

<b>WASTE STREAM</b>	<b>2C304</b>	<b>Graphite LLW</b>
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**SITE** Chapelcross  
**SITE OWNER** Nuclear Decommissioning Authority

**WASTE CUSTODIAN** Magnox Limited

**WASTE TYPE** LLW

Is the waste subject to Scottish Policy: No

**WASTE VOLUMES**

		Reported
Stocks:	At 1.4.2022.....	0 m <sup>3</sup>
Future arisings -	1.4.2089 - 31.3.2095.....	6.0 m <sup>3</sup>
Total future arisings:		6.0 m <sup>3</sup>
Total waste volume:		6.0 m <sup>3</sup>

Comment on volumes: For inventory purposes the arisings are assumed to arise at a uniform rate over 6 years. Final Dismantling & Site Clearance is assumed to commence in 2085 with reactor dismantling commencing in 2089 and lasting for 6 years. The volumes and radioactivity have been calculated for 85 years after reactor shutdown, i.e. 2089

Uncertainty factors on volumes: Stock (upper): x Arisings (upper) x 1.2  
 Stock (lower): x Arisings (lower) x 0.8

**WASTE SOURCE** Reflector graphite from reactor dismantling.

**PHYSICAL CHARACTERISTICS**

General description: Graphite blocks and other graphite components.

Physical components (%vol): Graphite (100%).

Sealed sources: The waste does not contain sealed sources.

Bulk density (t/m<sup>3</sup>): 1.25

Comment on density: Density estimate based upon the assumed packing efficiency of the waste. The density is the effective density for packaging assuming 90% of the graphite is in blocks and 10% is rubble.

**CHEMICAL COMPOSITION**

General description and components (%wt): Graphite and possibly traces of ferrous metals.

Chemical state: Neutral

Chemical form of radionuclides: H-3: Tritium may be chemically bound with the graphite.  
 C-14: The carbon 14 will be present as graphite.  
 Se-79: The selenium content is insignificant.  
 Tc-99: The technetium content is insignificant.  
 Ra: The radium content is insignificant.  
 Th: The thorium content is insignificant.  
 U: There may be traces of uranium as metal or oxide.  
 Np: The neptunium content is insignificant.  
 Pu: There may be traces of plutonium as metal or oxide.

Metals and alloys (%wt): There are no metallic items present.

	(%wt)	Type(s) / Grade(s) with proportions	% of total C14 activity
Stainless steel.....	0		
Other ferrous metals.....	TR	There may be trace contamination by ferrous metals.	
Iron.....			
Aluminium.....	0		
Beryllium.....			
Cobalt.....			

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Copper.....	0	
Lead.....	0	
Magnox/Magnesium.....	0	
Nickel.....		
Titanium.....		
Uranium.....		
Zinc.....	0	
Zircaloy/Zirconium.....	0	
Other metals.....	0	There are no "other" metals present.

Organics (%wt):                      None expected. No halogenated plastics or rubbers will be present.

	(%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)....			
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.....	100.0		100.0
Desiccants/Catalysts.....			

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Asbestos.....	0
Non/low friable.....	
Moderately friable.....	
Highly friable.....	
Free aqueous liquids.....	0
Free non-aqueous liquids.....	0
Powder/Ash.....	0

Inorganic anions (%wt):           None of the inorganic anions listed in the table is expected to be present at greater than trace concentrations.

	(%wt)	Type(s) and comment
Fluoride.....	TR	Detected at trace levels in inactive graphite material.
Chloride.....	TR	
Iodide.....	0	
Cyanide.....	0	
Carbonate.....	TR	
Nitrate.....	TR	
Nitrite.....	TR	
Phosphate.....	TR	Detected at trace levels in inactive graphite material.
Sulphate.....	TR	Detected at trace levels in inactive graphite material.
Sulphide.....	0	

Materials of interest for waste acceptance criteria:           No materials likely to pose a fire or other non-radiological hazard have been identified. Graphite presents a low fire risk; it is difficult but not impossible to ignite.

	(%wt)	Type(s) and comment
Combustible metals.....	0	
Low flash point liquids.....	0	
Explosive materials.....	0	
Phosphorus.....	TR	Detected at trace levels in inactive graphite material.
Hydrides.....	0	
Biological etc. materials.....	0	
Biodegradable materials.....		
Putrescible wastes.....	0	
Non-putrescible wastes.....		
Corrosive materials.....	0	
Pyrophoric materials.....	0	
Generating toxic gases.....	0	
Reacting with water.....	0	
Higher activity particles.....		
Soluble solids as bulk chemical compounds.....		

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Hazardous substances / non hazardous pollutants:      none expected

	(%wt)	Type(s) and comment
Acrylamide.....		
Benzene.....		
Chlorinated solvents.....		
Formaldehyde.....		
Organometallics.....		
Phenol.....		
Styrene.....		
Tri-butyl phosphate.....		
Other organophosphates.....		
Vinyl chloride.....		
Arsenic.....	TR	Detected at trace levels in inactive graphite material.
Barium.....		
Boron.....		
Boron (in Boral).....		
Boron (non-Boral).....		
Cadmium.....		
Caesium.....		
Selenium.....		
Chromium.....		
Molybdenum.....		
Thallium.....	TR	Detected at trace levels in inactive graphite material.
Tin.....		
Vanadium.....		
Mercury compounds.....		
Others.....	TR	Gallium, germanium and rubidium detected at trace levels in inactive graphite material.
Electronic Electrical Equipment (EEE)		
EEE Type 1.....		
EEE Type 2.....		
EEE Type 3.....		
EEE Type 4.....		
EEE Type 5.....		

Complexing agents (%wt):      Yes

	(%wt)	Type(s) and comment
EDTA.....		
DPTA.....		
NTA.....		
Polycarboxylic acids.....		
Other organic complexants.....		

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Total complexing agents..... TR

Potential for the waste to contain discrete items:      Yes. Graphite Bricks/Tiles assumed to be DIs. Bricks assumed drummed (ungouted) so assumed Bricks are DIs; If gouted, Drum is also a DI. "Rubble" pieces assumed drummed (ungouted) assumed NOT DIs; If gouted, Drum is a DI.

**TREATMENT, PACKAGING AND DISPOSAL**

Planned on-site / off-site treatment(s):

Treatment	On-site / Off site	Stream volume %
Low force compaction Supercompaction (HFC) Incineration Solidification Decontamination Metal treatment Size reduction Decay storage Recycling / reuse Other / various None		100.0

Comment on planned treatments:

-

**Disposal Routes:**

Disposal Route	Stream volume %	Disposal density t/m3
Expected to be consigned to the LLW Repository Expected to be consigned to a Landfill Facility Expected to be consigned to an On-Site Disposal Facility Expected to be consigned to an Incineration Facility Expected to be consigned to a Metal Treatment Facility Expected to be consigned as Out of Scope Expected to be recycled / reused Disposal route not known	100.0	1.3

Classification codes for waste expected to be consigned to a landfill facility:      17 09 04

**Upcoming (2022/23-2024/25) Waste Routing (if expected to change from above):**

Disposal Route	Stream volume %		
	2022/23	2023/24	2024/25
Expected to be consigned to the LLW Repository Expected to be consigned to a Landfill Facility Expected to be consigned to an On-Site Disposal Facility Expected to be consigned to an Incineration Facility Expected to be consigned to a Metal Treatment Facility Expected to be consigned as Out of Scope Expected to be recycled / reused Disposal route not known			

**Opportunities for alternative disposal routing:**      -

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

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**Waste Packaging for Disposal:** (Not applicable to this waste stream)

Container	Stream volume %	Waste loading m <sup>3</sup>	Number of packages
1/3 Height IP-1 ISO			
2/3 Height IP-2 ISO			
1/2 Height WAMAC IP-2 ISO			
1/2 Height IP-2 Disposal/Re-usable ISO			
2m box (no shielding)			
4m box (no shielding)			
Other			

Other information: -

**Waste Planned for Disposal at the LLW Repository:** (Not applicable to this waste stream)

Container voidage: -

Waste Characterisation Form (WCH): -

Waste consigned for disposal to LLWR in year of generation: -

**Non-Containerised Waste for In-Vault Grouting:** (Not applicable to this waste stream)

Stream volume (%): -

Waste stream variation: -

Bounding cuboidal volume:

Inaccessible voidage: -

Other information: -

**RADIOACTIVITY**

Source: Activation of the graphite and impurities.

Uncertainty: The values quoted were derived by calculation from available material specification and are indicative of the activities that are expected. The major source of uncertainty is the impurity levels.

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 specific activities have been estimated using a neutron activation calculation. With additional data from newly calculated inventories including 100ppb U precursor as per M/EF//GEN/EAN/0008/20. Additionally 440ppb of fuel contamination was included in CHA streams because of the known fuel fire event in 1967 - although this had a relatively small impact.

Other information: There may be some contamination by Cs137. The activities quoted are those at 85 years after reactor shutdown, i.e. in 2089. Fission of trace uranium impurity in the graphite may result in some fission product and nuclide activity.

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Nuclide	Mean radioactivity, TBq/m <sup>3</sup>				Nuclide	Mean radioactivity, TBq/m <sup>3</sup>			
	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			4.15E-06	CC 2	Gd 153				8
Be 10				8	Ho 163				8
C 14			6.31E-06	CC 2	Ho 166m		2.38E-09	CC	2
Na 22				8	Tm 170				8
Al 26				8	Tm 171				8
Cl 36			2.21E-08	CC 2	Lu 174				8
Ar 39				8	Lu 176				8
Ar 42				8	Hf 178n				8
K 40				8	Hf 182				8
Ca 41			1.46E-08	CC 2	Pt 193				8
Mn 53				8	Tl 204				8
Mn 54				8	Pb 205				8
Fe 55				8	Pb 210				8
Co 60				8	Bi 208				8
Ni 59			3.21E-09	CC 2	Bi 210m				8
Ni 63			1.82E-07	CC 2	Po 210				8
Zn 65				8	Ra 223				8
Se 79			1.56E-09	CC 2	Ra 225				8
Kr 81				8	Ra 226				8
Kr 85			9.73E-07	CC 2	Ra 228				8
Rb 87				8	Ac 227				8
Sr 90			2.99E-04	CC 2	Th 227				8
Zr 93			8.35E-08	CC 2	Th 228				8
Nb 91				8	Th 229				8
Nb 92				8	Th 230				8
Nb 93m			7.58E-08	CC 2	Th 232				8
Nb 94				8	Th 234				8
Mo 93				8	Pa 231				8
Tc 97				8	Pa 233		1.05E-09	CC	2
Tc 99			5.3E-07	CC 2	U 232				8
Ru 106				8	U 233				8
Pd 107			7.63E-09	CC 2	U 234		1.23E-08	CC	2
Ag 108m				8	U 235				8
Ag 110m				8	U 236				8
Cd 109				8	U 238		7.39E-09	CC	2
Cd 113m				8	Np 237		1.28E-09	CC	2
Sn 119m				8	Pu 236				8
Sn 121m			2.72E-07	CC 2	Pu 238		1.63E-05	CC	2
Sn 123				8	Pu 239		4.11E-06	CC	2
Sn 126			3.14E-08	CC 2	Pu 240		1.76E-05	CC	2
Sb 125				8	Pu 241		2.3E-05	CC	2
Sb 126			4.17E-09	CC 2	Pu 242		2.16E-07	CC	2
Te 125m				8	Am 241		3.7E-05	CC	2
Te 127m				8	Am 242m		4.96E-08	CC	2
I 129				8	Am 243		5.44E-06	CC	2
Cs 134				8	Cm 242		3.43E-08	CC	2
Cs 135			2.45E-08	CC 2	Cm 243		5.33E-08	CC	2
Cs 137			5.79E-04	CC 2	Cm 244		1.58E-04	CC	2
Ba 133				8	Cm 245		3.2E-07	CC	2
La 137				8	Cm 246		2.3E-06	CC	2
La 138				8	Cm 248				8
Ce 144				8	Cf 249		7.57E-09	CC	2
Pm 145				8	Cf 250		1.23E-09	CC	2
Pm 147				8	Cf 251				8
Sm 147				8	Cf 252				8
Sm 151			2.71E-06	CC 2	Other a				
Eu 152			3.96E-07	CC 2	Other b/g				
Eu 154			4.49E-07	CC 2	<b>Total a</b>	<b>0</b>	<b>2.41E-04</b>	<b>CC</b>	<b>2</b>
Eu 155				8	<b>Total b/g</b>	<b>0</b>	<b>9.17E-04</b>	<b>CC</b>	<b>2</b>

**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