

WASTE STREAM	7G104	Long-Lived ILW from Decommissioned Submarines
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SITE Rosyth & Devonport (Submarines)

SITE OWNER Ministry of Defence

WASTE CUSTODIAN Babcock and Ministry of Defence

WASTE TYPE ILW

Is the waste subject to Scottish Policy: No

WASTE VOLUMES

		Reported
Stocks:	At 1.4.2022.....	0 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 - 31.3.2026.....	2.5 m ³
	1.4.2026 - 31.3.2027.....	0 m ³
	1.4.2027 - 31.3.2028.....	0 m ³
	1.4.2028 - 31.3.2029.....	2.4 m ³
	1.4.2029 - 31.3.2030.....	2.5 m ³
	1.4.2030 - 31.3.2031.....	2.5 m ³
	1.4.2031 - 31.3.2032.....	2.5 m ³
	1.4.2032 - 31.3.2033.....	2.2 m ³
	1.4.2033 - 31.3.2034.....	2.5 m ³
	1.4.2034 - 31.3.2035.....	0 m ³
	1.4.2035 - 31.3.2036.....	2.4 m ³
	1.4.2036 - 31.3.2037.....	2.5 m ³
	1.4.2037 - 31.3.2038.....	0 m ³
	1.4.2038 - 31.3.2039.....	2.5 m ³
	1.4.2039 - 31.3.2040.....	0 m ³
	1.4.2040 - 31.3.2041.....	2.4 m ³
	1.4.2041 - 31.3.2042.....	0 m ³
	1.4.2042 - 31.3.2043.....	2.5 m ³
	1.4.2043 - 31.3.2044.....	2.4 m ³
	1.4.2044 - 31.3.2045.....	0 m ³
	1.4.2045 - 31.3.2046.....	2.4 m ³
	1.4.2046 - 31.3.2047.....	0 m ³
	1.4.2047 - 31.3.2048.....	2.3 m ³
	1.4.2048 - 31.3.2049.....	0 m ³
	1.4.2049 - 31.3.2050.....	2.5 m ³
	1.4.2050 - 31.3.2051.....	2.5 m ³
	1.4.2051 - 31.3.2052.....	0 m ³
	1.4.2052 - 31.3.2053.....	2.5 m ³
	1.4.2053 - 31.3.2054.....	0 m ³
	1.4.2054 - 31.3.2055.....	2.5 m ³
	1.4.2055 - 31.3.2056.....	0 m ³
	1.4.2056 - 31.3.2057.....	2.5 m ³
	1.4.2057 - 31.3.2058.....	2.5 m ³
	1.4.2058 - 31.3.2059.....	0 m ³
	1.4.2059 - 31.3.2060.....	2.5 m ³
	1.4.2060 - 31.3.2061.....	0 m ³
	1.4.2061 - 31.3.2062.....	2.0 m ³
	1.4.2062 - 31.3.2063.....	0 m ³
	1.4.2063 - 31.3.2064.....	2.0 m ³
	1.4.2064 - 31.3.2065.....	2.0 m ³
	1.4.2065 - 31.3.2066.....	0 m ³
	1.4.2066 - 31.3.2067.....	2.0 m ³
	1.4.2067 - 31.3.2068.....	0 m ³
	1.4.2068 - 31.3.2069.....	2.0 m ³
	1.4.2069 - 31.3.2070.....	3.0 m ³

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1.4.2070 - 31.3.2071.....	0 m ³
1.4.2071 - 31.3.2072.....	0 m ³
1.4.2072 - 31.3.2073.....	3.0 m ³
1.4.2073 - 31.3.2074.....	0 m ³
1.4.2074 - 31.3.2075.....	0 m ³
1.4.2075 - 31.3.2076.....	3.0 m ³
1.4.2076 - 31.3.2077.....	0 m ³
1.4.2077 - 31.3.2078.....	0 m ³
1.4.2078 - 31.3.2079.....	0 m ³
1.4.2079 - 31.3.2080.....	3.0 m ³
1.4.2080 - 31.3.2081.....	0 m ³
1.4.2081 - 31.3.2082.....	3.0 m ³
1.4.2082 - 31.3.2083.....	0 m ³
1.4.2083 - 31.3.2084.....	3.0 m ³
1.4.2084 - 31.3.2085.....	0 m ³
1.4.2085 - 31.3.2086.....	3.0 m ³
1.4.2086 - 31.3.2087.....	0 m ³
1.4.2087 - 31.3.2088.....	0 m ³
1.4.2088 - 31.3.2089.....	0 m ³
1.4.2089 - 31.3.2090.....	3.0 m ³
1.4.2090 - 31.3.2091.....	0 m ³
1.4.2091 - 31.3.2092.....	3.0 m ³
1.4.2092 - 31.3.2093.....	0 m ³
1.4.2093 - 31.3.2094.....	3.0 m ³
1.4.2094 - 31.3.2095.....	0 m ³
1.4.2095 - 31.3.2096.....	3.0 m ³
1.4.2096 - 31.3.2097.....	0 m ³
1.4.2097 - 31.3.2098.....	0 m ³
1.4.2098 - 31.3.2099.....	0 m ³
1.4.2099 - 31.3.2100.....	0 m ³
1.4.2100 - 31.3.2101.....	0 m ³
1.4.2101 - 31.3.2102.....	0 m ³
1.4.2102 - 31.3.2103.....	0 m ³
1.4.2103 - 31.3.2104.....	0 m ³
1.4.2104 - 31.3.2105.....	0 m ³
1.4.2105 - 31.3.2106.....	0 m ³
1.4.2106 - 31.3.2107.....	0 m ³
1.4.2107 - 31.3.2108.....	0 m ³
1.4.2108 - 31.3.2109.....	0 m ³
1.4.2109 - 31.3.2110.....	0 m ³
1.4.2110 - 31.3.2111.....	0 m ³
1.4.2111 - 31.3.2112.....	0 m ³
1.4.2112 - 31.3.2113.....	0 m ³
1.4.2113 - 31.3.2114.....	0 m ³

Total future arisings:	96.6 m ³
Total waste volume:	96.6 m ³

Comment on volumes: Existing stock is zero. Radioactive material within laid-up submarines is not categorised as waste until dismantling commences. The rate of arising will be determined by the submarine decommissioning project programme schedule. Estimates after the current SDP scope (Astute-class and Dreadnought-class) have been made based on rough in-service dates, pay-off date and layup period prior to dismantling operations. No information is available on the predicted activations of the Dreadnought-class reactors so the PWR2 data has been used as an approximation. Waste volumes are based on the raw ILW waste as a proportion of the total volume of materials from a reactor. ILW arising rate is based on the Submarine Dismantling Project's programme for the decommissioning of 27 nuclear submarines in scope with the inclusion of Astute-class and future Dreadnought-class. Reactor decommissioning will comprise removal and storage of reactor pressure vessels (RPV) for a minimum 20 year period pending availability of the GDF and an emplacement slot in the GDF programme. Volume figures are based on the raw volume of steel wastes based on an activation model that has been decayed to boat specific shutdown durations (time between final reactor shutdown and scheduled SDP dismantling). Volume uncertainty figures are based on the upper and lower estimates of waste mass, which is dependent on

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Zircaloy/Zirconium.....	~0	
Other metals.....	~0.40	The total of Cr, V, Ni and Ti <0.2%; S, P, Cu, Sn and As <0.18%.

Organics (%wt): None

	(%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): -

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

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Inorganic anions (%wt): There is no evidence of inorganic anions in this waste stream.

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

Hazardous substances / non hazardous pollutants: None

	(%wt)	Type(s) and comment
Acrylamide.....		
Benzene.....	0	
Chlorinated solvents.....		
Formaldehyde.....		
Organometallics.....		
Phenol.....	0	
Styrene.....		
Tri-butyl phosphate.....	0	

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Other organophosphates.....	
Vinyl chloride.....	0
Arsenic.....	0
Barium.....	
Boron.....	0
Boron (in Boral).....	
Boron (non-Boral).....	
Cadmium.....	0
Caesium.....	
Selenium.....	0
Chromium.....	0
Molybdenum.....	0
Thallium.....	
Tin.....	0
Vanadium.....	0
Mercury compounds.....	
Others.....	0
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.....	0	
Other organic complexants.....	0	
Total complexing agents.....	0	

Potential for the waste to contain discrete items: Yes.

PACKAGING AND CONDITIONING

Conditioning method: None planned.
Plant Name: -
Location: -
Plant startup date: -
Total capacity (m³/y incoming waste): -
Target start date for packaging this stream: -
Throughput for this stream (m³/y incoming waste): -

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Other information: -

Likely container type:	Container	Waste packaged (%vol)	Waste loading (m ³)	Payload (m ³)	Number of packages
	3m ³ box (square corners)	100.0	~0.28	~2.8	345

Likely container type comment: 3 cu.m box with displacement volume of 3.6m³. Baseline assumptions of 20te ILW and 9 boxes per submarine yield a loading of 0.28m³ per container. This baseline assumption reflects a change to the shutdown period which results in a reduced ILW volume/mass and is based on PWR1 reactors. The estimate for PWR2s (and PWR3s) is that unconditioned waste will be approximately 3m³ requiring 11 boxes per boat.

Range in container waste volume: A minimum of 7 and a maximum of 14 3m³ boxes per submarine will be required. Current assumption is that 9 boxes will be required for PWR1 boats and 11 for PWR2 boats.

Other information on containers: -

Likely conditioning matrix: None

Other information: -

Conditioned density (t/m³): ~0.6

Conditioned density comment: Conditioned density is the mass loaded per container (2.29 te) divided by the container displacement volume (3.6m³).

Other information on conditioning: Note that packaging of waste will be a "just in time" approach for disposal at the GDF. Current volume estimates are raw waste based on the proportion of ILW per reactor. Volumes of disposal containers will increase in accordance with the above assessment but exact quantities will depend on decay, cut plan and packing density.

Opportunities for alternative disposal routing: Yes

Baseline Management Route	Opportunity Management Route	Stream volume (%)	Estimated Date that Opportunity will be realised	Opportunity Confidence	Comment
Disposal at a Geological Disposal Facility	Disposal at a Near Surface / Near Site Disposal Facility	100.0	-	Medium	Opportunity will depend on WAC at a new Near Surface facility and the activity/risk assessments

RADIOACTIVITY

Source: The main source of radioactivity is due to the neutron activation of the steel PWR pressure vessel. Short-lived activity is present in activated corrosion products deposited on the internal surfaces of components within the RPV.

Uncertainty: ATTILA and CAIRN computer codes were used to model neutron fluxes for representative cores and operating histories. The flux modelling code was validated to within ±30% of measured values. Taking account of uncertainty in nuclear data, material composition and reactor power history increases this uncertainty to an overall value of ±50%.

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: ATTILA and CAIRN computer codes were used to model neutron fluxes for representative cores and operating histories. Crud deposition within primary circuit components was modelled using the Rolls Royce CRUD code. Material specifications, impurity levels and neutron fluxes were taken from manufacturer's data, safety justification studies and other available data sources.

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					Gd 153				
Be 10					Ho 163				
C 14			~5.76E-02	AB 2	Ho 166m				
Na 22					Tm 170				
Al 26					Tm 171				
Cl 36					Lu 174				
Ar 39					Lu 176				
Ar 42					Hf 178n				
K 40					Hf 182				
Ca 41					Pt 193				
Mn 53					Tl 204				
Mn 54			~1.70E-11	AB 2	Pb 205				
Fe 55			~2.56E-02	AB 2	Pb 210				
Co 60			~4.20E-01	AB 2	Bi 208				
Ni 59			~2.77E-01	AB 2	Bi 210m				
Ni 63			~2.48E+01	AB 2	Po 210				
Zn 65					Ra 223				
Se 79					Ra 225				
Kr 81					Ra 226				
Kr 85					Ra 228				
Rb 87					Ac 227				
Sr 90					Th 227				
Zr 93			~6.58E-11	AB 2	Th 228				
Nb 91					Th 229				
Nb 92					Th 230				
Nb 93m			~2.96E-04	AB 2	Th 232				
Nb 94			~2.19E-05	AB 2	Th 234				
Mo 93			~1.14E-04	AB 2	Pa 231				
Tc 97					Pa 233				
Tc 99			~1.54E-06	AB 2	U 232				
Ru 106					U 233				
Pd 107					U 234				
Ag 108m					U 235				
Ag 110m					U 236				
Cd 109					U 238				
Cd 113m					Np 237				
Sn 119m			~2.35E-15	AB 2	Pu 236				
Sn 121m			~2.59E-04	AB 2	Pu 238				
Sn 123			4.47E-31	AB 2	Pu 239				
Sn 126					Pu 240				
Sb 125			~1.28E-07	AB 2	Pu 241				
Sb 126					Pu 242				
Te 125m			~4.76E-61	AB 2	Am 241				
Te 127m			~1.68E-45	AB 2	Am 242m				
I 129					Am 243				
Cs 134					Cm 242				
Cs 135					Cm 243				
Cs 137					Cm 244				
Ba 133					Cm 245				
La 137					Cm 246				
La 138					Cm 248				
Ce 144					Cf 249				
Pm 145					Cf 250				
Pm 147					Cf 251				
Sm 147					Cf 252				
Sm 151					Other a				
Eu 152					Other b/g		~1.59E-15	AB 2	
Eu 154					Total a	0	0		
Eu 155					Total b/g	0	~2.56E+01	AB 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