WASTE STREAM 2D07 Pile Fuel Cladding and Miscellaneous Solid Waste

SITE	Sellafield
SITE OWNER	Nuclear Decommissioning Authority
WASTE CUSTODIAN	Sellafield Limited
WASTE TYPE	ILW
Is the waste subject to Scottish Policy:	No

WASTE VOLUMES

		Reported
Stocks:	At 1.4.2022.....	~3203.0 m^3
Total future arisings:		0 m^3
Total waste volume:		3203.0 m^3

Comment on volumes: Arisings have ceased. "Stock volume" uncertainty factors taken from the Pile Fuel Cladding Silo - Retrievals Feed Specification, RP/PFCS-PROG/PROJ/00001/E, A Khan, Oct 2020. The feed specification indicates the maximum 'as retrieved' of 3790m^3 and the observed volume of 3203m^3.

Uncertainty factors on volumes:				
	Stock (upper):	x 1.18	Arisings (upper)	x
	Stock (lower):	x 1.0	Arisings (lower)	x

WASTE SOURCE The wastes have predominately arisen from Windscale, Calder Hall and Chapelcross operations carried out between 1951 and 1965. Source of information is the Pile Fuel Cladding Silo - Retrievals Feed Specification, RP/PFCS-PROG/PROJ/00001/E, A Khan, Aug 2020.

PHYSICAL CHARACTERISTICS

General description: The waste contains swarf, principally aluminium and magnesium, from early reprocessing programmes. Other materials include graphite, organics, steel, ash, gravel and uranium residues.There may be some items that require special handling. The waste has been stored in a silo for ~60 years. Whilst the silo is nominally dry, it is known to be damp in parts with potential for discrete volumes of free liquor. The extent of any physical/chemical changes will be established on retrieval.

Physical components (%wt): Metal swarf, graphite, organics (e.g. wood, cloth, paper), scrap metal, ash, lead and uranium, as follows: Magnesium alloy swarf and magnesium hydroxide (assumed 750te) (36.7%), aluminium swarf (5.3%), graphite (16.47%), uranium (0.54%), gravel (6.64%), lead (1.96%), scrap metal - predominantly steel (28.35%), others - organics, ash, filters,etc. (3.96%).

Sealed sources: The waste contains sealed sources. A number of isotope cartridges have been confirmed to have been disposed to the Silo. The radioactivity in these cartridges will have decayed away to negligible levels.

Bulk density (t/m^3): 0.62

Comment on density: The quoted value is the average bulk density of the undisturbed waste in the silo (observed waste volume and 2000te waste mass used). Upon retrieval the average bulk density is expected to decrease. The retrieved volume (3790m3) is expected to have an average bulk density of 0.53 t/m^3. Should the waste mass be 1800te then in silo = 0.56 t/m3 and retrieved = 0.48 t/m3

CHEMICAL COMPOSITION

General description and components (%wt): Metal swarf, graphite, organics (e.g. wood, cloth, paper), scrap metal, ash, lead and uranium, as follows: Magnesium alloy swarf and magnesium hydroxide (assumed 750te) (36.7%), aluminium swarf (5.3%), graphite (16.47%), uranium (0.54%), gravel (6.64%), lead (1.96%), scrap metal - predominantly steel (28.35%), others - organics, ash, filters,etc. (3.96%).

Chemical state: Alkali

Chemical form of radionuclides:
H-3: Present as part of spent fuel components (predominantly trapped as gas within spent fuel).
C-14: Present as part of spent fuel components (trapped as gas within spent fuel components).
Cl-36: Present as part of spent fuel components (trapped as gas within spent fuel components).
Se-79: Present as part of spent fuel components (fission product within spent fuel).

Tc-99: Present as part of spent fuel components (associated with fission products within spent fuel).
I-129: Present as part of spent fuel components (fission product within spent fuel).
Ra: Present within spent fuel.
Th: Present within spent fuel.
U: Uranium metal and uranium corrosion products (associated with spent fuel).
Np: Present within spent fuel.
Pu: Both present within spent fuel and associated with Plutonium Contaminated Material.

Metals and alloys (%wt): Approximately 28.34% of the waste is present as scrap metal or cans. It is unknown how much is present as sheet. A normal limit of between 460 mm and 610 mm in any dimension was applied to items disposed in the Silo. However there are known to be many items larger than this. There are many metal rods, some up to 7 metres long. Approximately 50 x 200 litre drums. There are sections of aluminium decking up to 2.8 m long and 0.6 m wide, totalling 15 m in length. There are 4 sections of steel cover plate measuring approximately 1830 mm x 915 mm x 5 mm and 2 folded aluminium cover plates originally measuring 1830 mm x 1830 mm x 5 mm. There will also be sections of mild steel plate up to 1 m x 1 m, totalling 2 plates (1.8 m x 2.4 m) per compartment

	(%wt)	Type(s) / Grade(s) with proportions	% of total C14 activity
Stainless steel	P		
Other ferrous metals	28.3		
Iron	P		
Aluminium	5.2		
Beryllium	0		
Cobalt	0		
Copper	NE		
Lead	2.0		
Magnox/Magnesium	36.7		3.8
Nickel	TR		
Titanium	NE		
Uranium	0.54	Predominantly depleted/natural uranium.	0.2
Zinc	NE		
Zircaloy/Zirconium	TR		
Other metals	NE		

Organics (%wt): The waste contains a variety of organics and cellulosic materials including wood and paper. Rubber may be present in small amounts. Detailed organics inventory uncertain, total listed as "other organics". Most of the plastics are likely to be Bakelite, high density polythene or PVC, although there is photographic evidence of more modern ABS piping on top of the waste.

	(%wt)	Type(s) and comment	% of total C14 activity
Total cellulosics	P		
Paper, cotton	P		
Wood	P		
Halogenated plastics	NE		
Total non-halogenated plastics	NE		
Condensation polymers	NE		
Others	NE		
Organic ion exchange materials	0		
Total rubber	NE		
Halogenated rubber	NE		

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Non-halogenated rubber.....	NE	
Hydrocarbons.....	P	
Oil or grease	P	
Fuel.....	NE	
Asphalt/Tarmac (cont.coal tar)...	NE	
Asphalt/Tarmac (no coal tar).....	0	
Bitumen.....	NE	
Others.....		
Other organics.....	1.9	grouted and pile filters

Other materials (%wt): The gravel at bottom of silo compartments is listed as rubble. Fibreglass is present in pile filters. Incinerator ash (2.4%). Controls have been put in place for asbestos, which maybe have been disposed in the form of lagging, etc. Amounts/types not known.

	(%wt)	Type(s) and comment	% of total C14 activity
Inorganic ion exchange materials..	NE		
Inorganic sludges and flocs.....	P		
Soil.....	NE		
Brick/Stone/Rubble.....	6.8		
Cementitious material.....	NE		
Sand.....	P		
Glass/Ceramics.....	P		
Graphite.....	16.5		96.1
Desiccants/Catalysts.....	NE		
Asbestos.....	P		
Non/low friable.....	NE		
Moderately friable.....	NE		
Highly friable.....	NE		
Free aqueous liquids.....	P		
Free non-aqueous liquids.....	P		
Powder/Ash.....	~2.1		

Inorganic anions (%wt): If present, the listed anions are likely to be present only in small or trace quantities.

	(%wt)	Type(s) and comment
Fluoride.....	NE	
Chloride.....	NE	
Iodide.....	NE	
Cyanide.....	NE	
Carbonate.....	NE	
Nitrate.....	NE	
Nitrite.....	NE	
Phosphate.....	NE	
Sulphate.....	NE	
Sulphide.....	NE	

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Materials of interest for waste acceptance criteria: The waste contains uranium, magnesium, graphite, aluminium and combustible organics. It may also contain uranium hydride and alkali metals. During retrievals, disturbed magnox may come into contact with, and react with, free water to produce hydrogen gas. There may also be a very small number of sealed cans (<30) containing either uranium hydride or sodium, which may present an ignition source.

	(%wt)	Type(s) and comment
Combustible metals.....	P	Approx 36.5% w/w of the waste is Magnesium alloy. A small number of canned items may contain sodium or uranium hydride.
Low flash point liquids.....	P	Expected to be trace amounts.
Explosive materials.....	0	
Phosphorus.....	0	
Hydrides.....	P	Very small amounts of uranium hydride in sealed cans.
Biological etc. materials.....	0	
Biodegradable materials.....	P	Approximately 1.5% w/w of the waste is organic.
Putrescible wastes.....	P	
Non-putrescible wastes.....		
Corrosive materials.....	0	
Pyrophoric materials.....	P	Very small amounts of sodium and uranium hydride.
Generating toxic gases.....	0	
Reacting with water.....	P	Magnox reacts with water to from hydrogen.
Higher activity particles.....	P	10% w/w of the silo waste is expected to be particulate.
Soluble solids as bulk chemical compounds.....	0	

Hazardous substances / non hazardous pollutants: Lead is present and the presence of asbestos is suspected.

	(%wt)	Type(s) and comment
Acrylamide.....	NE	
Benzene.....	NE	
Chlorinated solvents.....	NE	
Formaldehyde.....	NE	
Organometallics.....	NE	
Phenol.....	P	Present within disposed plastics.
Styrene.....	NE	
Tri-butyl phosphate.....	NE	
Other organophosphates.....	NE	
Vinyl chloride.....	P	Present as PVC.
Arsenic.....	NE	
Barium.....	P	As Barium 137.
Boron.....	NE	
Boron (in Boral).....	NE	
Boron (non-Boral).....	NE	
Cadmium.....	NE	

Caesium.....	P	As Caesium 137
Selenium.....	NE	
Chromium.....	P	Present in disposed stainless steel .
Molybdenum.....	P	Potentially present in disposed stainless steel.
Thallium.....	NE	
Tin.....	P	Present in disposed scrap metal.
Vanadium.....	NE	May be present in scrap steel.
Mercury compounds.....	NE	
Others.....		
Electronic Electrical Equipment (EEE)		
EEE Type 1.....	0	
EEE Type 2.....	P	
EEE Type 3.....	P	
EEE Type 4.....	NE	
EEE Type 5.....	NE	

Complexing agents (%wt): Not yet determined

	(%wt)	Type(s) and comment
EDTA.....	NE	
DPTA.....	NE	
NTA.....	NE	
Polycarboxylic acids…….	NE	
Other organic complexants.....		
Total complexing agents.....	NE	

Potential for the waste to contain discrete items: Yes.

PACKAGING AND CONDITIONING

Conditioning method: Waste will be placed in 3m³ boxes for interim storage and subsequent conditioning and packaging.

Plant Name: Treatment options and plants under development.

Location: Sellafield.

Plant startup date: Under review.

Total capacity (m³/y incoming waste): -

Target start date for packaging this stream: -

Throughput for this stream (m³/y incoming waste): -

Other information: -

Likely container type:

Container	Waste packaged (%vol)	Waste loading (m³)	Payload (m³)	Number of packages
Sellafield enhanced 3m³ box	100.0	1.438	2.19	2228

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Likely container type comment:	-
Range in container waste volume:	The waste loading has been calculated based on an estimated 2,227 final packages being produced at the PFCS Treatment Plant (note - that this also includes 111 waste containers for residuals from the silos and 12 waste containers being exported to EPS3). The actual waste container loading is uncertain and will depend greatly on achievable packing fractions and filling efficiencies currently assumed to be 80% with 5% of this volume being taken up by secondary ILW. (CA/PFCSPROG/PROJ/00024. PFCS Programme PSWP Supporting Calculations. B Chapman. Feb '22)
Other information on containers:	Stainless steel. Interim waste container will be re-used for disposal if possible.
Likely conditioning matrix:	Not Specified
Other information:	-
Conditioned density (t/m³):	NE
Conditioned density comment:	-
Other information on conditioning:	-
Opportunities for alternative disposal routing:	Not yet determined

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

RADIOACTIVITY

Source:	The waste contains contaminated fuel cladding, residual uranium fuel from decanning operations and reactor structural components. The main sources of radioactivity are Cs-137, Sr-90, Pu-239, C14, Pu-241.
Uncertainty:	Actual Silo wall dose readings have been used to calculate the specific activities. The underlying assumptions in the calculation lead to uncertainties. These uncertainies are expected to be less than an order of magnitude.
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:	Specific activities have been predominately based on Silo dose reading and estimates of plutonium associated with PCM. All specific activies have been decayed to expected values in 2022. (CA/PFCS-PROG/PROC/00004/C, Best Estimate of PFCS Waste Specific Activity, R Fisher, March 2018)
Other information:	-

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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	4.24E-05	C C 1			Gd 153				
Be 10	2.27E-08	C C 1			Ho 163	7.17E-14	C C 1		
C 14	4.71E-03	C C 1			Ho 166m	1.01E-10	C C 1		
Na 22					Tm 170				
Al 26					Tm 171	4.88E-16	C C 1		
Cl 36	1.14E-06	C C 1			Lu 174				
Ar 39					Lu 176				
Ar 42					Hf 178n				
K 40					Hf 182				
Ca 41	1.06E-05	C C 1			Pt 193				
Mn 53	1.51E-15	C C 1			Tl 204				
Mn 54					Pb 205				
Fe 55	2.75E-08	C C 1			Pb 210	8.58E-11	C C 1		
Co 60	1.17E-04	C C 1			Bi 208				
Ni 59	4.56E-05	C C 1			Bi 210m				
Ni 63	3.65E-03	C C 1			Po 210	8.32E-11	C C 1		
Zn 65					Ra 223	9.59E-10	C C 1		
Se 79	1.52E-07	C C 1			Ra 225	1.83E-13	C C 1		
Kr 81	1.62E-15	C C 1			Ra 226	2.43E-10	C C 1		
Kr 85	7.15E-04	C C 1			Ra 228	7.26E-16	C C 1		
Rb 87	2.74E-12	C C 1			Ac 227	9.63E-10	C C 1		
Sr 90	5.70E-02	C C 1			Th 227	9.47E-10	C C 1		
Zr 93	5.07E-06	C C 1			Th 228	6.35E-10	C C 1		
Nb 91					Th 229	1.83E-13	C C 1		
Nb 92					Th 230	2.07E-08	C C 1		
Nb 93m	3.82E-06	C C 1			Th 232	2.19E-15	C C 1		
Nb 94	1.35E-10	C C 1			Th 234	4.20E-05	C C 1		
Mo 93	2.06E-09	C C 1			Pa 231	2.04E-09	C C 1		
Tc 97	2.70E-18	C C 1			Pa 233	1.61E-07	C C 1		
Tc 99	3.84E-05	C C 1			U 232	6.17E-10	C C 1		
Ru 106	5.24E-18	C C 1			U 233	5.33E-11	C C 1		
Pd 107	1.37E-07	C C 1			U 234	4.14E-05	C C 1		
Ag 108m	1.76E-11	C C 1			U 235	1.76E-06	C C 1		
Ag 110m					U 236	8.25E-07	C C 1		
Cd 109					U 238	4.20E-05	C C 1		
Cd 113m	5.07E-08	C C 1			Np 237	1.61E-07	C C 1		
Sn 119m					Pu 236	1.16E-14	C C 1		
Sn 121m	6.58E-07	C C 1			Pu 238	4.76E-05	C C 1		
Sn 123					Pu 239	1.28E-02	C C 1		
Sn 126	1.28E-06	C C 1			Pu 240	2.41E-03	C C 1		
Sb 125	1.01E-08	C C 1			Pu 241	3.50E-03	C C 1		
Sb 126	1.79E-07				Pu 242	5.79E-08	C C 1		
Te 125m	2.53E-09	C C 1			Am 241	1.67E-03	C C 1		
Te 127m					Am 242m	1.88E-07	C C 1		
I 129	7.22E-08	C C 1			Am 243	2.08E-08	C C 1		
Cs 134	6.42E-11	C C 1			Cm 242	1.55E-07	C C 1		
Cs 135	1.93E-06	C C 1			Cm 243	2.96E-09	C C 1		
Cs 137	7.06E-02	C C 1			Cm 244	1.11E-08	C C 1		
Ba 133	2.41E-13	C C 1			Cm 245	5.71E-13	C C 1		
La 137	5.88E-14	C C 1			Cm 246	9.28E-15	C C 1		
La 138	8.70E-17	C C 1			Cm 248				
Ce 144					Cf 249				
Pm 145	2.90E-17	C C 1			Cf 250				
Pm 147	2.12E-07	C C 1			Cf 251				
Sm 147	1.15E-12	C C 1			Cf 252				
Sm 151	2.49E-03	C C 1			Other a				
Eu 152	4.67E-07	C C 1			Other b/g				
Eu 154	8.28E-06	C C 1			**Total a**	**1.71E-02**	**C C 1**	**0**	
Eu 155	2.78E-06	C C 1			**Total b/g**	**1.43E-01**	**C C 1**	**0**	

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