

<b>WASTE STREAM</b>	<b>9A321</b>	<b>Graphite ILW</b>
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**SITE** Berkeley  
**SITE OWNER** Nuclear Decommissioning Authority  
**WASTE CUSTODIAN** Magnox Limited  
**WASTE TYPE** ILW

**WASTE VOLUMES**

		Reported
Stocks:	At 1.4.2019.....	0 m <sup>3</sup>
Future arisings -	1.4.2074 - 31.3.2077.....	3121.0 m <sup>3</sup>
Total future arisings:		3121.0 m <sup>3</sup>
Total waste volume:		3121.0 m <sup>3</sup>

Comment on volumes: This waste stream describes the graphite that is now identified as ILW. Waste arisings are assumed to occur at a uniform rate over 3 years. Final Dismantling & Site Clearance is assumed to commence in 2070 with reactor dismantling commencing in 2074 and lasting for 3 years. Volumes and radioactivity have been calculated for 85 years after reactor shutdown, i.e. 2074.

Uncertainty factors on volumes:

Stock (upper):	x	Arisings (upper)	x 1.2
Stock (lower):	x	Arisings (lower)	x 0.8

**WASTE SOURCE** Moderator and reflector graphite from reactor dismantling.

**PHYSICAL CHARACTERISTICS**

General description: Graphite blocks and other graphite components. Waste can be packaged in standard ILW packages.  
 Physical components (%vol): Graphite (100%).  
 Sealed sources: -  
 Bulk density (t/m<sup>3</sup>): ~1.25  
 Comment on density: The density is of the waste as cut for packaging. Density estimate based upon assumed packing efficiency of the waste with 90% of the graphite in blocks and 10% as 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.  
 Cl-36: The chlorine 36 will probably be chemically bound to the graphite. Some may be linked chemically with impurities in the graphite.  
 U: There may be traces of uranium as metal or oxide.  
 Pu: There may be traces of plutonium as metal or oxide.

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

Stainless steel.....	TR
Other ferrous metals.....	TR
Iron.....	
Aluminium.....	0
Beryllium.....	TR
Cobalt.....	
Copper.....	0
Lead.....	0
Magnox/Magnesium.....	0
Nickel.....	

There may be trace contamination by ferrous metals.

**WASTE STREAM****9A321****Graphite ILW**

	Titanium.....	
	Uranium.....	
	Zinc.....	0
	Zircaloy/Zirconium.....	0
	Other metals.....	0
		There are no "other" metals present.
Organics (%wt):	None expected. Halogenated plastics or rubbers will not be present.	
	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):	Expect only graphite.	
	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
	Desiccants/Catalysts.....	
	Asbestos.....	0
	Non/low friable.....	
	Moderately friable.....	
	Highly friable.....	
	Free aqueous liquids.....	0
	Free non-aqueous liquids.....	0
	Powder/Ash.....	0

<b>WASTE STREAM</b>	<b>9A321</b>	<b>Graphite ILW</b>
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Inorganic anions (%wt):

None of the inorganic anions listed in the table is expected to be present at greater than trace concentrations.

Fluoride.....	TR	Detected at trace levels in inactive graphite material.
Chloride.....	TR	
Iodide.....	0	
Cyanide.....	0	
Carbonate.....	TR	
Nitrate.....	TR	
Nitrite.....	0	
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.

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	
Active particles.....		
Soluble solids as bulk chemical compounds.....		

Hazardous substances / non hazardous pollutants:

None expected.

Acrylamide.....
Benzene.....
Chlorinated solvents.....
Formaldehyde.....
Organometallics.....
Phenol.....
Styrene.....
Tri-butyl phosphate.....
Other organophosphates.....
Vinyl chloride.....

**WASTE STREAM****9A321****Graphite ILW**

Arsenic.....	TR	Detected at trace levels in inactive graphite material.
Barium.....		
Boron.....		
Cadmium.....		
Caesium.....		
Selenium.....		
Chromium.....		
Molybdenum.....		
Thallium.....	TR	Detected at trace levels in inactive graphite material.
Tin.....		
Vanadium.....		
Mercury compounds.....		
Others.....	TR	
Electronic Electrical Equipment (EEE)		
EEE Type 1.....		
EEE Type 2.....		
EEE Type 3.....		
EEE Type 4.....		
EEE Type 5.....		
Complexing agents (%wt):		
EDTA.....		
DPTA.....		
NTA.....		
Polycarboxylic acids.....		
Other organic complexants.....		
Total complexing agents.....	TR	

**PACKAGING AND CONDITIONING**

Conditioning method:	The waste is not expected to be supercompacted. It will be placed in baskets in the waste packages followed by conditioning with BFS/OPC.
Plant Name:	None
Location:	Berkeley Site
Plant startup date:	2074
Total capacity (m <sup>3</sup> /y incoming waste):	~5000.0
Target start date for packaging this stream:	2074
Throughput for this stream (m <sup>3</sup> /y incoming waste):	~780.0
Other information:	It is currently intended that FSC wastes will be grouted.

**WASTE STREAM 9A321 Graphite ILW**

Likely container type:	Container	Waste packaged (%vol)	Waste loading (m <sup>3</sup> )	Payload (m <sup>3</sup> )	Number of packages
	4m box (no shielding)	100.0	16.2	18.9	193

Likely container type comment: The waste is assumed to be in baskets in the waste package so the occupied volume in the package is greater than the original waste volume. Container choice may be influenced by Transport Regulations at the time of Final Site Clearance.

Range in container waste volume: Not yet determined. No significant variability is expected.

Other information on containers: The container material is expected to be stainless steel.

Likely conditioning matrix: Blast Furnace Slag / Ordinary Portland Cement

Other information: -

Conditioned density (t/m<sup>3</sup>): ~1.7

Conditioned density comment: The conditioned waste density assumes the waste will be encapsulated.

Other information on conditioning: The waste will be in baskets placed in the waste packages. Baskets of different Final Dismantling & Site Clearance ILW wastes may be in the same waste package. As encapsulation is now intended, the matrix would be likely to be BFS/OPC and the density of the conditioned waste product would be about 1.7 t/m<sup>3</sup>.

Opportunities for alternative disposal routing: No

Treatment	Stream volume (%)	Comment
-	-	-

**RADIOACTIVITY**

Source: Activation of 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: Total beta/gamma is defined as the sum of the listed activities of all nuclides other than alpha emitters. Activity estimates for individual alpha emitting nuclides have not been provided.

Measurement of radioactivities: The specific activities have been estimated using a neutron activation calculation.

Other information: There may be some contamination by Cs137. The activities quoted are those at 85 years after reactor shutdown, i.e. in 2074. Fission of trace uranium impurity in the graphite may result in some fission product and actinide activity.

**WASTE STREAM 9A321 Graphite ILW**

Nuclide	Mean radioactivity, TBq/m <sup>3</sup>				Nuclide	Mean radioactivity, TBq/m <sup>3</sup>			
	Waste at 1.4.2019	Bands and Code	Future arisings	Bands and Code		Waste at 1.4.2019	Bands and Code	Future arisings	Bands and Code
H 3			6.09E-03	C C 2	Gd 153				8
Be 10				8	Ho 163				8
C 14			7.67E-02	C C 2	Ho 166m		4.92E-07	C C 2	
Na 22				8	Tm 170				8
Al 26				8	Tm 171				8
Cl 36			2.01E-04	C C 2	Lu 174				8
Ar 39				8	Lu 176				8
Ar 42				8	Hf 178n				8
K 40				8	Hf 182				8
Ca 41			2.02E-04	C C 2	Pt 193				8
Mn 53				8	Tl 204				8
Mn 54				8	Pb 205				8
Fe 55				8	Pb 210				8
Co 60			6.42E-07	C C 2	Bi 208				8
Ni 59			2.6E-05	C C 2	Bi 210m				8
Ni 63			1.85E-03	C C 2	Po 210				8
Zn 65				8	Ra 223				8
Se 79				8	Ra 225				8
Kr 81				8	Ra 226				8
Kr 85				8	Ra 228				8
Rb 87				8	Ac 227				8
Sr 90				6	Th 227				8
Zr 93				8	Th 228				8
Nb 91				8	Th 229				8
Nb 92				8	Th 230				8
Nb 93m				8	Th 232				8
Nb 94			1.68E-07	C C 2	Th 234				8
Mo 93				8	Pa 231				8
Tc 97				8	Pa 233				8
Tc 99				8	U 232				8
Ru 106				8	U 233				8
Pd 107				8	U 234				8
Ag 108m			3.47E-07	C C 2	U 235				8
Ag 110m				8	U 236				8
Cd 109				8	U 238				8
Cd 113m				8	Np 237				8
Sn 119m				8	Pu 236				8
Sn 121m			1.15E-04	C C 2	Pu 238				6
Sn 123				8	Pu 239				6
Sn 126				8	Pu 240				6
Sb 125				8	Pu 241				8
Sb 126				8	Pu 242				8
Te 125m				8	Am 241				6
Te 127m				8	Am 242m				8
I 129				8	Am 243				8
Cs 134				8	Cm 242				8
Cs 135				8	Cm 243				8
Cs 137				8	Cm 244				8
Ba 133			5.42E-07	C C 2	Cm 245				8
La 137				8	Cm 246				8
La 138				8	Cm 248				8
Ce 144				8	Cf 249				8
Pm 145			5.3E-08	C C 2	Cf 250				8
Pm 147				8	Cf 251				8
Sm 147				8	Cf 252				8
Sm 151			5.53E-07	C C 2	Other a				
Eu 152			1.33E-07	C C 2	Other b/g				
Eu 154			2.2E-07	C C 2	<b>Total a</b>	<b>0</b>	<b>0</b>		
Eu 155			1.22E-09	C C 2	<b>Total b/g</b>	<b>0</b>	<b>8.52E-02</b>	<b>C C 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