

WASTE STREAM	2S304	Windscale Piles Fuel and Isotopes
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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.....	<0.1 m ³
Future arisings -	1.4.2022 - 31.3.2023.....	0 m ³
	1.4.2023 - 31.3.2024.....	0 m ³
	1.4.2024 - 31.3.2025.....	0 m ³
	1.4.2025 - 31.3.2032.....	39.7 m ³
Total future arisings:		39.7 m ³
Total waste volume:		39.8 m ³

Comment on volumes: Pile 1 fuel and isotopes will be removed during 2034-2038. Future arisings are estimates based on what is believed to be present in the Piles. The estimated volume of material in the waste stream is approximately 5.3m³. However on recovery it is likely that this will bulk up such that the raw volume of waste generated is likely to be approximately 40 m³.

Uncertainty factors on volumes: Stock (upper): x 1.5 Arisings (upper) x 1.5
 Stock (lower): x 0.5 Arisings (lower) x 0.5

WASTE SOURCE Decommissioning of Windscale Piles air-cooled graphite-moderated reactors.

PHYSICAL CHARACTERISTICS

General description: The Pile 1 fuel is uranium metal clad in an aluminium can which was sat on a graphite boat and held in place by aluminium staples. The Isotope material from both Pile 1 and 2 reactors are isotope rods that are also aluminium clad. The isotope materials are lithium magnesium, bismuth oxide, aluminium nitride, potassium chloride, thulium, thallium, lead, stainless steel and cobalt. These materials are in a range of physical and chemical states due to the fire in Pile 1. This waste has remained in the Pile reactors since they were shut down. The fuel and isotopes in the Pile 1 reactor were subject to fire conditions and, as a result, may be in a variety of physical and chemical conditions.

Physical components (%wt): Uranium fuel (78.6%), Isotope materials (12.7%), Aluminium cans and staples (3.3%), Graphite (5.4%).

Sealed sources: -

Bulk density (t/m³): ~0.3

Comment on density: Density is calculated based on the estimated mass and the raw recovered volume.

CHEMICAL COMPOSITION

General description and components (%wt): Uranium fuel (78.6%), Aluminium (3.3%), Aluminium Nitride (0.1%), Lead (6.7%), Bismuth Oxide (3%), Pottasium Chloride (<<0.1%), Cobalt (<<0.1%), Thulium Oxide (TR), Thallium (<<0.1%), Lithium Magnesium (0.7%), Stainless Steel (2.2%), Graphite (5.4%).

Chemical state: -

Chemical form of radionuclides: H-3: Tritium isotope cartridges are present.
 C-14: Product from isotope cartridges.
 Se-79: Present as a fission product.
 Tc-99: Present as a fission product.
 Ra: Decay product of fuel.
 Th: Present as decay product of fuel.
 U: Present as fuel.
 Np: Activation product of fuel.
 Pu: Present due to activation of the fuel.

Metals and alloys (%wt): Metal present as fuel and isotope cartridge contents and cladding.

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	(%wt)	Type(s) / Grade(s) with proportions	% of total C14 activity
Stainless steel.....	2.2		
Other ferrous metals.....	0		
Iron.....			
Aluminium.....	3.3		
Beryllium.....			
Cobalt.....	0		
Copper.....	0		
Lead.....	6.7		
Magnox/Magnesium.....	0		
Nickel.....	0		
Titanium.....			
Uranium.....	78.6		
Zinc.....	0		
Zircaloy/Zirconium.....	0		
Other metals.....	0		
Organics (%wt):	-		
	(%wt)	Type(s) and comment	% of total C14 activity
Total cellulose.....	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)....			
Bitumen.....			
Others.....			
Other organics.....	0		

Other materials (%wt): Graphite is from the graphite boats and isotopes.

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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.....			
Glass/Ceramics.....	0		
Graphite.....	5.4		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 other than the potassium chloride isotope cartridges.

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

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	
Biological etc. materials.....	0	
Biodegradable materials.....	NE	
Putrescible wastes.....	0	
Non-putrescible wastes.....	NE	

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Corrosive materials.....	0
Pyrophoric materials.....	0
Generating toxic gases.....	0
Reacting with water.....	0
Higher activity particles.....	NE
Soluble solids as bulk chemical compounds.....	NE

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.....		

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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, damaged fuel elements and isotope cartridges will be present in this waste stream.

PACKAGING AND CONDITIONING

Conditioning method: The baseline assumption is that this waste will be treated in line with the Enterprise Fuel study through BEP

- Plant Name: -
- Location: Windscale.
- Plant startup date: 2026
- Total capacity (m³/y incoming waste): NE
- Target start date for packaging this stream: 2026
- Throughput for this stream (m³/y incoming waste): NE
- Other information: -

Likely container type:	Container	Waste packaged (%vol)	Waste loading (m ³)	Payload (m ³)	Number of packages
	Sellafield 3m ³ box	100.0	~1.3	~2.15	31

Likely container type comment: Conditioned waste volume comprises of the waste and an inert matrix i.e. does not include the waste crate.

Range in container waste volume: The loading volume varies depending on the waste type.

Other information on containers: -

Likely conditioning matrix: Not Specified

Other information: -

Conditioned density (t/m³): ~1.3

Conditioned density comment: -

Other information on conditioning: -

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:	The radionuclide activity of the waste is dominated by fission and activation products which will be present in the fuel and isotope cartridges.
Uncertainty:	The data has been derived from FISPIN, FISPACT, and WIMS modelling programmes.
Definition of total alpha and total beta/gamma:	To be determined by characterisation.
Measurement of radioactivities:	The main uncertainties in the activation modelling stem from elemental uncertainties in the composition of the materials used to manufacture fuel and isotope cartridges and for impurities in the isotope target materials. There are also some uncertainties in the flux modelling. The radionuclide data should however be an upper bound.
Other information:	-

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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	2.73E+01	BB 2	3.31E+01	BB 2	Gd 153				
Be 10	4.46E-07	BB 2	4.46E-07	BB 2	Ho 163	1.52E-05	BB 2	1.52E-05	BB 2
C 14	5.54E-02	BB 2	5.54E-02	BB 2	Ho 166m	4.90E-03	BB 2	4.90E-03	BB 2
Na 22					Tm 170				
Al 26					Tm 171	2.91E-12	BB 2	9.80E-12	BB 2
Cl 36	1.40E-04	BB 2	1.40E-04	BB 2	Lu 174	4.45E-10	BB 2	9.67E-10	BB 2
Ar 39	1.73E-03	BB 2	1.74E-03	BB 2	Lu 176	5.69E-09	BB 2	5.69E-09	BB 2
Kr 42	1.00E-09	BB 2	1.08E-09	BB 2	Hf 178n	5.43E-03	BB 2	5.87E-03	BB 2
K 40	1.12E-08	BB 2	1.12E-08	BB 2	Hf 182	2.15E-10	BB 2	2.15E-10	BB 2
Ca 41	7.51E-05	BB 2	7.51E-05	BB 2	Pt 193	5.66E-05	BB 2	5.94E-05	BB 2
Mn 53	1.76E-09	BB 2	1.76E-09	BB 2	Tl 204	8.15E-06	BB 2	1.53E-05	BB 2
Mn 54	1.73E-18	BB 2	2.32E-17	BB 2	Pb 205	6.82E-07	BB 2	6.82E-07	BB 2
Fe 55	1.05E-06	BB 2	2.56E-06	BB 2	Pb 210	1.26E-07	BB 2	1.09E-07	BB 2
Co 60	1.39E-02	BB 2	2.18E-02	BB 2	Bi 208	2.87E-07	BB 2	2.87E-07	BB 2
Ni 59	3.20E-02	BB 2	3.20E-02	BB 2	Bi 210m	1.28E-06	BB 2	1.28E-06	BB 2
Ni 63	2.42E+00	BB 2	2.48E+00	BB 2	Po 210	1.23E-07	BB 2	1.06E-07	BB 2
Zn 65	2.78E-33	BB 2	7.25E-32	BB 2	Ra 223	1.17E-06	BB 2	1.08E-06	BB 2
Se 79	4.19E-06	BB 2	4.19E-06	BB 2	Ra 225	3.90E-08	BB 2	3.66E-08	BB 2
Kr 81	6.08E-07	BB 2	6.08E-07	BB 2	Ra 226	2.69E-07	BB 2	2.48E-07	BB 2
Kr 85	7.74E-02	BB 2	9.70E-02	BB 2	Ra 228	7.62E-08	BB 2	7.62E-08	BB 2
Rb 87	1.90E-07	BB 2	1.90E-07	BB 2	Ac 227	1.17E-06	BB 2	1.08E-06	BB 2
Sr 90	1.08E+01	BB 2	1.17E+01	BB 2	Th 227	1.15E-06	BB 2	1.07E-06	BB 2
Zr 93	1.26E-03	BB 2	1.26E-03	BB 2	Th 228	2.95E-07	BB 2	2.98E-07	BB 2
Nb 91	3.52E-07	BB 2	3.53E-07	BB 2	Th 229	3.90E-08	BB 2	3.67E-08	BB 2
Nb 92	1.69E-10	BB 2	1.69E-10	BB 2	Th 230	1.24E-05	BB 2	1.24E-05	BB 2
Nb 93m	3.17E-03	BB 2	3.48E-03	BB 2	Th 232	7.62E-08	BB 2	7.62E-08	BB 2
Nb 94	3.75E-03	BB 2	3.75E-03	BB 2	Th 234	2.23E-02	BB 2	2.23E-02	BB 2
Mo 93	7.77E-05	BB 2	7.77E-05	BB 2	Pa 231	1.99E-06	BB 2	1.90E-06	BB 2
Tc 97	8.64E-11	BB 2	8.64E-11	BB 2	Pa 233	3.14E-05	BB 2	3.14E-05	BB 2
Tc 99	9.22E-03	BB 2	9.22E-03	BB 2	U 232	2.16E-07	BB 2	2.24E-07	BB 2
Ru 106	4.10E-20	BB 2	3.82E-19	BB 2	U 233	7.22E-06	BB 2	7.22E-06	BB 2
Pd 107	1.48E-05	BB 2	1.48E-05	BB 2	U 234	3.00E-03	BB 2	3.00E-03	BB 2
Ag 108m	3.13E-05	BB 2	3.15E-05	BB 2	U 235	1.27E-03	BB 2	1.27E-03	BB 2
Ag 110m	5.24E-34	BB 2	7.93E-33	BB 2	U 236	2.31E-04	BB 2	2.31E-04	BB 2
Cd 109	7.27E-21	BB 2	4.37E-20	BB 2	U 238	2.23E-02	BB 2	2.23E-02	BB 2
Cd 113m	1.83E-04	BB 2	2.16E-04	BB 2	Np 237	3.14E-05	BB 2	3.14E-05	BB 2
Sn 119m	4.05E-29	BB 2	6.38E-28	BB 2	Pu 236	2.27E-14	BB 2	5.14E-14	BB 2
Sn 121m	3.04E-03	BB 2	3.20E-03	BB 2	Pu 238	3.11E-03	BB 2	3.20E-03	BB 2
Sn 123					Pu 239	9.70E-01	BB 2	9.70E-01	BB 2
Sn 126	4.52E-05	BB 2	4.52E-05	BB 2	Pu 240	6.23E-02	BB 2	6.23E-02	BB 2
Sb 125	4.56E-08	BB 2	1.09E-07	BB 2	Pu 241	2.05E-02	BB 2	2.43E-02	BB 2
Sb 126					Pu 242	1.74E-07	BB 2	1.74E-07	BB 2
Te 125m					Am 241	2.00E-02	BB 2	2.00E-02	BB 2
Te 127m					Am 242m	5.35E-07	BB 2	5.44E-07	BB 2
I 129	1.54E-05	BB 2	1.54E-05	BB 2	Am 243	1.54E-08	BB 2	1.54E-08	BB 2
Cs 134	8.17E-10	BB 2	2.54E-09	BB 2	Cm 242	4.41E-07	BB 2	4.49E-07	BB 2
Cs 135	6.53E-04	BB 2	6.53E-04	BB 2	Cm 243	1.46E-09	BB 2	1.58E-09	BB 2
Cs 137	1.21E+01	BB 2	1.32E+01	BB 2	Cm 244	1.69E-09	BB 2	1.93E-09	BB 2
Ba 133	2.93E-05	BB 2	3.69E-05	BB 2	Cm 245	1.52E-13	BB 2	1.52E-13	BB 2
La 137	1.15E-06	BB 2	1.15E-06	BB 2	Cm 246	6.39E-15	BB 2	6.39E-15	BB 2
La 138	1.48E-10	BB 2	1.48E-10	BB 2	Cm 248	4.82E-22	BB 2	4.82E-22	BB 2
Ce 144	2.15E-25	BB 2	3.64E-24	BB 2	Cf 249	4.97E-22	BB 2	5.01E-22	BB 2
Pm 145	2.66E-07	BB 2	3.06E-07	BB 2	Cf 250	5.29E-29	BB 2	5.89E-29	BB 2
Pm 147	1.14E-06	BB 2	2.81E-06	BB 2	Cf 251				
Sm 147	6.46E-09	BB 2	6.46E-09	BB 2	Cf 252				
Sm 151	6.80E-01	BB 2	6.99E-01	BB 2	Other a				
Eu 152	2.79E-04	BB 2	3.35E-04	BB 2	Other b/g				
Eu 154	2.10E-04	BB 2	2.78E-04	BB 2	Total a	1.08E+00	BB 2	1.08E+00	BB 2
Eu 155	7.14E-05	BB 2	1.14E-04	BB 2	Total b/g	5.36E+01	BB 2	6.15E+01	BB 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