WASTE STREAM 9B316 Graphite LLW

SITE	Bradwell
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 m³
Future arisings -	1.4.2087 - 31.3.2090.....	215.0 m³
Total future arisings:		215.0 m³
Total waste volume:		215.0 m³

Comment on volumes: Some graphite that was previously identified as LLW is now ILW. Final Dismantling & Site Clearance is assumed to commence in 2083 with reactor dismantling commencing in 2087 and lasting for three years. Volumes and radioactivity have been calculated for 85 years after reactor shutdown, i.e. 2087.

Uncertainty factors on volumes:

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

WASTE SOURCE Reflector and thermal column graphite from reactor dismantling.

PHYSICAL CHARACTERISTICS

General description:	Graphite blocks and other graphite components. Waste can be packaged in standard waste packages.
Physical components (%wt):	Graphite (~100%).
Sealed sources:	The waste does not contain sealed sources.
Bulk density (t/m³):	~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: Carbon 14 will be present as graphite. Cl-36: Chlorine 36 will probably be chemically bound to the graphite. Some may be linked chemically with impurities in the graphite. Pu: Traces of plutonium as metal or oxide.
Metals and alloys (%wt):	-

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

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Magnox/Magnesium	0
Nickel	
Titanium	
Uranium	
Zinc	0
Zircaloy/Zirconium	0
Other metals	0

Organics (%wt): None expected.

	(%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): Expect only graphite.

	(%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			
Asbestos	0		
Non/low friable			

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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 concentration.

	(%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.....	0	
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.....		

Hazardous substances / non hazardous pollutants: None expected

	(%wt)	Type(s) and comment
Acrylamide.....		

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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.....		
Total complexing agents.....	TR	

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

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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		100.0
Decontamination		
Metal treatment		
Size reduction		
Decay storage		
Recyling / reuse		
Other / various		
None		

Comment on planned treatments: The waste will be placed into baskets. Baskets of different Final Site Clearance LLW may be placed in the same package. The occupied volume in the package is greater than the original waste volume. A conditioning factor of 1.167 has been assumed to allow for the waste being placed in baskets before loading into standard 4m boxes. The waste will then be encapsulated.

Disposal Routes:

Disposal Route	Stream volume %	Disposal density t/m3
Expected to be consigned to the LLW Repository	100.0	1.3
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		

Classification codes for waste expected to be consigned to a landfill facility: -

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
-	-	-	-	-	-

Waste Packaging for Disposal:

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Container	Stream volume %	Waste loading m³	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	100.0	16.2	14

Other information: Data have been presented as though the waste will be in dedicated containers. However it is likely that this waste will be placed in containers with other LLW. The type of container to be used is currently under review.

Waste Planned for Disposal at the LLW Repository:

Container voidage: Inaccessible voidage is not expected.

Waste Characterisation Form (WCH): The waste meets the LLWR's Waste Acceptance Criteria (WAC). The waste does not have a current WCH.

Waste consigned for disposal to LLWR in year of generation: It will not arise until the reactors are dismantled and it is expected to be packaged immediately for disposal.

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 were estimated from neutron activation calculations of the material and its impurities. Additional data from newly calculated inventories including 100 ppb U precursor as per M/EF/GEN/EAN/0008/20

Other information: The activities quoted are those at 85 years after reactor shutdown, i.e. in 2087. There may be some contamination by Cs137. Fission of trace uranium impurity in the graphite may result in some fission product and actinide activity.

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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			1.62E-03	C C 2	Gd 153				8
Be 10				8	Ho 163				8
C 14			3.42E-03	C C 2	Ho 166m			3.36E-08	C C 2
Na 22				8	Tm 170				8
Al 26				8	Tm 171				8
Cl 36			9.97E-06	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			8.45E-06	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			1.33E-08	C C 2	Bi 208				8
Ni 59			1.45E-06	C C 2	Bi 210m				8
Ni 63			8.39E-05	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			8.74E-07	C C 2	Ra 228				8
Rb 87				8	Ac 227				8
Sr 90			2.75E-04	C C 2	Th 227				8
Zr 93			7.91E-08	C C 2	Th 228				8
Nb 91				8	Th 229				8
Nb 92				8	Th 230				8
Nb 93m			7.58E-08	C C 2	Th 232				8
Nb 94			3.77E-09	C C 2	Th 234				8
Mo 93				8	Pa 231				8
Tc 97				8	Pa 233			1.05E-09	C C 2
Tc 99			4.93E-07	C C 2	U 232				8
Ru 106				8	U 233				8
Pd 107			7.4E-09	C C 2	U 234			6.28E-09	C C 2
Ag 108m			5.6E-08	C C 2	U 235				8
Ag 110m				8	U 236				8
Cd 109				8	U 238				8
Cd 113m				8	Np 237			1.05E-09	C C 2
Sn 119m				8	Pu 236				8
Sn 121m			8.01E-06	C C 2	Pu 238			1.59E-05	C C 2
Sn 123				8	Pu 239			1.73E-06	C C 2
Sn 126			2.97E-08	C C 2	Pu 240			1.52E-05	C C 2
Sb 125				8	Pu 241			1.97E-05	C C 2
Sb 126			4.16E-09	C C 2	Pu 242			2.14E-07	C C 2
Te 125m				8	Am 241			3.65E-05	C C 2
Te 127m				8	Am 242m			4.17E-08	C C 2
I 129				8	Am 243			5.44E-06	C C 2
Cs 134				8	Cm 242			3.44E-08	C C 2
Cs 135			2.24E-08	C C 2	Cm 243			5.3E-08	C C 2
Cs 137			5.44E-04	C C 2	Cm 244			1.58E-04	C C 2
Ba 133			1.73E-08	C C 2	Cm 245			3.2E-07	C C 2
La 137				8	Cm 246			2.31E-06	C C 2
La 138				8	Cm 248				8
Ce 144				8	Cf 249			7.58E-09	C C 2
Pm 145			2.22E-09	C C 2	Cf 250			1.23E-09	C C 2
Pm 147				8	Cf 251				8
Sm 147				8	Cf 252				8
Sm 151			3.31E-06	C C 2	Other a				
Eu 152			6.19E-06	C C 2	Other b/g				
Eu 154			6.14E-07	C C 2	**Total a**	**0**		**2.36E-04**	**C C 2**
Eu 155			1.62E-09	C C 3	**Total b/g**	**0**		**6.00E-03**	**C C 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