APPENDIX 1. CD Supplement

This Appendix contains information on the methods of sampling, measurement, presentation and assessment. It is provided on the CD accompanying the main report.

APPENDIX 2. Disposals of radioactive waste*

Table A2.1. Principal discharges of gaseous radioactive wastes from nuclear establishments in the United Kingdom, 2006

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2006	
			TBq	% of annual limit[b]
Nuclear fuel production and reprocessing				
Capenhurst (BNGSL)				
	Tritium	1600	$5.9\ 10^{-6}$	<1
	Uranium[c]	BPM	$7.20\ 10^{-8}$	NA
Capenhurst (Urenco)	Uranium	$2.5\ 10^{-6}$	$3.24\ 10^{-7}$	13
Sellafield[d]	Alpha	$8.8\ 10^{-4}$	$6.60\ 10^{-5}$	7.5
	Beta	0.042	$9.42\ 10^{-4}$	2.2
	Tritium	1100	185	17
	Carbon-14	3.3	0.71	22
	Krypton-85	$4.4\ 10^{5}$	$2.28\ 10^{4}$	5.2
	Strontium-90	$7.1\ 10^{-4}$	$4.80\ 10^{-5}$	6.8
	Ruthenium-106	0.028	0.00158	5.6
	Antimony-125	0.0023	0.00151	66
	Iodine-129	0.07	0.00665	9.5
	Iodine-131	0.055	$6.61\ 10^{-4}$	1.2
	Caesium-137	0.0058	$5.87\ 10^{-4}$	10
	Plutonium alpha	$1.9\ 10^{-4}$	$2.64\ 10^{-5}$	14
	Plutonium-241	0.003	$2.25\ 10^{-4}$	7.5
	Americium-241 and curium-242	$1.2\ 10^{-4}$	$2.54\ 10^{-5}$	21
Springfields	Uranium	0.0053	$4.40\ 10^{-4}$	8.3
Springfields (Nexia Solutions)	Tritium	10^{-4}	$2.50\ 10^{-7}$	<1
	Carbon-14	10^{-5}	$4.40\ 10^{-7}$	4.4
	Other alpha radionuclides	10^{-6}	Nil	Nil
	Other beta radionuclides	10^{-5}	$1.70\ 10^{-8}$	<1
Research establishments				
Dounreay (Fuel Cycle Area)	Alpha[e]	$9.8\ 10^{-4}$	$9.85\ 10^{-6}$	1.0
	Beta[f,g]	0.045	$2.39\ 10^{-4}$	<1
	Tritium	2	0.265	13
	Krypton-85	3000	1.24	<1
	Strontium-90	0.0042	$7.14\ 10^{-5}$	1.7
	Ruthenium-106	0.0039	$6.72\ 10^{-6}$	<1
	Iodine-129	0.0011	$1.65\ 10^{-4}$	15
	Iodine-131	$1.5\ 10^{-4}$	$7.96\ 10^{-5}$	53
	Caesium-134	$8.4\ 10^{-4}$	$8.42\ 10^{-7}$	<1
	Caesium-137	0.007	$3.99\ 10^{-5}$	<1
	Cerium-144	0.007	$4.70\ 10^{-6}$	<1
	Plutonium-241	0.0033	$8.20\ 10^{-6}$	<1
	Curium-242	$2.7\ 10^{-4}$	$7.05\ 10^{-8}$	<1
	Curium-244[h]	$5.4\ 10^{-5}$	$9.01\ 10^{-8}$	<1
Dounreay (Fast Reactor)	Alpha	10^{-5}	$7.80\ 10^{-9}$	<1
	Beta	0.0015	$2.97\ 10^{-8}$	<1
	Tritium	4.5	$1.33\ 10^{-3}$	<1
	Krypton-85	$4\ 10^{-4}$	Nil	Nil
Dounreay (Prototype Fast Reactor)	Alpha	$6\ 10^{-6}$	$3.71\ 10^{-8}$	<1
	Beta	$5.1\ 10^{-5}$	$1.30\ 10^{-6}$	2.5
	Tritium	10.5	$7.62\ 10^{-2}$	<1
	Krypton-85	4	3.64	91
Dounreay (PFR minor sources)	Alpha[i]	$6\ 10^{-8}$	$3.88\ 10^{-10}$	<1
	Beta[f]	$5\ 10^{-7}$	$1.50\ 10^{-9}$	<1
	Tritium	0.2	$3.85\ 10^{-3}$	1.9

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2006	
			TBq	% of annual limit[b]
Dounreay (East minor sources)	Alpha[i]	$1.37\ 10^{-5}$	$6.63\ 10^{-8}$	<1
	Beta[f,g]	$3.71\ 10^{-4}$	$3.95\ 10^{-7}$	<1
	Krypton-85[j]	1	Nil	Nil
Dounreay (West minor sources)	Alpha[i]	$3\ 10^{-7}$	$1.03\ 10^{-9}$	<1
	Beta[f,g]	$7.5\ 10^{-5}$	$4.27\ 10^{-9}$	<1
	Tritium	0.01	$3.24\ 10^{-4}$	3.2
Harwell (AEA Technology)	Alpha	$7\ 10^{-7}$	Nil	Nil
	Beta	$3\ 10^{-5}$	Nil	Nil
	Tritium	$2\ 10^{-4}$	Nil	Nil
Harwell (UKAEA)	Alpha	$8\ 10^{-7}$	$5.39\ 10^{-8}$	6.7
	Beta	$2\ 10^{-5}$	$1.10\ 10^{-6}$	5.5
	Tritium	15	0.23	1.6
	Krypton-85	2	0.118	5.9
	Radon-220	100	9.64	9.6
	Radon-222	3	0.29	9.7
	Iodines	0.01	Nil	Nil
	Other radionuclides	0.1	Nil	Nil
Harwell (GE Healthcare B10.23)				
	Alpha	$5\ 10^{-8}$	Nil	Nil
	Beta/gamma	$1.5\ 10^{-5}$	Nil	Nil
Harwell (GE Healthcare B443.26)				
	Alpha	$1\ 10^{-7}$	$1.64\ 10^{-9}$	1.6
	Beta/gamma	$3\ 10^{-5}$	$8.18\ 10^{-7}$	2.7
	Radon-222	1	Nil	Nil
	Tritium	2	Nil	Nil
	Krypton-85	0.06	Nil	Nil
Windscale	Alpha	$1.2\ 10^{-5}$	$1.05\ 10^{-7}$	<1
	Beta	$5\ 10^{-4}$	$1.66\ 10^{-6}$	<1
	Tritium	2.3	Nil	Nil
	Krypton-85	14	0.03	<1
	Iodine-131	0.0012	$8.64\ 10^{-7}$	<1
Winfrith[s] (AEA Technology to 23/03/06 WMT Ltd from 23/03/06)	Alpha	$1\ 10^{-7}$	Nil	Nil
	Beta	$2.5\ 10^{-5}$	$1.03\ 10^{-5}$	4.1
	Tritium	19.5	10.1	52
	Carbon -14	0.03	$3.86\ 10^{-6}$	<1
	Other	$1\ 10^{-7}$	Nil	Nil
Winfrith (UKAEA)	Alpha	$2\ 10^{-6}$	$2.06\ 10^{-9}$	<1
	Tritium	4	1.10	22
	Carbon-14	0.006	$8.6\ 10^{-4}$	14
	Other	$5\ 10^{-6}$	$1.47\ 10^{-8}$	<1
Minor sites				
Imperial College Reactor Centre Ascot	Tritium	$3\ 10^{-4}$	$4.20\ 10^{-5}$	14
	Argon-41	1.7	$9.49\ 10^{-2}$	5.6
Scottish Universities Environmental Research Centre East Kilbride	Beta	$5\ 10^{-7}$	Nil	Nil
	Tritium	0.05	Nil	Nil

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2006 TBq	Discharges during 2006 % of annual limit[b]
Nuclear power stations				
Berkeley[k]	Beta	$3\ 10^{-5}$	$4.04\ 10^{-7}$	1.3
	Tritium	0.075	0.00386	5.1
	Carbon-14	0.011	$1.66\ 10^{-4}$	1.5
Bradwell	Beta	$6\ 10^{-4}$	$9.76\ 10^{-6}$	1.6
	Tritium	1.5	0.00843	<1
	Carbon-14	0.6	$5.63\ 10^{-4}$	<1
Chapelcross	Tritium	5000	121	2.4
	Sulphur-35	0.05	$4.20\ 10^{-5}$	<1
	Argon-41	4500	Nil	Nil
Dungeness A' Station	Beta[q]	$5.5\ 10^{-4}$	$1.97\ 10^{-4}$	36
	Tritium	2.6	0.181	7.0
	Carbon-14	5	1.93	39
	Sulphur-35	0.15	0.047	31
	Argon-41	1700	1280	75
Dungeness B' Station	Beta[q]	0.001	$5.54\ 10^{-6}$	<1
	Tritium	15	2.99	20
	Carbon-14	5	0.601	12
	Sulphur-35	0.45	0.0201	4.5
	Argon-41	150	13.6	9.1
	Iodine-131	0.005	$2.19\ 10^{-6}$	<1
Hartlepool	Beta[q]	0.001	$4.32\ 10^{-6}$	<1
	Tritium	6	1.26	21
	Carbon-14	5	1.47	29
	Sulphur-35	0.16	0.0198	12
	Argon-41	60	4.52	7.5
	Iodine-131	0.005	$2.29\ 10^{-5}$	<1
Heysham Station 1	Beta[q]	0.001	$8.57\ 10^{-6}$	<1
	Tritium	6	1.04	17
	Carbon-14	4	1.72	43
	Sulphur-35	0.12	0.0241	20
	Argon-41	60	8.55	14
	Iodine-131	0.005	$1.10\ 10^{-4}$	2.2
Heysham Station 2	Beta[q]	0.001	$1.18\ 10^{-5}$	1.2
	Tritium	15	0.994	6.6
	Carbon-14	3	1.27	42
	Sulphur-35	0.3	0.0149	5.0
	Argon-41	85	11.8	14
	Iodine-131	0.005	$5.39\ 10^{-5}$	1.1
Hinkley Point A' Station	Beta	$1.5\ 10^{-4}$	$8.39\ 10^{-7}$	<1
	Tritium	1.5	0.121	8.1
	Carbon-14	0.6	$6.87\ 10^{-4}$	<1
Hinkley Point B' Station	Beta[q]	0.001	$2.48\ 10^{-5}$	2.5
	Tritium	30	6.52	22
	Carbon-14	8	1.32	17
	Sulphur-35	0.4	0.180	45
	Argon-41	300	8.04	2.7
	Iodine-131	0.005	$4.06\ 10^{-6}$	<1

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2006 TBq	Discharges during 2006 % of annual limit[b]
Hunterston A' Station	Beta[q]	6 10^{-5}	2.83 10^{-7}	<1
	Tritium	0.02	0.00197	9.9
	Carbon-14	0.002	1.84 10^{-4}	9.2
Hunterston B' Station	Beta[q]	0.002	3.40 10^{-5}	1.7
	Tritium	20	1.66	8.3
	Carbon-14	3	1.68	56
	Sulphur-35	0.8	0.0222	2.8
	Argon-41	220	20.6	9.4
Oldbury	Beta	10^{-4}	1.39 10^{-5}	14
	Tritium	9	1.72	19
	Carbon-14	4	0.887	22
	Sulphur-35	0.45	0.0412	9.2
	Argon-41	500	19.6	3.9
Sizewell A' Station	Beta	8.5 10^{-4}	2.23 10^{-4}	26
	Tritium	3.5	1.42	41
	Carbon-14	2	1.49	75
	Sulphur-35	0.35	0.143	41
	Argon-41	3000	2130	71
Sizewell B' Station	Noble gases	300	3.05	1.0
	Halogens	0.003	5.33 10^{-4}	18
	Beta[q]	0.01	4.52 10^{-5}	<1
	Tritium	8	1.23	15
	Carbon-14	0.6	0.169	28
Torness	Beta[q]	0.002	4.22 10^{-6}	<1
	Tritium	20	1.91	9.6
	Carbon-14	3	0.688	23
	Sulphur-35	0.8	0.0136	1.7
	Argon-41	220	3.76	1.7
Trawsfynydd	Beta	5 10^{-5}	2.69 10^{-7}	<1
	Tritium	0.75	0.11	15
	Carbon-14	0.01	0.00296	30
Wylfa	Beta	7 10^{-4}	3.69 10^{-5}	5.3
	Tritium	18	2.65	15
	Carbon-14	2.3	1.28	56
	Sulphur-35	0.45	0.161	36
	Argon-41	100	14.8	15
Defence establishments				
Aldermaston[a,m]	Alpha	4.5 10^{-7}	5.85 10^{-8}	13
	Tritium	170	1.16	<1
	Krypton-85	1	0.0217	2.2
	Plutonium-241	1.68 10^{-6}	1.82 10^{-7}	11
	Other beta and gamma emitters	5 10^{-6}	1.05 10^{-7}	2.1
Barrow[l]	Tritium	3.2 10^{-6}	Nil	Nil
	Argon-41	0.048	Nil	Nil
Burghfield[a,m]	Tritium	0.05	Nil	Nil
	Uranium	2 10^{-8}	4.60 10^{-10}	2.3
Coulport	Tritium	0.05	0.00407	8.1
Derby[n,r]	Uranium	4 10^{-6}	6.22 10^{-7}	16
	Alpha[q]	2.4 10^{-8}	1.98 10^{-10}	<1
	Beta[q]	1.8 10^{-6}	4.56 10^{-8}	2.5

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2006	
			TBq	% of annual limit[b]
Devonport[o]	Beta/gamma[q]	$3\ 10^{-7}$	$3.91\ 10^{-8}$	13
	Tritium	0.004	$4.28\ 10^{-4}$	11
	Carbon-14	0.043	$8.84\ 10^{-3}$	21
	Argon-41	0.015	$1.22\ 10^{-4}$	<1
Dounreay (Vulcan)	Alpha[q]	10^{-6}	$4.68\ 10^{-11}$	<1
	Beta[q]	10^{-4}	$1.20\ 10^{-6}$	1.2
	Noble gases	0.027	$3.26\ 10^{-4}$	1.2
	Iodine-131	$3.7\ 10^{-4}$	$2.60\ 10^{-5}$	7.0
Rosyth[p]	Beta	10^{-7}	Nil	Nil
	Argon-41	0.4	Nil	Nil
Radiochemical production				
Amersham (GE Healthcare)	Alpha	$2.25\ 10^{-6}$	$1.21\ 10^{-7}$	5.4
	Beta>0.4 MeV	0.0202	$5.42\ 10^{-5}$	<1
	Radionuclides T1/2<2hr	0.01	$7.59\ 10^{-4}$	7.6
	Tritium	2	$1.08\ 10^{-6}$	<1
	Sulphur-35	0.035	0.00787	22
	Selenium-75	0.0015	$2.12\ 10^{-4}$	14
	Iodine-125	0.02	0.00118	5.9
	Iodine-131	0.001	$4.55\ 10^{-4}$	46
	Radon-222	10	2.92	29
	Other noble gases	50	17.2	34
	Other	0.016	$5.87\ 10^{-4}$	3.7
Cardiff (GE Healthcare)	Soluble tritium	156	70.69	45
	Insoluble tritium	600	248	41
	Carbon-14	2.38	1.68	71
	Phosphorus-32/33	$5\ 10^{-6}$	$7.80\ 10^{-7}$	16
	Iodine-125	$1.8\ 10^{-4}$	$4.49\ 10^{-5}$	25
	Other radionuclides	0.001	Nil	Nil

* *As reported to SEPA and the Environment Agency*

[a] *Some discharge limits and discharges are aggregated from data for individual locations on the site. Percentages are given as a general guide to usage of the limits but should strictly be calculated for individual locations. All discharges were below the appropriate limit for each location*

[b] *Data quoted to 2 significant figures except where values are <1%*

[c] *There are no numerical limits for this discharge. However, the authorisation stipulates that the Best Practicable Means should be used to control the discharge*

[d] *Limits for tritium, carbon-14, krypton-85 and iodine-129 vary with the mass of uranium processed by THORP*

[e] *Excluding curium-242 and 244*

[f] *Excluding tritium*

[g] *Excluding krypton-85*

[h] *Data excludes any curium-243 present*

[i] *Excluding radon and daughter products*

[j] *Krypton-85 discharges are calculated monthly*

[k] *Combined data for Berkeley Power Station and Berkeley Technology Centre*

[l] *Discharges from Barrow are included with those from MOD sites because they are related to submarine activities. Discharges were made by BAE Systems Marine Ltd*

[m] *Discharges were made by AWE plc*

[n] *Discharges were made by Rolls Royce Marine Power Operations Ltd*

[o] *Discharges were made by Devonport Royal Dockyard Ltd*

[p] *Discharges were made by Rosyth Royal Dockyard Ltd*

[q] *Particulate activity*

[r] *Annual limits on beta and alpha derived from monthly and weekly notification levels*

[s] *New authorisation in force from 23 March 2006. Authorisation held by AEAT revoked at the same time. discharges include those from AEAT up to 23 March 2006. the authorisation from AEAT included a limit for beta which was revoked at the same time.*

NA Not applicable under authorisation

BPM Best practicable means

Table A2.2 Principal discharges of liquid radioactive waste from nuclear establishments in the United Kingdom, 2006

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2006	
			TBq[a]	% of annual limit[b]
Nuclear fuel production and reprocessing				
Capenhurst (Rivacre Brook)	Tritium[c]	78	$0.0325\ 10^{-4}$	<1
	Uranium	0.02	$9.50\ 10^{-5}$	<1
	Uranium daughters	0.02	$1.78\ 10^{-4}$	<1
	Non-uranic alpha	0.003	$2.07\ 10^{-5}$	<1
	Technetium-99	0.1	$8.50\ 10^{-5}$	<1
Sellafield[d] (sea pipelines)	Alpha	1	0.205	21
	Beta	220	29	13
	Tritium	$2\ 10^{4}$	1090	5.5
	Carbon-14	21	10.9	52
	Cobalt-60	3.6	0.14	3.9
	Strontium-90	48	4.96	10
	Zirconium-95 + Niobium-95	3.8	0.155	4.1
	Technetium-99[f]	10	5.62	56
	Ruthenium-106	63	3.51	5.6
	Iodine-129	2.0	0.198	9.9
	Caesium-134	1.6	0.154	9.6
	Caesium-137	34	5.93	17
	Cerium-144	4.0	0.553	14
	Neptunium-237	1.0	0.0548	5.5
	Plutonium alpha	0.7	0.147	21
	Plutonium-241	25	3.64	15
	Americium-241	0.3	0.0518	17
	Curium-243+244	0.069	0.00215	3.1
	Uranium[i]	2000	439	22
Sellafield (factory sewer)	Alpha	$3\ 10^{-4}$	$6.38\ 10^{-5}$	21
	Beta	0.0061	$5.78\ 10^{-4}$	9.5
	Tritium	0.068	0.0214	31
Springfields	Alpha	0.55	0.08	15
	Beta	140	20.7	15
	Technetium-99	0.6	0.065	11
	Thorium-230	0.4	0.0119	3.0
	Thorium-232	0.015	$3.10\ 10^{-4}$	2.1
	Neptunium-237	0.04	0.00158	4.0
	Other transuranic radionuclides	0.02	0.00235	12
	Uranium	0.1	0.026	26
Research establishments				
Dounreay PFR liquid metal disposal plant	Alpha[4]	0.02	$9.33\ 10^{-6}$	<1
	Beta[1]	0.11	$3.20\ 10^{-4}$	<1
	Tritium	1.4	0.00126	<1
	Sodium-22	1.8	0.0191	1.1
	Caesium-137	0.066	$1.48\ 10^{-4}$	<1
Dounreay Other facilities	Alpha	0.09	$4.08\ 10^{-4}$	<1
	Beta	0.62	$6.50\ 10^{-4}$	<1
	Tritium	5.5	0.335	6.1
	Strontium-90	0.77	0.0963	13
	Caesium-137	1.0	0.0116	1.2
Harwell (pipeline)	Alpha	5 10-5	$5.61\ 10^{-6}$	11
	Beta	0.0033	$1.93\ 10^{-4}$	5.9
	Tritium	0.3	0.00260	<1
	Cobalt-60	$1.2\ 10^{-4}$	$1.74\ 10^{-6}$	1.5
	Caesium-137	$5.4\ 10^{-4}$	$2.98\ 10^{-5}$	5.5
Harwell (Lydebank Brook)	Alpha	10^{-4}	$9.77\ 10^{-6}$	9.8
	Beta	$6\ 10^{-4}$	$4.81\ 10^{-5}$	8.0
	Tritium	0.08	0.00631	7.9

Table A2.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2006	
			TBq[a]	% of annual limit[b]
Winfrith (inner pipeline)[7]	Alpha	0.02	$1.01\ 10^{-4}$	<1
	Tritium	220	16.0	7.3
	Caesium-137	2	0.033	1.7
	Other radionuclides	1	0.00421	<1
Winfrith (outer pipeline)[7]	Alpha	0.002	$3.11\ 10^{-5}$	1.6
	Tritium	0.15	0.00513	3.4
	Other radionuclides	0.001	$4.93\ 10^{-5}$	4.9
Winfrith (River Frome)[7]	Tritium	0.75	Nil	Nil
Minor sites				
Imperial College Reactor Centre	Tritium	$4\ 10^{-5}$	$1.08\ 10^{-5}$	27
Ascot	Other radioactivity	10-4	$1.00\ 10^{-9}$	<1
Scottish Universities Environmental Research Centre				
East Kilbride	Total activity	0.00169	$6.34\ 10^{-5}$	3.8
Nuclear power stations				
Berkeley	Tritium	2	$2.34\ 10^{-4}$	<1
	Caesium-137	0.2	$7.20\ 10^{-4}$	<1
	Other radionuclides	0.4	$6.36\ 10^{-4}$	<1
Bradwell	Tritium	7	0.255	3.6
	Caesium-137	0.7	0.173	25
	Other radionuclides	0.7	0.263	38
Chapelcross	Alpha	0.1	$1.06\ 10^{-5}$	<1
	Beta[1]	25	0.0036	<1
	Tritium	5.5	0.0113	<1
Dungeness	Tritium	8	2.70	34
A' Station	Caesium-137	1.1	0.0789	7.2
	Other radionuclides	0.8	0.0908	11
Dungeness	Tritium	650	264	41
B' Station	Sulphur-35	2	0.249	12
	Cobalt-60	0.03	0.00356	12
	Other radionuclides	0.25	0.0213	8.5
Hartlepool	Tritium	1200	238	20
	Sulphur-35	3	0.275	9.2
	Cobalt-60	0.03	$2.08\ 10^{-4}$	<1
	Other radionuclides	0.3	0.0100	3.3
Heysham	Tritium	1200	351	29
Station 1	Sulphur-35	2.8	0.284	10
	Cobalt-60	0.03	$3.58\ 10^{-4}$	1.2
	Other radionuclides	0.3	0.0176	5.9
Heysham	Tritium	1200	321	27
Station 2	Sulphur-35	2.3	0.107	4.7
	Cobalt-60	0.03	$7.74\ 10^{-5}$	<1
	Other radionuclides	0.3	0.0124	4.1
Hinkley Point				
A' Station	Tritium	1.8	0.28	16
	Caesium-137	1	0.14	14
	Other radionuclides	0.7	0.13	19
Hinkley Point				
B' Station	Tritium	620	309	50
	Sulphur-35	5	0.381	7.6
	Cobalt-60	0.033	$1.35\ 10^{-4}$	<1
	Other radionuclides	0.235	0.0119	5.1

Table A2.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2006	
			TBq[a]	% of annual limit[b]
Hunterston A' Station	Alpha	0.04	$8.72\ 10^{-5}$	<1
	Beta	0.6	0.0455	7.6
	Tritium	0.7	$5.30\ 10^{-4}$	<1
	Plutonium-241	1.0	$6.30\ 10^{-5}$	<1
Hunterston B' Station	Alpha	0.001	$5.94\ 10^{-5}$	5.9
	Beta	0.45	0.00601	1.3
	Tritium	800	315	39
	Sulphur-35	10	0.582	5.8
	Cobalt-60	0.03	$5.30\ 10^{-4}$	1.8
Oldbury	Tritium	1	0.154	15
	Caesium-137	0.7	0.396	57
	Other radionuclides	0.7	0.115	16
Sizewell A' Station	Tritium	11	0.916	8.3
	Caesium-137	1	0.569	57
	Other radionuclides	0.7	0.398	57
Sizewell B' Station	Tritium	80	55.1	69
	Other radionuclides	0.2	0.0217	11
Torness	Alpha	0.001	$1.44\ 10^{-5}$	1.4
	Beta[2,3,6]	0.45	0.00217	<1
	Tritium	800	273	34
	Sulphur-35	10	0.0141	<1
	Cobalt-60	0.03	$2.46\ 10^{-4}$	<1
Trawsfynydd	Tritium	0.5	0.00332	<1
	Strontium-90	0.05	$3.2\ 10^{-4}$	<1
	Caesium-137	0.03	0.00192	5.3
	Other radionuclides[5]	0.17	0.00181	1.1
Wylfa	Tritium	15	3.27	22
	Other radionuclides	0.11	0.017	15
Defence establishments				
Aldermaston (River Thames)[g]	Alpha	$6\ 10^{-5}$	Nil	Nil
	Tritium	0.05	Nil	Nil
	Plutonium-241	$2.4\ 10^{-4}$	Nil	Nil
	Other radionuclides	$6\ 10^{-5}$	Nil	Nil
Aldermaston (Silchester)	Alpha	$4\ 10^{-5}$	$2.09\ 10^{-6}$	5.2
	Beta/gamma	$1.2\ 10^{-4}$	$1.01\ 10^{-5}$	8.4
	Tritium	0.05	$9.85\ 10^{-4}$	2.0
Aldermaston (to Stream)	Tritium	0.01	0.00110	11
Barrow[l]	Tritium	0.012	$2.80\ 10^{-4}$	2.3
	Other gamma emitting radionuclides	$3.5\ 10^{-6}$	$2.28\ 10^{-6}$	65
Derby[m]	Alpha[n]	0.002	$5.12\ 10^{-5}$	2.6
	Alpha[o]	$3\ 10^{-7}$	Nil	Nil
	Beta[o]	$3\ 10^{-4}$	$3.03\ 10^{-8}$	<1
Devonport[k] (sewer)	Tritium	0.002	$2.87\ 10^{-4}$	14
	Cobalt-60	$3.5\ 10^{-4}$	$1.50\ 10^{-5}$	4.3
	Other radionuclides	$6.5\ 10^{-4}$	$3.43\ 10^{-4}$	53

Table A2.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2006	
			TBq[a]	% of annual limit[b]
Devonport[k,p] (pipeline)	Tritium	0.7	0.127	18
	Carbon-14	0.0017	$3.25\ 10^{-4}$	19
	Cobalt-60	$8\ 10^{-4}$	$1.90\ 10^{-4}$	24
	Other radionuclides	$3\ 10^{-4}$	$1.54\ 10^{-4}$	51
Faslane	Alpha	$2\ 10^{-4}$	$7.10\ 10^{-7}$	<1
	Beta[3,6]	$5\ 10^{-4}$	$6.20\ 10^{-6}$	1.2
	Tritium	1	0.121	12
	Cobalt-60	$5\ 10^{-4}$	$3.01\ 10^{-6}$	<1
Rosyth[j]	Alpha	$5.00\ 10^{-7}$	$8.50\ 10^{-8}$	17
	Beta[3,6]	$4.80\ 10^{-4}$	$7.49\ 10^{-5}$	16
	Tritium	0.012	0.00112	9.4
	Cobalt-60	0.0025	$9.93\ 10^{-5}$	4.0
Radiochemical production				
Amersham (GE Healthcare)	Alpha	$3\ 10^{-4}$	$1.24\ 10^{-5}$	4.1
	Beta>0.4 MeV	0.06	$3.00\ 10^{-4}$	<1
	Tritium	0.141	$6.89\ 10^{-4}$	<1
	Iodine-125	0.004	$6.13\ 10^{-5}$	1.5
	Caesium-137	0.005	$1.54\ 10^{-5}$	<1
	Other radionuclides	0.215	$6.25\ 10^{-3}$	2.9
Cardiff (GE Healthcare)	Tritium	130	24.8	19
	Carbon-14	0.91	0.285	31
	Phosphorus-32/33	$8.5\ 10^{-5}$	$1.19\ 10^{-6}$	1.4
	Iodine-125	$3\ 10^{-4}$	$1.87\ 10^{-6}$	<1
	Others	$1.2\ 10^{-4}$	$1.85\ 10^{-7}$	<1
Industrial and landfill sites				
Drigg (sea pipeline)[e8]	Alpha	BPM	$7.37\ 10^{-5}$	NA
	Beta	BPM	$9.53\ 10^{-4}$	NA
	Tritium	BPM	0.157	NA
Drigg (stream)[h8]	Alpha	NA	NA	
	Beta	NA	NA	
	Tritium	NA	NA	

[a] Some discharges are upper estimates because they include 'less than' data derived from analyses of effluents at limits of detection. Data quoted to 3 significant figures except where fewer significant figures are provided in source documents
[b] Data quoted to 2 significant figures except when values are less than 1%
[c] The limit for tritium is derived from a limit on activity concentration in Rivacre Brook of 111 Bq ml^{-1} and a flow rate of 90 m^3 h^{-1}
[d] Limits for tritium and iodine-129 vary with the mass of uranium processed by the THORP plant
[e] Discharge authorisations at Drigg were revised with effect from 1 May 2006
[f] New authorisation 1 April 2006
[g] Discharge ceased from 15 March 2005
[h] Discharges and limits are expressed in terms of concentrations of activity in Bq m^{-3} (discharges are expressed as the annual mean)
[i] The limit and discharge data are expressed in kg
[j] Discharges were made by Rosyth Royal Dockyard Ltd
[k] Discharges were made by Devonport Royal Dockyard Ltd
[l] Discharges from Barrow are included with those from MOD sites because they are related to submarine activities. Discharges were made by BAE Systems Marine Ltd
[m] Discharges were made by Rolls Royce Marine Power Operations Ltd
[n] Discharge limit is for Nuclear Fuel Production Plant
[o] Discharge limit is for Neptune Reactor and Radioactive Components Facility
[p] Discharges were also made by the Ministry of Defence. Discharge limits amended to BPM (1 May 2006)
[1] All beta and gamma emitting radionuclides (excluding tritium, sodium-22 and caesium-137) taken together
[2] Excluding sulphur-35
[3] Excluding cobalt-60
[4] All alpha emitting radionuclides taken together
[5] Including strontium
[6] Excluding tritium
[7] New authorisation March 2006
[8] New authorisation from May 2006 - limits revoked
NA Not applicable under new authorisation
BPM Best practicable means

Table A2.3. Disposals of solid radioactive waste at nuclear establishments in the United Kingdom, 2006

Establishment	Radioactivity	Disposal limit, (annual equivalent) TBq	Disposals during 2006 TBq	Disposals during 2006 % of limit[a]
Drigg[b]	Tritium	10	0.470	4.7
	Carbon-14	0.05	0.0100	20
	Cobalt-60	2	0.150	7.5
	Iodine-129	0.05	$1.71\ 10^{-4}$	<1
	Radium-226 plus thorium-232	0.03	0.00661	22
	Uranium	0.3	0.03	10
	Other alpha[d]	0.3	0.184	61
	Others[d,e]	15	3.22	21
Dounreay[c]	Alpha		Nil	Nil
	Beta/gamma		Nil	Nil

[a] *Data quoted to 2 significant figures except where values are less than 1%*
[b] *Discharge authorisations at Drigg were revised with effect from 1 May 2006*
[c] *The current authorisation includes limits on concentrations of activity. At no time did the concentrations exceed the limits*
[d] *With half-lives greater than 3 months excluding uranium, radium-226 and thorium-232*
[e] *Iron-55 and beta-emitting radionuclides with half-lives greater than three months unless individually specified in this table*

APPENDIX 3. Abbreviations and glossary

AEA	Atomic Energy Authority
AGR	Advanced Gas-Cooled Reactor
AWE	Atomic Weapons Establishment
BNFL	British Nuclear Fuels plc
BNG	British Nuclear Group
BNGSL	British Nuclear Group Sellafield Ltd
CAC	Codex Alimentarius Commission
CEC	Commission of the European Communities
CEDA	Consultative Exercise on Dose Assessments
Cefas	Centre for Environment, Fisheries & Aquaculture Science
Defra	Department for Environment, Food and Rural Affairs
DETR	Department of the Environment, Transport and the Regions
DML	Devonport Management Ltd.
DPAG	Dounreay Particles Advisory Group
DRDL	Devonport Royal Dockyard Ltd
DSTL	Defence Science and Technology Laboratory
EA	Environment Agency
EARP	Enhanced Actinide Removal Plant
EC	European Commission
EHS	Environment and Heritage Service
EU	European Union
FEPA 85	Food and Environment Protection Act 1985
FHP	Fuel Handling Plant
FSA	Food Standards Agency
GDL	Generalised Derived Limit
GE	General Electric
HMIP	Her Majesty's Inspectorate of Pollution
HMNB	Her Majesty's Naval Base
HMSO	Her Majesty's Stationery Office
HPA	Health Protection Agency
HSE	Health & Safety Executive
HSL	Harwell Scientifics Limited
IAEA	International Atomic Energy Agency
IC	Imperial College
ICRP	International Commission on Radiological Protection
IRPA	International Radiation Protection Association
LLW	Low-Level Waste
LLWR	Low-Level Waste Repository
LoD	Limit of Detection
MAC	Medium Active Concentrate
MAFF	Ministry of Agriculture, Fisheries & Food
MoD	Ministry of Defence
MRL	Minimum reporting level
ND	Not detected
NDA	Nuclear Decommissioning Authority
NII	Nuclear Installations Inspectorate
NNC	National Nuclear Corporation
NRPB	National Radiological Protection Board
NRTE	Naval Reactor Test Establishment
NSL	Nexia Solutions Ltd
OBT	Organically bound tritium
OECD	Organisation for Economic Co-operation and Development
OSPAR	Oslo and Paris Convention
RIFE	Radioactivity in Food and the Environment
RRDL	Rosyth Royal Dockyard Ltd.
RRMPOL	Rolls Royce Marine Power Operations Ltd
RNAS	Royal Naval Air Station
RSA 93	Radioactive Substances Act 1993
SEPA	Scottish Environment Protection Agency
SFL	Springfields Fuels Ltd
SIXEP	Site Exchange Effluent Plant
SL	Scientific Ltd
SLC	Site Licence Company
SRP	Society for Radiological Protection
TDS	Total Diet Study
THORP	Thermal Oxide Reprocessing Plant
TNORM	Technologically enhanced Naturally-Occurring Radioactive Material
TPP	Tetrophenylphosphonium bromide
TRAMP	Terrestrial Radioactive Monitoring Programme
UK	United Kingdom
UKAEA	United Kingdom Atomic Energy Authority
VLA	Veterinary Laboratories Agency
WELL	Winfrith Environmental Level Laboratory
WFD	Water Framework Directive
WHO	World Health Organisation
WMTL	Waste Management Technology Limited
YP	Ystradyfodwg and Pontypridd

Absorbed dose	The ionising radiation energy absorbed in a material per unit mass. The unit for absorbed dose is the gray (Gy) which is equivalent toJ kg^{-1}.
Becquerel	One radioactive transformation per second.
Committed effective	The sum of the committed equivalent doses for all organs and tissues in the body resulting from an intake (of a radionuclide), having been weighted by their tissue weighting factors. The unit of committed effective dose is the Sievert (Sv). The 'committed' refers to the fact that the dose is received over a number of years but it is accounted for in the year of the intake of the activity.
Critical group	Those (or the 'representative individual') who receive the largest dose from artificially-produced radionuclides due to their habits, diet and where they spend their time.
Direct shine	Ionising radiation which arises directly from processes or operations on premises using radioactive substances and not as a result of discharges of those substances to the environment.
Dose	Shortened form of 'effective dose' or 'absorbed dose'.
Dose limits	Maximum permissible dose resulting from ionising radiation from practices covered by the Euratom Basic Safety Standards Directive, excluding medical exposures. It applies to the sum of the relevant doses from external exposures in the specified period and the 50 year committed doses (up to age 70 for children) from intakes in the same period. Currently, the limit has been defined as 1 mSv per year for the UK.
Dose rates	The radiation dose delivered per unit of time.
Effective dose	The sum of the equivalent doses from internal and external radiation in all tissue and organs of the body, having been weighted by their tissue weighting factors. The unit of effective dose is the Sievert (Sv). Environmental materials include freshwater, grass, seawater, seaweed, sediment, soil and various species of plants.
Equivalent dose	The absorbed dose in a tissue or organ weighted for the type and quality of the radiation by a radiation-weighting factor. The unit of equivalent dose is the Sievert (Sv).
External dose	Doses to humans from sources that do not involve ingestion or inhalation of the radionuclides.
Fragments	'Fragments' are considered to be fragments of irradiated fuel, which are up to a few millimetres in diameter.
Generalised derived limit	A convenient reference level against which the results of environmental monitoring can be compared. GDLs are calculated using deliberately cautious assumptions and are based on the assumption that the level of environmental contamination is uniform over the year. GDLs relate the concentrations of a single radionuclide in a single environmental material to the dose limit for members of the public.
Indicator materials	Environmental materials may be sampled for the purpose of indicating trends in environmental performance or likely impacts on the foodchain. These include seaweed, soil and grass.
In-growth	Additional activity produced as a result of radioactive decay of parent radionuclides.
Kerma air rate	Air kerma is the quotient of the sum of the kinetic energies of all the charged particles liberated by indirectly ionising particles in a specified mass of air.
Radiation exposure	Being exposed to radiation from which a dose can be received.
Radiation Weighting	Factor used to weight the tissue or organ absorbed dose to take account Factor of the type and quality of the radiation. Example radiation weighting factors: alpha particles = 20; beta particles = 1; photons = 1.
Radioactivity	The emission of alpha particles, beta particles, neutrons and gamma or x-radiation from the transformation of an atomic nucleus.
Radionuclide	An unstable form of an element that undergoes radioactive decay.
Representative individual	A hypothetical individual receiving a dose that is representative of the most exposed individuals in the population.
TNORM	Naturally-occurring radioactive materials that may have been tecnologically enhanced in some way. The enhancement has occurred when a naturally-occurring radioactive material has its composition, concentration, availability, or proximity to people altered by human activity. The term is usually applied when the naturally-occurring radionuclide is present in sufficient quantities or concentrations to require control for purposes of radiological protection of the public or the environment.
Tissue Weighting Factors	Factor used to weight the equivalent dose in a tissue or organ to take. Factors account of the different radiosensitivity of each tissue and organ. Example tissue weighting factors: lung = 0.12; bone marrow = 0.12; skin = 0.01
Total dose	An assessment of dose that takes into account all exposure pathways such as radionuclides in food and the environment and direct radiation

APPENDIX 4. Assessment of the *total dose* integrated across pathways

A4.1 Introduction

This appendix describes the methods, data and results used to assess *total dose* to the public near nuclear sites from all exposure pathways. The approach uses dietary and occupancy data collected from integrated habit surveys carried out around nuclear sites. The habit surveys are targeted at those most likely to be exposed around the site and gathers data on people's occupancy close to each site and local food intake rates. The sites for which integrated habit survey data are currently available are: Aldermaston and Burghfield, Amersham, Cardiff, Chapelcross, Devonport, Dounreay, Dungeness, Faslane, Hartlepool, Heysham, Hinkley Point, Hunterston, Rosyth, Sellafield, Sizewell, Springfields, Torness, Trawsfynydd, Winfrith and Wylfa. Further sites will be added in future RIFE reports as new integrated surveys are undertaken.

A4.2 Objectives

The Environment Agencies are required to ensure that doses to the public do not exceed 1 mSv per year from all routine man made sources, except certain medical ones. Doses to the public are assessed and compared with the dose limit. For nuclear sites the dose assessment takes into account exposure to radionuclides in food and the environment and direct radiation. The assessment makes use of the monitoring results reported elsewhere in this report. The monitoring and habits data used in the assessment are provided for each site on the CD accompanying this report.

A4.3 Methods and data

The calculation method relies on the application of data from site-specific habits surveys (Camplin *et al.,* 2005). This is possible because recent surveys have considered the habits of individuals in an integrated way, i.e. information for each individual has been recorded for all of the pathways of interest. Using the habits survey data, the people who are regarded as having the potential to receive the highest doses are identified for each major pathway at each site. Doses to the public from direct radiation are included in the assessment of *total dose* using information provided by the HSE who are responsible for regulating dose from direct radiation to the public (see Table A4.1) (Stephen, 2006 and Bunker, 2007).

Table A4.1. Individual radiation exposures - direct radiation pathway, 2006

Site	Exposure, mSv
Nuclear fuel production and reprocessing	
Capenhurst	0.085
Sellafield	Bgd[a]
Springfields	<0.020
Research establishments	
Dounreay	<0.010
Harwell	0.026
Winfrith	Bgd[a]
Nuclear power stations	
Berkeley	0.089[b]
Bradwell	<0.067[b]
Chapelcross	Bgd[a,c]
Dungeness	0.54[b]
Hartlepool	<0.020
Heysham	<0.020
Hinkley Point	<0.0021[b]
Hunterston	0.083[b]
Oldbury	<0.0049[b]
Sizewell	<0.026[b]
Torness	<0.020
Trawsfynydd	0.019[b]
Wylfa	0.0086[b]
Defence establishments	
Aldermaston	Bgd[a]
Burghfield	Bgd[a]
Derby	Bgd[a]
Radiochemical production	
Amersham	0.22
Cardiff (Amersham plc)	Bgd[a]
Industrial and landfill sites	
Drigg	<0.090

[a] *Doses not significantly different from natural background*
[b] *2005 data used due to unavailability of 2006 data*
[c] *2004 data used due to unavailability of 2005 and 2006 data*

The methodology may be summarised in four steps;

1) Starting with the first pathway, individuals are selected from the habit data based on the 'cut-off' method whereby all those who have habits within a factor of three of the maximum observed for the pathway are selected as members of the potential critical group for that pathway (Hunt *et al.*, 1982; Preston *et al.*,1974).

2) Habit profiles for a particular pathway (for example fish consumers) are calculated for the selected adults by averaging the habit data chosen by the cut-off method. The profile includes averages of *all the other habits* identified in the integrated habit survey. Habit profiles for children and infants are derived from the adult profiles using scaling factors.

3) Steps 1) and 2) are repeated for each pathway, thereby deriving a profile associated with each pathway and a series of potential critical groups.

4) Once all pathway profiles have been determined, doses are calculated for each profile using the environmental and food data. Doses from direct radiation are included via those profiled groups who spend time near to the nuclear site. The group with the highest dose near each site becomes the critical group.

The habit profiles that gave rise to the highest doses in this assessment of RIFE 2006 data are given in files on the CD accompanying this report. Care should be taken in using these data in other circumstance because the profile leading to the highest doses may change if the measured or forecast concentrations and dose rates change. Doses are calculated for each potential critical group using the same concentration and dose rate information used in the routine assessments earlier in this report. Pathways related to gaseous discharges, which are not included in the routine monitoring programmes (in particular inhalation and plume shine), were assessed using dispersion modelling within the PC CREAM assessment code (Mayall *et al.,* 1997). A similar approach is used for the routine assessments and is described in Appendix 1.

A4.4 Results of the assessment of *total dose*

The results of the assessment are summarised in Table A4.2 for each site. The data are presented in three parts. The group receiving the highest dose from the pathways predominantly relating to gaseous discharges and direct radiation are shown in the upper half of the tables, part A; those for liquid discharges in the middle part, part B. Occasionally the group receiving the highest dose from all pathways is different from that in A and B. Therefore we have also presented this case in part C. The major contributions to dose are also presented.

In all cases, doses estimated for 2006 were less than the limit of 1mSv for members of the public. The most important group for gaseous discharges and direct radiation varied from site to site but the dominant pathway was often direct radiation where it was applicable. The most important groups for liquid discharges were generally adult seafood consumers or occupants over contaminated substrates. The highest dose was at Dungeness and was mostly due to direct radiation. The next highest dose was at Sellafield and Whitehaven though about half was due to the legacy of discharges of naturally-occurring radionuclides from a phosphate processing works in Whitehaven. These broad results and the numerical values of dose are similar to those found in routine assessments earlier in this report, taking into account the additional effect of direct radiation where it is prominent

A4.5 Trends in *total dose*

Total doses have been calculated in RIFE using the methodology described in this Appendix since 2003. Over this time the number of sites with combined habits survey data has increased from 6 to the current 20. The *total doses* calculated for nuclear sites since 2003 are presented in Table A4.3. There has been a steady decrease in *total dose* at Cardiff due to reductions in discharges of tritium in liquid wastes. *Total dose* at Sellafield has also generally reduced due to reductions in discharges and their effects on food and the environment, but this effect is overlaid on changes to the occupancies and consumption rates of local consumers. There have been no other significant trends in *total dose* identified from the assessments undertaken.

Table A4.2. Individual radiation exposures integrated across pathways, 2006

Site	Critical group	Exposure, mSv	
		Total	Dominant contributions
A Gaseous releases and direct radiation from the site			
Aldermaston and Burghfield	Milk consumers aged 1y	<0.005	Milk, ^{3}H, ^{137}Cs, ^{234}U
Amersham	Local adult inhabitants (0 - 0.25km)	0.22	Direct radiation
Cardiff	Milk consumers aged 1y	<0.005	Milk, ^{3}H, ^{14}C, ^{32}P, ^{35}S, ^{137}Cs
Chapelcross	Milk consumers aged 1y	0.024	Milk, ^{14}C, ^{35}S, ^{90}Sr, ^{241}Am
Devonport	Prenatal children of green vegetable consumers	<0.005	Fruit, green vegetables, root vegetables, ^{3}H
Dounreay	Milk consumers aged 1y	0.029	Milk, ^{90}Sr, ^{106}Ru, ^{129}I, ^{144}Ce, ^{241}Am
Dungeness	Local adult inhabitants (0 - 0.25km)	0.55	Direct radiation
Faslane	-	-	
Hartlepool	Prenatal children of local inhabitants (0 - 0.25km)	0.021	Direct radiation
Heysham	Local adult inhabitants (0.25 - 0.5km)	0.021	Direct radiation
Hinkley Point	Prenatal children of local inhabitants (0.5 - 1km)	<0.005	Direct radiation, plume related pathways
Hunterston	Adult mushroom consumers	0.097	Direct radiation
Rosyth	-	-	
Sellafield and Whitehaven	Milk consumers aged 1y	0.019	Milk, ^{90}Sr, ^{60}Co, ^{137}Cs
Sizewell	Prenatal children of wild fruit and nut consumers	0.091	Direct radiation
Springfields	Adult mushroom consumers	0.020	Direct radiation
Torness	Adult root vegetable consumers	0.024	Direct radiation
Trawsfynydd	Local inhabitants aged 1 y (0.25 - 0.5km)	0.022	Direct radiation, milk
Winfrith	Adult green vegetable consumers	<0.005	Potatoes, root vegetables, green vegetables, milk, domestic fruit, gamma dose rate over sediment, ^{137}Cs
Wylfa	Adult local inhabitants (0 - 0.25km)	0.009	Direct radiation
B Liquid releases from the site			
Aldermaston and Burghfield	Adult occupants of river bank	<0.005	External dose from riverbank
Amersham	Adult occupants over sediment	<0.005	Gamma dose rate over sand/stone, freshwater fish, ^{241}Am
Cardiff	Prenatal children of fish consumers	0.011	Fish, ^{3}H, ^{14}C
Chapelcross	Adult occupants over sediment	0.015	Gamma dose rate over sediment
Devonport	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Dounreay	'Other' vegetable consumers aged 1 y	0.012	Potatoes, root vegetables, ^{90}Sr, ^{103}Ru
Dungeness	Adult occupants over sediment	0.011	Gamma dose rate over sediment
Faslane	Adult occupants over sediment	<0.005	Gamma dose rate over mud
Hartlepool	Prenatal children of mollusc consumers	<0.005	Direct radiation, molluscs, ^{14}C
Heysham	Adult occupants over sediment	0.037	Gamma dose rate over sediment
Hinkley Point	Adult mollusc consumers	0.048	Gamma dose rate over sediment
Hunterston	Adult occupants over sediment	0.009	Gamma dose rate over sediment
Rosyth	Adult crustacean consumers	<0.005	Fish, crustaceans, ^{241}Am
Sellafield and Whitehaven	Adult mollusc consumers	0.44	Molluscs, ^{210}Po, ^{241}Am
Sizewell	Prenatal children of occupants over sediment	<0.005	Direct radiation, gamma dose rate over sediment
Springfields	Adult occupants on houseboats	0.13	Gamma dose rate over sediment
Torness	Adult fish consumers	<0.005	Direct radiation, fish, ^{241}Am
Trawsfynydd	Prenatal children of occupants over sediment	0.007	Gamma dose rate over sediment, direct radiation, fish, ^{90}Sr
Winfrith	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Wylfa	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
C Combined releases from the site			
Aldermaston and Burghfield	Milk consumers aged 1y	<0.005	Milk, ^{3}H, ^{137}Cs, ^{234}U
Amersham	Local adult inhabitants (0 - 0.25km)	0.22	Direct radiation
Cardiff	Prenatal children of fish consumers	0.011	Fish, ^{3}H, ^{14}C
Chapelcross	Milk consumers aged 1y	0.024	Milk, ^{14}C, ^{35}S, ^{90}Sr, ^{241}Am
Devonport	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Dounreay	Milk consumers aged 1y	0.029	Milk, ^{90}Sr, ^{106}Ru, ^{129}I, ^{144}Ce, ^{241}Am

Table A4.2. continued

Site	Critical group	Exposure, mSv	
		Total	Dominant contribution
Dungeness	Local adult inhabitants (0 - 0.25km)	0.55	Direct radiation
Faslane	Adult occupants over sediment	<0.005	Gamma dose rate over mud
Hartlepool	Prenatal children of local inhabitants (0 - 0.25km)	0.021	Direct radiation
Heysham	Adult occupants over sediment	0.037	Gamma dose rate over sediment
Hinkley Point	Adult mollusc consumers	0.048	Gamma dose rate over sediment
Hunterston	Adult mushroom consumers	0.097	Direct radiation
Rosyth	Adult crustacean consumers	<0.005	Fish, crustaceans, ^{241}Am
Sellafield and Whitehaven	Adult mollusc consumers	0.44	Molluscs, ^{210}Po, ^{241}Am
Sizewell	Prenatal children of wild fruit and nut consumers	0.091	Direct radiation
Springfields	Adult occupants on houseboats	0.13	Gamma dose rate over sediment
Torness	Adult root vegetable consumers	0.024	Direct radiation
Trawsfynydd	Local inhabitants aged 1 y (0.25 - 0.5km)	0.022	Direct radiation, milk
Winfrith	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Wylfa	Adult local inhabitants (0.25 - 0.5km)	0.009	Direct radiation

Table A4.3. Trends in total dose from all sources[a]

Site	2003	2004	2005	2006
Aldermaston and Burghfield	<0.005	<0.005	<0.005	<0.005
Amersham		0.24	0.24	0.22
Cardiff	0.038	0.023	0.023	0.011
Chapelcross			0.023	0.024
Devonport		<0.005	<0.005	<0.005
Dounreay	0.012	0.011	0.043	0.029
Dungeness			0.55	0.55
Faslane				<0.005
Hartlepool	0.021	0.021	0.021	0.021
Heysham				0.037
Hinkley				0.048
Hunterston		0.10	0.090	0.097
Rosyth			<0.005	<0.005
Sellafield and Whitehaven	0.71	0.60	0.41	0.44
Sizewell			0.086	0.091
Springfields				0.13
Torness				0.024
Trawsfynydd			0.021	0.022
Winfrith	<0.005	<0.005	<0.005	<0.005
Wylfa		0.011	0.010	0.009

[a] *Where no data is given, no assessment was undertaken due to a lack of suitable habit data at the time*

APPENDIX 5. Research in support of the monitoring programmes

The Food Standards Agency and the Environment Agencies have programmes of special investigations and supporting research and development studies to complement the routine monitoring programmes. This additional work is primarily directed at the following objectives:

- to evaluate the significance of potential sources of radionuclide contamination of the food chain and the environment;
- to identify and investigate specific topics or pathways not currently addressed by the routine monitoring programmes and the need for their inclusion in future routine monitoring;
- to develop and maintain site-specific habit and agricultural practice data, in order to improve the realism of dose assessment calculations;
- to develop more sensitive and/or efficient analytical techniques for measurement of radionuclides in natural matrices;
- to evaluate the competence of laboratories' radiochemical analytical techniques for specific radionuclides in food and environmental materials;
- to develop improved methods for handling and processing monitoring data.

Other studies include projects relating to effects on wildlife, emergency response and planning and development of new environmental models and data.

The contents of the research programmes are regularly reviewed and open meetings are held to discuss ongoing, completed and potential future projects. Occasionally specific topics are the subject of dedicated workshops (e.g. Ould-Dada, 2000). A summary of all the research and development undertaken by the Environment Agency between 1996 and 2001 was published in 2002 (Environment Agency, 2002b). A review of research funded by the Food Standards Agency was published in 2004 (Food Standards Agency, 2004).

A list of related projects completed in 2006 is presented in Table A5.1. Those sponsored by the Environment Agency and the Food Standards Agency are also listed on the Internet (www.environment-agency.gov.uk, www.food.gov.uk, respectively). Copies of the final reports for each of the projects funded by the Food Standards Agency are available from the Emergency Planning, Radiation and Incidents Division, Aviation House, 125 Kingsway, London WC2B 6NH. Further information on studies funded by the Scottish Environment Protection Agency and the Scotland and Northern Ireland Forum for Environmental Research is available from Greenside House, 25 Greenside Place, Edinburgh, EH1 3AA. Environment Agency reports are available from www.environment-agency.gov.uk. A charge may be made to cover costs. Table A5.1 also provides information on projects that are currently underway. The results of these projects will be made available in due course. A short summary of the key points from specific monitoring projects that have recently been completed is given here.

Table A5.1. Extramural projects

Topic	Reference	Further details	Target completion date
Transfer of radionuclides into sewage sludge	SC020150	E	Complete
Soil and herbage survey	UKRSR01 and SC000027	E, S	Jun-07
Total diet studies	R03024	F	Mar-07
Discharges to sewer by non-nuclear industry in Scotland	SEPA	S	Sep-07
Tritium transfer from sewage sludge to plants	R01041	F	Sep-07
Availability of technetium-99 to seafood from contaminated sediments	R01062	F	Mar-08
Transfer from seaweed to terrestrial foods	R04003	F	Dec-08
Measurement of radioactivity in canteen meals for Euratom (2005-2008)	R03025	F	Mar-09

E Environment Agency
F Food Standards Agency
S Scotland and Northern Ireland Forum for Environmental Research or SEPA

Radionuclides in Sewage Systems – P3-109A and P3 -109B

In 2006, two research projects on the behaviour of radionuclides in sewage came to completion.

This first report described a set of laboratory experiments designed to provide robust sludge retention factors for using in predicting the partitioning of radionuclides between sludge and treated effluent during sewage treatment (Punt *et al*, in publication, 2007a).

The second report followed the fate of I-131 after discharge to a Sewage Treatment works in South West London (Punt *et al*, in publication, 2007b).

The first study (P3-109A) carried out partitioning experiments on the solid-solution behaviour of a range of radio-elements (Br; Ca; Co; Cu; Fe; Ga; I; In; La; Mn; Ni; P; Re (as an analogue for Tc); S; Sr; Th; U; V; and, Y. These elements were chosen because radioisotopes of these elements are discharged to sewers from a number of non-nuclear establishments in England and Wales and the radiological impact of the discharges can be relatively high. Experiments were carried out to emulate sewage treatment by specialist laboratories using sewage materials sourced from a domestic housing estate. The experiments were designed to assess the partitioning processes likely to occur during sewage transport through the sewer, the transfer to primary solids during primary settlement (Primary Settlement Retention Factor, PSRF), the transfer of tracer to solids during secondary (activated sludge) treatment (the Activated Sludge Retention Factor, ASRF); and the overall Sludge Retention Factor (SRF), likely to be achieved in a typical sewage works.

The second study (P3-109B) assessed iodine-131 activity concentrations in raw sewage, in sewage effluent and sludge cake and in river water and sediment in and around the Hogsmill sewage treatment works. 15.1 GBq of iodine-131 was discharged over three consecutive days in February 2006, leading to concentrations of up to 50 Bq l^{-1} in raw sewage, 20 Bq l^{-1} in treated effluent, 76 Bq l^{-1} in primary sludge, 130 Bq l^{-1} in activated sludge and 1800 Bq kg^{-1} in dewatered sludge. Gamma dose was also detected in river water, river sediment and Thames estuary sediment. Iodine-131 rates were measured and were found to be slightly enhanced relative to background (up to 10 nGy h^{-1}) near the pressed sludge cake.

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