Environmental Radioactivity Surveillance Programme: Results for 2011 Including Monitoring Following the Fukushima Dai-ichi Accident in Japan

D Hammond, R J Pritchard and M Davidson

ABSTRACT

This report is the latest of a series in which the results of the Health Protection Agency's Environmental Radioactivity Surveillance Programme are presented. It contains the measurement data for the year 2011. Within the main programme, samples of airborne dust and milk are collected routinely from selected locations within the UK, the Channel Islands and the Isle of Man. The activity concentrations of various radionuclides are measured. In general, the radionuclides detected result from nuclear weapons tested in the atmosphere in earlier years and from the nuclear reactor accident at Chernobyl in the Ukraine in 1986, although the programme is able to detect any other sources of significant contamination. In March 2011, the accident at the Fukushima Dai-ichi nuclear power plant in Japan gave rise to very low levels of radioactivity in the environment in the UK. The measurements undertaken by the Health Protection Agency following the accident are included in this report.

The results from the main programme indicate that concentrations of artificial radionuclides in the general environment remain at the low levels observed in recent years. ,

Centre for Radiation, Chemical and Environmental Hazards
Chilton, Didcot,
Oxfordshire OX11 0RQ

Approval: September 2012
Publication: September 2012
£13.00
ISBN 978-0-85951-725-6

This work was undertaken under the Environmental Assessment Department's Quality Management System, which has been approved by Lloyd's Register Quality Assurance to the Quality Management Standards ISO 9001:2008 and TickIT Guide Issue 5.5, Certificate No: LRQ 0956546.

The measurements included in this report were performed at laboratories at HPA-CRCE (UKAS accredited testing laboratories No 1269 and 1502). All the analyses and measurements are included within the relevant UKAS accreditation schedules.

CONTENTS

1	Introduction	1
2	Sampling and analysis	2
3	Results and discussion	3
	3.1 Airborne dust	3
	3.2 Milk	5
	3.3 Levels in airborne dust following the accident at the Fukushima Dai-ichi nuclear power plant in March 2011	6
4	Acknowledgements	10
5	References	10

1 INTRODUCTION

The Centre of Radiation, Chemical, Environmental Hazards of the Health Protection Agency, (HPA-CRCE), formerly the National Radiological Protection Board (NRPB), has carried out an environmental radioactivity surveillance programme since the 1970s. Of necessity during that period, the programme has changed due to differing circumstances.

The primary intention of this series of reports is to provide a compendium of surveillance data, detailed radiological or radio-ecological assessments using these data being outside the remit. Concentrations of radionuclides in milk and airborne particulates are provided for locations in the United Kingdom and Channel Islands. A principal objective of the main part of the programme is to provide data typical of the UK against which site specific monitoring data can be compared. The main part of the programme of milk sampling on the UK mainland makes use of dairy farms close to the HPA-CRCE laboratories in Chilton, Leeds and Glasgow. Milk is also collected from the Channel Islands and the Isle of Man. Air monitoring stations are located at Chilton, Glasgow, Seascale and Jersey. The sampling at the Channel Islands, Isle of Man and Seascale provide a convenient means of monitoring the effects of authorised discharges from the nearby nuclear fuel reprocessing plants at Cap de la Hague and Sellafield, respectively.

The air filter measurements made at Seascale, which is in the vicinity of the Sellafield reprocessing plant, enable trends resulting from authorised discharges to the environment to be determined and the effects of any episodic discharges to be discerned. The local environment around Sellafield is monitored extensively by the site operator, Sellafield Ltd, (formerly the British Nuclear Group Sellafield Limited (BNGSL), and prior to that British Nuclear Fuels plc), the Environment Agency (EA) and the Food Standards Agency (FSA). The results of these programmes are published annually, the latest reports being the Sellafield Ltd. annual report for 2010 [Sellafield Ltd, 2011] and Radioactivity in Food and the Environment (RIFE) report for 2010 [Environment Agency *et al*, 2011] for the government agencies, respectively. However, the results of the HPA surveillance programme provide independent evidence that could be used in support of responses to queries about the impact of Sellafield discharges to the environment. In addition, the data may find an application in the validation of predictive models of behaviour of radionuclides in the environment.

In March 2011, the Great East Japan earthquake and tsunami led to the accidental release of man made radionuclides into the global environment from the Fukushima Dai-ichi nuclear power plant. As a result of the detection of elevated levels of radioactivity in air in the UK, the frequency of the surveillance monitoring was increased and some additional environmental samples were taken and measured. The results from the enhanced monitoring undertaken for air and milk are included in this report. Details of the additional measurements made by HPA in rain water, soil and grass are also included.

2 SAMPLING AND ANALYSIS

The sampling programme originally planned for 2011 is shown in Table 1.

TABLE 1: The planned sampling programme for 2010

Sample	Location	Frequency	Determinants
Airborne dust	Chilton	Fortnightly	Gamma-ray emitters
	Glasgow	Fortnightly	Gamma-ray emitters
	Seascale	Fortnightly, bulked monthly for actinide analysis	Gamma-ray emitters, isotopes of Pu and Am
	Jersey	Fortnightly	Gamma-ray emitters
Cows Milk	Chilton	5 litres each quarter	^{137}Cs, ^{90}Sr
	Leeds	5 litres each quarter	^{137}Cs, ^{90}Sr
	Glasgow	5 litres each quarter	^{137}Cs, ^{90}Sr
	Isle of Man	1.5 litres per month, bulked quarterly	^{137}Cs, ^{90}Sr
	Channel Islands	1.5 litres per month, bulked quarterly	^{137}Cs, ^{90}Sr

Airborne dust is sampled continuously by drawing air through a polycarbonate filter at a flow rate of about 1 m^3 min^{-1} using a centrifugal fan assembly; the flow rate is measured by an axial flowmeter. The filters are changed twice per month. Each filter is compressed into a defined geometry and the activity concentrations of gamma-ray emitting radionuclides are determined directly using hyper-pure germanium detectors housed in a purpose-built low background facility and appropriately calibrated. Measurements of filters from Glasgow were carried out at CRCE's laboratory in Glasgow whilst all other filters were analysed at Chilton as in previous years. Measurements of plutonium (Pu) and americium (Am) are carried out on monthly bulk samples from Seascale using α-spectrometry following radiochemical separation.

From the beginning of 2011, air sampling at Guernsey was terminated for financial and operational reasons. Results for Jersey can be taken as being representative of Guernsey, so there is no reduction in surveillance coverage.

Milk is sampled from the bulk tank at farms or creameries. In this way, the milk is representative of either the whole herd of cows or a number of herds. Samples are despatched to the Chilton laboratory soon after collection. On receipt at Chilton, milk is freeze-dried, after which caesium-137 (^{137}Cs) is determined directly using gamma-ray spectrometry. Strontium (^{90}Sr) is measured by extraction of its yttrium daughter (^{90}Y) followed by beta counting several times over a period of a few days using a low-background gas-flow proportional counter. Measurements and analyses at Chilton are carried out under a quality system accredited to ISO 17025 by the United Kingdom Accreditation Service (accreditation number 1269). Measurements at Glasgow are carried out under a similar system also accredited to ISO 17025 (accreditation number 1502).

3 RESULTS AND DISCUSSION

The uncertainties quoted are based on standard uncertainties multiplied by a coverage factor of k=2 which provides a level of confidence of approximately 95%. The Minimum Detectable Activity quoted is the value for which there is a 5% probability of not detecting that activity if it is present in a sample.

3.1 Airborne dust

The results from gamma-ray spectrometric measurements on samples of airborne dust at Chilton, Jersey and Glasgow are listed in Tables 2, 3 and 4, respectively. The second quarter includes the period when elevated levels were observed in the UK following the Fukushima Dai-ichi accident; results for this period are presented separately in Section 3.3. The results in Tables 2, 3 and 4 are derived from the data from the fortnightly samples, averaged over a three month period. Activity concentrations of ^{137}Cs were below detection limits at both Channel island locations with the naturally occurring beryllium-7 (^{7}Be) levels measured on Guernsey and Jersey similar to those measured at Glasgow. Beryllium-7 results are used to show that the efficiency of the air sampling equipment is being maintained. Results for ^{7}Be indicate the sampling equipment is operating satisfactorily at all sites. Results from Seascale for ^{7}Be, ^{137}Cs and alpha emitting radionuclides are shown in Table 5. The observed values are consistent with the low levels reported in previous years and those values published by the site operator [Sellafield Ltd, 2011].

TABLE 2: Activity concentrations of ^{7}Be and ^{137}Cs in airborne dust at Chilton in 2011 (μBq m^{-3})

Quarter	^{7}Be	^{137}Cs
1[a]	1660 ± 170	<2
2	See section 3.3[b]	
3	1070 ± 130	<2
4	1230 ± 150	<2

a) Results up to 16/03/2012. See sec 3.3 for additional results from Quarter 1

b) Results for Quarter 2 include the additional measurements made following the Fukushima Dai-ichi accident in Japan in March 2011 and are given in Section 3.3 (see Tables 8 and 9)

TABLE 3: Activity concentrations of ^{7}Be and ^{137}Cs in airborne dust at Jersey in 2011 (µBq m^{-3})

Quarter	^{7}Be	^{137}Cs
1[a]	2610 ± 240	<2
2	See section 3.3[b]	
3	1980 ± 200	<2
4	2100 ± 200	<2

a) Results up to 15/03/2012. See sec 3.3 for additional results from Quarter 1.

b) Results for Quarter 2 include the additional measurements made following the Fukushima Dai-ichi accident in Japan in March 2011 and are given in Section 3.3 (see Table 10)

TABLE 4: Activity concentrations of ^{7}Be and ^{137}Cs in airborne dust at Glasgow in 2011 (µBq m^{-3})

Quarter	^{7}Be	^{137}Cs
1[a]	N/S	N/S
2	See section 3.3[b]	
3	1650 ± 180	<1
4	1680 ± 200	<1

N/S No samples received due to equipment failure

a) Results up to 10/03/2012. See sec 3.3 for additional results from Quarter 1.

b) Results for Quarter 2 include the additional measurements made following the Fukushima Dai-ichi accident in Japan in March 2011 and are given in Section 3.3 (see Table 11)

TABLE 5: Activity concentrations of ^{7}Be, ^{137}Cs and alpha emitting radionuclides in airborne dust at Seascale in 2011 (μBq m^{-3})

Month	^{7}Be	^{137}Cs	^{239,240}Pu	^{238}Pu	^{241}Am
January	1690 ± 380	<1	0.063± 0.010	0.017± 0.004	0.12± 0.01
	2550 ± 510	2 ± 1			
February	1430 ± 290	<1	0.042± 0.007	0.008± 0.003	0.081± 0.009
	1400 ± 300	<1			
March[a]	1870 ± 450	2 ± 1	0.038± 0.007	0.011± 0.003	0.068± 0.009
	2600 ± 400	12 ± 2			
April	See section 3.3[b]		0.089± 0.012	0.012± 0.004	0.12± 0.01
May			0.12± 0.01	0.021± 0.004	0.22± 0.02
June			0.10± 0.01	0.022± 0.004	0.17± 0.02
July	1770 ± 280	<1	0.049± 0.010	0.014± 0.005	0.078± 0.010
	1790 ± 280	1 ± 1			
August	1160 ± 180	<1	0.12± 0.01	0.021± 0.003	0.17± 0.02
	1850 ± 290	<1			
September	1680 ± 260	<11	0.17± 0.02	0.029± 0.004	0.32± 0.03
	2540 ± 390	2 ± 1			
October	2020 ± 310	1 ± 1	0.12± 0.01	0.023± 0.004	0.22± 0.02
	2250 ± 380	<1			
November	2080 ± 350	<1	0.083± 0.010	0.016± 0.003	0.14± 0.01
	2250 ± 350	<1			
December	1810 ± 280	<1	0.23± 0.02	0.034± 0.005	0.33± 0.03
	1620 ± 270	1 ± 1			

a) Results up to 01/04/2012.

b) Results for Quarter 2 include the additional measurements made following the Fukushima Dai-ichi accident in Japan in March 2011 and are given in Section 3.3 (see Table 12).

3.2 Milk

Activity concentrations of ^{137}Cs in milk from Chilton, Leeds and Glasgow and the offshore islands (Isle of Man, Guernsey and Jersey) are given in Table 6 and the corresponding data for ^{90}Sr in Table 7. The ^{137}Cs data from the off shore islands relate to samples that have been bulked on a quarterly basis. For ^{90}Sr, the milks are bulked into annual samples. The individual samples are retained so that if the activity concentrations on the annual samples have increased, the monthly samples can be analysed separately.

Activity concentrations of ^{137}Cs in all milk samples were close to or below detection limits, consistent with the trend observed in previous years [Wilding, 2011; Hammond and Wilding, 2012].The activity concentrations of ^{90}Sr in milk from Guernsey and Jersey were close to detection limits as were samples from the Isle of Man. The measured values were very similar to those observed at locations that are more remote from

nuclear licensed sites and consistent with the results from previous years [Wilding, 2011; Hammond and Wilding, 2012].

No caesium or iodine was detected in milk as a result of the Fukushima accident. This was expected as dairy cows were being kept indoors and eating stored feed at the time of the accident.

TABLE 6: Activity concentrations of ^{137}Cs in milk for 2011 (Bq l^{-1})

Location	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr
Chilton	<0.05	<0.04	N/S	N/S
Leeds	<0.06	<0.07	N/S	0.04 ± 0.03
Glasgow	0.05 ± 0.03	0.04 ± 0.02	<0.06	<0.07
Guernsey	<0.07	<0.06	<0.07	<0.09
Jersey	N/S	<0.06	<0.07	<0.08
Isle of Man	<0.05	0.08 ± 0.05	<0.08	<0.09

N/S No sample

TABLE 7: Activity concentrations of ^{90}Sr in milk for 2011 (Bq l^{-1})

Location	Annual bulked sample
Chilton	0.01 ± 0.01
Leeds	< 0.02
Glasgow	0.03 ± 0.01
Guernsey	< 0.05
Jersey	0.05 ± 0.04
Isle of Man	< 0.03

3.3 Levels in airborne dust following the accident at the Fukushima Dai-ichi nuclear power plant in March 2011

Following the Great East Japan earthquake and tsunami on 11 March 2011, an incident occurred at the Fukushima Dai-ichi nuclear power plant resulting in the release of radioactivity into the global environment. Towards the end of March, elevated levels ^{131}I, ^{134}Cs, ^{137}Cs and ^{132}Te were detected at HPA air monitoring stations in the UK and the Channel Islands resulting from this accident. No other radionuclides were measured using the very sensitive monitoring equipment used. Increased surveillance was required during this period to be able to provide public reassurance. The sampling frequency at all sampling locations was increased from fortnightly to weekly; in addition, a very high volume air sampler at HPA's Chilton site in Oxfordshire was also deployed. The very high volume air sampler at Chilton was able to sample the same volume of air in 1 day as the high volume air samplers routinely sample in 1 week (typically about 23000 m^3), so there was no change in detection limits.

The results for airborne dust measured at Chilton, Glasgow and Jersey during the Fukushima accident are given in Tables 8 - 12. A mid sample time in the sample period was taken to allow for radioactive decay. This is particularly important for the short lived radionuclides, ^{131}I and ^{132}Te, with half-lives of 8 days and 78 hrs, respectively.

From early May 2011, it was not possible to detect ^{131}I, ^{134}Cs and ^{137}Cs in the air in the UK using the very sensitive monitoring equipment used. As the levels of radiation detected were consistently extremely low, or not detectable, the frequency of air sampling returned to fortnightly. However, HPA continues to analyse for a wide range of radionuclides, including ^{131}I.

At the end of March, some air filters at Chilton and Glasgow were further analysed using radiochemical techniques for isotopes of plutonium and ^{90}Sr (Chilton only). No unusual levels of plutonium were found and ^{90}Sr was not detected.

TABLE 8: Activity concentrations of ^{137}Cs, ^{134}Cs, ^{132}Te and ^{131}I in airborne dust at Chilton in 2011 (μBq m^{-3}) following the Fukushima Dai-ichi accident.

Sample date off	Sampling period days	^{137}Cs	^{134}Cs	^{132}Te	^{131}I
25 March 2011	9	Not detectable[a]	Not detectable	Not detectable	11 ± 4
01 April 2011	7	22 ± 5	23 ± 4	6 ± 4	288 ± 45
08 April 2011	7	60 ± 10	60 ± 10	Not detectable	207 ± 33
15 April 2011	7	24 ± 4	26 ± 5	Not detectable	57 ± 10
21 April 2011	6	7 ± 3	10 ± 3	Not detectable	12 ± 5
28 April 2011	7	9 ± 3	9 ± 2	Not detectable	7 ± 3
12 May 2011	14	3 ± 1	4 ± 1	Not detectable	Not detectable
26 May 2011	14	Not detectable	Not detectable	Not detectable	Not detectable
10 June 2011	15	Not detectable	Not detectable	Not detectable	Not detectable
23 June 2011	13	Not detectable	Not detectable	Not detectable	Not detectable

a) Not detectable means the results was below detection limits

TABLE 9: Daily Activity concentrations of ^{137}Cs, ^{134}Cs, ^{132}Te and ^{131}I in airborne dust at Chilton in 2011 (μBq m^{-3}) following the Fukushima Dai-ichi accident.

Sample date off	Sampling period days	^{137}Cs	^{134}Cs	^{132}Te	^{131}I
28 March 2011	0.08	Not detectable[a]	Not detectable	Not detectable	327 ± 75
29 March 2011	0.27	Not detectable	Not detectable	Not detectable	310 ± 57
30 March 2011	0.96	86 ± 16	93 ± 17	25 ± 9	1090 ± 170
31 March 2011	1	90 ± 16	93 ± 16	19 ± 7	506 ± 80
01 April 2011	1	47 ± 9	50 ± 9	Not detectable	386 ±61
02 April 2011	1	90 ± 12	92 ± 12	10 ± 4	560 ± 66
03 April 2011	1	32 ± 8	36 ± 8	Not detectable	326 ± 53
04 April 2011	1	94 ± 16	96 ± 16	Not detectable	665 ± 105
05 April 2011	1	85 ± 14	93 ± 15	7 ± 4	477 ± 75
06 April 2011	1	46 ± 9	48 ± 9	Not detectable	242 ± 39
07 April 2011	0.88	39 ± 9	38 ± 9	Not detectable	222 ± 36
08 April 2011	1	48 ± 9	48 ± 8	Not detectable	228 ± 36
09 April 2011	0.42	102 ± 19	117 ± 20	Not detectable	385 ± 6
12 April 2011	0.17	Not detectable	25 ± 24	Not detectable	189 ± 37
13 April 2011	1	22 ± 6	23 ± 6	Not detectable	86 ± 16
14 April 2011	1	38 ± 8	39 ± 8	Not detectable	94 ± 17
15 April 2011	1	42 ± 9	46 ± 9	Not detectable	80 ± 15

a) Not detectable means the results was below detection limits

TABLE 10: Activity concentrations of ^{137}Cs, ^{134}Cs, ^{132}Te and ^{131}I in airborne dust at Jersey in 2011 (μBq m^{-3}) following the Fukushima Dai-ichi accident.

Sample date off	Sampling period days	^{137}Cs	^{134}Cs	^{132}Te	^{131}I
01 April 2011	15	3 ± 1	3 ± 1	Not detectable[a]	117 ± 19
08 April 2011	7	57 ± 10	60 ± 9	Not detectable	244 ± 39
15 April 2011	7	35 ± 6	36 ± 6	Not detectable	89 ± 15
22 April 2011	7	13 ± 3	13 ± 3	Not detectable	16 ± 9
29 April 2011	7	12 ± 3	14 ± 3	Not detectable	10 ± 4
13 May 2011	15	4 ± 1	4 ± 1	Not detectable	Not detectable
27 May 2011	14	Not detectable	Not detectable	Not detectable	Not detectable
10 June 2011	14	Not detectable	Not detectable	Not detectable	Not detectable
24 June 2011	14	Not detectable	Not detectable	Not detectable	Not detectable

a) Not detectable means the results was below detection limits

Samples of grass and the underlying soil from Chilton were also analysed during this period. The results are given in Table 13. Very low levels of ^{131}I and ^{137}Cs were detected in the grass samples. Iodine-131 was not detectable in the underlying soil and the levels of ^{137}Cs detected were consistent with normal background levels and are not attributable to the Fukushima accident. Measurements were also made on rainwater

collected from Glasgow and Chilton. The results are given in Table 14; low levels of ^{131}I were detected in two of the three samples.

TABLE 11: Activity concentrations of ^{137}Cs, ^{134}Cs, ^{132}Te and ^{131}I in airborne dust at Glasgow in 2011 ($\mu Bq\ m^{-3}$) following the Fukushima Dai-ichi accident.

Sample date off	Sampling period days	^{137}Cs	^{134}Cs	^{132}Te	^{131}I
19 March 2011	9	Not detectable[a]	Not detectable	Not detectable	8 ± 1
25 March 2011	2	Not detectable	Not detectable	Not detectable	Not detectable
31 March 2011	6	32 ± 3	31 ± 3	16 ± 4	585 ± 57
04 April 2011	4	58 ± 6	61 ± 6	4 ± 3	369 ± 37
07 April 2011	3	26 ± 4	29 ± 3	Not detectable	232 ± 23
11 April 2011	4	98 ± 14	84 ± 10	Not detectable	218 ± 25
14 April 2011	3	19 ± 3	19 ± 2	Not detectable	64 ± 8
18 April 2011	4	12 ± 2	12 ± 2	Not detectable	36 ± 5
21 April 2011	3	3 ± 2	6 ± 2	Not detectable	26 ± 6
26 April 2011	5	15 ± 2	16 ± 2	Not detectable	22 ± 4
28 April 2011	2	27 ± 3	28 ± 3	Not detectable	24 ± 4
12 May 2011	7	Not detectable	Not detectable	Not detectable	Not detectable

a) Not detectable means the results was below detection limits

TABLE 12: Activity concentrations of ^{137}Cs, ^{134}Cs, ^{132}Te and ^{131}I in airborne dust at Seascale in 2011 ($\mu Bq\ m^{-3}$) following the Fukushima Dai-ichi accident.

Sample date off	Sampling period days	^{137}Cs	^{134}Cs	^{132}Te	^{131}I
08/04/2011	7	78 ± 12	84 ± 13	Not detectable[a]	236 ± 38
15/04/2011	7	56 ± 9	57 ± 9	Not detectable	57 ± 10
22/04/2011	7	9 ± 2	7 ± 2	Not detectable	19 ± 6
29/04/2011	7	21 ± 4	17 ± 3	Not detectable	11 ± 5
16/05/2011	14	5 ± 1	4 ± 1	Not detectable	< 3
01/06/2011	14	<1	< 1	Not detectable	< 7
16/06/2011	14	2 ± 1	< 1	Not detectable	< 4
01/07/2011	14	4 ± 1	< 2	Not detectable	< 4

a) Not detectable means the results was below detection limits

TABLE 13: Activity concentrations of ^{137}Cs, ^{134}Cs, ^{132}Te and ^{131}I in grass and soil (Bq kg^{-1}) from Chilton following the Fukushima Dai-ichi accident.

Sample type	Sampling date	^{137}Cs	^{134}Cs	^{132}Te	^{131}I
Grass	30/03/2011	0.5 ± 0.2	Not detectable[a]	Not detectable	2.2 ± 0.4
Grass	31/03/2011	0.6 ± 0.2	0.6 ± 0.2	Not detectable	3.0 ± 0.5
Soil	30/03/2011	7.7 ± 1.4	Not detectable	Not detectable	Not detectable
Soil	31/03/2011	6.7 ± 1.2	Not detectable	Not detectable	Not detectable

a) Not detectable means the results was below detection limits

TABLE 14: Activity concentrations of ^{137}Cs, ^{134}Cs, ^{132}Te and ^{131}I in rainwater (Bq l^{-1}) following the Fukushima Dai-ichi accident.

Location	Sampling period/rainfall (mm)	^{137}Cs	^{134}Cs	^{132}Te	^{131}I
Glasgow	25/03 – 31/03 / (14)	Not detectable[a]	Not detectable	Not detectable	0.9 ± 0.3
Chilton	25/03 – 01/04 / (4)	Not detectable	Not detectable	Not detectable	2.0 ± 0.4
Glasgow	31/04 – 04/04 / (14)	Not detectable	Not detectable	Not detectable	0.7 ± 0.3
Chilton	01/04 – 08/04 / (2)	Not detectable	Not detectable	Not detectable	Not detectable
Glasgow	04/04 – 07/04 / (25)	Not detectable	Not detectable	Not detectable	Not detectable

a) Not detectable means the results was below detection limits

4 ACKNOWLEDGEMENTS

The authors are indebted to CRCE Scotland and all organisations and individuals who assisted with the operation of the air sampling stations, particularly during the period after the Fukushima Dai-ichi accident when the frequency of air monitoring increased. The authors would also like to thank all the farmers that participated in the milk sampling programme, with particular thanks to the creamery managers in Guernsey, Jersey and the Isle of Man.

5 REFERENCES

Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency (2011). Radioactivity in Food and the Environment, 2010, RIFE-16.http://www.food.gov.uk/multimedia/pdfs/publication/rife2010.pdf

Hammond DJ and Wilding D (2012). Environmental Radioactivity Surveillance Programme: Results for 2010. Chilton, HPA-CRCE-036.

Sellafield Ltd (2011). Monitoring our Environment. Discharges and Monitoring in the UK. Annual Report 2010. http://www.sellafieldsites.com/UserFiles/File/publications/monitoring/Monitoring%20Our%20Environment%

Wilding D (2011). Environmental radioactivity surveillance programme: Results for 2009. Chilton, HPA-CRCE-022.
http://www.hpa.org.uk/Publications/Radiation/CRCEScientificAndTechnicalReportSeries/HPACRCE022