WASTE STREAM 2S302 Windscale Pile1 and Pile 2 Graphite and Aluminium Charge Pans

SITE	Windscale
SITE OWNER	Nuclear Decommissioning Authority
WASTE CUSTODIAN	Sellafield Limited
WASTE TYPE	ILW
Is the waste subject to Scottish Policy:	No

WASTE VOLUMES

		Reported
Stocks:	At 1.4.2022.....	0 m³
Future arisings -	1.4.2022 - 31.3.2023.....	0 m³
	1.4.2023 - 31.3.2024.....	0 m³
	1.4.2024 - 31.3.2025.....	0 m³
	1.4.2025 - 31.3.2042.....	0 m³
	1.4.2042 - 31.3.2047.....	~964.0 m³
	1.4.2047 - 31.3.2052.....	~964.0 m³
Total future arisings:		1928.0 m³
Total waste volume:		1928.0 m³

Comment on volumes: The volumes provided are envelope volumes.

Uncertainty factors on volumes:

Stock (upper):	x	Arisings (upper)	x 1.5
Stock (lower):	x	Arisings (lower)	x 0.5

WASTE SOURCE The removal and packaging of the graphite cores of Windscale Pile 1 and Pile 2 reactors.

PHYSICAL CHARACTERISTICS

General description: The reactor cores of Pile 1 and Pile 2 are constructed from machined graphite blocks stacked in such a way as to make a horizontal cylinder approximately 15.3 m diameter and 7.4 m deep. The blocks are stacked vertically and located to the blocks above and below by graphite slats and tiles. There is no clearance vertically between blocks and tiles, though the blocks are separated horizontally from each other by a “Wigner gap” to allow for lateral expansion.

The sizes of the graphite segments are approximately: Full height blocks - 210 x 210 x 790 mm; Half height blocks - 210 x 210 x 370 mm; Slats - 400 x 26 x 90 mm; Tiles - 180 x 180 x 52 mm.

The charge pans are aluminium pressings and are fixed by self tapping screws to the adjacent graphite blocks on the charge face. The charge pans are located within the horizontal and vertical stringers and the openings align with the fuel and isotope channels. The charge pans were used to align the charge machine for the insertion of fuel and isotope cartridges.

There are 3 types of charge pans which all have same external dimensions (Length 0.392 m Width 0.392 m Height 0.121 m).

Debris contamination from the 1957 fire accident in Pile 1 is made up of the nuclide inventory of Mark X fuel. Debris and particulate removal operations are envisaged to remove 99% of the debris material. The 1% remaining (=77.85kg/ 0.01m³) will be residual surface particulate contamination and has therefore been included in this waste stream. Windscale Pile 1 fire accident in 1957 has left fuels debris contamination within the graphite core of Pile 1.

Physical components (%wt): Graphite 99.88%; Aluminium 0.12%; Mark X fuel 0.002%.

Sealed sources: The waste does not contain sealed sources.

Bulk density (t/m³): 1.34

Comment on density: Calculated by dividing the total mass of waste by the total envelope volume.

CHEMICAL COMPOSITION

General description and components (%wt): Graphite 99.88%; Aluminium 0.12%; Burnt Mark X fuel (assumed to be Uranium Dioxide) 0.002%.

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Chemical state: Neutral

Chemical form of radionuclides:
H-3: H3 present in the waste material as a product of activation.
C-14: C14 present in the waste material as a product of activation.
Se-79: Se79 present in the waste material as a product of activation.
Tc-99: Te99 present in the waste material as a product of activation.
Ra: Radium isotopes present in the waste material as a product of activation.
Th: Thorium isotopes present in the waste material as a product of activation.
U: Uranium isotopes present in the waste material as a product of activation.
Np: Neptunium isotopes present in the waste material as a product of activation.
Pu: Plutonium isotopes present in the waste material as a product of activation.

Metals and alloys (%wt): Not yet determined.

	(%wt)	Type(s) / Grade(s) with proportions	% of total C14 activity
Stainless steel	0		
Other ferrous metals	0		
Iron			
Aluminium	0.12		
Beryllium			
Cobalt	0		
Copper	0		
Lead	0		
Magnox/Magnesium	0		
Nickel	0		
Titanium			
Uranium	P		
Zinc	0		
Zircaloy/Zirconium	0		
Other metals	0		

Organics (%wt): -

	(%wt)	Type(s) and comment	% of total C14 activity
Total cellulosics	0		
Paper, cotton	0		
Wood	0		
Halogenated plastics	0		
Total non-halogenated plastics	0		
Condensation polymers	0		
Others	0		
Organic ion exchange materials	0		
Total rubber	0		
Halogenated rubber	0		
Non-halogenated rubber	0		
Hydrocarbons			
Oil or grease			
Fuel			
Asphalt/Tarmac (cont.coal tar)			
Asphalt/Tarmac (no coal tar)			

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Bitumen	
Others	
Other organics	0

Other materials (%wt): -

	(%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			
Glass/Ceramics	0		
Graphite	99.9		100.0
Desiccants/Catalysts			
Asbestos	NE		
Non/low friable			
Moderately friable			
Highly friable			
Free aqueous liquids	0		
Free non-aqueous liquids	0		
Powder/Ash	0		

Inorganic anions (%wt): No inorganic anions are present.

	(%wt)	Type(s) and comment
Fluoride	0	
Chloride	0	
Iodide	0	
Cyanide	0	
Carbonate	0	
Nitrate	0	
Nitrite	0	
Phosphate	0	
Sulphate	0	
Sulphide	0	

Materials of interest for waste acceptance criteria: -

	(%wt)	Type(s) and comment
Combustible metals	0	
Low flash point liquids	0	
Explosive materials	0	
Phosphorus	0	
Hydrides	0	

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Biological etc. materials.....	0
Biodegradable materials.....	NE
Putrescible wastes.....	0
Non-putrescible wastes.....	NE
Corrosive materials.....	0
Pyrophoric materials.....	0
Generating toxic gases.....	0
Reacting with water.....	0
Higher activity particles.....	NE
Soluble solids as bulk chemical compounds.....	0

Hazardous substances / non hazardous pollutants: -

	(%wt)	Type(s) and comment
Acrylamide.....		
Benzene.....	NE	
Chlorinated solvents.....		
Formaldehyde.....		
Organometallics.....		
Phenol.....	NE	
Styrene.....		
Tri-butyl phosphate.....	NE	
Other organophosphates.....		
Vinyl chloride.....	NE	
Arsenic.....	NE	
Barium.....		
Boron.....	NE	
Boron (in Boral).....		
Boron (non-Boral).....		
Cadmium.....	NE	
Caesium.....		
Selenium.....	NE	
Chromium.....	NE	
Molybdenum.....	NE	
Thallium.....		
Tin.....	NE	
Vanadium.....	NE	
Mercury compounds.....		
Others.....	NE	
Electronic Electrical Equipment (EEE)		
EEE Type 1.....		
EEE Type 2.....		
EEE Type 3.....		

EEE Type 4.....

EEE Type 5.....

Complexing agents (%wt): No

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

Potential for the waste to contain discrete items: Yes. Tools and steel fabrications are likely to be present in this waste stream.

PACKAGING AND CONDITIONING

Conditioning method: Bulk removal, loaded into waste baskets within the Core Containment Structure and packaged within Decommissioning Concrete Container (DCC). The graphite pieces will be removed from the core in an array of up to 8 by 4 blocks. Damaged graphite is expected to be retrieved in the same manner. It is envisaged that 4 waste baskets will fit into each container. It is not planned to anneal the graphite or encapsulate the waste in the containers.

Plant Name: -

Location: Windscale/ Sellafield.

Plant startup date: -

Total capacity (m^3/y incoming waste): -

Target start date for packaging this stream: 2033

Throughput for this stream (m^3/y incoming waste): -

Other information: -

Likely container type:

Container	Waste packaged (%vol)	Waste loading (m^3)	Payload (m^3)	Number of packages
Other(DCC)	100.0	~1.39	2.15	1388

Likely container type comment: DCC - external envelope of a Sellafield 3 m^3 box however it is made of fibre-reinforced concrete.

Range in container waste volume: The volume of raw waste in a container can vary from 5% to 65% by volume (Note a full container of dry sharp sand would be 50% by volume).

Other information on containers: Fibre-reinforced concrete for DCC.

Likely conditioning matrix: None

Other information: -

Conditioned density (t/m^3): 1.0

Conditioned density comment: The waste will not be encapsulted, therefore the density of the wasteform represents the average density of the total waste arising allowing for packing.

Other information on conditioning: Plans are under review and may change.

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Opportunities for alternative disposal routing: Not yet determined

Baseline Management Route	Opportunity Management Route	Stream volume (%)	Estimated Date that Opportunity will be realised	Opportunity Confidence	Comment
-	-	-	-	-	-

RADIOACTIVITY

Source:	Activation of graphite and aluminium. Plus residual fuel debris contamination.
Uncertainty:	It has been assumed that all the graphite components have the same radiological properties. This assumption represents the worst case, as inevitably the radionuclide inventory will vary with position in the core. The main source of uncertainty in the activation modelling is the elemental uncertainties in the material compositions. The uncertainties relate to the trace elements present within the graphite and aluminium material. Wherever possible specific compositions and trace element data was used for each component. There is also uncertainty in the inventory from the flux modelling. However, the uncertainty presented by the flux modelling is regarded to be much less than that presented by the elemental uncertainties.
Definition of total alpha and total beta/gamma:	Where totals are shown on the table of radionuclide activities they are the sums of the listed alpha or beta/gamma emitting radionuclides plus 'other alpha' or 'other beta/gamma'.
Measurement of radioactivities:	The principal source for the radionuclide data is the results of FISPIN modelling. In addition WIMS was used to develop a 172 group neutron flux over the graphite moderator. The neutron flux was then applied in activation calculations to derive the inventory for the waste.
Other information:	-

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Nuclide	Mean radioactivity, TBq/m³ Waste at 1.4.2022	Bands and Code	Future arisings	Bands and Code	Nuclide	Mean radioactivity, TBq/m³ Waste at 1.4.2022	Bands and Code	Future arisings	Bands and Code
H 3			1.38E-02	B B 2	Gd 153				
Be 10			1.27E-06	B B 2	Ho 163			6.81E-08	B B 2
C 14			5.70E-03	B B 2	Ho 166m			2.08E-05	B B 2
Na 22					Tm 170				
Al 26					Tm 171			3.66E-12	B B 2
Cl 36			7.48E-05	B B 2	Lu 174			4.12E-12	B B 2
Ar 39			1.45E-04	B B 2	Lu 176			6.05E-13	B B 2
Ar 42			2.98E-09	B B 2	Hf 178n			2.76E-05	B B 2
K 40			3.59E-09	B B 2	Hf 182			2.13E-12	B B 2
Ca 41			3.57E-04	B B 2	Pt 193			1.83E-04	B B 2
Mn 53			2.10E-12	B B 2	Tl 204			8.37E-05	B B 2
Mn 54			1.14E-23	B B 2	Pb 205			9.52E-11	B B 2
Fe 55			8.81E-08	B B 2	Pb 210			2.24E-12	B B 2
Co 60			2.09E-04	B B 2	Bi 208			5.95E-12	B B 2
Ni 59			1.69E-04	B B 2	Bi 210m			2.65E-11	B B 2
Ni 63			1.43E-02	B B 2	Po 210			2.20E-12	B B 2
Zn 65					Ra 223			2.78E-09	B B 2
Se 79			1.27E-08	B B 2	Ra 225			5.35E-08	B B 2
Kr 81			5.07E-06	B B 2	Ra 226			4.78E-12	B B 2
Kr 85			1.41E-04	B B 2	Ra 228			1.56E-08	B B 2
Rb 87			1.20E-07	B B 2	Ac 227			2.79E-09	B B 2
Sr 90			5.53E-04	B B 2	Th 227			2.74E-09	B B 2
Zr 93			4.54E-08	B B 2	Th 228			1.34E-07	B B 2
Nb 91			4.10E-10	B B 2	Th 229			5.35E-08	B B 2
Nb 92			6.14E-13	B B 2	Th 230			3.02E-10	B B 2
Nb 93m			1.72E-05	B B 2	Th 232			1.56E-08	B B 2
Nb 94			2.02E-05	B B 2	Th 234			3.42E-07	B B 2
Mo 93			1.65E-07	B B 2	Pa 231			5.75E-09	B B 2
Tc 97			3.15E-10	B B 2	Pa 233			1.39E-09	B B 2
Tc 99			2.63E-07	B B 2	U 232			1.26E-07	B B 2
Ru 106			7.18E-20	B B 2	U 233			1.07E-05	B B 2
Pd 107			4.59E-09	B B 2	U 234			2.14E-07	B B 2
Ag 108m			1.13E-06	B B 2	U 235			1.89E-08	B B 2
Ag 110m					U 236			4.90E-09	B B 2
Cd 109			2.19E-18	B B 2	U 238			3.42E-07	B B 2
Cd 113m			7.02E-08	B B 2	Np 237			1.39E-09	B B 2
Sn 119m			6.83E-28	B B 2	Pu 236			1.66E-17	B B 2
Sn 121m			4.24E-07	B B 2	Pu 238			1.53E-06	B B 2
Sn 123					Pu 239			4.96E-05	B B 2
Sn 126			2.35E-09	B B 2	Pu 240			2.41E-05	B B 2
Sb 125			2.86E-10	B B 2	Pu 241			1.34E-04	B B 2
Sb 126					Pu 242			6.87E-09	B B 2
Te 125m			7.16E-11	B B 2	Am 241			5.93E-05	B B 2
Te 127m					Am 242m			5.73E-08	B B 2
I 129			5.57E-10	B B 2	Am 243			5.81E-09	B B 2
Cs 134			1.00E-09	B B 2	Cm 242			4.73E-08	B B 2
Cs 135			2.72E-08	B B 2	Cm 243			9.70E-10	B B 2
Cs 137			5.74E-04	B B 2	Cm 244			1.66E-09	B B 2
Ba 133			1.16E-05	B B 2	Cm 245			7.32E-13	B B 2
La 137			6.14E-08	B B 2	Cm 246			3.50E-14	B B 2
La 138			1.75E-12	B B 2	Cm 248			2.68E-21	B B 2
Ce 144			9.01E-24	B B 2	Cf 249			2.62E-21	B B 2
Pm 145			1.80E-06	B B 2	Cf 250				
Pm 147			2.96E-09	B B 2	Cf 251				
Sm 147			6.41E-12	B B 2	Cf 252				
Sm 151			9.42E-05	B B 2	Other a				
Eu 152			4.03E-05	B B 2	Other b/g				
Eu 154			1.72E-04	B B 2	**Total a**	**0**		**1.46E-04**	**B B 2**
Eu 155			1.22E-06	B B 2	**Total b/g**	**0**		**3.68E-02**	**B B 2**

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