WASTE STREAM 5B01 PFR Raffinate

SITE	Dounreay
SITE OWNER	Nuclear Decommissioning Authority
WASTE CUSTODIAN	Dounreay Site Restoration Limited
WASTE TYPE	ILW
Is the waste subject to Scottish Policy:	Yes

WASTE VOLUMES

		Reported
Stocks:	At 1.4.2022.....	166.2 m³
Future arisings -	1.4.2023 - 31.3.2024.....	-83.1 m³
	1.4.2024 - 31.3.2025.....	-83.1 m³
Total future arisings:		-166.2 m³
Total waste volume:		0 m³

Comment on volumes: Programme is from DSRL's provisional LTP. There will be no further arisings of this waste stream. Stocks will reduce in the coming submissions as the waste is conditioned. This will produce waste within 5B01/C. Stocks uncertainty related only to tank level monitoring equipment error margin. There will be no future arisings. Tank washouts will be undertaken but have not been quantified as yet.

Uncertainty factors on volumes:

Stock (upper):	x 1.05	Arisings (upper)	x 1.05
Stock (lower):	x 0.95	Arisings (lower)	x 0.95

WASTE SOURCE The source of this waste is from the reprocessing of Prototype Fast Reactor (PFR) fuel.

PHYSICAL CHARACTERISTICS

General description: The waste is a raffinate from fuel reprocessing. There are no large items in the waste. Some of the raffinate has been evaporated to reduce its volume.

Physical components (%wt): Aqueous liquor (100%).

Sealed sources: The waste does not contain sealed sources.

Bulk density (t/m³): 1.27

Comment on density: The density of the raffinate has historically been measured at about 1.27 t/m³.

CHEMICAL COMPOSITION

General description and components (%wt): The raffinate is a nitric acid solution containing fission products and trace quantities of uranium and plutonium. Nitric acid (96.6%) and metals in solution (copper, sodium, iron, cadmium, nickel and zinc) (3.4%).

Chemical state: Acid

Chemical form of radionuclides:
H-3: Likely to be present as water.
C-14: Unknown - possibly present as traces of dissolved solvent.
Cl-36: Likely to be present, form unknown.
Se-79: Likely to be present, form unknown.
Tc-99: Likely to be present, form unknown.
I-129: Likely to be present, form unknown.
Ra: Likely to be present as nitrate.
Th: Present as nitrate.
U: Present as nitrate.
Np: Likely to be present, form unknown.
Pu: Present as nitrate.

Metals and alloys (%wt): -

	(%wt)	Type(s) / Grade(s) with proportions	% of total C14 activity
Stainless steel.....	0		
Other ferrous metals.....	P		
Iron.....			
Aluminium.....			

WASTE STREAM 5B01 PFR Raffinate

Beryllium	0	
Cobalt	0	
Copper	P	
Lead	0	
Magnox/Magnesium	0	
Nickel	P	
Titanium	0	
Uranium	0	
Zinc	P	
Zircaloy/Zirconium	0	
Other metals	3.4	Covers a range of metallic species which are in solution including sodium, cadmium and nickel.

Organics (%wt): The only organic materials present in the waste are trace quantities of complexing agents.

	(%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): -

	(%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		

WASTE STREAM 5B01 PFR Raffinate

Glass/Ceramics	0
Graphite	0
Desiccants/Catalysts	
Asbestos	0
Non/low friable	
Moderately friable	
Highly friable	
Free aqueous liquids	96.6
Free non-aqueous liquids	0
Powder/Ash	0

Inorganic anions (%wt): The waste contains nitrate and traces of sulphates, phosphates and chlorides.

	(%wt)	Type(s) and comment
Fluoride	0	
Chloride	TR	
Iodide	0	
Cyanide	0	
Carbonate	0	
Nitrate	30.0	
Nitrite	0	
Phosphate	TR	
Sulphate	TR	
Sulphide	0	

Materials of interest for waste acceptance criteria: The waste contains nitric acid.

	(%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	96.6	
Pyrophoric materials	0	
Generating toxic gases	96.6	
Reacting with water	0	
Higher activity particles	0	
Soluble solids as bulk chemical compounds	0	

WASTE STREAM 5B01 PFR Raffinate

Hazardous substances / non hazardous pollutants: Cadmium is present in solution in small quantities. Nitric acid (96.6%).

	(%wt)	Type(s) and comment
Acrylamide.....		
Benzene.....		
Chlorinated solvents.....		
Formaldehyde.....		
Organometallics.....		
Phenol.....		
Styrene.....		
Tri-butyl phosphate.....		
Other organophosphates.....		
Vinyl chloride.....		
Arsenic.....		
Barium.....		
Boron.....		
Boron (in Boral).....		
Boron (non-Boral).....		
Cadmium.....	P	
Caesium.....		
Selenium.....		
Chromium.....		
Molybdenum.....		
Thallium.....		
Tin.....		
Vanadium.....		
Mercury compounds.....		
Others.....		
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.....	TR	Traces of organic complexing agents (MDP, DBP, TBP) may be present.
Total complexing agents.....	TR	

WASTE STREAM 5B01 PFR Raffinate

Potential for the waste to contain discrete items: No.

PACKAGING AND CONDITIONING

Conditioning method: The current strategy is neutralisation of the PFR raffinate followed by immobilisation with cement into 500 litre drums in a modified Dounreay Cementation Plant.

Plant Name: Dounreay Cementation Plant

Location: Dounreay

Plant startup date: 01/09/1996

Total capacity (m^3/y incoming waste): ~200.0

Target start date for packaging this stream: 2023

Throughput for this stream (m^3/y incoming waste): ~83.0

Other information: Active commissioning commenced in 2018 - full operations to commence in 2023

Likely container type:

Container	Waste packaged (%vol)	Waste loading (m^3)	Payload (m^3)	Number of packages
500 l drum	100.0	0.228	0.5	0

Likely container type comment: The loading will vary slightly , depending upon the chemical composition of the raffinate in that tank.

Range in container waste volume: The target loading is 0.228 m3 of raw raffinate per drum, but is dependent on composition of the raffinate in the tank. A final volume of 328 l of neutralised liquor will be dispensed to each drum.

Other information on containers: Stainless Steel. The container will be manufactured from 316 stainless steel.

Likely conditioning matrix: PFA/OPC

Other information: The raffinate will probably be incorporated into a cement based lattice using a 1:2 PFA/OPC formulation, with an average of 227 litres of raffinate being incorporated into each drum. The waste will undergo a neutralisation process using sodium hydroxide.

Conditioned density (t/m^3): ~1.77

Conditioned density comment: The density of the conditioned waste will probably be about 1.8 t/m^3.

Other information on conditioning: -

Opportunities for alternative disposal routing: No

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

RADIOACTIVITY

Source: Activity arises mainly from the fission products separated from the irradiated Prototype Fast Reactor fuel at reprocessing

Uncertainty: The activity accuracy is within a factor of 3 for stocks.

WASTE STREAM 5B01 PFR Raffinate

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:	Samples were taken from the tanks and subsequently analysed. These results gave specific activities for the principle radionuclides. Other specific activities were estimated from earlier results and Fispin calculations.
Other information:	Activities are based on a combination of analysis and FISPIN data. The total activities of stocks are for partially evaporated liquor; there will be no further arisings. The range in activity levels are based on samples of the PFR raffinate tanks in November 2003. Alpha 11 - 99 TBq/m³, beta/gamma 150 - 1,300 TBq/m³. The intention is to blend liquors from each of the four tanks to provide a consistent feedstock for processing.

WASTE STREAM 5B01 PFR Raffinate

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	6.88E-03	B B 1	6.88E-03	B B 1	Gd 153	1.14E-17	B B 2	1.14E-17	B B 2
Be 10	2.32E-09	B B 2	2.32E-09	B B 2	Ho 163	6.89E-10	B B 2	6.89E-10	B B 2
C 14	9.52E-05	B B 2	9.52E-05	B B 2	Ho 166m	7.32E-08	B B 2	7.32E-08	B B 2
Na 22					Tm 170	5.07E-27	B B 2	5.07E-27	B B 2
Al 26					Tm 171	9.14E-09	B B 2	9.14E-09	B B 2
Cl 36	4.73E-09	B B 2	4.73E-09	B B 2	Lu 174	3.25E-09	B B 2	3.25E-09	B B 2
Ar 39					Lu 176	3.19E-14	B B 2	3.19E-14	B B 2
Ar 42					Hf 178n	1.14E-07	B B 2	1.14E-07	B B 2
K 40	3.49E-10	B B 2	3.49E-10	B B 2	Hf 182	5.94E-13	B B 2	5.94E-13	B B 2
Ca 41	3.92E-07	B B 2	3.92E-07	B B 2	Pt 193	4.48E-06	B B 2	4.48E-06	B B 2
Mn 53	2.99E-09	B B 2	2.99E-09	B B 2	Tl 204	1.39E-05	B B 2	1.39E-05	B B 2
Mn 54	1.86E-10	B B 2	1.86E-10	B B 2	Pb 205	1.72E-10	B B 2	1.72E-10	B B 2
Fe 55	1.45E-03	B B 2	1.45E-03	B B 2	Pb 210	2.07E-10	B B 2	2.07E-10	B B 2
Co 60	1.69E-02	B B 1	1.69E-02	B B 1	Bi 208	1.29E-10	B B 2	1.29E-10	B B 2
Ni 59	7.06E-04	B B 2	7.06E-04	B B 2	Bi 210m	4.35E-11	B B 2	4.35E-11	B B 2
Ni 63	3.03E-02	B B 2	3.03E-02	B B 2	Po 210	2.00E-10	B B 2	2.00E-10	B B 2
Zn 65	3.57E-14	B B 2	3.57E-14	B B 2	Ra 223	3.19E-09	B B 2	3.19E-09	B B 2
Se 79	2.16E-04	B B 2	2.16E-04	B B 2	Ra 225	1.44E-10	B B 2	1.44E-10	B B 2
Kr 81					Ra 226	6.74E-10	B B 2	6.74E-10	B B 2
Kr 85					Ra 228	5.74E-12	B B 2	5.74E-12	B B 2
Rb 87	4.39E-08	B B 2	4.39E-08	B B 2	Ac 227	3.20E-09	B B 2	3.20E-09	B B 2
Sr 90	6.65E+01	B B 1	6.65E+01	B B 1	Th 227	3.15E-09	B B 2	3.15E-09	B B 2
Zr 93	4.72E-03	B B 2	4.72E-03	B B 2	Th 228	1.98E-07	B B 2	1.98E-07	B B 2
Nb 91	5.33E-06	B B 2	5.33E-06	B B 2	Th 229	1.44E-10	B B 2	1.44E-10	B B 2
Nb 92	1.73E-10	B B 2	1.73E-10	B B 2	Th 230	7.47E-08	B B 2	7.47E-08	B B 2
Nb 93m	5.42E-03	B B 2	5.42E-03	B B 2	Th 232	5.91E-12	B B 2	5.91E-12	B B 2
Nb 94	5.57E-05	B B 2	5.57E-05	B B 2	Th 234	4.41E-06	B B 2	4.41E-06	B B 2
Mo 93	4.11E-04	B B 2	4.11E-04	B B 2	Pa 231	5.56E-09	B B 2	5.56E-09	B B 2
Tc 97	3.37E-12	B B 2	3.37E-12	B B 2	Pa 233	4.32E-04	B B 2	4.32E-04	B B 2
Tc 99	4.96E-02	B B 2	4.96E-02	B B 2	U 232	1.86E-07	B B 2	1.86E-07	B B 2
Ru 106	1.33E-05	B B 2	1.33E-05	B B 2	U 233	6.44E-08	B B 2	6.44E-08	B B 2
Pd 107	1.08E-03	B B 2	1.08E-03	B B 2	U 234	1E-04	B B 1	1E-04	B B 1
Ag 108m	3.50E-06	B B 2	3.50E-06	B B 2	U 235	1.71E-07	B B 1	1.71E-07	B B 1
Ag 110m	1.69E-12	B B 2	1.69E-12	B B 2	U 236	4.56E-07	B B 1	4.56E-07	B B 1
Cd 109	8.89E-10	B B 2	8.89E-10	B B 2	U 238	4.41E-06	B B 1	4.41E-06	B B 1
Cd 113m	5.88E-03	B B 2	5.88E-03	B B 2	Np 237	4.33E-04	B B 2	4.33E-04	B B 2
Sn 119m	2.34E-12	B B 2	2.34E-12	B B 2	Pu 236	5.96E-10	B B 2	5.96E-10	B B 2
Sn 121m	1.60E-01	B B 2	1.60E-01	B B 2	Pu 238	1.29E+00	B B 1	1.29E+00	B B 1
Sn 123	1.17E-23	B B 2	1.17E-23	B B 2	Pu 239	1.49E-01	B B 1	1.49E-01	B B 1
Sn 126	1.89E-03	B B 2	1.89E-03	B B 2	Pu 240	1.63E-01	B B 1	1.63E-01	B B 1
Sb 125	4.23E-02	B B 2	4.23E-02	B B 2	Pu 241	1.8E+00	B B 1	1.8E+00	B B 1
Sb 126	2.65E-04	B B 2	2.65E-04	B B 2	Pu 242	1.25E-04	B B 1	1.25E-04	B B 1
Te 125m	1.06E-02	B B 2	1.06E-02	B B 2	Am 241	2.75E+01	B B 1	2.75E+01	B B 1
Te 127m	6.93E-30	B B 2	6.93E-30	B B 2	Am 242m	7.71E-01	B B 2	7.71E-01	B B 2
I 129	1.25E-04	B B 2	1.25E-04	B B 2	Am 243	5.06E-02	B B 2	5.06E-02	B B 2
Cs 134	4.06E-03	B B 1	4.06E-03	B B 1	Cm 242	6.36E-01	B B 2	6.36E-01	B B 2
Cs 135	6.1E-03	B B 2	6.1E-03	B B 2	Cm 243	1.39E-01	B B 2	1.39E-01	B B 2
Cs 137	1.93E+02	B B 1	1.93E+02	B B 1	Cm 244	1.16E+00	B B 2	1.16E+00	B B 2
Ba 133	2.21E-05	B B 2	2.21E-05	B B 2	Cm 245	1.36E-04	B B 2	1.36E-04	B B 2
La 137	4.38E-08	B B 2	4.38E-08	B B 2	Cm 246	5.39E-06	B B 2	5.39E-06	B B 2
La 138	2.1E-13	B B 2	2.1E-13	B B 2	Cm 248	1.91E-11	B B 2	1.91E-11	B B 2
Ce 144	3.81E-08	B B 2	3.81E-08	B B 2	Cf 249	1.45E-10	B B 2	1.45E-10	B B 2
Pm 145	3.39E-07	B B 2	3.39E-07	B B 2	Cf 250	4.58E-11	B B 2	4.58E-11	B B 2
Pm 147	4.98E-01	B B 2	4.98E-01	B B 2	Cf 251	2.68E-14	B B 2	2.68E-14	B B 2
Sm 147	3.25E-08	B B 2	3.25E-08	B B 2	Cf 252	5.01E-17	B B 2	5.01E-17	B B 2
Sm 151	1.07E+01	B B 2	1.07E+01	B B 2	Other a				
Eu 152	6.24E-05	B B 2	6.24E-05	B B 2	Other b/g				
Eu 154	9.11E-01	B B 1	9.11E-01	B B 1	**Total a**	**3.11E+01**	**B B 2**	**3.11E+01**	**B B 2**
Eu 155	4.89E-01	B B 1	4.89E-01	B B 1	**Total b/g**	**2.75E+02**	**B B 2**	**2.75E+02**	**B B 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