E-10 | AA 2 | | 4 | Tl 204 | 1.04E-10 | AA 2 | | 4 |
| Mn 54 | 3.19E-11 | AA 2 | | 4 | Pb 205 | 2.87E-11 | AA 2 | | 4 |
| Fe 55 | 1.90E-02 | AA 2 | | 4 | Pb 210 | 1.33E-06 | AA 2 | | 4 |
| Co 60 | 1.64E+00 | AA 2 | | 4 | Bi 208 | 6.91E-15 | AA 2 | | 4 |
| Ni 59 | 3.88E-03 | AA 2 | | 4 | Bi 210m | 1.41E-15 | AA 2 | | 4 |
| Ni 63 | 3.48E-01 | AA 2 | | 4 | Po 210 | 1.31E-06 | AA 2 | | 4 |
| Zn 65 | 3.02E-12 | AA 2 | | 4 | Ra 223 | 9.45E-06 | AA 2 | | 4 |
| Se 79 | 2.54E-02 | AA 2 | | 4 | Ra 225 | 2.13E-08 | AA 2 | | 4 |
| Kr 81 | | 8 | | 4 | Ra 226 | 2.26E-06 | AA 2 | | 4 |
| Kr 85 | | 8 | | 4 | Ra 228 | 4.28E-11 | AA 2 | | 4 |
| Rb 87 | 9.34E-06 | AA 2 | | 4 | Ac 227 | 9.46E-06 | AA 2 | | 4 |
| Sr 90 | 1.09E+04 | AA 2 | | 4 | Th 227 | 9.32E-06 | AA 2 | | 4 |
| Zr 93 | 8.05E-01 | AA 2 | | 4 | Th 228 | 1.84E-06 | AA 2 | | 4 |
| Nb 91 | 5.62E-09 | AA 2 | | 4 | Th 229 | 2.14E-08 | AA 2 | | 4 |
| Nb 92 | 4.62E-11 | AA 2 | | 4 | Th 230 | 9.18E-05 | AA 2 | | 4 |
| Nb 93m | 6.83E-01 | AA 2 | | 4 | Th 232 | 4.35E-11 | AA 2 | | 4 |
| Nb 94 | 4.03E-05 | AA 2 | | 4 | Th 234 | 3.34E-05 | AA 2 | | 4 |
| Mo 93 | 1.71E-05 | AA 2 | | 4 | Pa 231 | 1.25E-05 | AA 2 | | 4 |
| Tc 97 | 2.61E-11 | AA 2 | | 4 | Pa 233 | 1.55E-02 | AA 2 | | 4 |
| Tc 99 | 2.02E+00 | AA 2 | | 4 | U 232 | 5.62E-07 | AA 2 | | 4 |
| Ru 106 | 6.34E-05 | AA 2 | | 4 | U 233 | 3.00E-06 | AA 2 | | 4 |
| Pd 107 | 4.06E-02 | AA 2 | | 4 | U 234 | 1.15E-04 | AA 2 | | 4 |
| Ag 108m | 5.90E-06 | AA 2 | | 4 | U 235 | 1.30E-06 | AA 2 | | 4 |
| Ag 110m | 1.86E-10 | AA 2 | | 4 | U 236 | 1.16E-05 | AA 2 | | 4 |
| Cd 109 | 2.74E-09 | AA 2 | | 4 | U 238 | 3.34E-05 | AA 2 | | 4 |
| Cd 113m | 1.24E+00 | AA 2 | | 4 | Np 237 | 1.55E-02 | AA 2 | | 4 |
| Sn 119m | 3.37E-11 | AA 2 | | 4 | Pu 236 | 2.60E-08 | AA 2 | | 4 |
| Sn 121m | 5.83E+00 | AA 2 | | 4 | Pu 238 | 4.19E-01 | AA 2 | | 4 |
| Sn 123 | 2.79E-20 | AA 2 | | 4 | Pu 239 | 5.45E-02 | AA 2 | | 4 |
| Sn 126 | 5.87E-02 | AA 2 | | 4 | Pu 240 | 8.48E-02 | AA 2 | | 4 |
| Sb 125 | 5.83E-01 | AA 2 | | 4 | Pu 241 | 1.26E+00 | AA 2 | | 4 |
| Sb 126 | 4.34E-02 | AA 2 | | 4 | Pu 242 | 9.03E-05 | AA 2 | | 4 |
| Te 125m | 1.42E-01 | AA 2 | | 4 | Am 241 | 3.05E+02 | AA 2 | | 4 |
| Te 127m | 1.37E-21 | AA 2 | | 4 | Am 242m | 1.30E+00 | AA 2 | | 4 |
| I 129 | | 8 | | 4 | Am 243 | 4.58E-01 | AA 2 | | 4 |
| Cs 134 | 1.84E-01 | AA 2 | | 4 | Cm 242 | 1.07E+00 | AA 2 | | 4 |
| Cs 135 | 3.54E-01 | AA 2 | | 4 | Cm 243 | 1.71E-01 | AA 2 | | 4 |
| Cs 137 | 1.53E+04 | AA 2 | | 4 | Cm 244 | 6.57E+00 | AA 2 | | 4 |
| Ba 133 | 1.10E-06 | AA 2 | | 4 | Cm 245 | 1.89E-03 | AA 2 | | 4 |
| La 137 | 1.38E-06 | AA 2 | | 4 | Cm 246 | 3.44E-04 | AA 2 | | 4 |
| La 138 | 3.97E-11 | AA 2 | | 4 | Cm 248 | 2.97E-09 | AA 2 | | 4 |
| Ce 144 | 8.52E-07 | AA 2 | | 4 | Cf 249 | 3.05E-08 | AA 2 | | 4 |
| Pm 145 | 1.08E-06 | AA 2 | | 4 | Cf 250 | 5.25E-08 | AA 2 | | 4 |
| Pm 147 | 8.33E+00 | AA 2 | | 4 | Cf 251 | 1.34E-09 | AA 2 | | 4 |
| Sm 147 | 4.16E-06 | AA 2 | | 4 | Cf 252 | 2.42E-10 | AA 2 | | 4 |
| Sm 151 | 1.53E+02 | AA 2 | | 4 | Other a | NE | 6 | | 4 |
| Eu 152 | 7.69E-01 | AA 2 | | 4 | Other b/g | NE | 6 | | 4 |
| Eu 154 | 4.56E+01 | AA 2 | | 4 | Total a | 3.14E+02 | AA 2 | 0 | 4 |
| Eu 155 | 4.99E+00 | AA 2 | | 4 | Total b/g | 2.63E+04 | AA 2 | 0 | 4 |

Bands (Upper and Lower)

- A a factor of 1.5
- B a factor of 3
- C a factor of 10
- D a factor of 100
- E a factor of 1000

Note: Bands quantify uncertainty in mean radioactivity.

Code

- 1 Measured activity
- 2 Derived activity (best estimate)
- 3 Derived activity (upper limit)
- 4 Not present
- 5 Present but not significant
- 6 Likely to be present but not assessed
- 7 Present in significant quantities but not determined
- 8 Not expected to be present in significant quantity