

WASTE STREAM	7G103	LLW 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 LLW

Is the waste subject to
Scottish Policy: No

WASTE VOLUMES

	Reported
Stocks:	At 1.4.2022..... 29.6 m ³
Future arisings -	
	1.4.2022 - 31.3.2023..... 9.3 m ³
	1.4.2023 - 31.3.2024..... 18.0 m ³
	1.4.2024 - 31.3.2025..... 0 m ³
	1.4.2025 - 31.3.2026..... 10.6 m ³
	1.4.2026 - 31.3.2027..... 0 m ³
	1.4.2027 - 31.3.2028..... 20.0 m ³
	1.4.2028 - 31.3.2029..... 20.0 m ³
	1.4.2029 - 31.3.2030..... 10.6 m ³
	1.4.2030 - 31.3.2031..... 20.0 m ³
	1.4.2031 - 31.3.2032..... 0 m ³
	1.4.2032 - 31.3.2033..... 2.0 m ³
	1.4.2035 - 31.3.2036..... 40.0 m ³
	1.4.2039 - 31.3.2040..... 20.0 m ³
	1.4.2041 - 31.3.2042..... 20.0 m ³
	1.4.2043 - 31.3.2044..... 20.0 m ³
	1.4.2044 - 31.3.2045..... 20.0 m ³
	1.4.2046 - 31.3.2047..... 20.0 m ³
	1.4.2048 - 31.3.2049..... 20.0 m ³
	1.4.2049 - 31.3.2050..... 20.0 m ³
	1.4.2051 - 31.3.2052..... 20.0 m ³
	1.4.2052 - 31.3.2053..... 20.0 m ³
	1.4.2055 - 31.3.2056..... 20.0 m ³
	1.4.2056 - 31.3.2057..... 20.0 m ³
	1.4.2058 - 31.3.2059..... 20.0 m ³
	1.4.2060 - 31.3.2061..... 20.0 m ³
	1.4.2062 - 31.3.2063..... 20.0 m ³
	1.4.2064 - 31.3.2065..... 20.0 m ³
	1.4.2065 - 31.3.2066..... 20.0 m ³
	1.4.2067 - 31.3.2068..... 20.0 m ³
	1.4.2068 - 31.3.2069..... 20.0 m ³
	1.4.2069 - 31.3.2070..... 5.1 m ³
	1.4.2070 - 31.3.2071..... 30.2 m ³
	1.4.2071 - 31.3.2072..... 30.2 m ³
	1.4.2072 - 31.3.2073..... 30.2 m ³
	1.4.2073 - 31.3.2074..... 10.2 m ³
	1.4.2074 - 31.3.2075..... 30.2 m ³
	1.4.2075 - 31.3.2076..... 30.2 m ³
	1.4.2076 - 31.3.2077..... 10.2 m ³
	1.4.2077 - 31.3.2078..... 30.2 m ³
	1.4.2078 - 31.3.2079..... 30.2 m ³
	1.4.2079 - 31.3.2080..... 10.2 m ³
	1.4.2080 - 31.3.2081..... 10.2 m ³
	1.4.2081 - 31.3.2082..... 30.2 m ³
	1.4.2082 - 31.3.2083..... 10.2 m ³
	1.4.2083 - 31.3.2084..... 10.2 m ³
	1.4.2084 - 31.3.2085..... 10.2 m ³
	1.4.2085 - 31.3.2086..... 10.2 m ³
	1.4.2086 - 31.3.2087..... 5.1 m ³

WASTE STREAM	7G103	LLW from Decommissioned Submarines
---------------------	--------------	---

	1.4.2090 - 31.3.2091.....	25.1 m ³
	1.4.2092 - 31.3.2093.....	25.1 m ³
	1.4.2094 - 31.3.2095.....	25.1 m ³
	1.4.2096 - 31.3.2097.....	25.1 m ³

Total future arisings: 944.3 m³

Total waste volume: 973.9 m³

Comment on volumes: Production period is based on the 27 boats currently within scope of SDP, plus seven existing/planned Astute boats and four future Dreadnought class boats. Existing stock comprises LLW from the first two initial-dismantled submarines, including steam generators from one of those submarines. Subsequently, primary circuit LLW will be disposed of at approximately two-year intervals, lagging completion of the ABC23 dismantling programme by one year. It is assumed that a GDF is operational from 2040 and that RPVs are removed from the interim ILW store from 2070, size-reduced, and ILW consigned to the GDF and LLW to a LLW disposal site at six-month intervals. Dreadnought RPVs would be consigned direct to the GDF. LLW/ILW partitioning in RPV body and internal components has not been determined empirically and is subject to +/- 50% modelling error.

Uncertainty factors on volumes:

Stock (upper):	x 1.0	Arisings (upper)	x 1.5
Stock (lower):	x 1.0	Arisings (lower)	x 0.5

WASTE SOURCE Dismantling of nuclear steam-raising plant.

PHYSICAL CHARACTERISTICS

General description: The waste is composed of PWR primary circuit components that are contaminated with activated crud, together with activated structural steel from the primary shield tank. Baseline assumption is that at the end of decay storage the RPV will be size-reduced and LLW disposed to the LLWR. Size reduction of vessels, pipework, and components, will be performed to achieve configuration that is compatible with standard disposal containers.

Physical components (%wt): Primary circuit vessels, pumps etc. (45%); steam generators (25%); Primary Shield Tank structure (10%); RPV LLW (20%).

Sealed sources: The waste does not contain sealed sources.

Bulk density (t/m³): ~7.9

Comment on density: Quoted density is that of stainless steel.

CHEMICAL COMPOSITION

General description and components (%wt): Stainless steel and ferrous metal (100%wt).

Chemical state: Neutral

Chemical form of radionuclides:

- H-3: Present in magnetite crud layer
- C-14: Present in magnetite crud layer and activated steel
- Cl-36: Present in magnetite crud layer
- Tc-99: Present in magnetite crud layer
- I-129: Present in magnetite crud layer
- U: Present in magnetite crud layer

Metals and alloys (%wt): Steel plate 6% - thickness approximately 50mm; steel plate 4% - thickness 25mm; stainless steel 85% - pipework outside diameters approximately 13mm to 360mm. Low alloy steel (5%) pipework outside diameters 13mm to 360mm.

	(%wt)	Type(s) / Grade(s) with proportions	% of total C14 activity
Stainless steel.....	~90.0	Stainless steel: C <0.08%; Si >0.2<0.8%; Cr >16.25 <17.5%; Ni >11<13%; Mn<2%; Co <0.05%; Ta <0.03%; P <0.035%; S <0.03%; N <0.08%; Mo >2<2.7%; Fe balance.	100.0
Other ferrous metals.....	~10.0	Structural (low alloy) steel: C <0.15%; Si <0.3%; Mn <1.2%; Ni <1.2%; Mo <0.5%; V <0.12%; S <0.04%; P <0.03%.	
Iron.....			
Aluminium.....	0		

WASTE STREAM	7G103	LLW from Decommissioned Submarines
---------------------	--------------	---

Beryllium.....	0
Cobalt.....	TR
Copper.....	TR
Lead.....	0
Magnox/Magnesium.....	0
Nickel.....	0
Titanium.....	0
Uranium.....	0
Zinc.....	0
Zircaloy/Zirconium.....	TR
Other metals.....	0

Organics (%wt): -

	(%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.....	TR		
Oil or grease	TR		
Fuel.....	0		
Asphalt/Tarmac (cont.coal tar)...	0		
Asphalt/Tarmac (no coal tar)....	0		
Bitumen.....	0		
Others.....	0		
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		

WASTE STREAM	7G103	LLW from Decommissioned Submarines
---------------------	--------------	---

Graphite.....	0	
Desiccants/Catalysts.....		
Asbestos.....	TR	
Non/low friable.....	TR	Small quantities contained in valve gaskets
Moderately friable.....		
Highly friable.....		
Free aqueous liquids.....	0	
Free non-aqueous liquids.....	0	
Powder/Ash.....	0	

Inorganic anions (%wt): No inorganic anions will be present 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: None known.

	(%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	

WASTE STREAM	7G103	LLW from Decommissioned Submarines
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Hazardous substances /
non hazardous pollutants:

Internal surfaces of primary shield tank may contain trace level of potassium chromate deposits.

	(%wt)	
Acrylamide.....		Type(s) and comment
Benzene.....	0	
Chlorinated solvents.....		
Formaldehyde.....		
Organometallics.....		
Phenol.....	0	
Styrene.....		
Tri-butyl phosphate.....	0	
Other organophosphates.....		
Vinyl chloride.....	0	
Arsenic.....	0	
Barium.....		
Boron.....	0	
Boron (in Boral).....		
Boron (non-Boral).....		
Cadmium.....	0	
Caesium.....		
Selenium.....	0	
Chromium.....	TR	Possible trace K ₂ CrO ₄ (Cr(vi)) deposits on some components/
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)	
EDTA.....		Type(s) and comment
DPTA.....		
NTA.....		
Polycarboxylic acids.....	0	
Other organic complexants.....		
Total complexing agents.....	0	

WASTE STREAM 7G103 LLW from Decommissioned Submarines

Potential for the waste to contain discrete items: Yes. Yes - steam generators and primary shield tanks may be categorised as discrete items.

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	Off-site	20.0

Comment on planned treatments:

Reactor pressure vessels will be decay-stored at the Capenhurst interim ILW store pending opening of a GDF, at which point they will be size-reduced and segregated into ILW and LLW. It is assumed LLW sections will be loaded into THISO containers and consigned to LLWR for disposal.

Disposal Routes:

Disposal Route	Stream volume %	Disposal density t/m3
Expected to be consigned to the LLW Repository	~53.0	~7.9
Expected to be consigned to a Landfill Facility	~47.0	~7.9
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: 17 04 07

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	100.0	100.0	100.0
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: Yes

Baseline Management Route	Opportunity Management Route	Stream volume (%)	Estimated Date that Opportunity will be realised	Opportunity Confidence	Comment
Authorised landfill Disposal at LLWR	Metal treatment Disposal at a Near Surface / Near Site Disposal Facility	~47.0 ~20.0	2024	Medium Medium	Treatment trials underway Potential for RPV emplacement, including LLW component, at NSD

WASTE STREAM	7G103	LLW from Decommissioned Submarines
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Waste Packaging for Disposal:

Container	Stream volume %	Waste loading m ³	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	~28.0	~2	137

Other information: -

Waste Planned for Disposal at the LLW Repository:

Container voidage: Predicted THISO container loading to comply with gross weight limit - 2 m3 steel resulting in 9.5 m3 voidage per container.

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: Not yet determined.

Non-Containerised Waste for In-Vault Grouting:

Stream volume (%): ~25.0

Waste stream variation: There is no existing waste stream variation for this waste

Bounding cuboidal volume: ~895.4

Inaccessible voidage: ~19 m3 (subject to assessment)

Other information: Whole steam generators likely to be grouted directly into LLWR vault subject to BPM assessment. Bounding volume is that of two steam generators from thirty-eight boats

RADIOACTIVITY

Source: Contamination of PWR primary circuit components with activated crud. Neutron activation of reactor pressure vessel and shield tank.

Uncertainty: Activation of RPV and shield tank steel using ATTILA and CAIRN codes. Error in flux model assessed to be +/-30%. Uncertainty in nuclear data, material composition and operating history increases the overall error to +/-50%. Activity of surface contaminated objects derived by application of a radionuclide fingerprint developed from a primary circuit sampling and analysis campaign. Fingerprint applied to ISOCS measurement of cobalt-60 concentrations in packaged waste; error in ISOCS measurements arising from geometry/packaging uncertainty estimated to be +/-25%.

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: Activity of surface contaminated objects derived by application of a radionuclide fingerprint developed from a primary circuit sampling and analysis campaign. Fingerprint applied to ISOCS measurement of cobalt-60 concentrations in packaged waste. Activated component radioactivity content estimated by numerical modelling and subject to ongoing programme of characterisation.

Other information: -

WASTE STREAM 7G103 LLW from Decommissioned Submarines

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	-8.83E-08	AA 1	-6.53E-08	AA 2	Gd 153				
Be 10					Ho 163				
C 14	~1.76E-04	BB 2	~1.87E-04	BB 2	Ho 166m				
Na 22					Tm 170				
Al 26					Tm 171				
Cl 36	-8.64E-07	AA 1	-9.85E-07	AA 2	Lu 174				
Ar 39					Lu 176				
Ar 42					Hf 178n				
K 40					Hf 182				
Ca 41					Pt 193				
Mn 53					Tl 204				
Mn 54					Pb 205				
Fe 55	~1.4E-05	AA 1	~5.33E-06	AA 2	Pb 210				
Co 60	-1.78E-03	AA 1	~8.44E-04	AA 2	Bi 208				
Ni 59	-2.53E-05	AA 1	~2.76E-05	AA 2	Bi 210m				
Ni 63	-2.88E-03	AA 1	~2.94E-03	AA 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	-5.93E-07	AA 1	~5.53E-07	AA 2	Th 227				
Zr 93					Th 228				
Nb 91					Th 229				
Nb 92					Th 230				
Nb 93m					Th 232				
Nb 94					Th 234				
Mo 93					Pa 231				
Tc 97					Pa 233				
Tc 99	~7.35E-07	AA 1	~8.38E-07	AA 2	U 232				
Ru 106					U 233				
Pd 107					U 234				
Ag 108m	~1.39E-06	AA 1	~1.56E-06	AA 2	U 235	-8.11E-11	AA 1	~9.24E-11	AA 2
Ag 110m					U 236				
Cd 109					U 238	~1.91E-09	AA 1	~2.81E-09	AA 2
Cd 113m					Np 237				
Sn 119m					Pu 236				
Sn 121m					Pu 238				
Sn 123					Pu 239				
Sn 126					Pu 240				
Sb 125					Pu 241				
Sb 126					Pu 242				
Te 125m					Am 241	~2.31E-10	AA 1	~2.61E-10	AA 2
Te 127m					Am 242m				
I 129	~2.12E-07	AA 1	~2.42E-07	AA 2	Am 243				
Cs 134					Cm 242				
Cs 135					Cm 243				
Cs 137	~6.03E-07	AA 1	~5.66E-07	AA 2	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	~7.73E-06	AA 1	5.9E-06	AA 2	Other b/g	~6.13E-08	AA 1	~4.78E-08	AA 2
Eu 154					Total a	2.22E-09	AA 1	~3.16E-09	AA 2
Eu 155					Total b/g	4.88E-03	AA 1	~4.01E-03	AA 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