3 Year Report: 2002 - 2005

NORTHERN IRELAND RADIATION MONITORING CO-ORDINATING COMMITTEE

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SUMMARY

This report for the Northern Ireland Radiation Monitoring Group (NIRMG) is a compilation of radiochemical data for samples submitted from participating authorities at intervals during the contract period April 2002 and March 2005. Samples taken from the marine, estuarine and terrestrial environment are examined and also a variety of locally produced foodstuffs.

Very small levels of anthropogenic (man-made or artificial) radionuclides have been identified in many of the materials examined although none of the levels found is expected to be hazardous to the public. The levels represent a tiny fraction of the national legislative (cautionary) limits of radiation dose to members of the public. The maximum dose likely to be experienced by an adult living in Northern Ireland, derived from artificial sources of radioactivity, is low and within expected natural variations.

Data for the naturally occurring isotopes ^{40}K and ^{7}Be also are reported. The levels of these radioisotopes in natural materials are determined by the chemical composition of the sample and exposure to the atmosphere respectively. They are included for comparison with data presented by other groups. Additionally, they help put the reported anthropogenic radionuclide activities in a radiological context.

MAIN CONCLUSIONS FOR RESULTS APRIL 2002 - MARCH 2005

The results obtained are briefly discussed below and a full set of data is given in the section NORTHERN IRELAND DATA.
Although anthropogenic (man-made or artificial) radionuclides have been identified in many of the materials examined none of the levels found is expected to be hazardous to the public. The levels represent a small fraction of the national legislative (cautionary) limits of radiation dose to members of the public. All the contamination values are well below the Investigation Levels (i.e. 10% GDL*; NRPB , 1998).

INTERPRETATION OF GAMMA SPECTROMETRY RESULTS

The results from all environmental samples show the region to be one of low radiological significance as far as anthropogenic (man-made or artificial) radioactive materials are concerned. Anthropogenic radioisotopes of caesium and americium are seen in minute quantities in some samples from the marine environment. These are probably derived from a combination of the Chernobyl accident, weapons' testing and BNFL Sellafield (Appendix D).

Caesium isotopes in terrestrial samples (soils and vegetation) are due to past depositions from the Chernobyl cloud and weapons’ testing. The levels are extremely low in all samples examined.

Data for the naturally occurring isotopes ^{40}K and ^{7}Be are are included for interest and for comparison with data presented by other groups. Additionally, they help place the reported anthropogenic radionuclide activities in context.

INTERPRETATION OF ALPHA SPECTROMETRY RESULTS

Transuranic radionuclides, plutonium and americium, originating from Sellafield discharges and from weapons' tests are all found to be low and should be of no radiological concern. This conclusion is clearly shown by comparing the Generalised Derived Limit (GDL) data with the measured sample activity data (NORTHERN IRELAND DATA). The highest levels of contamination are found in fine-grained marine sediments.

INTERPRETATION OF TECHNETIUM-99 ANALYSES

The technetium results in samples of edible materials (lobsters, prawns and dulse seaweed) do not show any levels of Tc-99 that would lead to any radiological concerns. The main concentrators of technetium are the seaweeds *Fucus vesiculosus* and *Ascophyllum nodosum* (Table 5 Appendix C). The magnitude of the activity concentration for any particular species reflects the age of the plant, the contact time with contaminated seawater and the trends of marine currents from the eastern Irish Sea. Dulse, which is consumed by some people, is not a significant concentrator of Tc-99. It is known that lobsters can concentrate technetium (Table 5 Appendix C) but the results so far do not indicate any significant radiological problems.

INTERPRETATION OF CARBON-14 ANALYSES

This is the first contract to have analysed for Carbon-14 in marine fish. The results do not indicate any significant problem and compare well with data given in the Radioactivity in food and the Environment (RIFE) reports.

COMPARATIVE RADIOMETRIC DATA

Reliability and consistency are checked by comparing data from different monitoring groups or agencies (Appendix C). Quality assurance is evaluated by participating in intercomparison exercises with international and UK national organisations (eg: IAEA and NPL, Appendix F).

Notes:

* GDLs are explained in Appendix E

LONG TERM TRENDS

A selected set of data are given in Figure 1 to evaluate some long term trends with samples taken from the Northern Ireland environment. This shows variation in the activity of Cs-137 with time for sediments, periwinkles and seafish. Data are in Bq/kg. The significant decline in Cs-137 activities is a result of improved clean-up of effluents by SIXEP (Site Ion-eXchange Plant) and EARP (Enhanced Actinide Recovery Plant). The trend for Tc-99 in seaweed (Figure 2a) shows there has been a significant increase in activity since 1994 but that it is currently decreasing. This reflects the reported increase and subsequent decrease in discharge of Tc-99 from Sellafield (Figure 2b)

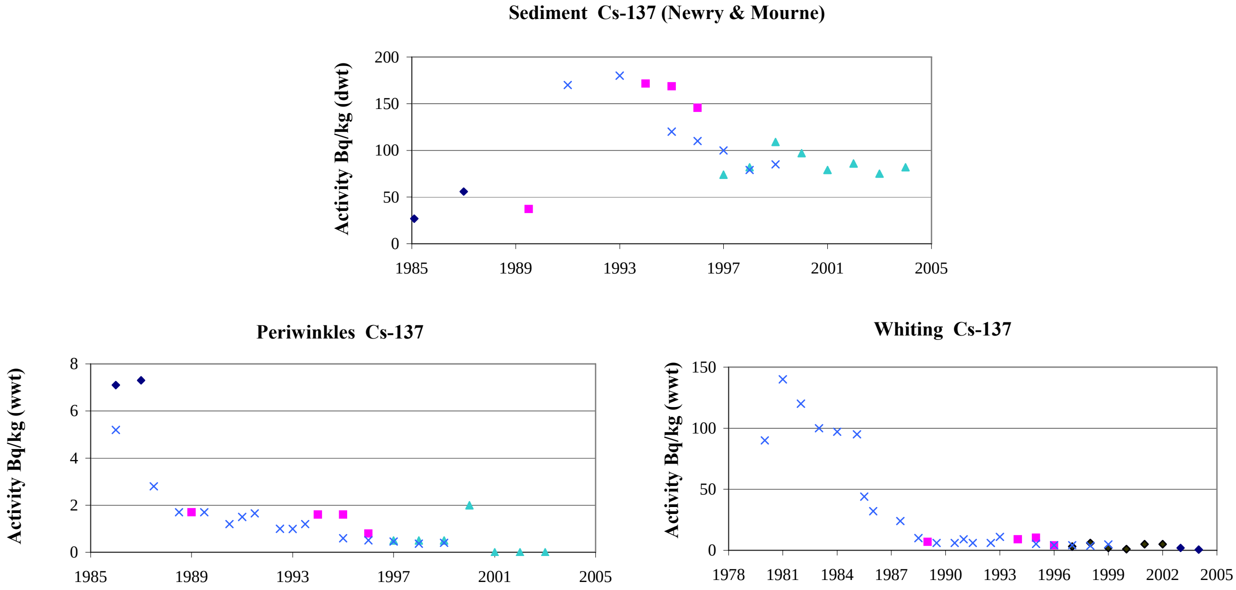


FIGURE 1: Variations in the activity of Cs-137 with time. (◆ - Surrey, ■ - Lancaster, ▲ - Southampton, × - MAFF)
(data taken from MAFF, Lancaster University and University of Southampton reports)

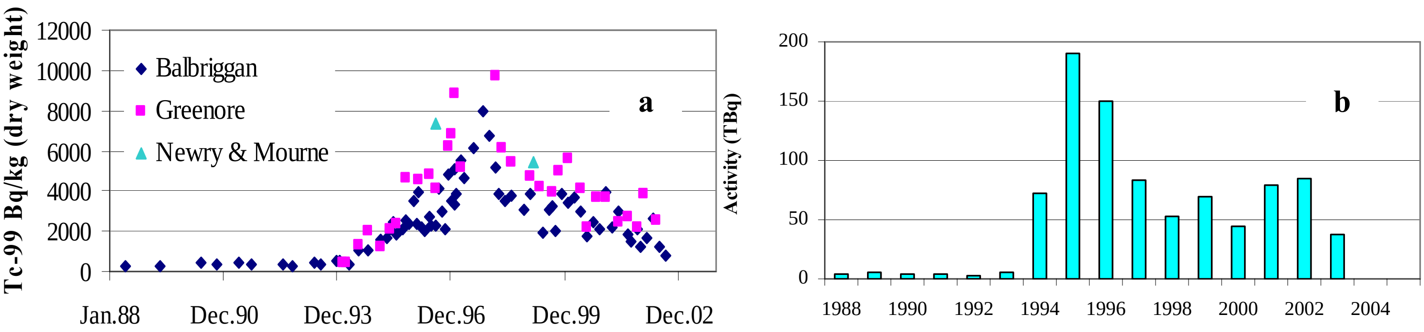


FIGURE 2

a: ^{99}Tc activity concentrations in *Fucus vesiculosus* sampled at Balbriggan and Greenore (Eastern Ireland) in the period 1988 – 2002. **(Adapted from Smith *et al* (1997)[@]. Extra data supplied by RPII., (www.rpii.ie))**

b: Sellafield discharges of ^{99}Tc to the Irish Sea 1988 – 2003 (BNFL 2003)

Notes:

[@] Smith V., Ryan R.W., Pollard D., Mitchell P.I., & Ryan T.P. Temporal and geographical distribution of ^{99}Tc in inshore waters around Ireland following increased discharges from Sellafield. Radioprotection - Colloques, 32, 71-77 (1997)

THE NORTHERN IRELAND RADIATION MONITORING SCHEME

NORTHERN IRELAND DISTRICT COUNCILS

HISTORY

1984	District Councils began monitoring radioactivity in the marine environment as a consequence of public concern about BNFL Sellafield.
1988	Report entitled 'The Northern Ireland Local Authority Environmental Monitoring Programme' was presented to District Councils in the Province by Dr Stephen Harris of the University of Surrey.
June 1988	Northern Ireland Working Party of Environmental Health Officers recommended that District Councils in Northern Ireland be integrated into LARRMACC (now LARnet) and that a Joint Radiation Committee be formed in the Province comprising elected members and officers from Belfast and the four Environmental Health Groupings of Councils.
Sept 1989	Inaugural meeting of the Joint Radiation Committee to become known as the 'Northern Ireland Radiation Monitoring Co-ordinating Committee' (NIRMCC)
1990 - 1996	Analytical laboratory services contracted to the University of Lancaster.
April 1996	Installation of the ARGUS Continuous Monitoring Network.
1996 - 1999	Analytical laboratory services contracted to the University of Southampton.
2002 - 2005	Analytical laboratory services contracted to the University of Southampton for a second term.
2002 – 2005	Analytical laboratory services contracted to the University of Southampton for a third term.
2002	Update of Continuous Gamma Monitoring system to ARGUS 3000
2004	Introduction of a NIRMG website: www.nirmg.org.uk

OBJECTIVES

The objectives have evolved over time as follows:

- to monitor levels of gamma radioactive contamination of marine biota and sediments in the Irish Sea as a consequence of routine radioactive discharges from the UK mainland and to ensure that doses due to Caesium-137 continue to fall.
- to monitor levels of actinides in sediments from Northern Ireland coastlines and in fish and shellfish from the Irish Sea.
- to monitor levels of the beta emitter ^{99}Tc in shellfish and seaweeds from the Irish Sea.
- to monitor levels of contamination from gamma emitters in freshwater and terrestrial environments in Northern Ireland as a consequence of airborne releases of radioactivity such as that from Chernobyl.
- to provide independent information and data on radioactivity in the environment in order to address public concerns in Northern Ireland.
- to provide a system of radiation monitoring which is capable of adaptation to cope with abnormal/emergency releases and/or situations.
- to seek and retain accreditation from LARnet (formerly LARRMACC) technical contractors in respect of those quality manuals relevant to Northern Ireland.

PARTICIPATING LOCAL AUTHORITIES

Northern Group
Antrim
Ballymena
Ballymoney
Carrickfergus
Coleraine
Cookstown
Larne
Magherafelt
Moyle
Newtownabbey

Southern Group
Armagh
Banbridge
Craigavon
Dungannon
Newry & Mourne

Eastern Group
Ards
Castlereagh
Down
Lisburn
North Down

Western Group
Derry
Fermanagh
Limavady
Strabane
Omagh

Belfast City Council

THE 3-YEAR CONTRACT REPORT, 2002 - 2005

INTRODUCTION

An important objective of the NIRMG Scheme is to provide background information for the area over a period of time so that any fluctuations in the radioactive content of environmental materials derived from man-made sources can quickly be identified. The proximity of the Sellafield nuclear reactors and nuclear reprocessing plant highlights the need for continuing monitoring as this is the greatest source of radioactivity concerning Northern Ireland.

This Report presents radiometric results for the period April 2002 - March 2005 for foodstuffs and environmental materials submitted during that period by the Northern Ireland Radiation Monitoring Group.

The measurements involved a detailed radiochemical analysis of environmental samples collected by the participant local authorities for a wide range of alpha, beta and gamma emitting isotopes. This approach makes a measurement of individual sample types and provides information on most man-made radioactive elements that exist in any given sample and gives a good indication of the nature and magnitude of environmentally significant radioactivity.

The subject of radioactive monitoring is a complex one, but this report endeavours to present the subject in a clear and understandable form, although sometimes it is necessary to use technical language. A glossary of terms and explanations can be found in Appendix G of this report and some technical concepts and issues are covered in more detail in Appendices E (reference levels and safety limits) and F (methodology and quality assurance).

The section, NORTHERN IRELAND DATA, gives the detailed results for the three years in respect of environmental samples collected by Local Authorities. Sampling locations are given in Appendix A and a summary of the data collected by the ARGUS continuous gamma monitoring system is given in Appendix B. Appendix C gives comparative data.

A summary of incidents relating to the nuclear industry follow a short description of the influence of the activities of BNFL Sellafield on the environment of Northern Ireland in Appendix D

GENERAL INFORMATION
TO ASSIST IN UNDERSTANDING DATA TABLES

The data tables that follow contain information on the numerous samples that have been taken during the year, as to the type of sample, where it was taken, its radiological content and the sampling authority. There is also information drawn from other sampling bodies and compared with results found in this report.

The tables are set out as follows:-

1. **NORTHERN IRELAND DATA: Results April 2002 - March 2005**

   This Appendix sets out the results for the year April 2002 - March 2005. A sample catalogue shows the type of samples submitted by each Local Authority, and the gamma spectrometry results are ordered by sample type for the terrestrial and marine environment.

2 **APPENDIX C: Selected Comparative Data**

   This Appendix sets out monitoring and sampling results from the Northern Ireland Radiation Monitoring Group for this year and compares them with results from sampling undertaken by the Food Standards Agency and British Nuclear Fuels plc (BNFL) at Sellafield.

All tables of results give the sample type, the date of sample collection and the measured level of radiological activity from man-made sources either in Becquerels per kilogram (Bq/kg) or Becquerels per litre (Bq/l). Results for the naturally occurring ^{40}Potassium and ^{7}Beryllium are given for comparison. Data showing a dash are below detection limits, whereas data with a less than value (e.g. < 1 Bq/kg) are at the detection limit and a signal is seen but is too small to quantify.

A Becquerel describes the rate at which radioactive decay takes place and corresponds to the decay or disintegration of one radioactive atom per second. It is an extremely small measure of radioactivity.

A radionuclide is an unstable form of an element that emits radioactivity. The following radionuclides are referred to in the tables (with the abbreviations used given after):

NATURAL

^{40}Potassium	-	^{40}K
^{7}Beryllium	-	^{7}Be

ANTHROPOGENIC

^{134}Caesium	-	^{134}Cs
^{137}Caesium	-	^{137}Cs
^{57}Cobalt	-	^{60}Co
^{58}Cobalt	-	^{60}Co
^{60}Cobalt	-	^{60}Co
^{54}Manganese	-	^{54}Mn
^{65}Zinc	-	^{65}Zn
^{131}Iodine	-	^{131}I
^{238}Plutonium	-	^{238}Pu
^{239,240}Plutonium	-	^{239,240}Pu
^{241}Americium	-	^{241}Am
^{99}Technetium	-	^{99}Tc

Note

Other conventions may be used in other literature e.g. ^{99}Technetium may also be referred to as Technetium-99 or Tc-99.

To assist with understanding the significance of the radiological levels reported, Generalised Derived Limits (GDLs) are included after the tables, where appropriate. A full explanation of GDLs and summarised values are given in Appendix E but they are basically cautionary indicators of levels that should not be exceeded for specific materials and particularly foodstuffs..

SAMPLE CATALOGUE BY AUTHORITY

** Belfast City Council

*** Belfast**

11.06.02	Water
27.09.02	Sediment
06.06.03	Sediment
04.06.04	Sediment

** Eastern Group Public Health Committee

*** Ards**

06.06.02	Shellfish
10.06.02	Sediment
27.09.02	Seaweed
28.09.02	Shellfish
30.09.02	Seaweed
04.06.03	Seaweed
18.09.03	Seaweed
18.09.03	Shellfish
18.09.03	Sediment
01.06.04	Seaweed
21.09.04	Sediment
22.09.04	Fish
21.09.04	Seaweed

*** Down**

09.05.02	Shellfish
10.06.02	Honey
11.06.02	Fish
27.09.02	Shellfish
30.09.02	Sediment
30.09.02	Fish
30.05.03	Shellfish
03.06.03	Shellfish
06.06.03	Fish
22.09.03	Honey
22.09.03	Sediment
02.06.04	Shellfish
03.06.04	Shellfish
03.06.04	Fish
27.09.04	Sediment
27.09.04	Honey

*** Lisburn**

11.06.02	Water
09.06.03	Water
03.06.04	Water

*** North Down**

10.06.02	Meat
09.06.03	Fish
19.09.03	Meat

** Northern Group Public Health

*** Ballymena**

11.06.02	Water
18.10.02	Honey
22.09.03	Water
27.09.04	Water

*** Carrickfergus**

10.06.02	Sediment
24.10.02	Sediment
06.06.03	Sediment
19.09.03	Sediment
27.05.04	Sediment
23.09.04	Sediment

**Northern Group Public Health

*** Coleraine**

10.06.02	Fish

*** Larne**

04.06.03	Shellfish
26.05.04	Shellfish

*** Moyle**

11.06.02	Seaweed
11.06.02	Shellfish
25.10.02	Shellfish
25.10.02	Seaweed
25.10.02	Fish
25.11.02	Fish
25.10.02	Shellfish
02.06.03	Shellfish
09.06.03	Seaweed
09.09.03	Fish
09.09.03	Fish
18.09.03	Honey
24.09.03	Seaweed
04/06/04	Shellfish
04.06.04	Seaweed
27.09.04	Fish
27.09.04	Seaweed
27.09.04	Fish
27.09.04	Honey

** Southern Group Public Health

*** Armagh**

06.06.03	Fish
19.09.03	Fish
04.06.04	Fish

*** Banbridge**

11.06.02	Fish
11.06.02	Water
22.09.03	Honey
04.06.04	Fish

*** Craigavon**

11.06.02	Fish
11.06.02	Meat
09.06.03	Fish
22.09.03	Meat
03.06.04	Fish
27.09.04	Meat

*** Dungannon**

07.01.02	Fish
04.06.04	Water

*** Newry & Mourne**

10.06.02	Seaweed
27.09.02	Shellfish
27.09.02	Sediment
06.06.03	Shellfish
06.06.03	Seaweed
19.09.03	Sediment4
19.09.03	Shellfish
04.06.04	Shellfish
04.06.04	Seaweed
23.09.04	Shellfish
23.09.04	Sediment

SAMPLE CATALOGUE BY AUTHORITY

** Western Group Public Health

*** Derry**

11.06.02	Water
11.06.02	Shellfish
11.06.02	Seaweed
30.09.02	Seaweed
09.06.03	Seaweed
09.06.03	Seaweed
19.09.03	Fish
19.09.03	Fish
22.09.03	Water
22.09.03	Shellfish
04.06.04	Seaweed
04.06.04	Fish
04.06.04	Shellfish
07.06.04	Water
27.09.04	Fish
27.09.04	Water
27.09.04	Shellfish

*** Fermanagh**

06.06.03	Meat

*** Limavady**

11.06.02	Sediment
11.06.02	Seaweed
27.09.02	Sediment
30.09.02	Seaweed
09.06.03	Sediment
22.09.03	Seaweed
04.06.04	Sediment
04.06.04	Seaweed
27.09.04	Sediment
27.09.04	Seaweed

*** Strabane**

09.06.03	Water

TABLE 1
MONITORING THE TERRESTIAL ENVIRONMENT

Date	Authority	Type	Locality	^{134}Cs	^{137}Cs	^{7}Be	^{40}K
				Activity (Bq/kg wet weight)			
*** Honey**							
*** Eastern Group Public Health Committee**							
10.06.02	Down	Heather	Dundrum	-	1	-	39
22.09.03	Down	Heather	Dundrum	-	3	-	34
27.09.04	Down	Heather	Dundrum	-	6	-	40
*** Northern Group Public Health Committee**							
18.10.02	Ballymena	-	-	-	-	-	31
18.09.03	Moyle	Chunk	Cushendall	-	8	-	13
27.09.04	Moyle	Chunk honey	Cushendall	-	-	-	67
*** Southern Group Public Health Committee**							
22.09.03	Banbridge	Heather	Unknown	-	13	-	42
GENERALISED DERIVED LIMITS				1200[1]	1700[1]		

Date	Authority	Type	Locality	^{134}Cs	^{137}Cs	^{7}Be	^{40}K
				Activity (Bq/kg wet weight)			
*** Meat**							
*** Eastern Group Public Health Committee**							
10.06.02	North Down	Venison	Bangor	-	<1	-	99
19.09.03	North Down	Venison	Bangor	-	<1	-	94
*** Southern Group Public Health Committee**							
11.06.02	Craigavon	Venison	Finnebrogue	-	<1	-	103
22.09.03	Craigavon	Venison	Unknown	-	<1	-	109
27.09.04	Craigavon	Venison	Unknown	-	-	-	103
*** Western Group Public Health Committee**							
06.06.03	Fermanagh	Venison	Brookeborough	-	8	-	100
GENERALISED DERIVED LIMITS							
		Pig		1000	2000		
		Cattle		1000	2000		
		Sheep		2000	3000		
		Offal		3000	4000		
		Poultry		2000	2000		

Date	Authority	Type	Locality	^{134}Cs	^{137}Cs	^{7}Be	^{40}K
				Activity (Bq/litre)			
*** Water**							
*** Belfast City Council**							
11.06.02	Belfast	Well	-	-	-	-	-
*** Eastern Group Public Health Committee**							
11.06.02	Lisburn	Borehole	Lisburn	-	-	-	-
09.06.03	Lisburn	Borehole	Lisburn	-	-	-	-
03/06/04	Lisburn	Borehole	Lambeg	-	-	-	-
*** Northern Group Public Health Committee**							
11.06.02	Ballymena	Borehole	Ballymena	-	-	-	-
22.09.03	Ballymena	Borehole	Ballymena	-	-	-	-
27.09.04	Ballymena	Borehole	Ballymena	-	-	-	-

Note:.
- below limit of detection
[1] (Honey) Calculated from NRPB-GS7 for an adult critical group assuming a consumption of 50 kg /yr and an effective dose equivalent of 1 mSv/yr.

TABLE 1
MONITORING THE TERRESTIAL ENVIRONMENT

Date	Authority	Type	Locality	Activity (Bq/litre) ^{134}Cs	^{137}Cs	^{7}Be	^{40}K
*** Water**							
*** Southern Group Public Health Committee**							
11.06.02	Banbridge	Well	Stramore Road	-	-	-	-
04/06/04	Dungannon	Borehole	Moy Park	-	-	-	-
*** Western Group Public Health Committee**							
11.06.02	Derry	Well	Claudy	-	-	-	-
09.06.03	Strabane	Borehole	Strabane	-	-	-	-
22.09.03	Derry	Well	Claudy	-	-	3	17
07/06/04	Derry	Well	Claudy	-	-	-	-
27.09.04	Derry	Borehole	Claudy	-	-	-	-

GENERALISED DERIVED LIMITS

	^{134}Cs	^{137}Cs	^{7}Be	^{40}K
Drinking water		**90**	**100**	
Fresh water		**1**	**2**	

Note:.
- below limit of detection

TABLE 2
MONITORING THE MARINE ENVIRONMENT

Date	Authority	Type	Locality	^{134}Cs	^{137}Cs	^{7}Be	^{40}K
				Activity (Bq/kg wet weight)			
* **Fish**							
* **Eastern Group Public Health Committee**							
11.06.02	Down	Cod	Unknown	-	1	-	100
30.09.02	Down	Haddock	-	-	<1	-	99
06.06.03	Down	Haddock	Unknown	-	<1	-	96
09.06.03	North Down	Whiting	Unknown	-	<1	-	88
03/06/04	Down	Haddock	Unknown	-	<1	-	119
22.09.04	Ards	Whiting	Irish Sea	-	<1	-	92
* **Northern Group Public Health Committee**							
10.06.02	Coleraine	Whiting	North of Port Stewart	-	<1	-	97
25.10.02	Moyle	Whiting	Northern Channel	-	1	-	118
09.09.03	Moyle	Haddock	North Channel	-	<1	-	131
09.09.03	Moyle	Whiting	North Channel	-	2	-	135
27.09.04	Moyle	Haddock	North Channel	-	<1	-	118
27.09.04	Moyle	Whiting	North Channel	-	<1	-	123
* **Southern Group Public Health Committee**							
07.01.02	Dungannon	Cod	Irish Sea	-	2	-	112
11.06.02	Craigavon	Cod	Unknown	-	1	-	58
11.06.02	Banbridge	Whiting	Unknown	-	<1	-	105
11.06.02	Craigavon	Cod	Unknown	-	1	-	88
06.06.03	Armagh	Haddock	Unknown	-	2	-	85
19.09.03	Armagh	Haddock	Unknown	-	<1	-	114
04/06/04	Armagh	Haddock	Unknown	-	<1	-	102
04/06/04	Banbridge	Whiting	Unknown	-	<1	-	99
* **Western Group Public Health Committee**							
19.09.03	Derry	Haddock & whiting	Unknown	<1	-	-	107
27.09.04	Derry	Haddock	Malin Head	-	-	-	102
GENERALISED DERIVED LIMITS					**700**		

Date	Authority	Type	Locality	^{131}I	^{54}Mn	^{65}Zn	^{57}Co	^{58}Co	^{60}Co	^{134}Cs	^{137}Cs	^{7}Be	^{40}K
				Activity (Bq/kg wet weight)									
* **Seaweed**													
* **Eastern Group Public Health Committee**													
27.09.02	Ards	Dulse	Ballyhalbert	-	-	-	-	-	-	-	5	-	1152
04.06.03	Ards	Dulse	Unknown	-	-	-	-	-	-	-	5	-	2130
01/06/04	Ards	Dulse	-	-	-	-	-	-	2	-	5	-	3270
* **Northern Group Public Health Committee**													
11.06.02	Moyle	Laminaria	Northern Channel	-	-	-	-	-	-	-	<1	-	226
24.09.03	Moyle	Dulse	Ballycastle	-	-	-	-	-	-	-	2	7	451
27.09.04	Moyle	Dulse	Colliery Bay	-	-	-	-	-	-	-	-	-	84
* **Southern Group Public Health Committee**													
10.06.02	Newry & Mourne	Fucus vesiculosus	Warrenpoint	-	-	-	-	-	-	-	1	6	172
10.06.02	Newry & Mourne	Fucus vesiculosus	Warrenpoint	-	-	-	-	-	-	-	1	7	171

Note:.
- below limit of detection

TABLE 2
MONITORING THE MARINE ENVIRONMENT

Seaweed — Activity (Bq/kg wet weight)

Date	Authority	Type	Locality	^{131}I	^{54}Mn	^{65}Zn	^{57}Co	^{58}Co	^{60}Co	^{134}Cs	^{137}Cs	^{7}Be	^{40}K
*** Western Group Public Health Committee**													
11.06.02	Derry	Dulse	Unknown	-	-	-	-	-	-	-	-	7	1193
11.06.02	Limavady	Fucus vesiculosus	Carrickhugh Bridge	-	-	-	-	-	-	-	1	8	165
30.09.02	Derry	Dulse	-	-	-	-	-	-	-	-	-	-	902
30.09.02	Limavady	Fucus vesiculosus	Balls Point	-	-	-	-	-	-	-	<1	-	232
09.06.03	Derry	Dulse	Unknown	-	-	-	-	-	-	-	-	-	2500
22.09.03	Limavady	Fucus vesiculosus	Balls Point	-	-	-	-	-	-	-	<1	16	313
04/06/04	Derry	Dulse	-	-	-	-	-	-	-	-	-	-	1990

Sediment — Activity (Bq/kg dry weight)

Date	Authority	Type	Locality	^{241}Am	^{131}I	^{54}Mn	^{65}Zn	^{57}Co	^{58}Co	^{60}Co	^{134}Cs	^{137}Cs	^{7}Be	^{40}K
*** Belfast City Council**														
27.09.02	Belfast	-	Belfast Lough	14	-	-	-	-	-	-	-	33	7	526
06.06.03	Belfast	Silt	-	6	-	-	-	-	-	-	-	26	-	525
04/06/04	Belfast	-	Belfast Lough		7	-	-	-	-	-	-	18	4	467
*** Eastern Group Public Health Committee**														
10.06.02	Ards	Silt	Millisle	-	-	-	-	-	-	-	-	6	4	366
30.09.02	Down	-	Killough Harbour	1	-	-	-	-	-	-	-	10	-	417
18.09.03	Ards	-	Millisle	1	-	-	-	-	-	-	-	4	3	331
22.09.03	Down	-	Killough Harbour	2	-	-	-	-	-	-	-	11	13	421
21.09.04	Ards	-	Millisle	3	-	-	-	-	-	-	-	6	2	364
27.09.04	Down	-	Killough Harbour	2	-	-	-	-	-	-	-	10	14	514
*** Northern Group Public Health Committee**														
10.06.02	Carrickfergus	-	Carrickfergus	-	-	-	-	-	-	-	-	6	8	234
24.10.02	Carrickfergus	-	Carrickfergus	2	-	-	-	-	-	-	-	5	3	208
06.06.03	Carrickfergus	-	Carrickfergus	3	-	-	-	-	-	-	-	10	7	281
19.09.03	Carrickfergus	-	Carrickfergus	2	-	-	-	-	-	-	-	6	6	248
27/05/04	Carrickfergus	-	Carrickfergus	-	-	-	-	-	-	-	-	5	2	213
23.09.04	Carrickfergus	-	Carrickfergus	2	-	-	-	-	-	-	-	6	6	270
*** Southern Group Public Health Committee**														
27.09.02	Newry & Mourne	-	Warrenpoint	7	-	-	-	-	-	-	-	96	44	717
19.09.03	Newry & Mourne	-	Warrenpoint	8	-	-	-	-	-	-	-	75	40	960
*** Western Group Public Health Committee**														
11.06.02	Limavady	Estuarine	Carrickhugh Bridge	-	-	-	-	-	-	-	-	51	93	759
27.09.02	Limavady	-	Carrickhugh Bridge	3	-	-	-	-	-	-	-	44	-	696
09.06.03	Limavady	Silt	-	4	-	-	-	-	-	-	-	10	28	395
04/06/04	Limavady	-	Carrickhugh	-	-	-	-	-	-	-	-	5	15	228
27.09.04	Limavady	-	Carrickhugh	5	-	-	-	-	-	-	-	10	46	290
GENERALISED DERIVED LIMITS											2000	5000		

Shellfish — Activity (Bq/kg wet weight)

Date	Authority	Type	Locality	^{131}I	^{54}Mn	^{65}Zn	^{57}Co	^{58}Co	^{60}Co	^{134}Cs	^{137}Cs	^{7}Be	^{40}K
*** Eastern Group Public Health Committee**													
06.06.02	Ards	Winkles	Portavogie	-	-	-	-	-	-	-	<1	4	68
27.09.02	Down	Winkles	St John's Point	-	-	-	-	-	-	-	<1	-	108
28.09.02	Ards	Winkles	Ballyhalbert	-	-	-	-	-	-	-	<1	-	79
30.05.03	Down	Lobster	St John’s Point	-	-	-	-	-	-	-	<1	-	95

Note:.
- below limit of detection

TABLE 2
MONITORING THE MARINE ENVIRONMENT

Activity (Bq/kg wet weight)

* **Shellfish**				^{131}I	^{54}Mn	^{65}Zn	^{57}Co	^{58}Co	^{60}Co	^{134}Cs	^{137}Cs	^{7}Be	^{40}K
* **Eastern Group Public Health Committee**													
03.06.03	Down	Mussels	St John's Point	-	-	-	-	-	-	-	<1	-	41
18.09.03	Ards	Winkles	Ballyhalbert	-	-	-	-	-	-	-	-	-	65
03/06/04	Down	Mussels	St Johns Point	-	-	-	-	-	-	-	<1	-	17
* **Northern Group Public Health Committee**													
11.06.02	Moyle	Lobster	Northern Channel	-	-	-	-	-	-	-	<1	-	124
25.10.02	Derry	Crab	North Channel	-	-	-	-	-	-	-	<1	-	116
02.06.03	Moyle	Lobster	Ballycastle	-	-	-	-	-	-	-	<1	-	78
04.06.03	Larne	Mussels	Larne Lough	-	-	-	-	-	-	-	<1	-	24
26/05/04	Larne	Mussels	Shingle Bay	-	-	-	-	-	-	-	-	-	20
04/06/04	Moyle	Lobster	Colliery Bay	-	-	-	-	-	-	-	-	-	82
* **Southern Group Public Health Committee**													
27.09.02	Newry & Mourne	Lobster	-	-	-	-	-	-	-	-	<1	-	81
06.06.03	Newry & Mourne	Mussels	Warrenpoint	-	-	-	-	-	-	-	<1	-	38
04/06/04	Newry & Mourne	Mussels	Warrenpoint	-	-	-	-	-	-	-	<1	-	42
* **Western Group Public Health Committee**													
11.06.02	Derry	Mussels	Longfield Bank	-	-	-	-	-	-	-	<1	-	66
25.10.02	Derry	Crab	Longfield Bank	-	-	-	-	-	-	-	<1	-	116
22.09.03	Derry	Mussels	Derry	-	-	-	-	-	-	-	-	-	37
04/06/04	Derry	Mussels	Derry	-	-	-	-	-	-	-	-	-	36
27.09.04	Derry	Mussels	Longfield Bank	-	-	-	-	-	-	-	-	-	-
GENERALISED DERIVED LIMITS													
		Molluscs								**3000**	**4000**		
		Crustacea								**3000**	**4000**		

Note:

- below limit of detection

TABLE 3

RESULTS OF TRANSURANIC ELEMENT DETERMINATIONS

Date	Authority	Type	Locality	Activity (Bq/kg wet weight)		
				^{238}Pu	$^{239,240}Pu$	^{241}Am
*** Belfast City Council**						
27.09.02	Belfast	Silt	Belfast Lough	2.1	12.1	11.9
06.06.03	Belfast	Sediment*	-	1.03	5.73	6.01
04/06/04	Belfast	Sediment*	Belfast Lough	1.44	10.92	8.51
*** Eastern Group Public Health Committee**						
10.06.02	Ards	Silt	Millisle	0.4	2.3	2.3
11.06.02	Down	Cod	Unknown	-	-	0.2
03.06.03	Down	Mussels	St John's Point	0.01	0.20	0.17
18.09.03	Ards	Sediment*	Millisle	0.16	0.86	1.36
21.09.04	Ards	Sediment*	Millisle	0.56	5.02	4.17
*** Northern Group Public Health Committee**						
10.06.02	Carrickfergus	Silt	Carrickfergus	1.2	6.6	2.6
25.10.02	Moyle	Whiting	Northern Channel	<0.1	<0.1	<0.1
04.06.03	Larne	Mussels	Larne Lough	0.02	0.16	0.22
06.06.03	Carrickfergus	Sediment*	Carrickfergus	0.66	3.66	3.26
27/05/04	Carrickfergus	Sediment*	Carrickfergus	0.52	2.77	2.40
26/05/04	Larne	Mussels	Shingle Bay	0.02	0.15	0.18
*** Southern Group Public Health Committee**						
07.01.02	Dungannon	Cod	Irish Sea	-	-	0.7
27.09.02	Newry & Mourne	Sediment*	Warrenpoint	2.2	14.0	6.3
06.06.03	Newry & Mourne	Mussels	Warrenpoint	0.02	0.09	-
19.09.03	Newry & Mourne	-	Warrenpoint	1.11	7.79	7.28
04/06/04	Newry & Mourne	Mussels	Warrenpoint	-	0.06	0.05
23.09.04	Newry & Mourne	Sediment*	Warrenpoint	0.046	2.32	3.86
*** Western Group Public Health Committee**						
11.06.02	Limavady	Estuarine*	Carrickhugh Bridge	1.16	7.6	9.6
27.09.02	Limavady	Silt*	Carrickhugh Bridge	0.5	5.6	2.0
09.06.03	Limavady	Sediment*	-	0.39	2.62	3.45
22.09.03	Derry	Mussels	Derry	0.02	0.04	0.12
19.09.03	Derry	Haddock & whiting	-	-	-	<0.05
04/06/04	Derry	Mussels	Derry	-	0.05	0.08
27.09.04	Derry	Mussels	Longfield Bank	0.004	0.07	0.13

Note:

- below limit of detection
- sediment reported as dry weight

TABLE 4

ANALYSIS FOR TECHNETIUM-99

Date	Authority	Type	Locality	Activity (Bq/kg wet weight) ^{99}Tc
*** Eastern Group Public Health Committee**				
09.05.02	Down	Lobster	Ballyhoman	201
11.06.02	Down	Cod	Unknown	3
27.09.02	Ards	Dulse	Ballyhalbert	45
30.09.02	Ards	Fucus vesiculosus	Ballyhalbert	473
04.06.03	Ards	Dulse	Unknown	-
30.05.03	Down	Lobster	St John's Point	122
03.06.03	Down	Mussels	St John's Point	131
18.09.03	Ards	Fucus vesiculosus	Ballyhalbert	364
01/06/04	Ards	Dulse	-	8
02/06/04	Down	Lobster	Killough	48
03/06/04	Down	Mussels	St Johns Point	-
21.09.04	Ards	Seaweed	Portavigie	260
*** Northern Group Public Health Committee**				
11.06.02	Moyle	Laminaria	Northern Channel	419
11.06.02	Moyle	Lobster	Northern Channel	1250
25.10.02	Moyle	Fucus vesiculosus	Northern Channel	334
25.10.02	Moyle	Whiting	Northern Channel	2
04.06.03	Larne	Mussels	Larne lough	65
02.06.03	Moyle	Lobster	Ballycastle	133
09.06.03	Moyle	Dulse	Ballycastle	20
24.09.03	Moyle	Dulse	Ballycastle	5
26/05/04	Larne	Mussels	Shingle Bay	106
04/06/04	Moyle	Lobster	Colliery Bay	137
04/06/04	Moyle	Chorda filum	Colliery Bay	47
27.09.04	Moyle	Dulse	Colliery Bay	70
*** Southern Group Public Health Committee**				
07.01.02	Dungannon	Cod	Irish Sea	578
11.06.02	Craigavon	Cod	Unknown	18
10.06.02	Newry & Mourne	Fucus vesiculosus	Warrenpoint	1011
27.09.02	Newry & Mourne	Lobster	-	374
06.06.03	Newry & Mourne	Ascophyllum nodosum	Warrenpoint	1303
06.06.03	Newry & Mourne	Mussels	Warrenpoint	82
19.09.03	Newry & Mourne	Lobster	Unknown	247
04/06/04	Newry & Mourne	Mussels	Warrenpoint	71
04/06/04	Newry & Mourne	Ascophyllum nodosum	Warrenpoint	1902
23.09.04	Newry & Mourne	Lobster	Irish Sea	162
*** Western Group Public Health Committee**				
11.06.02	Derry	Dulse	Unknown	2
11.06.02	Limavady	Fucus vesiculosus	Carrickhugh Bridge	220
30.09.02	Derry	Dulse	Unknown	6
30.09.02	Limavady	Fucus vesiculosus	Balls Point	91
09.06.03	Derry	Dulse	Unknown	-
09.06.03	Derry	Ascophyllum nodosum	Longfield Bank	442
19.09.03	Derry	Haddock & whiting	Unknown	0
22.09.03	Derry	Mussels	Derry	5
22.09.03	Limavady	Fucus vesiculosus	Balls Point	35
04/06/04	Derry	Mussels	Derry	16
04/06/04	Limavady	Fucus vesiculosus	Balls Point	22
27.09.04	Derry	Mussels	Longfield Bank	21
27.09.04	Limavady	Fucus vesiculosus	Carrickhugh	34

TABLE 5
ANALYSIS FOR CARBON-14

Date	Authority	Type	Locality	Activity (Bq/kg wet weight) ^{14}C
*** Eastern Group Public Health Committee**				
06.06.03	Down	Haddock	Unknown	28
03/06/04	Down	Haddock	-	20
21.09.04	Ards	Seaweed	Portavogie	20
*** Northern Group Public Health Committee**				
09.09.03	Moyle	Haddock	North Channel	47
27.09.04	Moyle	Haddock	North Channel	13
*** Southern Group Public Health Committee**				
09.06.03	Craigavon	Cod	Unknown	23
03/06/04	Craigavon	Cod	-	14
*** Western Group Public Health Committee**				
19.09.03	Derry	Haddock	Unknown	31
04/06/04	Derry	Haddock	-	13

Notes:
Measurements given in 'Radioactivity in Food and the Environment, 2001' for fish in the Irish Sea are in range 41 - 120 Bq/kg wet weight

- below limit of detection

TABLE 6
INSTANTANEOUS GAMMA MONITORING

The following data were collected with samples submitted for gamma and alpha analysis.

Date	Authority	Type	Locality	Doserate µGy/hr
*** Belfast City Council**				
06.06.03	Belfast	-	-	0.073
04/06/04	Belfast	-	Belfast Lough	0.073
*** Eastern Group Public Health Committee**				
21.09.04	Ards	Sediment	Millisle	0.060
*** Southern Group Public Health Committee**				
27.09.02	Newry & Mourne	-	Warrenpoint	0.090
19.09.03	Newry & Mourne	-	Warrenpoint	0.089
*** Western Group Public Health Committee**				
27.09.02	Limavady	-	Carrickhugh Bridge	0.040
09.06.03	Limavady	-	-	0.042
04/06/04	Limavady	-	Carrickhugh	0.070
27.09.04	Limavady	Sediment	Carrickhugh	0.050

NORTHERN IRELAND SAMPLE SITES

(The numbered sites are shown on the map on the following page)

Map no.	Authority	Details	Locality	Grid reference	Gamma	Alpha	^{99}Tc	^{14}C
Belfast City Council								
1	Water	Belfast	-	J 328 380	✓			
2	Sediment	Belfast	Belfast Lough	J 350 794	✓	✓		
Eastern Group Public Health Committee								
3	Sediment	Ards	Millisle	J 601 755	✓	✓		
4	Seaweed	Ards	Ballyhalbert	J 653 635	✓		✓	
5	Seaweed, shellfish	Ards	Ballyhalbert	J 661 620	✓		✓	✓
*	Fish, seaweed	Ards	*	*	✓		✓	
6	Honey	Down	Dundrum	J 409 373	✓			
7	Shellfish	Down	St John's Point	J 530 330	✓	✓	✓	
8	Sediment	Down	Killough Harbour	J 538 366	✓			
9	Shellfish	Down	Ballyhoman	J 580 380			✓	
10	Seaweed	Down	Sheepland Harbour	J 581 390		✓	✓	
*	Fish	Down	*	*	✓			✓
11	Water	Lisburn	Lisburn	J 282 663	✓			
12	Water	Lisburn	Lisburn	J 283 657	✓			
*	Shellfish	Lisburn	*	*	✓	✓	✓	
13	Meat	North Down	Bangor	J 474 795	✓			
*	Fish	North Down	*	*	✓			
Northern Group Public Health Committee								
14	Fresh water fish	Ballymena	Ballymena	D 105 024	✓			
15	Sediment	Carrickfergus	Carrickfergus	J 429 882	✓	✓		
*	Fish	Coleraine	North of Port Stewart	C 180 440	✓			
*	Shellfish	Larne	Shingle Bay	D 448 986	✓	✓	✓	
16	Fish	Moyle	North Channel	D 010 550	✓			✓
17	Seaweed	Moyle	Colliery Bay	D 145 419				
18	Shellfish	Moyle	Colliery Bay, Ballycastle	D 150 420	✓		✓	
19	Shellfish	Moyle	Northern Channel	D 155 420	✓		✓	
20	Seaweed, shellfish	Moyle	Ballycastle	D 160 425	?		✓	
21	Seaweed	Moyle	East of Colliery bay	D 164 426			✓	
22	Shellfish	Moyle	Northern Channel	D 165 455	✓		✓	
23	Honey	Moyle	Cushendall	D 200 275	✓			
24	Honey	Moyle	Cushendall	D 234 275	✓			
25	Fish	Moyle		D 290 500	✓			✓
Southern Group Public Health Committee								
	Fish	Armagh	Unknown	*	✓			
26	Water	Banbridge	Stramore Road	J 063 482	✓			
*	Fish, honey	Banbridge	Unknown	*	✓			
27	Meat	Craigavon	Finnebrogue	J 475 474	✓			
	Fish, meat	Craigavon	Unknown	*	✓			✓
28	Water	Dungannon	Moy Park	H 817 615	✓			
*	Fish	Dungannon	Irish Sea	*	✓	✓	✓	
29	Seaweed, sediment	Newry & Mourne	Warrenpoint	J142 180	✓	✓	✓	
308	Shellfish	Newry & Mourne	Warrenpoint	J153 183	✓	✓	✓	
*	Shellfish	Newry & Mourne	North Channel	*			✓	

NORTHERN IRELAND SAMPLE SITES

(The numbered sites are shown on the map on the following page)

Map no.	Authority	Details	Locality	Grid reference	Gamma	Alpha	^{99}Tc	^{14}C
Western Group Public Health Committee								
31	Water	Derry	Claudy	C 530 072	✓			
32	Shellfish	Derry	Longfield Bank	C 545 235	✓	✓	✓	
33	Shellfish, seaweed	Derry	Derry	C 545 245	✓	✓	✓	
34	Seaweed	Derry		C 545 265			✓	
35	Water	Derry	Claudy	C 553 043	✓			
*	Fish, shellfish, seaweed	Derry	-	*	✓	✓	✓	✓
36	Meat	Fermanagh	Brookeborough	H410 445	✓			
37	Sediment	Limavady	Carrickhugh	C 603 227	✓	✓		
38	Sediment, seaweed	Limavady	Carrickhugh Bridge	C 603 230	✓	✓		
39	Seaweed	Limavady	Balls Point	C 628 298	✓		✓	
40	Seaweed	Limavady	Balls Point	C 646 300			✓	
41	Water	Strabane	Strabane	C 363 937	✓			

* grid reference unknown

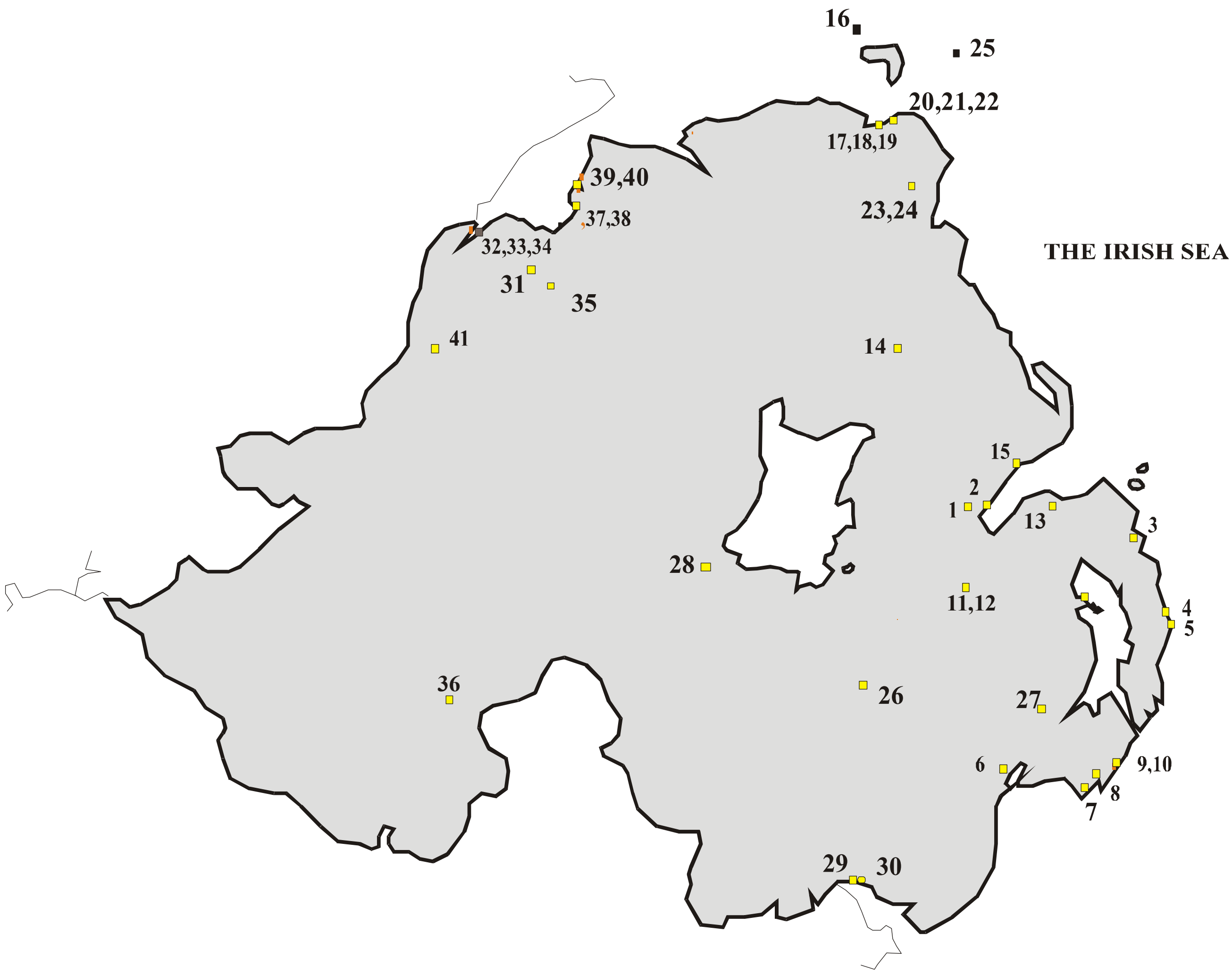


FIGURE 3

NORTHERN IRELAND SAMPLING SITES
APRIL 2002 – MARCH 2005

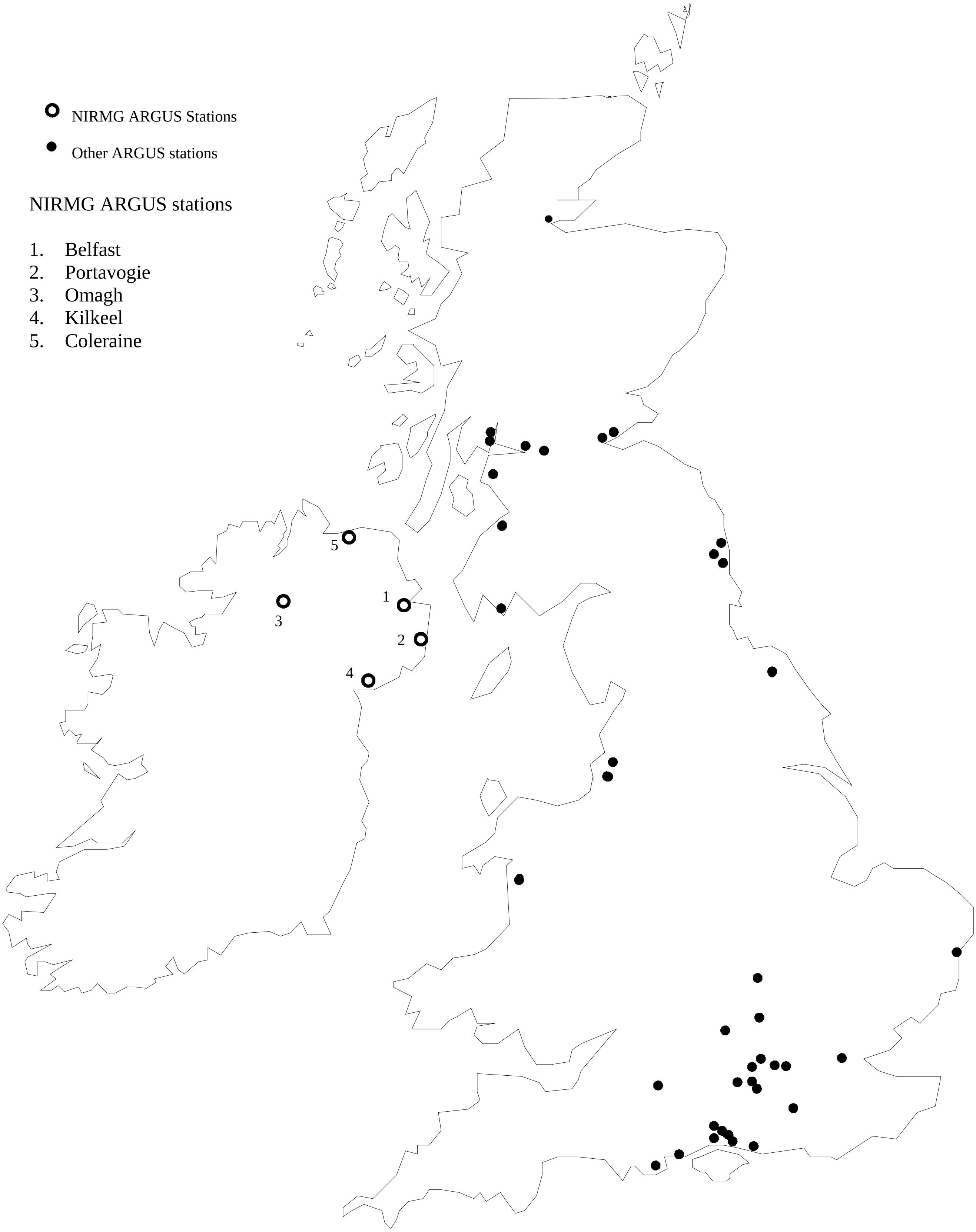


FIGURE 4: THE UK NETWORK OF ARGUS CONTINUOUS GAMMA MONITORING STATIONS (www. environment.org.uk)

NORTHERN IRELAND CONTINUOUS MONITORING ARGUS NETWORK

In 1994 the Northern Ireland Radiation Monitoring (NIRMG) investigated the feasibility of installing a network of gamma radiation monitoring stations within district councils in Northern Ireland. These unattended stations would be required to provide reliable regularly updated information about background gamma radiation and, in the event of an increase in background, would be required to provide an automatic comprehensive alert warning .
Representatives from NIRMG visited a number of sites in the North-East of England where a variety of installed systems were available in a geographically small area. It was recognised that, in addition to providing information on background gamma radiation and alerting in an emergency, provision of an automated system would significantly reduce the staff resources required for the manual operation of the Mini 6-80 instruments for instantaneous gamma monitoring of background.

Following a report, of this visit a specification of the equipment needed for a networked system was prepared and quotations were sought from prospective suppliers in Great Britain. A detailed assessment of each system was undertaken together with costs and a recommendation made to NIRMG that Argus be employed to install a network of five outstations in Northern Ireland linked to a host computer based in Belfast.

In April 1996 the equipment was installed and made operational at the sites named below and a 24-hour communications procedure was established to provide notification of an alert from any outstation to a designated contact officer.

Authority	**Site of Outstation**
Belfast City Council	Dunbar Street, Belfast
EGEHC	Harbour Master’s Office, Portavogie
WGEHC	Mountjoy Road, Omagh
SGEHC	Sports Centre, Kilkeel
Northern Group Systems	Cloonavin, Coleraine

Argus Data Logging

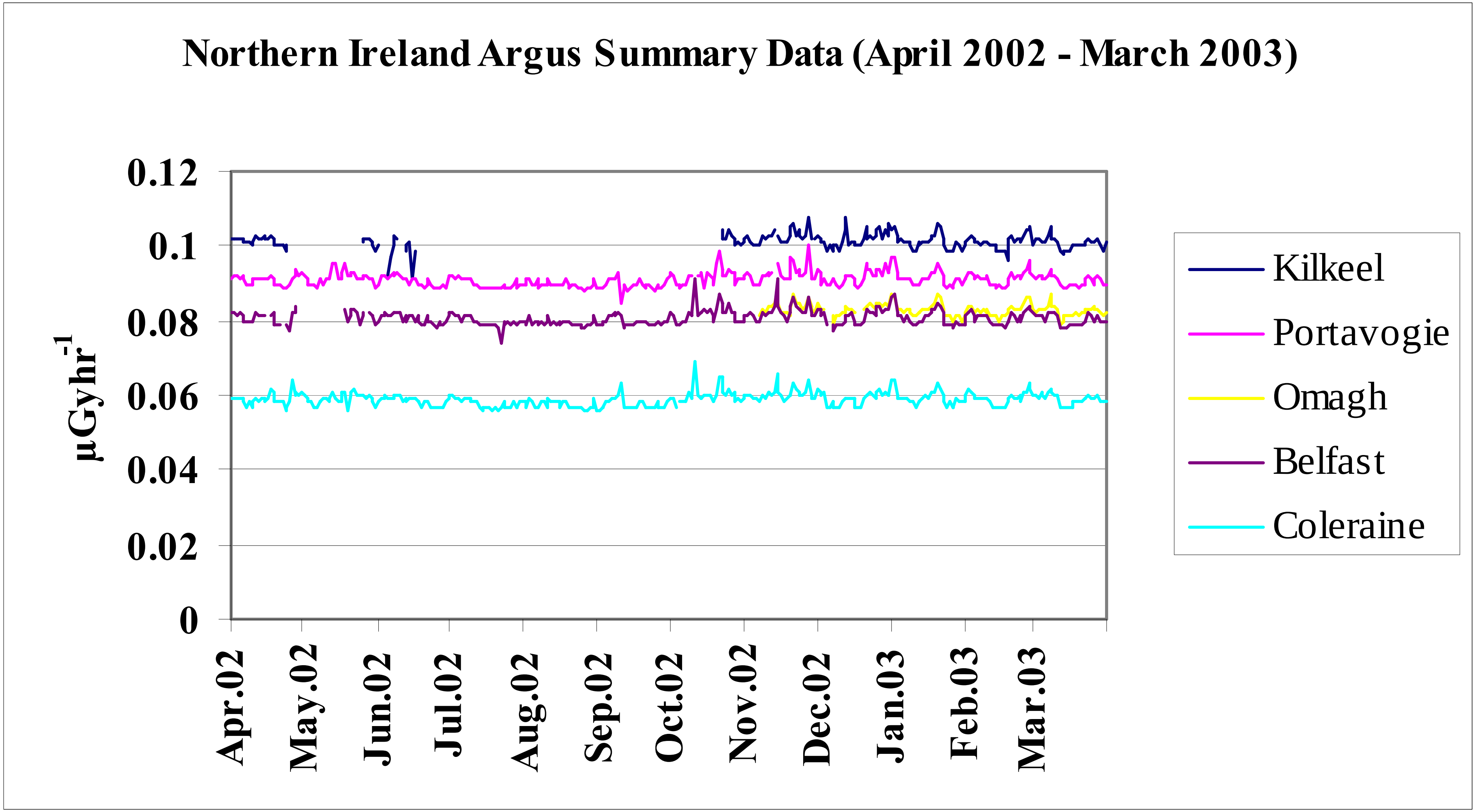
In the original ARGUS installation each outstation had its own remote station management software allowing access to background gamma readings accumulated over successive ten-minute periods. The stations also transferred results to the host computer in Belfast by modem connection. Using a Windows-based software package, ADVENT, data accessed remotely by PC could be viewed for each outstation. Local data were downloaded into spreadsheet or as a graph plotting average readings at two hourly intervals in nanograys/hour. The host computer in Belfast also checked and maintained each outstation at all times, ensuring optimum reliability and data integrity.

ARGUS 3000

A new much improved ARGUS system is now available via the Internet (www.environment.org.uk). After 24 hours all data are available on the Internet through a standard browser. Parameters for alert levels may be updated by individual station owners, text messages sent to nominated phones and up-to-the-minute data may be viewed on a secure private website. The system is built with standard PC components and can be maintained by in-house IT personnel. Any software updates and improvements will be available from the Internet. Northern Ireland has almost completed the upgrade to three systems that now have meteorological probes providing weather data as well as a gamma detector. Omagh is soon to come on line, and Coleraine and Portavogie are expecting to upgrade shortly.

Data for April 2002 – March 2005

Data downloaded from the central database at www.environment.org.uk are summarised in the following three graphs.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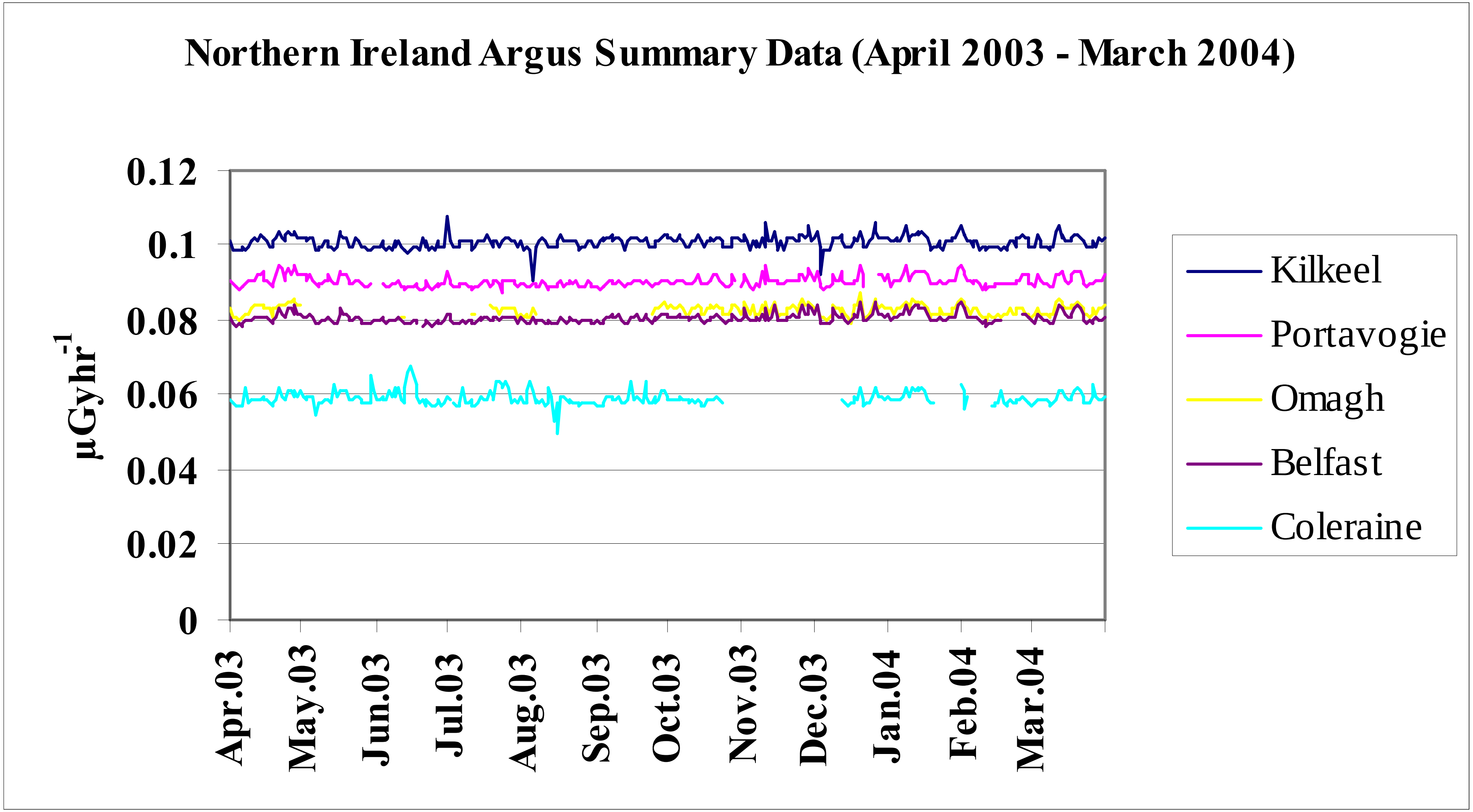
0.1
0.08
0.06
0.04
0.02
0
µGyhr-1
Apr.02
May.02
Jun.02
Jul.02
Aug.02
Sep.02
Oct.02
Nov.02
Dec.02
Jan.03
Feb.03
Mar.03
Kilkeel
Portavogie
Omagh
Belfast
Coleraine


Northern Ireland Argus Summary Data (April 2003 - March 2004)
µGyhr-1
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0.1
0.08
0.06
0.04
0.02
0
Apr.03
May.03
Jun.03
Jul.03
Aug.03
Sep.03
Oct.03
Nov.03
Dec.03
Jan.04
Feb.04
Mar.04
Kilkeel
Portavogie
Omagh
Belfast
Coleraine

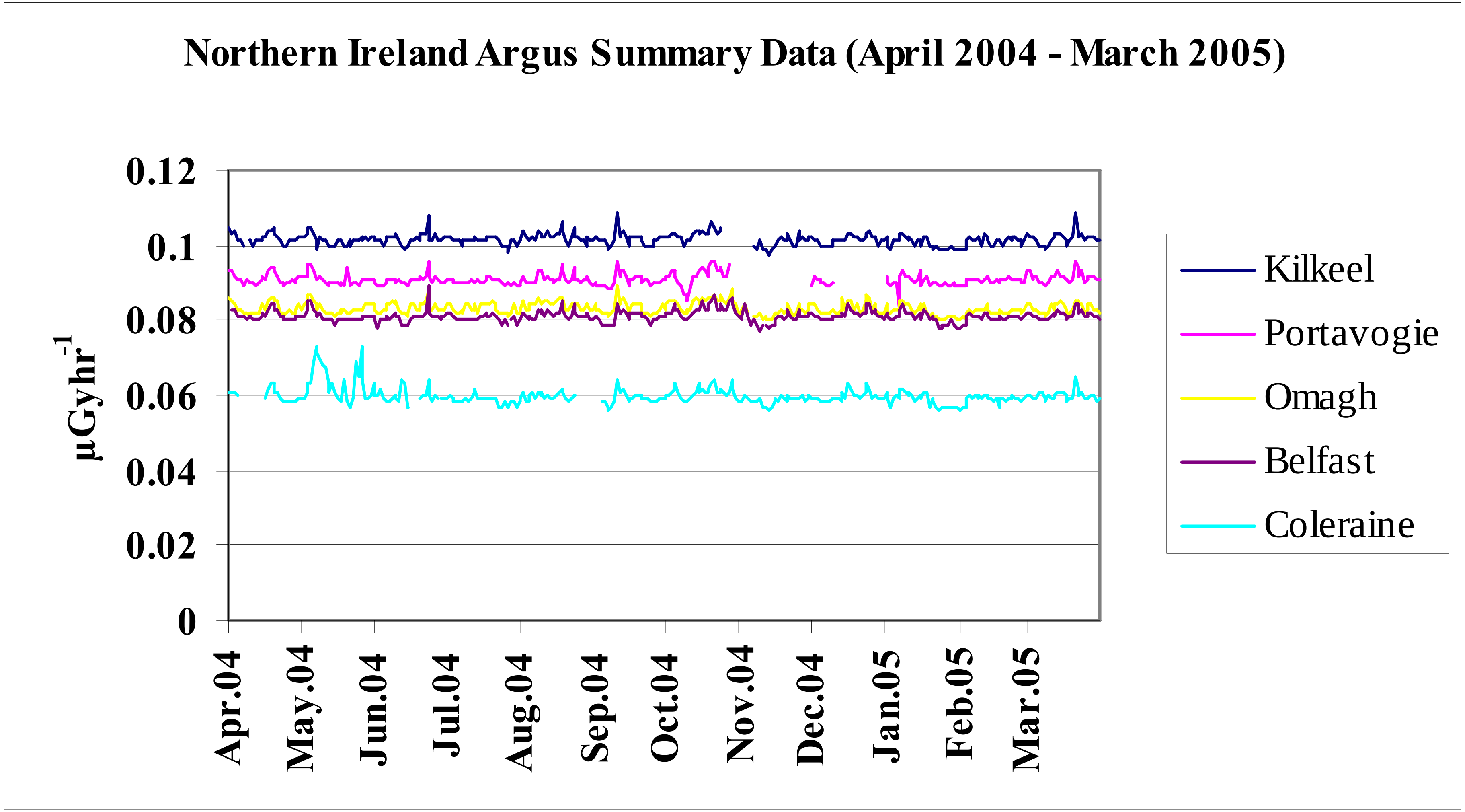
Northern Ireland Argus Summary Data (April 2004 - March 2005)
µGyhr-1
0.12
0.1
0.08
0.06
0.04
0.02
0
Apr.04
May.04
Jun.04
Jul.04
Aug.04
Sep.04
Oct.04
Nov.04
Dec.04
Jan.05
Feb.05
Mar.05
Kilkeel
Portavogie
Omagh
Belfast
Coleraine

TABLE 1

SELECTED GAMMA DOSERATE COMPARATIVE DATA

	Ground type	Locality	Activity (μ Gyh^{-1})
1.	Silt	Warrenpoint, Newry & Mourne (9/02)	0.09
	Silt	Warrenpoint, Newry & Mourne (9/02)	0.09
	Silt	Belfast Lough (6/03)	0.07
	Silt	Limavady (6/04)	0.07
2.	Sand	Sellafield (2001 – mean of 4 measurements)	0.073
	Salt marsh	Ravenglass - Carlton Marsh (2001)	0.18
	Mud/sand	Ravenglass - Raven Villa (2001 - mean of 9 measurements)	0.11
	Mussel bed	Drigg Barn Scar (2001 - mean of 4 measurements)	0.086
	Mud and sand	Whitehaven – outer harbour (2001 - mean of 12 measurements)	0.084
	Sand	Sellafield (2002 – mean of 4 measurements)	0.068
	Salt marsh	Ravenglass - Carlton Marsh (2002 - mean of 4 measurements)	0.16
	Mud/sand	Ravenglass - Raven Villa (2002 - mean of 7 measurements)	0.10
	Mussel bed	Drigg Barn Scar (2002 - mean of 4 measurements)	0.089
	Mud and sand	Whitehaven – outer harbour (2002 - mean of 12 measurements)	0.081
	Sand	Sellafield (2003 – mean of 4 measurements)	0.071
	Salt marsh	Ravenglass - Carlton Marsh (2003 - mean of 4 measurements)	0.18
	Mud/sand	Ravenglass - Raven Villa (2003)	0.10
	Mussel bed	Drigg Barn Scar (2003 - mean of 4 measurements)	0.086
	Mud and sand	Whitehaven – outer harbour (2003 - mean of 12 measurements)	0.087
3	Silt	Belfast Lough (1/97)	0.07
	Silt	Warrenpoint, Newry & Mourne (6/97)	0.088
	Silt	Derry (9/97)	0.068
		Millisle (11/97)	0.055
	Silt	Carrickhugh, Limavady (1/98)	0.05
	Silt	Warrenpoint, Newry & Mourne (6/98)	0.08
	Silt	Longfield Bank, Limavady (11/99)	0.04
	Silt	Warrenpoint, Newry & Mourne (3/00)	0.08
	Silt	Culmore Point, Derry (3/00)	0.05
	Sand	Butterlump Rock, Ballyhalbert (4/01)	0.10
4.	Mud/Silt	Ravenglass - Raven Villa (2001)	0.14
	Mud/sand	Whitehaven - outer harbour (2001)	0.12
	Mud/Silt	Ravenglass - Raven Villa (2002)	0.16
	Mud/sand	Whitehaven - outer harbour (2002)	0.13
	Dunes & grass banks	Sellafield (2002)	0.09
	Mud/Silt	Ravenglass - Raven Villa (2003)	0.14
	Mud/sand	Whitehaven - outer harbour (2003)	0.13
	Dunes & grass banks	Sellafield (2003)	0.12

Notes:
1. Results from Northern Ireland Radiation Monitoring Group (2002 - 2005).
2. Results from 'Radioactivity in Food & the Environment, Food Standards Agency.(2001- 2003)
3. Results from previous Northern Ireland Reports.
4. Results from Annual Report of BNFL Sellafield (2001 – 2003)

TABLE 2
SELECTED GAMMA COMPARATIVE DATA FOR THE TERRESTRIAL ENVIRONMENT

	Category	Locality	Activity (Bq/kg wet weight) ^{137}Cs
MEAT			
1.	Venison	North Down (6/02)	<1
	Venison	Craigavon (6/02)	<1
	Venison	Fermanagh (6/03)	8
3.	Venison	Bangor (10/99)	<1
	Venison	Fermanagh (10/99)	<1
	Venison	Fermanagh (10/00)	31
	Venison	Colebrook(10/01)	<1
	Venison	Ballymena (01/02)	-
4.	Beef	Seascale (2001)	0.29
	Mutton	Ravenglass (2001)	0.53
	Venison	Gosforth (2001)	11
	Beef	Seascale (2002)	0.78
	Mutton	Ravenglass (2002)	1.6
	Venison	Gosforth (2002)	11
	Beef	Seascale (2003)	0.31
	Mutton	Ravenglass (2003)	1.7
	Venison	Gosforth (2002)	130
GENERALISED DERIVED LIMITS			
		Sheep	**3000**
			2000

Notes:
The GDLs quoted include revised limits (January 1996). A full explanation of GDLs is given in Appendix D.

1. Results from Northern Ireland Radiation Monitoring Group (2002 - 2005).
2. Results from 'Radioactivity in Food & the Environment, Food Standards Agency.(2001- 2003)
3. Results from previous Northern Ireland Reports.
4. Results from Annual Report of BNFL Sellafield (2001 – 2003)

- below the limit of detection

<1 activity seen but near the detection limit
na not analysed
nr not recorded.

TABLE 3
SELECTED GAMMA COMPARATIVE DATA FOR THE MARINE ENVIRONMENT

	Category	Locality	Activity (Bq/kg wet weight)		
			^{137}Cs	^{60}Co	^{131}I
FISH					
1	Haddock	Northern Ireland (09/03)	<1	-	-
	Cod	Northern Ireland (6/02)	1	-	-
	Haddock	North Channel (09/03)	<1	-	-
	Whiting	North Channel (09/04)	<1		
2.	Plaice	Sellafield coastal area (2001 - mean of 4 measurements)	6.5	<0.2	nr
	Whiting	Northern Ireland (2001– mean of 6 measurements)	4.0	<0.08	nr
	Cod	Northern Ireland (2001– mean of 6 measurements)	2.2	<0.07	nr
	Plaice	Sellafield coastal area (2002 - mean of 4 measurements)	4.2	<0.16	nr
	Whiting	Northern Ireland (2002– mean of 7 measurements)	2.5	<0.06	nr
	Cod	Northern Ireland (2002– mean of 8 measurements)	1.9	<0.06	nr
	Plaice	Sellafield coastal area (2003 - mean of 4 measurements)	5.0	<0.13	nr
	Whiting	Northern Ireland (2003– mean of 6 measurements)	2.6	<0.05	nr
	Cod	Northern Ireland (2003– mean of 6 measurements)	1.7	<0.10	nr
3.	Whiting	Kilkeel (1/98)	3	-	-
	Ling	Kilkeel (03/99)	8	<1	-
	Whiting	Unknown (03/01)	5	-	-
	Whiting	Unknown (10/99)	<1	-	-
	Whiting	Unknown (10/01)	1	-	-
	Whiting	Irish Sea (01/02)	5	-	-
	Whiting	Irish Sea (01/02)	<1	-	-
4.	Plaice	St Bees (2001)	5.2	<0.33	nr
	Cod	St Bees (2001)	5.9	<0.27	nr
	Whiting	Sellafield coastal area (2001)	8.3	<0.16	nr
	Plaice	St Bees (2002)	4.5	<0.25	nr
	Cod	St Bees (2002)	6.3	<0.27	nr
	Whiting	Sellafield coastal area (2002)	3.0	<0.19	nr
	Plaice	St Bees (2003)	4.1	<0.22	nr
	Cod	St Bees (2002)	6.0	0.26	nr
GENERALISED DERIVED LIMITS			**800**	**1290***	**500**

	Category	Locality	Activity (Bq/kg wet weight)		
			^{137}Cs	^{60}Co	^{131}I
SEAWEED					
1.	Fucus vesiculous	Warrenpoint (6/02)	1	-	
	Dulse	Ballyherbert	5	-	-
	Dulse	Ballycastle (09/03)	2	-	<1
	Dulse	Colliery Bay (09/04)	-	-	<1
2.	Fucus vesiculosus	Sellafield (2001 – mean of 4 measurements)	6.5	18	nr
	Fucus vesiculosus	Ardglass (2001 – mean of 4 measurements)	1.2	<0.18	nr
	Fucus serratus	Portrush (2001 – mean of 3 measurements)	0.19	<0.06	nr
	Fucus vesiculosus	Sellafield (2002 – mean of 4 measurements)	7.3	13	nr
	Fucus vesiculosus	Ardglass (2002 – mean of 4 measurements)	0.60	<0.15	nr
	Fucus serratus	Portrush (2002 – mean of 2 measurements)	<0.19	<0.11	nr
	Fucus vesiculosus	Sellafield (2003 – mean of 4 measurements)	8.1	12	nr
	Fucus vesiculosus	Ardglass (2003 – mean of 3 measurements)	0.99	<0.16	nr
	Fucus spp	Portrush (2003 – mean of 4 measurements)	<0.16	<0.08	nr

Notes:
The GDLs quoted include revised limits (January 1996). A full explanation of GDLs is given in Appendix D.
* Calculated from NRPB-GS7. They are for an adult criical group assuming a consumption rate of 50kg/year and an effective dose limit of 1mSv/year.
1. Results from Northern Ireland Radiation Monitoring Group (2002 - 2005).
2. Results from 'Radioactivity in Food & the Environment, Food Standards Agency.(2001- 2003)
3. Results from previous Northern Ireland Reports.
4. Results from Annual Report of BNFL Sellafield (2001 – 2003)
- below the limit of detection
<1 activity seen but near the detection limit
na not analysed
nr not recorded.

TABLE 3 (Cont)

SELECTED GAMMA COMPARATIVE DATA FOR THE MARINE ENVIRONMENT

	Category	Locality	Activity (Bq/kg wet weight) ^{137}Cs	^{60}Co	^{131}I
SEAWEED					
3.	Fucus vesiculous	Warrenpoint (11/99)	2	-	347
	Fucus serratus	Ballycastle Bay (4/01)	<1	-	-
	Fucus vesiculosus	Warrenpoint (11/00)	1	-	<1
	Fucus serratus	Warrenpoint (3/00)	2	-	-
	Dulse	Killough (03/00)	1	-	<1
	Fucus serratus	Ballycastle Bay (04/01)	<1	-	-
	Fucus vesiculosus	Killough Harbour (01/02)	<1	-	-
4.	Fucus vesiculosus	Seascale (2001)	5.6	14	nr
	Fucus vesiculosus	Seascale (2002)	4.8	14	nr
	Fucus vesiculosus	Seascale (2003)	4.8	6.9	nr

	Category	Locality	Activity (Bq/kg dry weight) ^{137}Cs	^{60}Co
SEDIMENT				
1.	Silt	Belfast Lough (09/02)	33	-
	Silt	Millisle (06/02)	6	-
	-	Belfast Lough (06/03)	26	-
	-	Warrenpoint (09/03)	75	-
	-	Carrickhugh (06/04)	5	-
	-	Carrickfergus (09/04)	6	-
2	sand	Sellafield (2001 – mean of 4 measurements)	90	5.2
	mud & sand	Ravenglass (2001 – mean of 4 measurements)	210	26
	mud & sand	Lough Foyle (2001 – mean of 2 measurements)	8.6	<0.35
	sand	Sellafield (2002 – mean of 4 measurements)	78	4.5
	mud & sand	Ravenglass (2002 – mean of 4 measurements)	280	31
	mud	Lough Foyle (2002)	2	<0.34
	mud & sand	Ravenglass (2003 – mean of 4 measurements)	260	39
	mud	Lough Foyle (2003)	4.7	<0.37
3	Silt	Belfast Lough(10/99)	44	-
	Silt	Millisle(10/99)	8	-
	-	Belfast Lough (11/00)	-	-
	-	Warrenpoint (3/01)	-	-
	-	Warrenpoint(01/02)	86	-
	-	Coshowen(01/02)	86	-
4.	silt	Ravenglass - Raven Villa (2001)	160	22
	silt	Whitehaven - Outer 2 South (2001)	200	<2.5
	silt	Ravenglass - Raven Villa (2002)	210	37
	silt	Whitehaven - Outer 2 South (2002)	180	<3.2
	silt	Ravenglass - Raven Villa (2003)	170	24
	silt	Whitehaven - Outer 2 South (2003)	170	-
GENERALISED DERIVED LIMITS			**5000**	

Notes:
The GDLs quoted include revised limits (January 1996). A full explanation of GDLs is given in Appendix D.
* Calculated from NRPB-GS7. They are for an adult criical group assuming a consumption rate of 50kg/year and an effective dose limit of 1mSv/year.

1. Results from Northern Ireland Radiation Monitoring Group (2002 - 2005).
2. Results from 'Radioactivity in Food & the Environment, Food Standards Agency.(2001- 2003)
3. Results from previous Northern Ireland Reports.
4. Results from Annual Report of BNFL Sellafield (2001 – 2003)

- below the limit of detection
<1 activity seen but near the detection limit
na not analysed
nr not recorded.

TABLE 3 (Cont)
SELECTED GAMMA COMPARATIVE DATA FOR THE MARINE ENVIRONMENT

	Category	Locality	Activity (Bq/kg wet weight) ^{137}Cs	^{60}Co
SHELLFISH				
1.	Lobster	Ballyhoman (05/02)	<1	-
	Lobster	Newry & Mourne (09/02)	<1	-
	Mussels	St Johns Point (06/03)	<1	-
	Mussels	ShingleBay (05/04)	-	-
	Lobster	Colliery Bay (06/04)	-	-
2	Mussels	Northern Ireland (2001 – mean of 2 measurements)	0.40	<0.12
	Mussels	Sellafield coastal area (2001 – mean of 4 measurements)	2.2	8.2
	Winkles	Northern Ireland (2001 – mean of 4 measurements)	0.29	<0.14
	Winkles	Sellafield coastal area (2001 – mean of 4 measurements)	7.3	13
	Mussels	Northern Ireland (2002 – mean of 2 measurements)	0.46	<0.12
	Mussels	Sellafield coastal area (2002 – mean of 4 measurements)	2.5	6.7
	Winkles	Northern Ireland (2002 – mean of 4 measurements)	0.30	<0.10
	Winkles	Sellafield coastal area (2002 – mean of 4 measurements)	3.6	18
	Mussels	Northern Ireland (2003 – mean of 2 measurements)	0.35	<0.13
	Mussels	Sellafield coastal area (2003 – mean of 4 measurements)	3.6	7.7
	Winkles	Northern Ireland (2002 – mean of 4 measurements)	<0.21	<0.15
	Winkles	Sellafield coastal area (2003 – mean of 4 measurements)	5	4.9
3.	Nephrops	(11/99)	2	-
	Mussels	Balls Point (3/00)	<1	-
	Lobster	Ballyhoman (10/00)	<1	-
	Nephrops	(9/00)	1	-
	Winkles	Portavogie (04/01)	-	-
	Lobster	Rathlin (10/01)	<1	-
	Crab	Cushendall (01/02)	-	-
4.	Mussels	St Bees (2001)	2.5	10
	Winkles	St Bees (2001)	5.7	13
	Mussels	St Bees (2002)	2.4	7.6
	Winkles	St Bees (2002)	6.8	11
	Mussels	St Bees (2003)	2.3	7.5
	Winkles	St Bees (2003)	7.3	12
GENERALISED DERIVED LIMITS			4000	20000*

Notes:
The GDLs quoted include revised limits (January 1996). A full explanation of GDLs is given in Appendix D.
* Calculated from NRPB-GS7. They are for an adult criical group assuming a consumption rate of 50kg/year and an effective dose limit of 1mSv/year.
1. Results from Northern Ireland Radiation Monitoring Group (2002 - 2005).
2. Results from 'Radioactivity in Food & the Environment, Food Standards Agency.(2001- 2003)
3. Results from previous Northern Ireland Reports.
4. Results from Annual Report of BNFL Sellafield (2001 – 2003)

- below the limit of detection

<1 activity seen but near the detection limit
na not analysed
nr not recorded.

TABLE 4

SELECTED ALPHA COMPARATIVE DATA FOR THE MARINE ENVIRONMENT

	Locality	Activity (Bq/kg dry weight)		
		^{238}Pu	^{239,240}Pu	^{241}Am
SEDIMENT				
1.	Belfast Lough (09/02)	2.1	12.1	11.9
	Carrickfergus (06/03)	0.66	3.66	3.26
	Warrenpoint (09/03)	1.11	7.79	7.28
	Belfast Lough (06/04)	1.44	10.92	8.51
	Carrickfergus (05/04)	0.52	2.77	2.40
2	Ballymacormick (2001)	1.7	9.5	13
	Sellafield (2001 – mean of 4 measurements)	na	na	230
	Ravenglass (2001 – mean of 4 measurements)	na	na	500
	Ballymacormick (2002 – mean of 2 measurements)	1.9	10	15
	Sellafield (2002 – mean of 4 measurements)	na	na	na
	Ravenglass (2002 – mean of 4 measurements)	na	na	670
	Ballymacormick (2003 – mean of 2 measurements)	1.7	9.2	15
	Whitehaven Outer Harbour (2003 – mean of 3 measurements)	9.6	5.2	540
	Ravenglass (2003 – mean of 4 measurements)	na	na	670
3.	Longfield Bank (9/95)	2.7	17.0	21.0
	River Foyle (8/96)	1.76	10.01	17.49
	Larne Lough (6/97)	0.96	5.33	7.45
	Belfast Lough (11/98)	0.64	3.66	3.62
	Larne Lough (11/99)	0.59	3.72	5.25
	Belfast Lough (10/99)	1.95	12.21	15.29
	Warrenpoint (3/01)	1.60	11.03	7.10
	Belfast Lough (11/00)	1.28	7.65	8.70
	Warrenpoint (01/02)	2.29	13.51	8.92
	Coshowen (01/02)	2.03	11.88	18.14
		Total Pu		
4.	Whitehaven - Outer 2, South (2001)	88		110
	Ravenglass - Raven Villa (2001)	350		490
	Whitehaven - Outer 2, South (2002)	79		110
	Ravenglass - Raven Villa (2002)	410		610
	Whitehaven - Outer 2, South (2001)	99		130
	Ravenglass - Raven Villa (2001)	330		480
GENERALISED DERIVED LIMITS		100000	90000	90000

Notes:

The GDLs quoted include revised limits (1998). A full explanation of GDLs is given in Appendix D.
Results for transuranic element determinations are reported on a wet basis except for sediment.
1. Results from Northern Ireland Radiation Monitoring Group (2002 - 2005).
2. Results from 'Radioactivity in Food & the Environment, Food Standards Agency.(2001- 2003)
3. Results from previous Northern Ireland Reports.
4. Results from Annual Report of BNFL Sellafield (2001 – 2003)

- below the limit of detection
<1 activity seen but near the detection limit
na not analysed

TABLE 5
SELECTED ^{99}Tc COMPARATIVE DATA FOR THE MARINE ENVIRONMENT

	Category	Locality	Activity (Bq/kg wet weight) ^{99}Tc
SEAWEED			
1.	Fucus vesiculosus	Warrenpoint (06/02)	1011
	Fucus vesiculosus	Carrickhugh Bridge (06/02)	220
	Dulse	Ballycastle (06/03)	20
2	Fucus vesiculosus	Sellafield (2001 – mean of 4 measurements)	17000
	Fucus vesiculosus	Ardglass (2001 – mean of 4 measurements)	290
	Rhodymenia spp.	Strangford Lough (2001 – mean of 4 measurements)	69
	Fucus vesiculosus	Sellafield (2002 – mean of 4 measurements)	29000
	Fucus vesiculosus	Ardglass (2002 – mean of 4 measurements)	590
	Rhodymenia spp.	Strangford Lough (2002 – mean of 4 measurements)	24
	Fucus vesiculosus	Sellafield (2003 – mean of 4 measurements)	27000
	Fucus vesiculosus	Ardglass (2003 – mean of 3 measurements)	580
	Rhodymenia spp.	Strangford Lough (2003 – mean of 4 measurements)	35
3	Fucus vesiculosus	Warrenpoint (11/99)	990
	Fucus vesiculosus	Carrickhugh Bridge (3/00)	423
	Dulse	Ballywalter (shop bought)	4
	Fucus spiralis	Ards (10/99)	450
	Fucus vesiculosus	Warrenpoint (3/01)	4774
	Fucus vesiculosus	Ards (4/01)	1528
	Fucus vesiculosus	Ballyhalbert (01/02)	3685
	A.nodosum	Warrenpoint (01/02)	3635
4.	Fucus vesiculosus	Seascale (2001)	13000
	Fucus vesiculosus	Nethertown (2001)	19000
	Fucus vesiculosus	Seascale (2002)	38200
	Fucus vesiculosus	Nethertown (2002)	19400
	Fucus vesiculosus	Seascale (2002)	25700
	Fucus vesiculosus	Nethertown (2003)	22000
SHELLFISH			
1.	Lobster	Down (05/02)	201
	Lobster	Newry & Mourne (09/02)	374
	Mussels	Larne (06/03)	65
	Mussels	Derry (09/04)	103
	Lobster	Newry & Mourne (09/04)	162
2.	Lobsters	Sellafield coastal area (2003 - mean of 8 measurements)	3600
	Lobsters	Northern Ireland (2003 - mean of 7 measurements)	170
	Nephrops	Northern Ireland (2003 - mean of 8 measurements)	50
3.	Lobster	Down (10/99)	57
	Nephrops	(11/99)	96
	Crab	Fairhead (3/00)	60
	Lobster	Down (10/00)	442
	Lobster	Newry & Mourne (10/00)	253
	Lobster	Ballyhoman (10/01)	520
	Nephrops	Unknown (09/01)	103
4.	Lobsters	St Bees (2001)	4500
	Nephrops	Irish Sea (2001)	830
	Lobsters	St Bees (2002)	5000
	Nephrops	Irish Sea (2003)	1700

Notes
1. Results from Northern Ireland Radiation Monitoring Group (2002 - 2005).
2. Results from 'Radioactivity in Food & the Environment, Food Standards Agency.(2001- 2003)
3. Results from previous Northern Ireland Reports.
4. Results from Annual Report of BNFL Sellafield (2001 – 2003)
- below the limit of detection
<1 activity seen but near the detection limit
na not analysed

TABLE 5
SELECTED ^{14}C COMPARATIVE DATA FOR THE MARINE ENVIRONMENT

	Category	Locality	Activity (Bq/kg wet weight) ^{14}C
SEAFISH			
1.	Haddock	Down (2003)	28
	Haddock	North Channel (2003)	47
	Cod	Craigavon (2004)	23
	Haddock	Derry (2004)	13
2	Cod	Sellafield offshore (2001)	54
	Plaice	Sellafield offshore (2001 – mean of 2 measurements)	120
	Cod	Northern Ireland (2001 – mean of 6 measurements)	11
	Cod	Sellafield offshore (2002 - mean of 6 measurements)	160
	Plaice	Sellafield offshore (2002 – mean of 2 measurements)	100
	Cod	Northern Ireland (2002 – mean of 8 measurements)	36
	Whiting	Northern Ireland (2002))	na
	Cod	Sellafield offshore (2003)	190
	Plaice	Sellafield offshore (2003 – mean of 2 measurements)	150
	Cod	Northern Ireland (2003 – mean of 6 measurements)	40
	Whiting	Northern Ireland (2003))	na
4.	Whiting	Sellafield coastal area (2001)	36
	Cod	Whitehaven (2001)	54
	Cod	Whitehaven (2002)	51
	Cod	St Bees (2003)	130
	Plaice	St Bees (2003)	120

Notes
1. Results from Northern Ireland Radiation Monitoring Group (2002 - 2005).
2. Results from 'Radioactivity in Food & the Environment, Food Standards Agency.(2001- 2003)
3. Results from previous Northern Ireland Reports.
4. Results from Annual Report of BNFL Sellafield (2001 – 2003)
- below the limit of detection
<1 activity seen but near the detection limit
na not analysed

THE NUCLEAR ENVIRONMENT, INCIDENTS AND EVENTS

Radioactivity in Northern Ireland is derived mainly from weapons testing, Chernobyl and BNFL Sellafield. This Appendix contains information on the activities at Sellafield and brief summaries of recent nuclear incidents and events.

BNFL SELLAFIELD

British Nuclear Fuels plc (BNFL) is concerned mainly with the design and production of fuel for nuclear reactors and its reprocessing after irradiation. The company also operates a solid waste disposal site and nuclear power plant that supplies electricity to the national grid. Regular monitoring is carried out of the environmental consequences of discharges of radioactive waste from four BNFL sites in England, namely Sellafield, Drigg, Springfields and Capenhurst. These nuclear sites are responsible for the largest discharges of radioactive material and are the prime focus of MAFF & EA monitoring. Most sampling and direct monitoring is conducted in the site's immediate vicinity. However, because of the ability to detect the effects of the discharges of liquid effluent from BNFL Sellafield in many parts of north-European waters, the MAFF programme for this site extend beyond national boundaries.

Operations and facilities at Sellafield include fuel element storage and decommissioning, the Magnox and oxide fuel reprocessing plants and the Calder Hall Magnox nuclear power station. Radioactive waste discharges include a very minor contribution from the adjoining UKAEA Windscale facilities. The most significant discharges are made from the BNFL fuel element storage ponds and the reprocessing plants, through which pass irradiated Magnox and oxide fuel from the UK nuclear power programme, and some fuel from abroad. [1]

Authorisation for discharge is given by the Environment Agency. At the end of 1999 the discharge limit for Tc-99 was reduced from 200TBq/y to 90TBq/y. A review of all discharges from Sellafield commenced in April 2000 after initial public consultation. In November 2000 the Agency started consultation on proposals for future discharge of Tc-99 to the sea. Proposals include that the limit is reduced to 10 TBq/y in 2006. This would allow the backlog of untreated Tc-99 waste to be treated by that date.

Discharges of Tc-99 decreased significantly during 2003 due to trials with tetraphenylphosphonium bromide (TPPBr). This reacts with the Tc-99 to form a salt which is subsequently retained and encapsulated. This treatment will continue with all medium active concentrate (MAC)[2]

Notes:

1 Taken from 'Radioactivity in Food & the Environment 1995', Food Standards Agency.

2 Taken from BNFL Annual Report 2003.

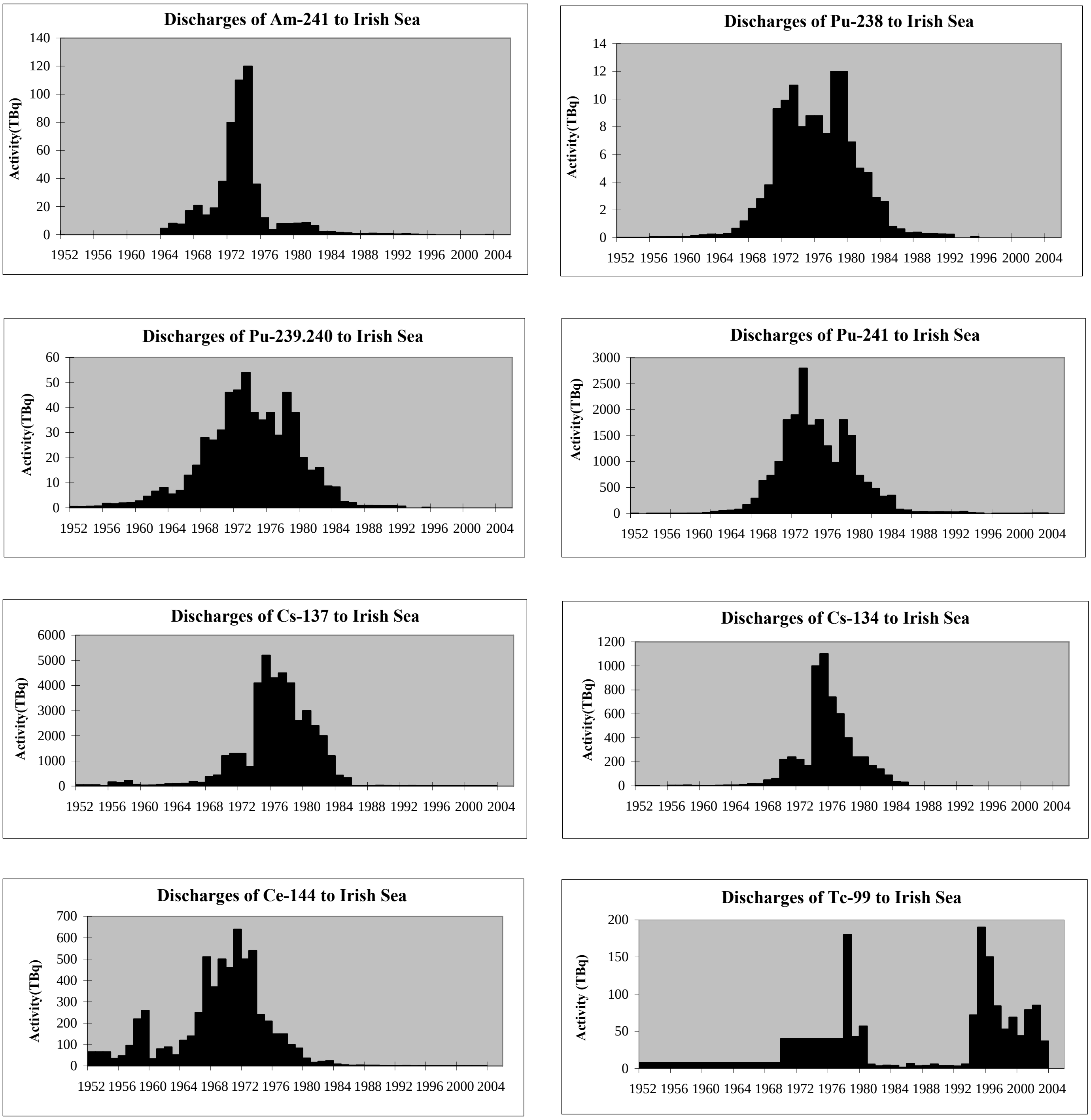

FIGURE 5: SELLAFIELD DISCHARGES TO THE IRISH SEA, 1952 – 2003 (BNFL 2003)

TABLE 1
SELLAFIELD DISCHARGES TO THE IRISH SEA, 1998 - 2003 (BNFL 2003)

Nuclide	Annual discharge (Terabecquerel) **						Authorised Limit (TBq) [a]
	1998	1999	2000	2001	2002	2003	
Tritium	2300	2500	2300	2600	3300	3900	25000
Americium-241	0.05	0.03	0.03	0.04	0.04	0.06	0.3
Antimony-125	0.05	7.9	7.8	13	17	23	-
Caesium-134	0.32	0.34	0.23	0.48	0.49	0.39	6.6
Caesium-137	7.5	9.1	6.9	9.6	7.7	6.2	75
Carbon-14	3.7	5.8	4.6	9.5	13.0	17	20.8
Cerium-144	0.76	0.60	0.55	0.79	0.97	0.88	8
Cobalt-60	2.4	0.89	1.2	1.2	0.89	0.43	13
Curium-242	0.006	0.003	0.003	0.006	0.003	0.003	-
Curium-243+244	0.003	0.002	0.003	0.006	0.02	0.01	-
Europium-152	0.16	0.11	0.07	0.11	0.13	0.23	-
Europium-154	0.10	0.05	0.06	0.08	0.13	0.22	-
Europium-155	0.09	0.04	0.05	0.07	0.10	0.19	-
Iodine-129	0.55	0.48	0.47	0.63	0.73	0.55	1.6
Iron-55	0.01	0.02	0.04	0.02	0.03	0.02	-
Manganese-54	0.07	0.04	0.01	0.03	0.02	0.02	-
Neptunium-237	0.04	0.04	0.03	0.04	0.06	0.05	-
Nickel-63	0.4	0.58	0.43	0.27	0.46	0.39	-
Niobium-95	0.35	0.08	0.09	0.35	0.08	0.09	*
Plutonium alpha	0.14	0.11	0.11	0.16	0.34	0.36	0.7
Plutonium-241	3.5	2.9	3.2	4.6	10	10	27
Promethium-147	0.39	0.41	0.35	0.42	0.79	0.67	-
Ruthenium-103	0.15	0.13	0.11	0.15	0.18	0.18	-
Ruthenium-106	5.6	2.7	2.7	3.9	6.0	12	63
Silver-110m	0.12	0.09	0.08	0.12	0.09	0.08	-
Strontium-89	0.88	0.60	0.64	0.76	0.52	0.56	-
Strontium-90	18	31	20	26	20	14	48
Sulphur-35	0.43	0.32	0.36	0.43	0.32	0.36	-
Technicium-99	53	69	44	79	85	37	90
Zinc-65	0.14	0.07	0.03	0.05	0.03	0.03	-
Zirconium-95	0.30	0.10	0.10	0.13	0.17	0.14	9*
Total alpha [b]	0.17	0.13	0.12	0.20	0.35	0.4	1.0
Total beta [b]	0.86	110	77	120	110	83	400
Uranium (kg)	550	540	610	390	440	480	2040

Notes:

** million million becquerel, 10^{12}Bq,

* Niobium-95 and Zirconium-95 have a combined authorised limit of 9TBq

[a] Applied from 1st January 1995. Different limits applied in previous years.

[b] Total alpha and total beta are overall control measures that do not reproduce precisely the contributions of individual nuclides.

TRANSPORT OF DISSOLVED RADIOACTIVITY IN WESTERN EUROPEAN AND ARCTIC WATERS

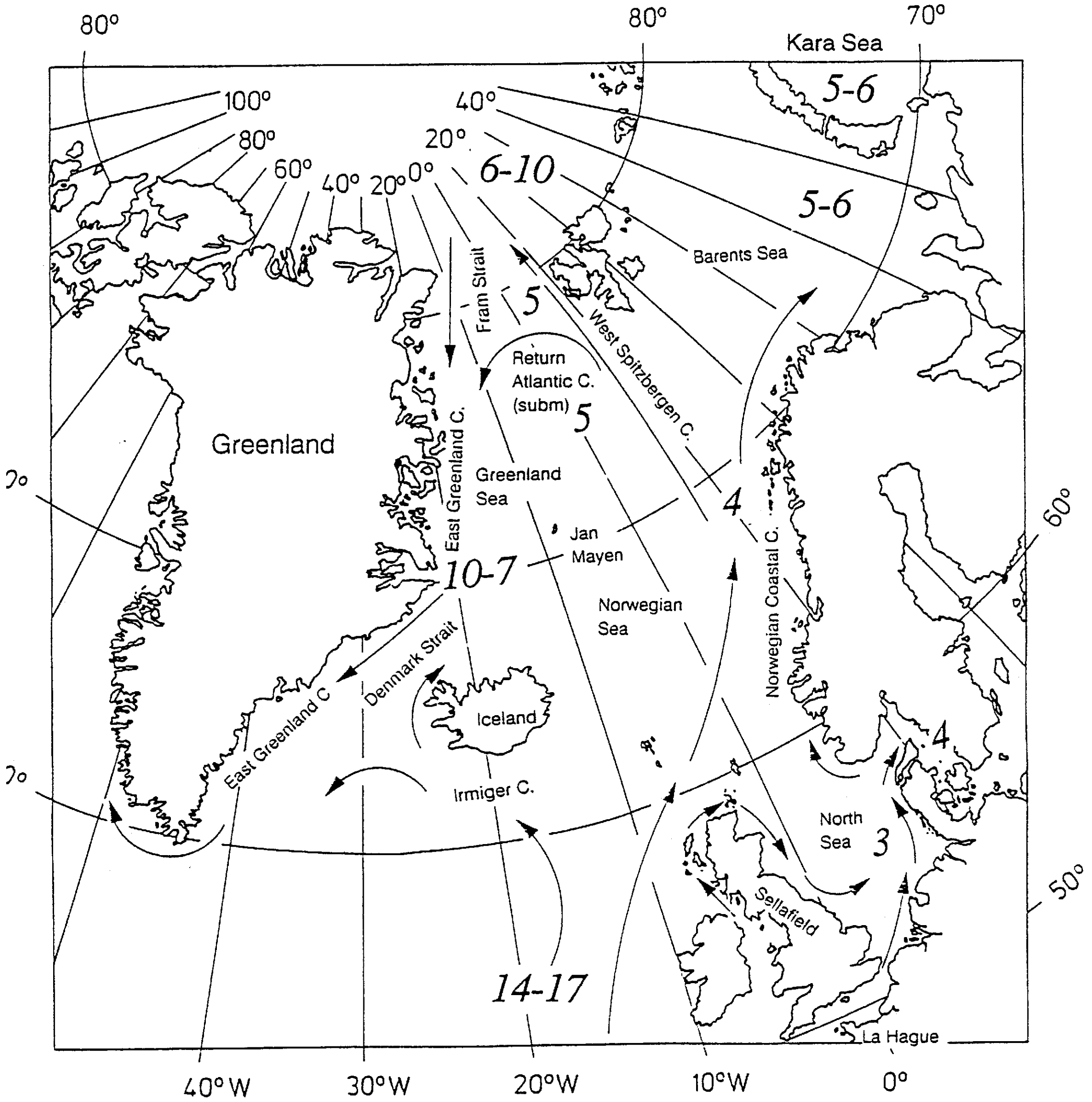

FIGURE 6

Major surface currents and transit times in years from Sellafield to different areas.
(Extract from Marine Pollution Bulletin Vol 32,1995 – H. Dahlgaard, Q. Chan, J. Herrman, H. Nies, R.D. Ibbett, P. J. Kerrshaw (1995) on the background level of ^{99}Tc, ^{90}Sr and ^{137}Cs in the North Atlantic, J Mar. Sys 6, 571-578)

Contours of ^{99}Tc (mBq/litre) in the Irish Sea

Pre-EARP 1992

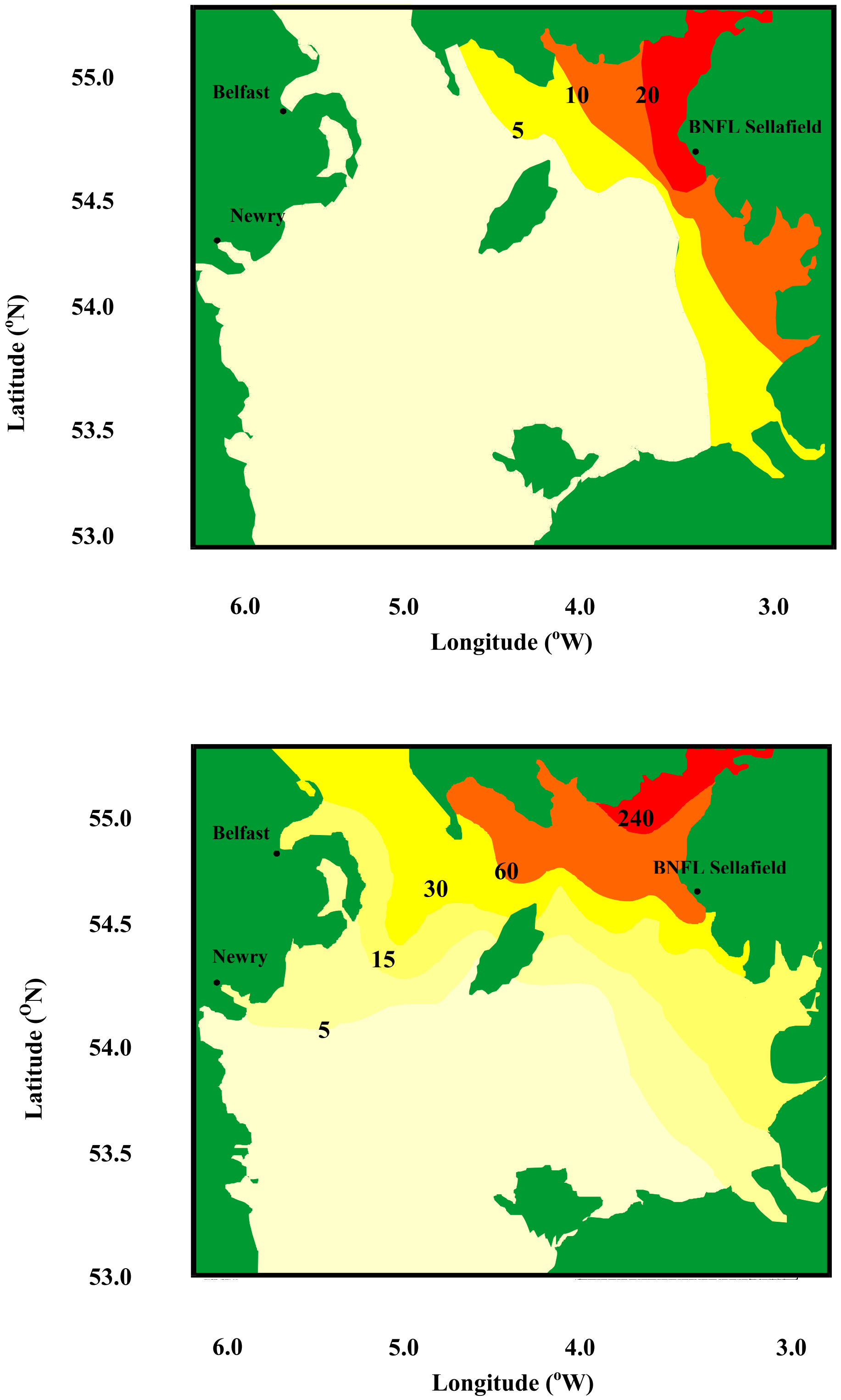

FIGURE 7

Adapted from K.S. Leonard, D. McCubbin, J. Brown, R. Bonfield, T. Brooks, 1997. A summary report of the distribution of ^{99}Tc in UK Coastal Waters. Radioprotection – Colloques, 32, C2-109-114.

Note: EARP is the Enhanced Actinide Recovery Plant at BNFL Sellafield

NUCLEAR INCIDENTS AT BRITISH NUCLEAR INSTALLATIONS REPORTED DURING THE PERIOD JANUARY 2002 TO DECEMBER 2004

The nuclear industry in Britain is required to report nuclear incidents to the Health & Safety Executive under powers derived from Section 11 of the Health & Safety at Work Act 1974. The Health & Safety Executive publish Quarterly Incident Statements for installations. Single copies can be obtained, free of charge, from the Library, Health & Safety Executive, Ground Floor North Wing, Rose Court, 2 Southwark Bridge, LONDON SE1 9HS. (Tel: 0171 717 60000 Fax: 0171 928 6635). The International Atomic Energy Authority (IAEA) and the OECD Nuclear Energy Agency have developed the International Nuclear Event Scale (INES), to categorise the significance of nuclear events. The following table was taken from the LARRMACC (now LARnet) Emergency Handbook for Members.

LEVEL	DESCRIPTOR	THE SCALE	EXAMPLES
Accidents: 7	Major accident	Major release of radioactivity. Widespread health and environmental effects.	Chernobyl USSR 1986
6	Serious accident	Significant release of radioactivity. Full implementation of local counter-measures.	
5	Accident with off-site risks	Limited release of radioactivity. Partial implementation of local counter measures.	Windscale UK 1957 Three Mile Island USA 1979
4	Accident without significant off-site risks	Minor release of radioactivity in the order of prescribed limits. Local protective measures unlikely except for some food monitoring and control. Significant plant damage. Fatal exposure of a worker.	Saint-Laurent France 1980
Incidents: 3	Serious incident	Very small release of radioactivity, a fraction of the prescribed limits. Local protective measures unlikely. Possible acute health effects of a worker.	Vandellos Spain 1989 Sosndy Bar 1992 Tomsk 7 FSU 1993
2	Incident	Incident with potential safety consequences on-site. Insignificant release of radioactivity off-site.	
1	Anomaly	Variation from permitted procedures.	
0	Below scale	No safety significance.	

Extracts from the Health and Safety Executive Quarterly Incident Statements:

Incident 02/1/1 **Dungeness B (British Energy Generation Limited - BEGL)**

In January two events led to leaks in the Water Spray Fire System that protects the safety related equipment from fire. The reators were shut down to maintain nuclear safety. Investigations were initiated to reassess the adequacy of the system.

Incident 02/1/2 **Heysham 1 (British Energy Generation Limited - BEGL)**

A sequence of events led to the failure of a mechanical interlock that prevents the fuelling machine from moving until safe to do so. Movement of the machine caused the severence of a shield plug part of which fell into a storage tube. The NII site inspector confirmed the nuclear safety significance was low but that the incident could have benn more serious if the failure had taken place at the reactor although other interlocks would have provided protection. The safety case for refuelling was revalidated before the machine was returned to service. (Level 2)

Incident 02/3/1 **Torness (British Energy - BE)**

The failure of a gas circulator highlighted problems of fatigue in the impeller. Later a similar proble was identified in another impeller before failure of the circulator. A more rigourous routine of monitoring has been set in place and permission given for replacement of the failed generator.

Incident 04/2/1 **Hartlepool Power Station (British Energy)**

Contaminated water leaked via a flange from the radioactive effluent treatment plant. A site incdent was declared and access limited only to authorized workers effecting the containment of the leak and effecting the clear up. There was a small loss through evaporation, the dose from which was insignificant, but the main part was retained within the treatment plant. A Panel of Enquiry set up by British Energy and details, conclusions and recommendations distributed to all sites. It is unlikely a prosecution will be brought. (Incident level not stated)

Incident 04/2/2 **Bradwell Power Station (Magnox Electric plc)**

During preparations to lower a camera into the reactor some radioactivity was released into the building as the result of the wrong valve being openedand the reactor was unexpectedly put under pressure. There was some delay in evacuating the area after the sounding of the alarm. Six members of staff received doses of radiation below legal limits. AN NII investigation is taking place. (Incident level not state

RADIATION MONITORING IN THE UNITED KINGDOM

In the United Kingdom all sites where ionising radiation is used (eg hospitals, universities, nuclear establishments) have a statutory responsibility to monitor their environment and keep records of any disposals. The means of monitoring are diverse and often complex radiological protection instrumentation capable of measuring specific isotopes or kinds of radiation are deployed. For example specific measuring systems dedicated to the monitoring of Plutonium isotopes and ^{131}Iodine exist around and within nuclear sites.

Public concern following the Chernobyl incident stimulated many local authorities to engage in some kind of local radiological assessment. In some cases the authorities conduct monitoring themselves although generally an independent third party is used (university, hospital, commercial laboratories). Over two hundred local authorities are involved in some kind of independent radiation monitoring. This involvement has followed advice from the Institute of Environmental Health Officers (now CIEHO).

The responsibility for discharges of radioactive material into the environment rests with the Environment Agency (EA) and the Scottish Environment Protection Agency (SEPA). MAFF or a delegated laboratory conducts the monitoring of these discharges, particularly around nuclear sites. Additionally, individual sites monitor their local environment eg. UKAEA Winfrith reports. In recent times, following Chernobyl, a more wide ranging assessment of other areas has also been undertaken (eg Radioactivity in Food and the Environment 1995 RIFE, MAFF, HMSO). The levels permitted are determined from a detailed consideration of the likely pathways of the radionuclides, their physical lifetime and the possible radiation doses that might affect the *critical group*. This is the group of people who are likely to receive the highest radiation exposure as a result of the discharges. The *critical group* is usually identified after a careful survey of the eating habits of the local population has been undertaken. The nuclear establishment and the government department that issue the authorisations are strongly of the opinion that radiation doses to the public are well below internationally agreed limits in all UK sites. Indeed, the National Radiological Protection Board (NRPB), on the basis of comprehensive monitoring around British Nuclear Fuels Limited sites believes that exposure to the general public from effluent discharges is within their guidance level of 0.5 milli-Sieverts/year.

DOSE LIMITS: ORIGINS AND USES

Radiation dose limits are those that should not be exceeded in order that a normal member of society is not exposed to an unacceptable risk. These dose limits are determined from a wide range of criteria such as epidemiological studies (especially from Japanese bomb survivors) and are set in the first instance by the ICRP (International Commission for Radiological Protection). In radiological practice the dose limit is considered to be a precautionary limit and not a danger limit. That is, if the limit is exceeded a situation should not arise that was irremediable. Thus, the risk associated with an increase in dose by several times the dose limit may only cause a very slight increase in the real risk of, for example, death from cancer. Another radiological principle recommended by the ICRP and accepted by the UK establishment is that doses should be as low as reasonably achievable, the ALARA principle. This means that it is not sufficient to merely ensure that dose limits are complied with but that all efforts should be made to minimise them to the lowest practicable levels.

The annual dose limit for radiation exposure is 1 mSv for man-made sources. For authorised discharges there is a single source constraint of 0.3mSv/y and a site constraint of 0.5 mSv/year regardless of the number of owners or operators at that. site. These guidelines apply to existing plants and where compliance is not possible then the ALARA principle should hold and the operation should be within dose limits. (CM 2919, 1995)

The inference to be drawn from this proposal is that there are no sites in the UK that constitute any appreciable radiological hazard to members of the public. To place these dose limits into perspective the average annual dose, from all sources is 2.6 mSv (i.e. natural and made-made sources).

DERIVED LIMITS AND ANNUAL LIMITS OF INTAKE, ALI

The primary dose limit for members of the public is set at 1 mSv per year for artificial sources of radiation. This does not include medical exposure but does include any possible incorporation, via ingestion or inhalation, of radioactive substances. In the latter case where incorporation may take place over some time it is difficult to make any direct measurement of the dose received. In order to comply with the limits, therefore, the ICRP has calculated the CED (committed effective dose) which enables the dose taken into the body to be estimated. In order to do this the Commission has calculated dose factors for the whole body and for each organ or tissue, which expresses the total dose received per unit of activity intake. These factors can then be used to calculate the total activity of a particular radionuclide taken into the body. These calculations take into consideration the physical, chemical and metabolic properties (assimilation, organ concerned, retention period in the organ etc) of the nuclide in question.

i THE USE OF ANNUAL LIMITS OF INTAKE, ALIs

Annual limits of intake of radioactive substances (an ICRP concept) should be used with caution. For example, with the isotope ^{137}Caesium, it is possible to calculate the mass concentration that should be tolerated in foods liable to be consumed on a daily basis by the population. The figure calculated represents the acceptable concentration for the consumption of the contaminated food, day after day, year after year throughout the lifetime of the individual *critical group* member in order to comply with the ICRP dose limit. However, consumption is rarely continuous and therefore measured concentrations may be much in excess of the calculated figure. Thus, although a particular isotope may be found having an elevated level in a particular foodstuff, its long-term radiological significance may be less serious than is evident at first seen if measures are taken to counteract the observed levels. As with all radiological data, caution should be exercised in their interpretation and an understanding of their limitations should be borne in mind.

ii GENERALISED DERIVED LIMITS AND DERIVED LIMITS

Generalised derived limits (GDLs) and derived limited (DLs) are values expressed as an activity per unit weight or unit volume. The GDL is a generally applicable value based on detailed habit surveys. DLs may have a more restricted significance but are based on similar considerations. They are secondary standards set and used to ensure virtual certainty that a critical group will not be exposed to a radiation dose in excess of the recommended limit, at present 1mSv per annum. They are calculated generally only for those environmental materials which are considered important to a particular critical group. GDLs and DLs are calculated using data published by the ICRP, presented as the committed effective dose (CED). From these data the Annual Limits of Intake ALIs are calculated (which may be quoted for three main age groups, *viz* infants, children or adults). From this information a GDL or DL may be determined by dividing the ALI by the mass of food consumed, volume of air inhaled etc. The following scheme shows the sequence involved in their calculation.

a. Obtain CED from tabulations eg ICRP-72
b Calculate ALI by dividing 1 mSv by the CED,
c. Calculate GDL or DL by dividing ALI by the consumption factor.

N.B. In all calculations the units should be consistent.

In Northern Ireland the effluent discharges from BNFL Sellafield are the current main source of environmentally significant radioisotopes. In all cases no levels of these nuclides have been measured which either exceed or even approach closely the GDLs or DLs.

RADIATION FROM NATURAL SOURCES

The NRPB maintains surveillance on levels of radiation affecting the general public, and others, in the UK and publishes reports. The data used to construct the graphs in Figures 1 and 2 are extracted from a review conducted during 1993 (NRPB R263 - Radiation Exposure of the UK Population 1993 Review). The dose to the average person in the UK is from all sources but there can be wide variations based on geographical location. These are fully described in the report NRPB R311 that has superseded NRPB R263.

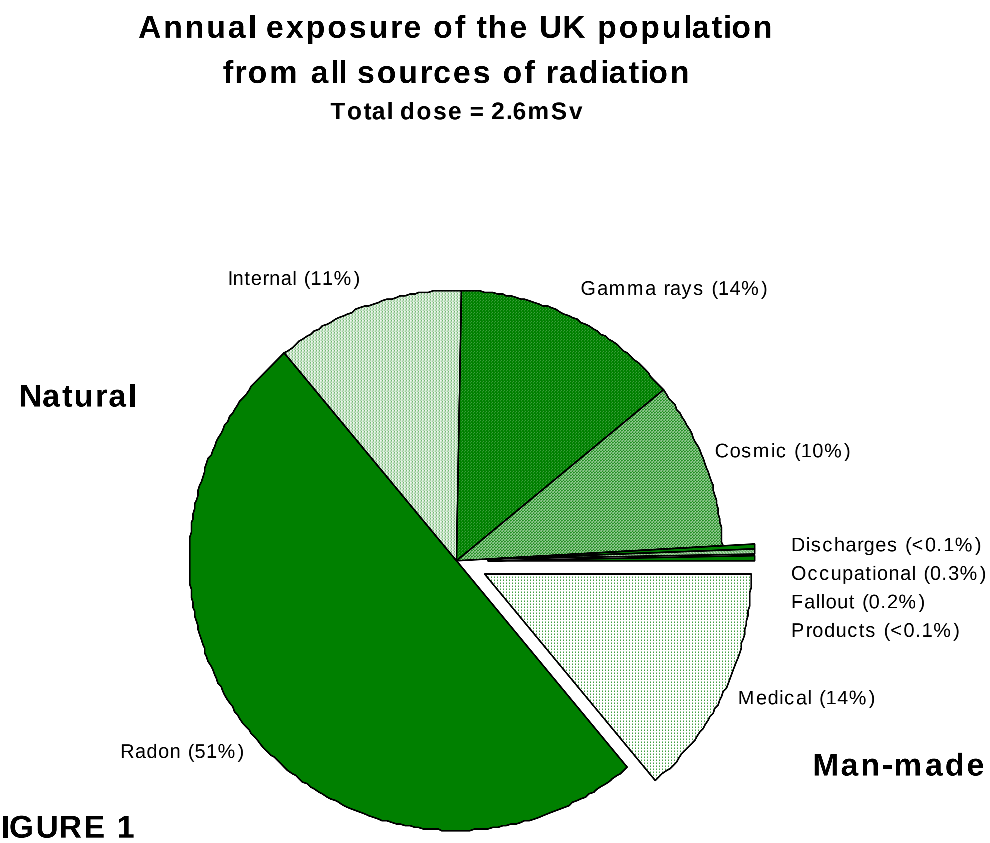

FIGURE 1

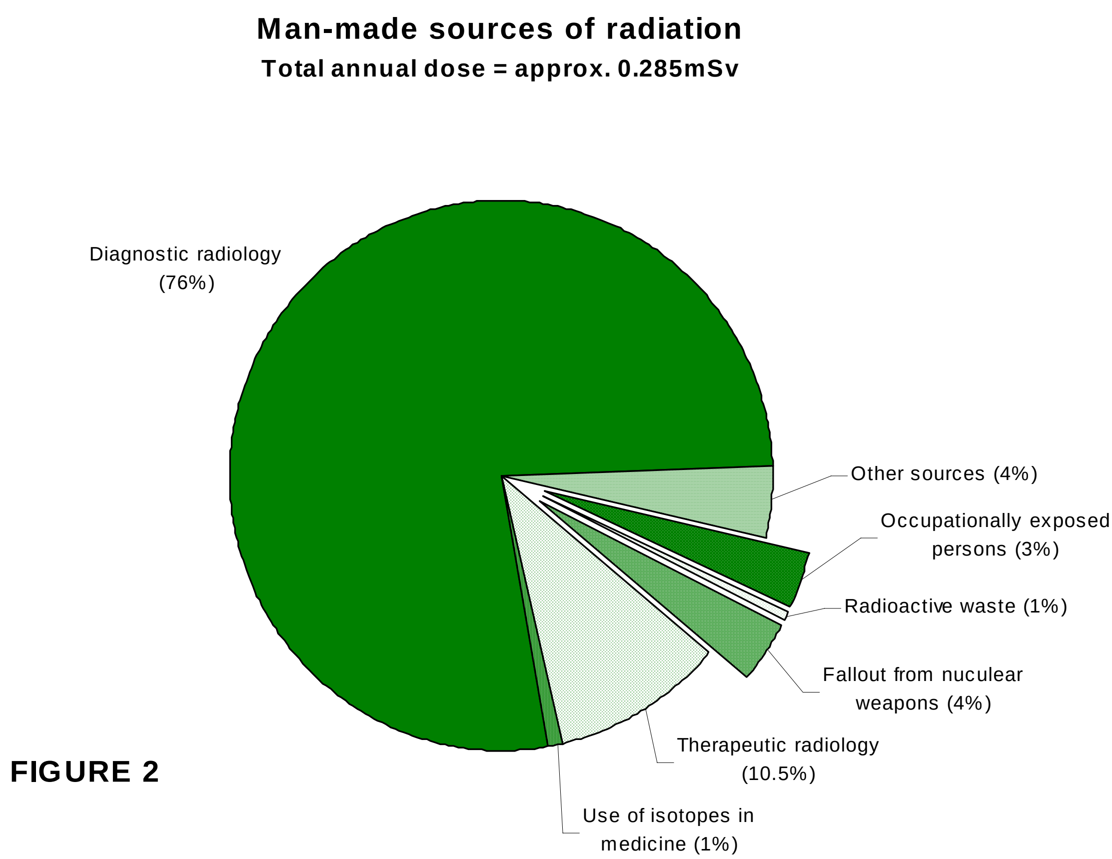

FIGURE 2

OTHER GUIDELINES

World Health Organisation (WHO) Guidelines for drinking water

Guideline values recommended by the WHO propose a total alpha activity level of 100Bq/m^3. These values ‘are specified assuming that only the most toxic radionuclides are present in significant quantities', and the recommendations conclude with the statement 'A value in excess of the guideline figure does not in itself imply that the water is unsuitable for consumption'.

Soil and other solids

The level of activity in unspecified soil, or other solid materials, below which no special precautions need to be considered in the disposal of that material is given as 400 Bq/kg (0.4 kBq/kg) in 'A review of Cmnd 884: The Control of Radioactive Wastes'. Certain elements have been exempted - see Statutory Instrument 1002 (June 1986)

Radiation Exposure

The principal limit for radiation exposure is now an effective dose of 1 mSv per year. The site constraint to be used in Waste Discharge Agreements with the EA is 0.5 mSv/year. This is based on the annual risk being less than the risk corresponding to an annual effective dose of 0.5 mSv ie a mortality risk of $5x10^{-6}$ per annum, based on 1977 ICRP values.

LARnet (formerly LARRMACC) - LOCAL AUTHORITY RADIATION MONITORING NETWORK

The Local Authority Radiation and Radioactivity Monitoring Advice and Collation Centre (LARRMACC) was established to collate and co-ordinate Local Authority radioactivity monitoring throughout the UK. The proposals for a LARRMACC system came to fruition in January 1990. Following tender the first 3 year contract (extended for a further year) was given to London Scientific Services (now Stanger Science Environment) and the Institution of Environmental Health Officers. LSS dealt mostly with technical matters while administrative issues were initially handled by the IEHO. In 1994 the contract was awarded to NNC Limited of Knutsford, Cheshire (subsidiary of GEC) and NNC continues to be the technical contractor. In March 2001 LARRMACC was renamed LARnet. The main work of LARnet is to establish comparability between differing schemes throughout the country by means quality assurance manuals and carrying out, where appropriate, quality assurance audits of individual schemes. It is important to note that LARRMACC does not undertake radiation monitoring.

RIMNET (Radiation Incident Monitoring Network)

RIMNET is acknowledged as the national database of all radiological data and information collected in the event of a nuclear incident. The system comprises 92 background gamma dose radiation detectors located across the UK that are interrogated hourly by a Central Database Facility. The Central Database Facility also has the ability to store radionuclide specific information (known as Supplementary Data) as provided by other Government Departments, Local Authorities and Local Authority monitoring groups.

The RIMNET system Phase 2 was fully operational from April 1994. Supplementary Data Entry was achieved by use of a PC based software package (SDE) supplied by the DETR (Department of the Environment, Transport and the Regions) to organisations accredited for the sampling and analysis of radiological data. Data were uploaded freely to the RIMNET database, on the basis of planned mutual benefit to the individual suppliers concerned. The data supplied and data from other sources in that region are downloaded to the data supplier on request. These uploads and downloads were achieved using an X.400 based mailbox system.

RIMNET plays a role in all overseas, domestic and MoD exercises where the release of radioactivity is simulated. In such exercises the RIMNET system is used for the co-ordination of monitoring resources for the provision of radiological data.

The RIMNET fileservers utilises World Wide Web technologies and enable users of RIMNETpc to access data from the fileserver and overlay it on maps. RIMNETpc is currently used by SEPA, DETR, DERA, EA and NRPB. RIMNET 3 became operational in January 2005 with extensive enhancement of the technology of the previous system which has proved reliable and accessible to authorized users. Real time readings from the telemetry network is collected by the central facility and made accessible to users such as local government, government departments and other agencies. RIMNET 3 does not use the X400 mailboxes.

Enquiries about the RIMNET Approved Data Suppliers scheme should be addressed to Mr Keith Binfield, RIMNET 3H/32, Ashdown House, 123 Victoria Street, London, SW1E 6DE.

REFERENCE LEVELS
FOR RADIOACTIVE MATERIALS IN THE ENVIRONMENT

GENERALISED DERIVED LIMITS

Generalised Derived Limits (GDLs) are derived and published by the National Radiological Protection Board (NRPB) for the radioactive isotopes of a small number of elements. GDLs represent a cautionary indicator taking into account the various environmental pathways to man. The limits given below apply to uniform conditions over a year and are based on the limiting age group, which is adults for all foods, except as indicated in the tables. The GDLs/DLs for food products are expressed as fresh mass (for ingestion), for grass and sediments are expressed as dry mass (for external irradiation).

Activity (Bq/kg)

	^{137}Cs	^{134}Cs	^{60}Co	^{65}Zn	^{131}I
TERRESTRIAL					
Fresh water sediment	20000[4]	8000[4]			
Eggs	3000	2000			400
Freshwater Fish	4000	3000			2000
Fruit	1000	700			200[2]
Grass	3000	2000			700[2]
Honey	1700[3]	1200[3]			
Meat					
Pig	2000	1000			800[4]
Cattle	2000	1000			600[2]
Sheep	3000	2000			2000
Offal	4000	3000			1000[2]
Poultry	2000	2000			1000[2]
Milk (Bq/L)	100	100			20
Milk products	1000	900			100[2]
Soil	1000	600			
Vegetables					
Rootcrop	600	400			100[2]
Other	900	700			400[2]
Marine					
Seafish	700	500	1290[1]	2300[1]	500
Sediment	5000	2000			
Shellfish					
Molluscs	4000	3000	20000[1]	36000[1]	2000
Crustacea	4000	3000	7900[1]	14200[1]	2000

Notes

1 Not GDLs but derived limits calculated from NRPB-GS7 and NRPB-GS8. They are for the adult critical group consumers assuming an effective dose equivalent limit of lmSv.
2 For infants aged 1 year
3 Not GDLs but derived limits calculated from NRPB-GS7. They are for an adult critical group assuming an intake of 25 kg/yr and an effective dose equivalent limit of lmSv.
4 For children aged 10 years

Activity (Bq/kg)

	^{238}Pu	$^{239,240}Pu$	^{241}Am
Freshwater Fish[2]	20	200	200
Sediment			
Marine	100000	90000	80000
Freshwater	400000[3]	300000[3]	300000[3]
Seafish[2]	40	40	50
Shellfish			
Molluscs[2]	200	200	200
Crustacea[2]	200	200	200
Soil	5000	5000	5000

Notes

1 For infants of 1 year.
2 Only the edible fraction included.
3 For children aged 10 years.

NBThese radioisotopes are considered to be the only ones that need to be considered in Northern Ireland at present.

METHODOLOGY USED IN GAMMA RAY SPECTROMETRY OF ENVIRONMENTAL MATERIALS

Radiation detection is possible using a variety of techniques and the method chosen depends on the kind of information sought and the level of sensitivity required. There are numerous detectors ranging from technically simple photographic emulsions through to very sophisticated and expensive electronic devices such as that used in the present scheme. A distinction can be made between those detectors that provide general information about radiation doses or the existence of radiation emitters and those which are spectrometric. Radiation spectrometers are generally designed to measure a specific kind of radiation, ie alpha, beta or gamma radiation. Spectrometric devices can identify the emitters (ie specific isotopes) and are an essential part of a radiation monitoring scheme concerned with determining the possible extent of environmental contamination.

The current scheme operating at the National Oceanography Centre, Southampton involves the counting of environmental materials using high resolution gamma ray and alpha spectrometers.

GAMMA RAY SPECTROMETRY

All laboratory measurements are made using Canberra Industries gamma ray spectrometers (30% efficiency P-type HPGe, high purity germanium) linked to associated pulse processing NIM modules (Nuclear Instrument Modules). The counting electronics are of the latest Canberra design (AIM & ICB) and run under control from Genie-PC. The radiation detectors are housed in purpose-built lead shields in order to reduce the contribution from background radioactivity. There are several orders of magnitude reduction in the intensity of such isotopes as ^{40}K and uranium and thorium decay chain products (ie isotopes occurring in the immediate environment which exist naturally) when using such a well-shielded set-up. Specially selected 'low background' lead is used in the shields and they consist of a closed cylinder having a wall thickness of 100 mm.

Samples are generally counted in 0.5 or 1 litre Marinelli beakers. Most samples have been counted for approximately 12 hours.

TABLE 1: NOMINAL DETECTION LIMITS FOR GAMMA-EMITTING RADIONUCLIDES

Radionuclide	Detection Limit	Isotope	Detection Limit
^{54}Mn	1 Bq/kg	^{60}Co	1 Bq/kg
^{51}Cr	10 Bq/kg	^{65}Zn	2 Bq/kg
^{59}Fe	2 Bq/kg	^{131}I	1 Bq/kg
^{57}Co	1 Bq/kg	^{134}Cs	1 Bq/kg
^{58}Co	1 Bq/kg	^{137}Cs	1 Bq/kg

Notes

1. Detection limits are calculated for a 60,000 second count.
2. Detection limits are calculated according to Currie (Analytical Chemistry Vol 40 1968).
3. Detection limits should be viewed with respect to the Generalised Derived Limits (GDL) given for a particular material. In all cases the detection limits are well below the GDLs (see comparative table of results).
4. The detection limits shown are those for a particular sample type and may be higher or lower for other samples. For example, the detection limits for milk will be slightly lower than those shown above.

SPECTRAL DATA REDUCTION

Gamma ray spectra are processed using a sophisticated PC software package FITZPEAKS (JF Computing Services, Stanford in the Vale, Oxon). It uses sophisticated mathematical fitting routines to derive a reliable indicator that is proportional to the activity of an isotope. Numerous other features are available which correct for decay and aid in the identification of the isotopes. The ultimate assigning of isotopes is always accompanied by a close visual inspection of each gamma spectrum to ensure that no errors have occurred.

DETECTOR EFFICIENCY CALIBRATION [1]

The calibration of a gamma ray spectrometer for activity measurements requires considerable care if reliable low-level data are to be obtained. The need for such a calibration is due to the non-uniform response of HPGe radiation detectors to gammas of different energy and because the detector does not record all nuclear decays. A mixed radionuclide solution of known and certified activity was obtained from Amersham International (code QCY.44) or the National Physical Laboratory (Teddington) and was carefully diluted in a polythene bottle. Carefully weighed portions of this solution were then weighted into PTFE beakers and about 2 grams of a mixture of 200-400 mesh cation exchange resin (in equilibrium with distilled water) and chromatographic cellulose were added. The mixture was stirred for about 1 hour and the solution was then slowly evaporated to dryness. The resulting dry residue containing the radionuclides was ground with a portion of one of several matrices (powdered shale, alcohol-washed and sieved dried fish and cellulose powder). The remaining part of the chosen matrix (which had been previously found to be sufficient to occupy the counting beaker) was then shaken for about 30 minutes in a large plastic tub with the radionuclide bearing powder. Care was taken to ensure that no activity remained in any container at any stage of the preparation. This was achieved by counting the empty containers in the gamma ray spectrometer to confirm that all activity was quantitatively transferred. Each kind of sample was counted and its activity determined using a calibration standard of equivalent composition and geometrical form.

SAMPLE PREPARATION FOR GAMMA SPECTROSCOPY

Generally, large samples of biological materials contain low levels of radionuclides. Sample preparation is concerned with fitting the maximum amount of material into a fixed geometry after minimum pre-treatment. Most biological materials have a very high water content (50-90% body weight). Thus, for samples of biological origin, volume reduction is achieved by dehydration using freeze-drying.

Solid biological materials - vegetation, fish, shellfish and meat - are chopped into strips/cubes prior to freezing on stainless steel trays. In the case of consumable produce (such as root crop, fish and shellfish) only the edible fractions are frozen. The frozen products are loaded onto heater mats within the vacuum chamber of the freeze-drying apparatus. The chamber is evacuated to a set minimum pressure, at which heat is supplied from the heater mats to the frozen samples. Under these conditions, ice within the samples is changed directly from the solid to the vapour state. The evolved water vapour is trapped within the condenser of the refrigerator unit. The dry tissues are removed from the trays and set aside for counting. Where necessary, materials undergo further chopping to ensure a homogenous distribution within the counting receptacle.

Non-biological samples (ie soils and sediment) are oven-dried at 80^{o}C.

The dried materials can be stored almost indefinitely at room temperature without the addition of a preservative.

[1] I. W. Croudace (1991) A reliable and accurate procedure for preparing low-activity efficiency calibration standards for germanium gamma-ray spectrometers. J. Radioanal.Nucl.Chem.Lett. 153, 151-162.

ALPHA SPECTROMETRY & THE TRANSURANIC ELEMENTS

The large-scale introduction of transuranic elements into the environment arose initially from the detonation of nuclear weapons in the atmosphere in the 1950s. A test-ban treaty on atmospheric testing was agreed between the USSR, USA and the UK in 1963; China, France, India and Pakistan are still not signatories. In addition the burn-up on re-entry of satellite power packs for example a SNAP-9, has added to the inventory. The radionuclide content of these events has resulted in widespread low-level contamination. Another major source of transuranics has been the deliberate, controlled discharge of low-level effluents from the nuclear power industry. Accidental releases of transuranics to the environment have occurred from nuclear plant operations and from the transport of nuclear weapons (ie Windscale fire 1957; Three Mile Island 1978; Chernobyl 1986; Palomares, Spain 1966 and Thule, Greenland 1968.)

TABLE 2: TRANSURANIUM ELEMENTS RELEASED TO THE ATMOSPHERE

Nuclide	Amount, TBq	Half life, years
^{238}Pu	890	87.7
^{239}Pu	5.7×10^3	2.41×10^4
^{240}Pu	7.7×10^3	6.57×10^3
^{241}Pu*	3.6×10^5	14.1
^{241}Am#	1.2×10^4	433

Notes
* Largely decayed to ^{241}Am
\# Derived from ^{241}Pu by decay
1 TBq = 10^{12}Bq

RECOGNITION OF TRANSURANIC SOURCES

^{239,240}Plutonium and ^{241}Americium are the main transuranics produced from nuclear weapons testing, whereas ^{238}Plutonium and ^{241}Americium will be the main isotopes from nuclear reactor operations. The ratio, ^{238}Plutonium/^{239,240}Plutonium, can be used to elucidate the origin of Plutonium in the environment. The various potential sources of Plutonium and some typical ratios associated with these operations are listed in Table 3.

TABLE 3: TYPICAL ^{238}PLUTONIUM/^{239,240}PLUTONIUM RATIOS

Source	Ratio
Atmospheric fallout from nuclear weapons testing	0.036 - 0.076
Satellite re-entries	0.5 - 2.0
Nuclear fuel reprocessing	0.2 - 3.0
Nuclear power stations	0.4 - 0.8

COMPARATIVE DATA

The major repositories of transuranics in the environment are in soils and sediments. Some typical activity values are listed in Table 4 in order to put our data in perspective.

TABLE 4: PLUTONIUM IN SOILS AND SEDIMENTS

Source and Location	Amount Bq/kg
Nuclear weapon testing	
Global fallout[1]	0.02 - 0.7
Chemical reprocessing	
Irish Sea (sediment)[1]	10 - 2000
Winfrith (silt)	1.12 - 1.34
Channel Islands (sediment)[2]	0.371 - 2.49

Notes

1 Allard et. al. 1984
2 MAFF aquatic environment monitoring report No 19 1988.

CHEMICAL SEPARATION PROCEDURES

Since alpha particles have very short penetration depths it is necessary to apply complex means to identify their presence. They have to be isolated from all other elements and presented to the detector as an ultra-thin layer (via electrodeposition, for example) if high quality data are to be obtained. The critical factor in the determination of transuranic elements by alpha spectrometry is how effectively a chosen separation scheme can eliminate not only the interfering natural alpha emitters i.e. uranium, thorium and polonium but also stable elements such as iron, rare earth elements, manganese etc. These elements can impair the alpha spectra when they are electrodeposited together with the transuranics onto the counting planchettes. Consequently an adequate scheme of sequential procedures for the separation of transuranic elements should eliminate all these interferences. The radiochemical scheme for the separation of transuranic elements preferred at Southampton is outlined below.

The scheme can be divided into 4 parts

i) Pretreatment (freeze-drying, ashing etc)
ii) Fusion
iii) Chemical Separation
iv) Electrodeposition

Inspection of the alpha spectra of plutonium and americium shows that the separation scheme used performs satisfactorily. The chemical yield ranges normally between 30-100%. The electrodeposition of the plutonium and americium (plated separately) takes place in an ammonium oxalate-HCl medium at a pH of 2-3, onto a stainless steel disc under an electric current of 300mA (nominally 10 V for 2.5 hours).

Internal tracers are used in each sample to facilitate activity determinations and to monitor the chemical efficiency of the procedure. ^{242}Pu and ^{243}Am are used as tracers because of their long half lives, thereby not requiring any decay corrections and also because their respective peaks can be easily resolved from the nuclides of interest. Blank analyses are also made to monitor the effect of reagent impurities. Results so far indicate that this represents less than 1% of the recorded activity. Cross contamination of glassware etc is avoided by the use of good laboratory practices, namely the soaking of all glassware in acid, then Decon for 24 hours, followed by washing in hot water and distilled water.

In many analytical techniques a lower limit of detection is defined in terms of the background. Since there is zero background in alpha spectrometry this is not possible. Any background that is present is non-random and is due mostly to the contamination of the detectors. In alpha spectrometry the question is, whether a peak is real or not and thus it is necessary to define a threshold value for peak recognition. This value is set arbitrarily at 10 counts over a 200,000 second counting time and the detection limits for isotopes is 0.01Bq.

ALPHA SPECTROMETRY

The electroplated discs are counted with Passivated Implanted Planar Silicon (PIPS) detectors (Canberra Industries), with active areas of 450 mm^2 (res. <20 keV), installed in a Canberra Quad® chamber connected through ICB ADC and mixer-routers. A GENIE-PC system controls the system hardware. A counting time of at least 300000 seconds is used to count the very low activity levels of transuranics found in the samples examined to date.

The alpha spectrometers are calibrated for their energy response and counting efficiency. All the detectors are calibrated to have an energy response that places the various alpha-energies in the same relative positions. The counting efficiency is essentially the geometrical efficiency of the detector relative to the source position for accepting alpha particles from the source. It is determined from counts for a source that has a known activity but the quantification of the sample activities does not depend on this efficiency.

METHODOLOGY USED IN BETA ANALYSIS OF ENVIRONMENTAL MATERIALS

Technetium-99 (^{99}Tc) is a low energy, pure beta emitter which concentrates in some marine biota. The element is highly volatile in certain oxidation states and to prevent loss of Tc controlled conditions have to be applied throughout the methodology to ensure complete chemical recovery along with ensuring good decontamination from interfering isotopes. Isotopes which will interfere with the beta analysis, such as Ruthenium isotopes, have to be completely eliminated along with stable elements such as iron and calcium which will adversely affect the determination of Tc.

The final measurement of the samples is performed using Liquid Scintillation Counting (LSC). ^{99m}Tc as pertechnate is used as a yield monitor.

The analytical scheme can be divided into four parts

i)	Preliminary treatment	(ashing, acid digestion)
ii)	Purification	(precipitation, solvent extraction)
iii)	Final measurement	(LSC)

METHODOLOGY USED IN BETA ANALYSIS OF ENVIRONMENTAL MATERIALS (cont)

The samples are ashed under controlled conditions after the ^{99m}Tc yield monitor has been added. An acid digestion stage follows which solubilises the Tc present. A precipitation step is carried out to remove any iron and calcium that can cause interferences and reduce the solvent extraction efficiency. ^{99}Tc is purified by a combination of anion exchange and solvent extraction.

The organic phase is mixed directly with a commercially available scintillant and ^{99m}Tc determined by gamma spectrometry. The sample was stored for a week to allow the ^{99m}Tc to completely decay and the ^{99}Tc activity is determined by LSC.

References

1 F Wigley, P E Warwick, I W Croudace, J Caborn & A.L. Sanchez (1999) Optimised method for the routine determination of Technetium-99 in environmental samples by liquid scintillation counting. Analytica Chimica Acta 380, 73 - 82

ASSESSMENT OF DATA QUALITY

The activity data quoted in the appendices are reported without any uncertainties or confidence limits. The reason for this is to prevent needless clutter or confusion. However, data quality assessments are made regularly by the following means:-

a. measuring certified reference materials (e.g. those produced by the International Atomic Energy Authority, (IAEA))
b. measuring reference samples produced by other independent laboratories (e.g. Natural Environment Research Council Laboratories - Institute of Terrestrial Ecology, NERC- ITE Merlewood)
c. producing multiple standards using certified and traceable activity standards (eg. as supplied through Amersham International and the National Physical Laboratory.)

Results of inter-laboratory measurements and detection limits allow some assessment of data accuracy and precision without the need for quoting confidence limits with all the reported data.

The following tables present data produced in various quality assessment exercises.

QUALITY ASSURANCE - GAMMA

An assessment of the accuracy of sample activities can be achieved in a number of ways. One means is to count a sample measured in one or more independent laboratories and to compare the results.

The method used to check data accuracy involves using a range of natural matrix reference materials, NMRMs or prepared standards. (See tables 5 - 7).

Data from intercomparison exercises are presented in Table 11

TABLE 5: QUALITY ASSURANCE ASSESSMENTS (Bq/kg) – GAMMA

IAEA[1] Sample	Isotope	Recommended or Certified Value	Measured at Southampton	Measured at ITE[3]
Fish F72	^{137}Cs	14.2	15.3	16.0
	^{40}K	-	340	330
Sediment S36	^{60}Co	11.5	10.8	12.2
	^{137}Cs	13.9	14.6	14.1
Sediment S71	^{137}Cs	-	52.7	55.0
Sediment S43	^{137}Cs	53.7	54.9	52.8
Seaweed A17	^{54}Mn	19.7	nd	nd
	^{60}Co	1360	1340	1396
	^{137}Cs	16.7	17.0	15.8
Pine needles CLV-1[2]	^{137}Cs	110	112	-

Notes

[1] IAEA International Atomic Energy Authority reference samples.
[2] CLV-1 Pine needles reference samples supplied by the Canadian National Uranium Tailings Program.
[3] ITE Institute of Terrestrial Ecology, Merelwood Laboratory, Grange-over-Sands, Cumbria, Results reported by Dr F Livens.

TABLE 6: QUALITY ASSURANCE DATA - GAMMA

	Sample CLV-1[1]	Measured at Southampton	Provisional Value[2]
1.[3]	^{137}Cs	0.115 Bq/g	0.11 Bq/g
	U (via ^{234}Th)	1.12 Bq/g	1.07 ± 0.06 Bq/g
2.[3]	^{137}Cs	0.112 Bq/g	0.11 Bq/g
	U (via ^{234}Th)	1.11 Bq/g	1.07 ± 0.06 Bq/g

Notes

[1] CLV-1 Pine needles reference samples supplied by the Canadian National Uranium Tailings Program.
[2] Values taken from 'Vegetative radionuclide reference materials' by L Dalton and W S Bowman (1986), NUTP-4E, ISBN 0-660-12231-6.
[3] Samples 1 and 2 were prepared using different weighed portions of CLV-1 independently as two samples in different counting geometries.

TABLE 7: PROFICIENCY TESTING SCHEME - AEA TECHNOLOGY plc (JAN 1999)

Sample	Isotope	AEA Target Value	Measured at Southampton	All Laboratory Range
Milk	^{137}Cs	182	217 226	162 - 279
Cabbage	^{137}Cs	63.5	73	58 - 85

QUALITY ASSURANCE - ALPHA

In any chemical procedure continuous quality control is required which is able to assess both the precision and accuracy of the methods used. The precision or reproducibility of a method can be monitored by including a suitably reliable 'in-house' reference sample with each batch of samples. Accuracy is more difficult to assess and is partly controlled by the reliability of the isotopic tracer used. The use of natural matrix reference materials (NMRM) provide a way of assessing the accuracy (Tables 8 – 9).

TABLE 8: ANALYSIS OF REFERENCE SAMPLES (Bq/kg) – ALPHA EMITTERS

IAEA[1] Sample	Isotope	Recommended or Certified Value	Measured at Southampton
IAEA-307	^{238}Pu	0.025	1) 0.03
(Sea-plant)	$^{239,240}Pu$	0.72	1) 0.69
(Posidonia oceanica)	^{241}Am	-	1) 0.2
IAEA-308	^{238}Pu	0.017	1) 0.03
(Mediterranean seaweed)	$^{239,240}Pu$	0.5	1) 0.48
	^{241}Am	0.17	1) 0.3
IAEA-134	$^{239,240}Pu$	15	14
	^{241}Am	38	36
IAEA-135	$^{239,240}Pu$	213	187
	^{241}Am	318	318
IAEA-367	$^{239,240}Pu$	38	34
	^{241}Am	26.4	24
IAEA-384	^{238}Pu	38.1 – 40.1	36.70
(Sediment)	$^{239,240}Pu$	105 - 110	103.35
	^{241}Am	6.7 – 7.6	24

Notes

1 IAEA International Atomic Energy Authority reference samples.

- not counted

TABLE 9: PROFICIENCY TESTING SCHEME - AEA TECHNOLOGY plc (JAN 1999)

Sample	Isotope	AEA Target Value	Measured at Southampton
Milk	^{239}Pu	0.512	0.56
			0.62
Cabbage	^{239}Pu	1.072	1.08
			1.02

QUALITY CONTROL - BETA

Quality control in the analysis of Technetium-99 is aimed at ensuring the precision of the measurement. A spiked sample is analysed along with each batch of samples. The background and counting efficiency of the samples are determined for each batch of samples counted. Participation in intercomparison exercises helps estimate the accuracy of the procedure (see Tables 10 - 11). For the National Physical Laboratory Intercomparison, 1995 only spiked water samples were supplied and the validation was limited. The MAFF/FSA exercise of 2000 supplied samples more appropriate for the assessment of analysis of environmental and food material.

TABLE 10 : TECHNETIUM 99 CALIBRATION EXERCISE (SURRC 1998)

	Measured at Southampton: Bq kg^{-1}			
Sample	**A**	**B**	**C**	**D**
	3.9	35.7	4.21	16.3
	6.8	36.9	4.32	16.5
		33.8	4.17	17.7
			4.13	15.2
Mean	**5.3**	**36.7**	**4.21**	**16.4**

	Measured at all laboratories (8): Bq kg^{-1}			
Sample	**A**	**B**	**C**	**D**
Mean	8.0	61.3	5.3	18.2
High	18.8	88.5	15.7	23.2
Low	1.8	36.7	2.99	12.8

TABLE 11: INTERCOMPARISON EXERCISES

Sample	Isotope	Recommended Activity (Bq/kg)	Measured Activity
IAEA-321*	^{134}Cs	15.5 ± 1.5	14.9 ± 0.4 **
(Milk powder)	^{137}Cs	72.6 ± 1.5	72.1 ± 1.7
	^{40}K	552.0 ± 16.0	531.0 ± 6.0
IAEA-156	^{134}Cs	132.0	138.7 ± 5 **
(Clover)	^{137}Cs	264.0	261.0 ± 6
	^{40}K	657.0	640.0 ± 10
UK-NPL (1993)	^{60}Co	91.34 ± 0.91	90.4 ± 1.0
(Inter-comparison exercise)	^{106}Ru	48.74 ± 0.49	49.5 ± 1.4
	^{134}Cs	13.85 ± 0.14	13.6 ± 0.3**
	^{137}Cs	22.35 ± 0.22	22.3 ± 0.5
	^{144}Ce	44.33 ± 0.44	46.9 ± 1.3
	^{154}Eu	28.15 ± 0.28	26.4 ± 0.5
	^{155}Eu	49.20 ± 0.49	40.3 ± 0.7
UK-NPL (1995) - BG005/95	^{7}Be	38.5 ± 0.33	40.1 ± 5.0
(Inter-comparison exercise)	^{60}Co	51.2 ± 0.4	50.2 ± 0.5
	^{106}Ru	44.6 ± 0.5	43.7 ± 0.2
	^{134}Cs	14.7 ± 0.1	14.5 ± 0.3
	^{137}Cs	36.6 ± 0.4	37.6 ± 0.5
	^{154}Eu	54.03 ± 0.5	54.3 ± 0.5
	^{155}Eu	40.1 ± 0.4	33.6 ± 0.5 #
UK-NPL (1995) - KA02/95	^{134}Cs	2210.0 ± 195	2311.0 ± 40
(Intercomparison exercise)	^{137}Cs	4800.0 ± 398	5036.0 ± 37
	^{154}Eu	3750.0 ± 260	4321.0 ± 16
	^{155}Eu	5536.0 ± 300	5246.0 ± 60 #
NPL (1995)		44.0 ± 0.1	43 ± 4
UK-NPL (1996) - BG033/96	^{57}Co	42.7 ± 0.7	55.0 ± 2.2
(Intercomparison exercise)	^{60}Co	40.39 ± 0.61	42.7 ± 1.8
	^{134}Cs	26.36 ± 0.43	18.7 ± 1.1 #
	^{137}Cs	35.65 ± 0.55	41.4 ± 1.7
	^{154}Eu	22.44 ± 0.38	13.9 ± 2.1
	^{155}Eu	41.09 ± 0.63	43.4 ± 5.9 #
UK-NPL (1996) - AB013/96	^{238}Pu	8.10 ± 0.16	7.37 ± 0.32
(Intercomparison exercise)	^{239,240}Pu	8.29 ± 0.07	8.29 ± 0.2
MAFF/FSA (2000)			
(Mussel)	^{137}Cs	405	438 ± 27
	^{241}Am	50	45.1 ± 3
(Lobster)	^{137}Cs	101	102 ± 7
	^{241}Am	121	96 ± 7
(Liver)	^{137}Cs	1165	1197 ± 70
	^{241}Am	56	49.2 ± 4
MAFF/FSA (2000)			
(Mussel)	^{99}Tc	946	979 ± 108
(Lobster	^{99}Tc	23181	23237 ± 2535
(Liver)	^{99}Tc	162	157 ± 20
NPL (2001) ABL019	^{238}Pu	2.526 ± 0.050	2.16 ± 0.09
Intercomparison exercise	^{239}Pu	2.523 ± 0.053	2.39 ± 0.1
(low-level activity)	^{241}Am	2.576 ± 0.054	2.352 ± 0.08
	^{60}Co	2.562 ± 0.030	2.62 ± 0.18
	^{65}Zn	2.537 ± 0.072	2.65 ± 0.45
	^{134}Cs	2.583± 0.026	2.71 ± 0.18
	^{137}Cs	2.581 ± 0.027	2.39 ± 0.19
NPL (1995)	^{99}Tc	44.0 ± 0.1	43 ± 4
NPL (2001)	^{99}Tc	2.539 ± 0.051	2.47± 0.46

Notes

* IAEA International Atomic Energy Agency reference sample (see report IAEA/AL/026 1990).

** 11% cascade sum correction applied for a 1 litre Marinelli

\# No cascade sum correction applied

TABLE 11: INTERCOMPARISON EXERCISES

Sample	Isotope	Recommended Activity (Bq/kg)	Measured Activity
NPL (2002)	^{22}Na	2.024 ± 0.010	1.95 ± 0.07
Comparison exercise	^{57}Co	2.024 ± 0.020	1.99 ± 0.06
(high-level activity - N.B. Bq/g)	^{60}Co	2.008 ± 0.008	1.97 ± 0.06
BGH009/02	^{95}Zr	1.943 ± 0.032	1.89 ± 0.12
ABH006/002	^{106}Ru	2.012 ± 0.011	1.92 ± 0.18
	^{134}Cs	2.025 ± 0.016	1.90 ± 0.06
	^{137}Cs	2.015 ± 0.015	1.98 ± 0.06
	^{154}Eu	2.081 ± 0.017	1.92 ± 0.06
	^{155}Eu	2.041 ± 0.024	2.01 ± 0.15
	^{238}Pu	2.000 ± 0.016	2.02 ± 0.04
	^{239}Pu	1.991 ± 0.023	2.00 ± 0.04
UK-NPL (2003)			
(Inter-comparison exercise)			
BGL/03/***	^{60}Co	2.247 ± 0.007	2.39 ± 0.35
	^{134}Cs	3.937 ± 0.029	3.93 ± 0.35
	^{137}Cs	2.522 ± 0.021	2.88 ± 0.40
(ABL/03/***)	^{90}Sr	11.942 ± 0.035	11.72 ± 0.51
	^{238}Pu	2.763 ± 0.011	2.59 ± 0.10
	^{239}Pu	3.293 ± 0.016	3.16 ± 0.12
	^{241}Am	3.058 ± 0.023	2.37 ± 0.08

Notes

* IAEA International Atomic Energy Agency reference sample (see report IAEA/AL/026 1990).
** 11% cascade sum correction applied for a 1 litre Marinelli
\# No cascade sum correction applied

GLOSSARY OF TERMS

Activation Products
Activation products are the radioactive atoms formed by the absorption of neutrons in and around the reactor core. For example, some of the trace quantities of cobalt and zinc in the water passed through the core become ^{60}Co and ^{65}Zn.

Activity
Attribute of an amount of a radionuclide. Describes the rate at which decays occur in it. The unit becquerel, Bq corresponds to the decay of one radionuclide atom per second.

Alpha particle
A particle consisting of 2 protons plus 2 neutrons which is effectively a helium nucleus. They are emitted generally by heavy radionuclides.

Annual limits of intake, ALIs
These values are calculated from the committed effective dose equivalent, CEDE. They represent activity data that are equivalent to the annual dose limit produced by a particular radioisotope. This is an ICRP concept.

Becquerel
Unit of amount of radioactivity, Bq (see activity). 1 nuclear disintegration per second.

CED
Committed effective dose. The dose equivalents which relate to a 50 year integration period.

Decay
The spontaneous transformation of a radionuclide. The decrease in the activity of a radioactive substance.

Decay product
A nuclide or radionuclide produced by decay. It may be formed directly from a radionuclide or as a result of a series of successive decays through several radionuclides.

Derived limits
See Generalised Derived Limits.

Dose
General term for quantity of radiation. See absorbed dose, dose equivalent, effective dose equivalent, committed effective dose equivalent, genetically significant dose. Frequently used for effective dose equivalent.

Fallout
The global deposition of very fine particulate material following testing of nuclear weapons in the atmosphere during the period 1952-1963 or due to nuclear accidents.

Fission Products
Fission is the division of a nucleus (e.g. ^{235}U) into two (usually unequal) radioactive parts. These nucleii are called fission products.

Gamma ray
A discrete quantity of electromagnetic radiation emitted during radioactive decay that originates from the nucleus.

Germanium gamma ray Spectrometer
A semiconductor detector that is most often used to measure gamma emitters because it offers the best energy resolution of any device.

Generalised derived limits
These are general secondary standards, derived from the primary dose limits, which are used as cautionary indicators for materials of environmental significance. They are quoted for specific radionuclides and are expressed in activity units per unit mass, unit volume or unit time. They express a value that will virtually guarantee compliance with legislation dose limits. Fractional GDLs are summed for different radioisotopes to give an assessment of the overall effective dose equivalent.

Gray
A measure of absorbed dose being the amount of energy imparted to unit mass of matter such as tissue. Symbol Gy. 1Gy = 1 joule per kilogram.

Half-life
The time taken for the activity of a radionuclide to lose half its value by decay. Symbol $t_{1/2}$.

ICRP
International Commission on Radiological Protection.

Nuclide
A species of atom characterised by the number of protons and neutrons and, in some cases, by the energy state of the nucleus.

Radiation
The process of emitting energy as waves or particles. The energy thus radiated. Frequently used for ionising radiation in the text.

Radioactive
Possessing radioactivity.

Radioactivity
The property of radionuclides of spontaneously emitting ionising radiation normally associated with nuclear decay to another nuclide.

Radon
An unstable, chemically inert, radioactive, heavy gas produced during the decay of natural uranium and thorium. Radon and its daughters accumulate in soil and may be drawn into dwellings through slight under-pressure. Radon activity generally represents the main contribution to the dose received by members of the public.

Sievert
See effective dose equivalent. An S.I. unit of radiation dose.