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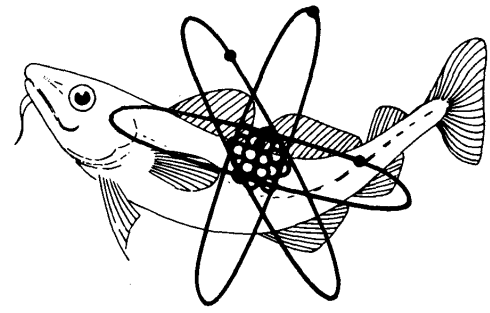
AQUATIC ENVIRONMENT MONITORING REPORT



NUMBER 14

RADIOACTIVITY IN SURFACE AND COASTAL WATERS OF THE BRITISH ISLES, 1985

G.J. HUNT

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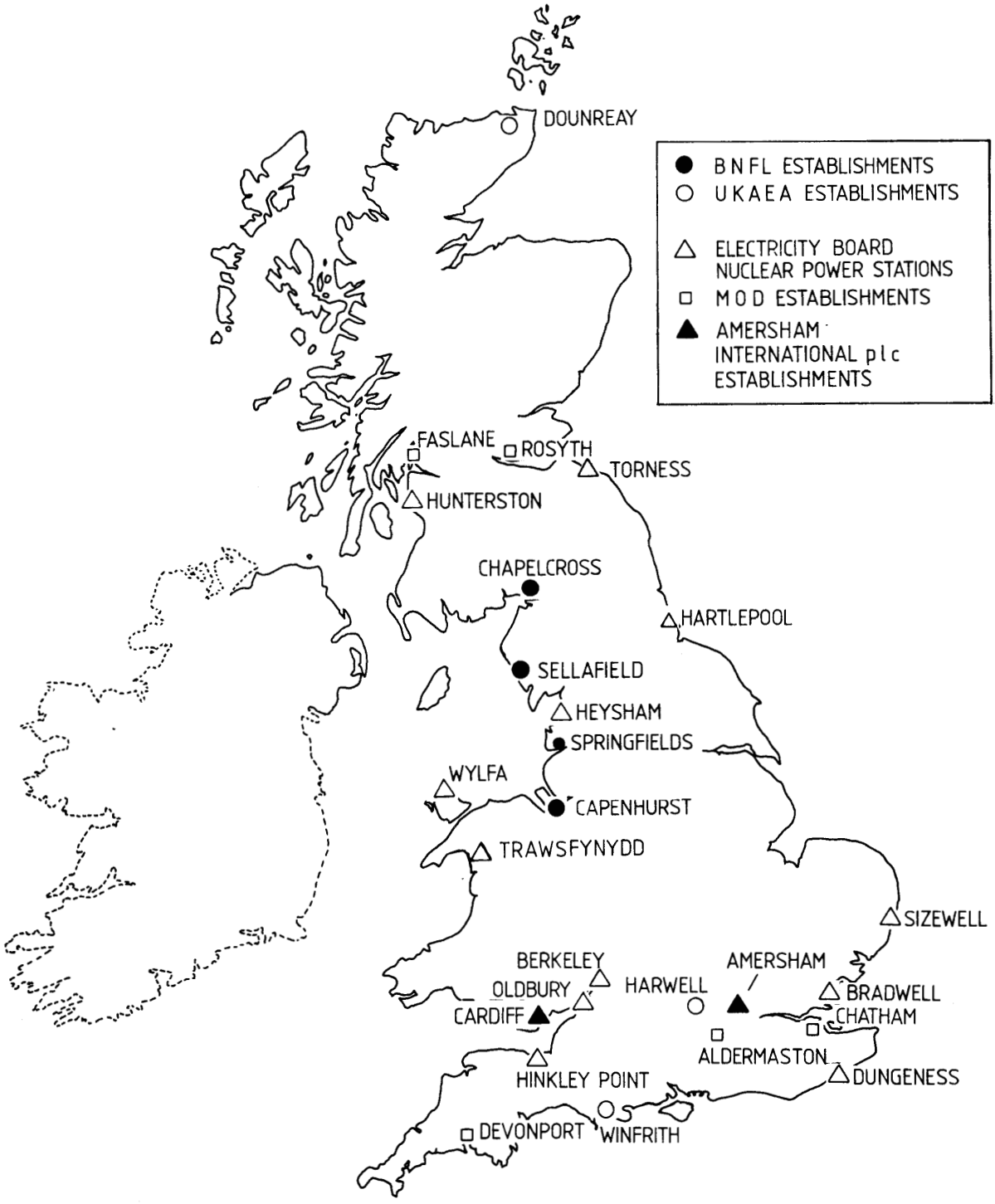

Figure 1 UK nuclear establishments giving rise to principal discharges of liquid radioactive waste.

1. Introduction

This report presents the results of the environmental monitoring programme carried out during 1985 by staff of the Directorate of Fisheries Research, Lowestoft. The monitoring programme is part of the Ministry's responsibilities under the Radioactive Substances Act, 1960 (Great Britain – Parliament, 1960). The programme is set up to verify the satisfactory control of liquid radioactive waste discharges to the aquatic environment, and to ensure that the resulting public radiation exposure is within nationally-accepted limits. The monitoring is independent of similar programmes carried out by nuclear site operators as a condition of their authorisations to discharge radioactive wastes. This report also includes results of monitoring carried out on behalf of departments of the Scottish Office, the Welsh Office, the Department of the Environment for Northern Ireland (DOE (NI)) and the Channel Islands States. Where appropriate, the information presented is supplemented by results from our extensive programme of research into the behaviour of radioactivity in the aquatic environment.

To set the monitoring results in proper context, liquid radioactive discharges from UK nuclear establishments to the aquatic environment in 1985 are first summarised. Before exposition of the monitoring results, an explanatory section gives details of how the results are presented and interpreted in terms of public radiation exposures.

2. Discharges of radioactive waste

Data on radioactive discharges are published annually by the Environment Departments. Data for 1985 are being prepared for publication, but to enable the results of environmental monitoring presented in this report to be considered readily in the context of relevant discharges, a summary is included here.

2.1 Liquid radioactive waste

Table 1 lists the principal discharges of liquid radioactive waste from UK nuclear establishments during 1985. The locations of these establishments are shown in Figure 1. Table 1 also lists the discharge limits which are authorised or, in the case of Crown establishments, administratively agreed. Discharges are given both in terabecquerels (see sub-section 3.1) and curies. The limits are given in the units specified in the relevant authorisation. In some cases, the authorisations specify limits in greater detail than can be summarised in a single table: in particular, where periods shorter than one year are specified the annual equivalent has been used. The limits are usually very much lower than the activities which could be released without exceeding the dose limits recommended by the International Commission on Radiological Protection (ICRP), embodied in national policy (Great Britain – Parliament, 1982). For each discharge the percentage of the authorised (or agreed) limit taken up in 1985 is also stated in Table 1.

For completeness, data are included here on the very small discharges into Holy Loch from the US Navy Submarine Base. Radiological safety for the Holy Loch base is the responsibility of the US Navy in association with the Ministry of Defence who have supplied the following information. For the year 1985 the radioactivity released into the waters of Holy Loch was less than 0.04 GBq (1 mCi) of long-lived gamma radioactivity, primarily cobalt-60; less than 0.04 GBq (1 mCi) of short-lived radionuclides; less than 0.04 GBq (1 mCi) of fission product radionuclides; and less than 0.4 GBq (10 mCi) of tritium.

2.2 Solid radioactive waste

In addition to receiving most of the above liquid discharges the marine environment has also received low specific activity packaged solid waste, disposed of not in coastal waters but in an area of the Deep Atlantic Ocean. The disposals have conformed to the requirements of the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (The London Dumping Convention (LDC)), including the Definition of High-Level Radioactive Waste Unsuitable for Dumping at Sea and Recommendations on Dumping Procedure promulgated by the International Atomic Energy Agency (IAEA) for contracting parties to the Convention. Disposals have been organised within the Multilateral Consultation and Surveillance Mechanism operated by the Nuclear Energy Agency (NEA) of the Organisation for Economic Cooperation and Development (OECD). No disposal operation was carried out in 1985 pending the completion of international reviews of these disposals by the IAEA, OECD and LDC and an examination by the Government of the Best Practicable Environmental Options (BPEOs) for different wastes. The quinquennial review by the OECD (NEA) of the suitability of the dumpsite is complete (OECD (NEA), 1985) and has concluded that the site could continue to be used for the next five years although its suitability should be reconsidered if disposal rates should exceed ten times those in recent years. The IAEA review of the Definition and Recommendations referred to above is also complete (International Maritime Organisation, 1985a), as is the *ad hoc* review by the London Dumping Convention of the Scientific and Technical Considerations (International Maritime Organisation, 1985b). The expert panel which carried out this *ad hoc* review concluded that no scientific or

Table 1 Principal discharges of liquid radioactive waste from UK nuclear establishments, 1985

Establishment	Radioactivity	Discharge limit (annual equivalent), Ci*	Discharges during 1985		
			TBq	Ci	% of limit
BRITISH NUCLEAR FUELS plc					
Sellafield					
Sea pipeline	Total beta	200 000	587	15 857	7.9
	Ruthenium-106	40 000	81	2 187	5.5
	Strontium-90	20 000	52	1 412	7.1
	Total alpha	600	5.7	154	26
Seaburn sewer	Total activity	4	0.0065	0.18	4.4
Springfields	Total alpha	360	0.70	19	5.2
	Total beta	12 000	157	4 240	35
Chapelcross	Total activity[1]	700	2.0	54	7.7
	Tritium	150	0.90	24.4	16
Capenhurst					
Rivacre Brook	Total activity[2]	0.04	0.000022	0.0006	1.5
Meols outfall	Technetium-99	4	0.000033	0.0009	<1
UNITED KINGDOM ATOMIC ENERGY AUTHORITY					
Winfrith	Total activity	30 000	70	1 903	6.3
	Ruthenium-106	9 000	0.49	13	<1
	Strontium-90	1 200	0.29	7.8	<1
	Total alpha	1 200	0.035	0.94	<1
Harwell	Total activity[1,3]	240	0.62	17	6.9
	Tritium	240	2.3	62	26
Dounreay	Total activity	24 000	25	673	2.8
	Strontium-90	2 400	4.0	109	4.5
	Total alpha	240	0.37	10	4.2
CENTRAL ELECTRICITY GENERATING BOARD					
Berkeley	Total activity[1]	200	0.29	7.8	3.9
	Tritium	1 500	0.52	14	0.94
Bradwell	Total activity[1]	200	1.5	40	20
	Zinc-65	5	0.0024	0.065	1.3
	Tritium	1 500	1.3	35	2.4
Dungeness					
"A" Station	Total activity[1]	200	2.2	59	30
	Tritium	2 000	0.83	22	1.1
"B" Station	Total activity[1,4]	4 TBq	0.038	1.0	<1
	Sulphur-35	25 TBq	0.14	3.8	<1
	Tritium	650 TBq	46	1 242	7.1
Hartlepool	Total activity[1,4]	4 TBq	0.017	0.46	<1
	Sulphur-35	7.5 TBq	0.18	4.9	2.4
	Tritium	1 850 TBq	22	594	1.2
Heysham[5]	Total activity[1,4]	4 TBq	0.0092	0.25	<1
	Sulphur-35	7.5 TBq	0.051	1.4	<1
	Tritium	1 850 TBq	25	675	1.3
Hinkley Point[6]					
"A" Station	Total activity[1]	200	3.7	100	50
	Tritium	2 000	23	621	31
"B" Station	Total activity[1,4]	100	0.048	1.3	1.3
	Sulphur-35	700	0.79	21	3.0
	Tritium	18 000	336	9 072	50
Oldbury	Total activity[1]	100	1.1	30	30
	Tritium	2 000	0.77	21	1.0
Sizewell	Total activity[1]	200	1.0	27	14
	Tritium	3 000	9.9	267	9.0
Trawsfynydd	Total activity[1]	40	0.43	12	29
	Caesium-137	7	0.063	1.7	24
	Tritium	2 000	2.48	65	3.2
Wylfa	Total activity[1]	65	0.048	1.3	2.0
	Tritium	4 000	7.0	189	4.7

Table 1 Continued

Establishment	Radioactivity	Discharge limit (annual equivalent), Ci*	Discharges during 1985		
			TBq	Ci	% of limit
SOUTH OF SCOTLAND ELECTRICITY BOARD					
Hunterston					
"A" Station	Total activity[1]	7.5 TBq	3.6	97	48
	Tritium	48 TBq	1.9	51	3.9
"B" Station	Total activity[1,4]	100	0.085	2.3	2.3
	Sulphur-35	700	3.2	86	12
	Tritium	40 000	342	9 240	23
MINISTRY OF DEFENCE (PROCUREMENT EXECUTIVE)					
Aldermaston	Total activity[1,3]	156	0.086	2.3	1.5
	Tritium	156	0.19	5.1	3.2
MINISTRY OF DEFENCE (NAVY DEPARTMENT)					
Chatham[7]	Total activity[1]	20	0.0020	0.054	<1
	Cobalt-60	10	0.0020	0.054	<1
	Tritium	20	0.0	0.0	0.0
Devonport	Total activity[1]	4	0.0070	0.19	4.7
	Cobalt-60	1	0.0066	0.18	18
	Tritium	10	0.039	1.1	11
Faslane	Total activity[1]	1	0.000046	0.0012	<1
Rosyth	Total activity[1]	30	0.0067	0.18	<1
AMERSHAM INTERNATIONAL plc					
Amersham	Total activity[1,3]	72	0.33	9.0	12
	Tritium	400	0.082	2.2	<1
Cardiff	Beta/gamma activity[8]	96 GBq	0.023	0.63	24
	Carbon-14	2 TBq	1.1	29	54
	Tritium	1 400 TBq	769	20 784	55

[1]Excluding tritium.
[2]Excluding uranium and its decay products.
[3]Authorisation or agreement specifies a control formula in which the total activity is calculated in equivalent curies, intended to allow for the relative radiotoxicities of different nuclides. The sums of the actual discharges in curies were lower than the values indicated. Column 4 gives equivalent terabecquerels.
[4]Excluding sulphur-35.
[5]Discharges are from Heysham I.
[6]A single site authorisation applies at Hinkley Point. The table format represents the way in which it has been agreed that the authorisation should be apportioned in practice.
[7]Discharges are due to decommissioning work following closure of the site on 31 March 1984.
[8]Excluding tritium, carbon-14 and radioisotopes of calcium and strontium.
*Unless otherwise stated.

technical grounds could be found to treat the option of sea dumping differently from other available options when applying internationally accepted principles of radiological protection to radioactive waste disposal. The BPEO study (DOE, 1986) indicates a continuing role for sea dumping as an option in UK radioactive waste disposal strategy.

International surveillance of the effects of these disposals is coordinated by the OECD (NEA) by means of a Coordinated Research and Environmental Surveillance Programme (CRESP) (OECD (NEA), 1981). Routine environmental monitoring does not provide an effective means of assessing radiation exposure from these disposals as their effects are largely undetectable (OECD (NEA), 1985). In the absence of readily detectable effects, radiation exposure is assessed mainly by the use of mathematical modelling. The emphasis of surveillance within CRESP has been to improve, by means of appropriate research, the data for modelling assessments. These assessments indicate that the environmental impact of these disposals is negligible (OECD (NEA), 1985).

3. Methods of analysis and of presentation and interpretation of results

3.1 SI units

In this report data are presented using the Système Internationale (SI) radiological units recommended for use in the UK by the British Committee on Radiation Units and Measurements (BCRU, 1978). Table 2 summarises the radiological units used in this report, and provides relevant conversion factors to relate SI units to the old radiological units.

Table 2 Radiological units used in this report

Quantity	New SI unit and symbol	Definition	Old unit and symbol	Definition	Conversion data
Radioactivity	becquerel (Bq)	disintegration per second	curie (Ci)	$3.7\ 10^{10}$ disintegrations per second	1 Ci = $3.7\ 10^{10}$ Bq 1 Bq = $2.7\ 10^{-11}$ Ci = 27 pCi
Notes: 1 The terabecquerel (TBq) is used in this report for radioactive discharges:					1 TBq = 10^{12} Bq = 27 Ci
2 Radioactivity concentrations are given in becquerels per kilogram (Bq kg^{-1}):					1 Bq kg^{-1} = 1 mBq g^{-1} = 27 pCi kg^{-1} 1 pCi g^{-1} = 37 Bq kg^{-1}
Absorbed dose	gray (Gy)	J kg^{-1} (joule per kilogram)	rad (rad)	10^{-2} J kg^{-1}	1 rad = 10^{-2} Gy 1 Gy = 10^{2} rad
Dose equivalent	sievert (Sv)	J kg^{-1} x (modifying factors)	rem (rem)	10^{-2} J kg^{-1} x (modifying factors)	1 rem = 10^{-2} Sv = 10 mSv 1 Sv = 10^{2} rem

3.2 Summary of analytical methods

Although some of the analytical methods which we have used are detailed elsewhere (Dutton, 1968, 1969), a very brief summary is given here in support of the measurements and the method of their presentation. The tables of results mostly include measurements of total beta radioactivity and of specific gamma-emitting nuclides. Pure beta emitters and alpha emitters (including transuranics) are also measured in appropriate cases.

Total beta radioactivity is measured using thin sources with a potassium-40 standard (Dutton, 1968). The efficiency of the method is nearly constant over a wide range of beta energies and the result gives a measure of the total radioactivity of the beta emitters present, including natural radioactivity. However, agreement with the total as derived from isotopic analysis is not expected to be exact. The main advantage of total beta measurements is that they can be carried out quickly to give an early warning of any change in radioactivity concentrations which might require further investigation.

Gamma-emitting nuclides are analysed by gamma spectrometry. This is carried out using both NaI(Tl) and Ge detectors, calibrated using suitable reference sources. The spectra are reduced by computer-aided techniques to give radioactivity concentrations of detected nuclides. For samples of biota and sediments, searches are routinely made for, amongst others, the following artificial gamma emitters: manganese-54, cobalt-60, zinc-65, zirconium-95 plus niobium-95, ruthenium-106, silver-110m, antimony-124 and -125, caesium-134 and -137, and cerium-144. In the tables of results for these materials the absence of a column for any of these nuclides indicates non-detectability in each sample in that table.

Pure beta emitters, such as strontium-90, technetium-99 and promethium-147, are chemically separated from samples before beta counting. Transuranic nuclides are chemically separated and analysed by alpha spectrometry using silicon surface-barrier detectors, or in the case of plutonium-241 by liquid scintillation counting. Radiochemical procedures are generally labour-intensive and are carried out on samples in which these nuclides are of particular relevance, often on an annual bulk (sub-section 3.3).

3.3 Methods of presentation of measurements

The tables of monitoring results generally contain summarised values of observations obtained during the year under review. Observations of a given quantity may vary throughout the year; in general any variations are larger than the analytical errors inherent in the observations. The variations may, for example, be due to changes in rates of discharge or to different dispersion conditions in the receiving environment. The presentation of the summarised results reflects the purpose of this monitoring which is interpretation in terms of public radiation exposures. The method of interpretation is described more fully in sub-section 3.4. The appropriate integration period for comparison with recommended limits is at least one year; standard practice is to combine annual rates of consumption or occupancy of the more highly exposed members of the public (the critical group) with the arithmetic means of observed radioactivity concentrations or dose rates, respectively, during the year. The use of, say, the highest observed (but unsustained) radioactivity concentration with an annual consumption rate would not provide a realistic comparison with the recommended limits. Therefore, the tables present the arithmetic means of observations made during the year.

The frequency of sampling reflects the resolution (which affects the accuracy) judged to be necessary in the assessment of dose and is largely governed by the radiological importance. The tables indicate the number of sampling observations during the year. Observations on biota consist of the results of analysing suitably large samples of material; for fish and shellfish a sufficient number of individual animals is sampled

and analysed for each observation so as to allow for statistical variations. The number of individuals sampled also reflects the radiological importance. Thus, as in previous years, the number of individual animals sampled within an observation varied — up to several hundred for fish and molluscs from near Sellafield. For gamma dose rates, which are measured using portable instruments, each observation consists of the mean of a number of individual readings at a given location. This number again depends upon the radiological importance of the observation; the locations chosen are generally those where there is likely to be occupancy by persons as determined by habits surveys (see sub-section 3.4).

Analyses requiring radiochemical separation may be carried out on individual samples directly or on bulks made up of a number of individual samples collected over an extended period; in tables combining the results of gamma spectrometry and radiochemical analysis the extended period is one year unless otherwise stated.

Measurements on biota are given in terms of concentrations in wet material in the state in which it is collected. For fish and shellfish the concentrations apply to the edible fractions, because the purpose is assessment of internal exposure of the consumer. For sediments, whose water content is more variable, dry concentrations are given.

The results for certain measurements, particularly total beta radioactivity concentrations and gamma dose rates, include a contribution due to natural radioactivity. Further analysis of samples (usually by gamma spectrometry) indicates the component of total beta radioactivity which is due to artificial sources and the component due to natural radionuclides (mainly potassium-40 and the decay products of uranium and thorium). In the case of gamma dose rates, an indication of the natural background component can be gained from measurements at similar locations remote from nuclear activities or from experience before these activities began. For both types of measurement, however, experience is also useful. Table 3 lists representative values to be expected from natural sources. It is also to be noted that concentrations of alpha-emitting radioactivity can be due to natural radionuclides. For example, concentrations of polonium-210, a decay product of radon, of up to 4 Bq kg^{-1} (wet), have been observed in fish and up to 100 Bq kg^{-1} (wet) in mussels from a variety of locations (Pentreath *et al.*, 1979; McDonald *et al.*, in press). Radiation exposures from natural sources are in most cases greater than from artificial radioactivity, although the ICRP dose limits (sub-section 3.4) do not apply to natural and medical irradiation.

Table 3 Natural radioactivity concentrations of various environmental materials and natural background dose rates around the British Isles

Material	Total beta radioactivity concentration (wet)*	
	Bq kg^{-1}	Comments
Fish	40 to 100	Mostly ^{40}K
Shellfish	40 to 100	"
Seaweed	200 to 600	"
Sand	200 to 400	^{40}K and decay products of U and Th
Mud	700 to 1000	"
Gamma dose rates in air over intertidal sediments:		μGy h^{-1}
	Sand, shingle	0.03 to 0.05
	Mud	0.05 to 0.1

*Except sediments for which dry concentrations apply.

3.4 Methods of interpretation

The monitoring results in this report are interpreted in terms of radiation exposures of the public. The standards against which these exposures are judged are the recommendations of the ICRP. For many years these recommendations have been endorsed for use in the UK by appropriate advisory bodies. Current UK practice relevant to the general public is mainly based on the recommendations of the ICRP as set out in ICRP Publication 26 (ICRP, 1977). The dose limitation system embodied therein has been accepted as national policy (Great Britain — Parliament, 1982). The Euratom Directive on Basic Radiation Safety Standards (Commission of the European Communities, 1980), with which UK legislation complies, is based on the recommendations of ICRP Publication 26, as are the Basic Safety Standards for Radiation Protection promulgated by the International Atomic Energy Agency (IAEA, 1982). In this report, results have been interpreted also on the basis of the recommendations of ICRP Publication 26, taking account of recent explanatory statements by the ICRP.

The effect of these recommendations on the interpretation of the results will be briefly described. The ICRP prescribes a system of dose limitation which includes, within appropriate dose limits to individuals, that "all exposures shall be kept as low as reasonably achievable..." (ALARA). The requirement for ALARA involves consideration of collective as well as individual doses in radiological control procedures. As in previous reports in this series, collective doses from liquid radioactive waste discharges continue to be kept under review. ICRP Publication 26 does not

recommend a dose limit for populations; such a limit might be regarded as suggesting the acceptability of a higher population exposure than is either necessary or probable. The ICRP concludes that its system of dose limitation is likely to ensure that the annual dose equivalent averaged over the population from all sources, excluding natural and medical irradiation, will not exceed 0.5 mSv. The NRPB considers (NRPB, 1978) that maintenance of the annual dose equivalent below this value when averaged over the whole UK population is a reasonable objective; further, that the contribution from all UK waste management practices is unlikely to exceed one tenth of this, that is 0.05 mSv year^{-1}. In this report an annual average dose equivalent of 0.05 mSv has been used for reference purposes regarding collective doses. By comparison, the average annual effective dose equivalent in the UK from natural radiation is approximately 2 mSv (Hughes and Roberts, 1984).

ICRP Publication 26 recommends that doses should meet the ALARA objective, subject to compliance with appropriate individual dose limits. Control of individual exposures is intended to limit stochastic effects (i.e. those whose probability depends on the dose) to an acceptable level and to prevent non-stochastic (threshold) effects. For stochastic effects, it is recommended that the risk should be equal whether the whole body is irradiated uniformly or non-uniformly; weighting factors proportional to the risk are defined for different organs. The weighted sum of organ doses is called the effective dose equivalent. Exposures from intakes of radioactivity can continue for a number of years, depending upon body retention time. The committed effective dose equivalent represents the integrated exposure over 50 years following an intake. The ICRP has recently (ICRP, 1985) made known its present view that the principal limit for the committed effective dose equivalent received by a member of the public is 1 mSv in a year. However, it is permissible to use a subsidiary dose limit of 5 mSv in a year for some years provided that the average annual committed effective dose equivalent over a lifetime does not exceed 1 mSv year^{-1}. The ICRP-recommended dose limits apply to the sum of the effective dose equivalent resulting from external exposure during 1 year and the committed effective dose equivalent incurred from that year's intake of radionuclides. For members of the public, the dose limits apply to appropriate critical groups of people likely to be the most exposed. The NRPB has advised (NRPB, 1984a) that procedures leading to exposure of the public should be controlled deliberately to ensure that the lifetime committed effective dose equivalent does not exceed 70 mSv, and that in practice, the simplest way to ensure compliance is to apply the single annual limit on effective dose equivalent of 1 mSv (NRPB, 1986). The ICRP has indicated (ICRP, 1984) that because of the limitation on lifetime exposure, non-stochastic effects in members of the public will be avoided. This applies for those organs included in assessment of effective dose; for a few special cases, specific non-stochastic limits are appropriate. For example, the ICRP continues to recommend (ICRP, 1985) the limit for skin of 50 mSv year^{-1}.

In this report, committed effective dose equivalents to appropriate critical groups are presented. These are compared with the principal ICRP-recommended dose limit of 1 mSv year^{-1}. Where appropriate, consideration is given to compliance with the limitation on lifetime exposure.

Only general guidance has been given by the ICRP (ICRP, 1984) on the calculation of committed effective dose equivalents following intakes of radionuclides by members of the public. In this report, the data on committed effective dose equivalents per unit intake for workers, derived from supplements to ICRP Publication 30 (ICRP, 1979, 1981, 1982a, 1982b), have been used, together with modifications for members of the public described below. This basic procedure, which we have used since the inception of ICRP-26 rather than the direct use of Annual Limits on Intake, has essentially been reaffirmed by the ICRP statement on avoidance of non-stochastic effects (ICRP, 1984), and no change in methods is needed. Our methods include appropriate modifications for members of the public incorporating consideration of children where they are known to be members of critical groups and the use of appropriate gut transfer factors. In advance of a review by the ICRP, the NRPB has published (NRPB, 1984b) advice on gut transfer factors for actinides. This advice is that, for adult members of the public ingesting low concentrations of plutonium in food, an appropriate value of absorption factor by the gut is a factor of 5 higher than that currently used in ICRP Publication 30 for relevant forms of plutonium, except when a lower value can be justified. The effect is to enhance estimates of dose from plutonium essentially by this factor, and these higher values are quoted in this report; alongside are given, in important cases, the doses derived using the unenhanced gut transfer factor used in ICRP Publication 30. Recent work at this laboratory (Hunt *et al.*, in press) has provided evidence that for plutonium in winkles from near Sellafield, use of the higher factor would be conservative and that the factor used in ICRP Publication 30 would be adequate for assessments of dose to consumers (sub-section 4.1.1) of these shellfish.

In the case of external exposure to penetrating radiation, uniform whole body exposure has been assumed. The measured quantity is absorbed dose rate in air. When interpreting this in terms of radiological

effect, an absorbed dose rate in air of 1 μGy h^{-1} has been taken as producing an effective dose equivalent rate of 0.87 μSv h^{-1} (Spiers *et al.*, 1981).

In order to interpret monitoring results in terms of committed effective dose equivalents to critical groups, the remaining data required are, as appropriate, rates of food consumption or occupancy of areas relevant to external exposure. These are obtained by habits surveys specific to and generally near each nuclear establishment of interest. The results are kept under review and the surveys are repeated at intervals. The main purpose of the surveys is to identify and to quantify the relevant habits of the critical group of persons most highly exposed through a particular pathway or pathways. In this report, critical group habits data relevant to a given establishment are combined with the results of environmental monitoring and appropriate dosimetric data as above to estimate the committed effective dose equivalent to the critical group, which may then be compared with the ICRP-recommended dose limits.

4. British Nuclear Fuels plc (BNFL)

BNFL is concerned mainly with the design and production of fuel for nuclear reactors and its reprocessing after irradiation. The company also operates nuclear power plant supplying electricity to the national grid. We regularly monitor the environmental consequences of discharges of liquid radioactive waste from four BNFL sites, namely Sellafield, Springfields, Capenhurst and, on behalf of departments of the Scottish Office, Chapelcross.

4.1 Sellafield, Cumbria

Operations and facilities at this establishment include fuel element storage and decanning, the Windscale nuclear fuel reprocessing plant and the Calder Hall Magnox-type nuclear power station. The most significant liquid radioactive waste discharges are from the fuel element storage ponds and the reprocessing plant, through which passes all the irradiated Magnox fuel from the UK nuclear power programme, and some fuel from abroad. Most of the nuclear waste separated from the fuel is presently stored on site; relatively small quantities of radioactivity are discharged to the north-east Irish Sea, through pipelines which terminate 2.1 km beyond low-water mark. With effect from 1 January 1985 the authorisation to discharge these wastes was varied, in advance of the major revision which has now been implemented. The 1985 variation specified lower limits, and introduced short-term limits, to radioactivity in discharges. It also specified controls on solvents and particulate material. A further condition requires BNFL to use best practicable means (BPM) to control discharges with regard to the objective of keeping radiation exposures as low as reasonably achievable (ALARA). This objective had been reflected in the authorisation since 16 February 1983, and before that the need to meet it had been recognised (e.g. Hunt, 1984) in compliance with ICRP principles, as described in sub-section 3.4.

Discharges from the Sellafield pipelines during 1985 are summarised in Table 1, and were within the limits set by the authorising Departments. Discharges of total beta activity, at 587 TBq, were less than in 1984 (1190 TBq). Total beta discharges are substantially dependent upon releases of radiocaesium which orginate from the fuel element storage ponds as well as the reprocessing plant. In 1985 caesium-137 pipeline discharges totalled 325 TBq, a lower total than in 1984 (434 TBq). This reduction was brought about by the introduction during May 1985 of the new site ion-exchange effluent plant (SIXEP) to remove radiocaesium and other radionuclides from the pond effluent streams. The introduction and operation of SIXEP and, beforehand, the use of zeolite skips in the ponds to absorb caesium were invigilated by the authorising Departments to ensure compliance with the conditions of authorisation, including the requirement to use BPM to control discharges.

In March 1985, new plant became available to concentrate by evaporation and store salt-bearing effluent streams so as to allow short-lived radionuclides to decay prior to further treatment and disposal. As a result of its operation, discharges of ruthenium-106, which derives mainly from operations other than in the ponds, were 81 TBq, significantly less than for 1984 (348 TBq). Discharges of plutonium were also reduced by operation of the salt evaporator, such that site releases of alpha-emitting radionuclides in 1985 totalled 5.7 TBq, substantially less than in 1984 (14 TBq).

Our regular monitoring continued to increase during 1985. The critical radiation exposure pathway was still from consumption of fish and shellfish, with other pathways, especially from external exposure to gamma rays from occupancy over sediments, being kept under review. Following established practice, the largest monitoring effort has been expended on these more important pathways. In 1985, as in previous recent years, there was no harvesting of *Porphyra* in the immediate Sellafield vicinity for manufacture of laverbread, but some monitoring was continued because the pathway remains potentially important. An extensive research programme was also continued. The aims of this programme are to improve our knowledge of the distribution and behaviour of radio-nuclides in the marine environment, especially in relation to the critical exposure pathways, and also to provide a means of assessing other pathways of lower current importance, thereby assisting in keeping all exposure pathways under review. Results from our research programme are included where relevant.

Table 4(a) Beta/gamma radioactivity in fish from the Irish Sea vicinity and further afield, 1985

Sampling area/landing point	Sample	No. of sampling observations[3]	Mean radioactivity concentration (wet), Bq kg^{-1}		
			Total beta	^{134}Cs	^{137}Cs
Sellafield coastal area[1]	Cod	8	350	11	240
	Plaice	2	260	5.0	150
	Bass	1	410	11	330
	Grey mullet	1	130	3.0	90
Sellafield offshore area[1]	Cod	3	250	5.0	110
	Plaice	4	250	5.5	130
	Flounder	1	280	2.6	200
	Dab	4	220	4.5	110
	Skate	1	240	7.3	160
	Whiting	2	340	7.5	230
	Spurdog	2	140	2.0	61
Ravenglass[2]	Cod[4]	11	310	10	220
	Plaice[4]	8	230	6.0	140
	Whiting[5]	1	320	7.6	220
	Cod[5]	6	310	10	220
	Plaice[5]	3	300	6.4	170
	Whitebait	1	220	5.2	82
Morecambe Bay[1]	Flounder	4	300	5.6	200
Whitehaven[2]	Cod	4	200	3.5	93
	Plaice	4	180	3.5	88
Fleetwood[2]	Cod	4	190	3.0	84
	Plaice	4	160	1.9	51
Cumbrian rivers[6]	Sea trout	5	230	5.4	140
Isle of Man[2]	Cod	2	140	1.0	21
	Plaice	3	140	0.6	29
	Herring	2	140	0.9	28
	Saithe	1	210	3.0	93
	Lemon sole	1	120	1.0	16
	Whiting	1	180	2.5	78
	Skate	1	160	2.1	73
Inner Solway[1]	Salmon	1	140	ND	3.1
	Sea trout	1	180	3.2	96
	Flounder	4	250	4.4	190
Kirkcudbright[2]	Plaice	4	150	1.9	53
Northern Ireland[2]	Whiting	3	140	0.7	44
Ayr[2]	Plaice	4	NA	0.7	24
	Cod	4	"	1.2	37
West of Scotland[1]	Mackerel	1	97	ND	1.2
Minch[1]	Plaice	3	120	0.2	9.6
	Cod	3	130	0.3	11
Shetland[1]	Fish meal[7]	2	530	ND	5.2
	Norway pout	1	100	"	1.1
Northern North Sea[1]	Plaice	5	110	0.03	3.0
	Cod	9	130	0.03	4.6
	Haddock	4	NA	ND	2.8
	Saithe	2	"	"	3.4
Mid-North Sea[1]	Plaice	9	96	"	3.4
	Cod	10	130	0.06	7.3
	Haddock	5	NA	ND	4.7
	Whiting	3	NA	0.2	8.5
Southern North Sea[1]	Plaice	4	88	ND	2.0
	Cod	3	120	"	4.6
	Whiting	2	NA	0.1	2.9
Iceland area[1]	Cod	2	110	ND	0.8
	Plaice	1	80	"	0.2
Icelandic processed	Cod	2	97	"	0.2
	Plaice	2	78	"	0.2

ND = not detected; NA = not analysed; [1]Sampling area; [2]Landing point; [3]See section 3.3 for definition; [4]Samples provided by fisherman A; [5]Samples provided by fisherman B; [6]Samples collected from a number of rivers by the North West Water Authority; [7]Concentrations refer to weight of sample as supplied.

4.1.1 *The fish and shellfish consumption pathway*

Public radiation exposure from Sellafield discharges by consumption of fish is still predominantly due to radiocaesium. Concentrations of total beta activity and caesium-134 and -137 in fish from the vicinity of the Irish Sea and from further afield are given in Table 4(a). Data are listed by location of sampling or landing point, in approximate order of increasing distance from Sellafield. So as to be representative of consumption by the public, samples are generally obtained from commercial sources. However, to minimise the risk of underestimating exposures, and as certain species of fish or shellfish may not be available commercially, we also carry out specific surveys. The "Sellafield Coastal Area" extends 15 km north and south of Sellafield from St Bees Head to Selker and 11 km offshore; most of the local fish and shellfish consumed by the critical group is taken from this Area (Leonard and Hunt, 1985). Our own sampling of fish is carried out in the smaller "Sellafield Offshore Area" where experience has shown that good catch rates may be obtained. This Area consists of a rectangle, one nautical mile wide and two nautical miles long, situated south of the pipeline with the long side parallel to the shoreline; it averages about 5 km from the pipeline outlet.

The results reflect the progressive dilution of radiocaesium with increasing distance from Sellafield. They also reflect the age of the radioactivity, such that the ratio of caesium-137 to caesium-134 (half-lives 30 years and 2 years respectively) increases with distance. At large distances, and remote from the smaller discharges from elsewhere, concentrations of artificial radioactivity tend towards those from weapons-test fallout. For caesium-137 in fish, measurements remote from land run-off indicate a value of about 0.1-0.4 Bq kg^{-1} from this source. Variations between species for a given area, while not large, are mainly to be explained in terms of residence time in the area as well as feeding habits. These variations are likely to be most apparent in the results close to Sellafield because of the relatively steep concentration gradient of radiocaesium in sea water. To obtain representative results for dose estimation, samples include large numbers of individual fish (sub-section 3.3).

Concentrations of radiocaesium in 1985 were generally less than in 1984 for fish from all sea areas but particularly the Irish Sea and Scottish waters. This is attributed to reduced concentrations in sea water, following the decreasing trend in radiocaesium discharges, particularly the significant reduction for 1984 (Hunt, 1985a) followed by the further decrease in 1985.

Analyses of samples of fish for strontium-90, technetium-99 and promethium-147 were included in our monitoring programme for 1985, to enable results based on measurements to be included later in consideration of critical group and collective dose. Analyses for these radionuclides are particularly labour-intensive, thus a selection of samples was made based on potential radiological significance. Estimates of concentrations of these nuclides in past years were based on discharge data, and showed that their radiological significance was low, and much less than for radiocaesium. The data for 1985, shown in table 4(b), confirm this observation, giving only very small contributions to the total exposures presented later in this report.

Table 4(b) Strontium-90, technetium-99 and promethium-147 in fish from the Irish Sea vicinity, 1985

Sampling area/ landing point	Sample	No. of sampling observations[3]	Mean radioactivity concentration (wet), Bq kg^{-1}		
			^{90}Sr	^{99}Tc	^{147}Pm
Sellafield coastal area[1]	Plaice	1	0.73	0.33	NA
	Cod	2	0.81	0.7	1.2
Ravenglass[1]	Whitebait	1	2.7	NA	NA
Whitehaven[2]	Plaice	1	0.36	"	"
	Cod	1	0.48	"	"
Shetland[1]	Fish meal[4]	1	5.5	"	"

NA = not analysed; [1]Sampling area; [2]Landing point; [3]See section 3.3 for definition; [4]Concentrations refer to weight of sample as supplied.

For shellfish, a wide range of radionuclides contributes to radiation exposure of consumers owing to generally greater uptake in these organisms than in fish. Table 5 lists concentrations of total beta activity and beta/ gamma-emitting nuclides in shellfish from the Irish Sea and further afield. Results for strontium-90, technetium-99 and promethium-147 are included for 1985. Winkles are of particular radiological importance to the critical group near to Sellafield, as described later in this section. In addition to our own sampling, supplies of winkles, mussels and limpets were obtained from consumers who collected them in the Sellafield Coastal Area exploited by this critical group.

Concentrations of radionuclides in shellfish, as with fish, diminish with increasing distance from Sellafield; the rate of reduction is least for nuclides which are conservative to sea water, such as isotopes of caesium. There are substantial variations between species: in general, molluscs tend to concentrate the less conservative nuclides to a greater extent than do crustaceans, which in turn tend to concentrate them more than do fish; the reverse behaviour is generally observed for conservative nuclides.

Concentrations of radiocaesium in shellfish in 1985, as for fish, showed general reductions as compared with 1984, reflecting the trend of discharges. This trend was also observed for most other nuclides including ruthenium-106.

Table 5 Beta/gamma radioactivity in shellfish from the Irish Sea vicinity and further afield, 1985

Sampling area/ landing point	Sample	No. of sampling observations[3]	Mean radioactivity concentration (wet), Bq kg^{-1}																
			Total beta	^{54}Mn	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr + ^{95}Nb	^{99}Tc	^{103}Ru	^{106}Ru	^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{147}Pm	^{154}Eu	^{155}Eu
Sellafield coastal area[1]	Crabs	6	290	ND	4.4	ND	2.3	ND	1.3	ND	140	3.8	ND	3.1	57	1.4	1.9	ND	ND
	Lobsters	7	340	"	2.1	"	NA	"	NA	"	24	2.9	"	5.4	85	ND	NA	"	"
	Winkles[4]	12	2200	0.2	22	"	57	200	43	1.6	1200	20	1.8	5.1	120	25	82	3.3	2.6
	Winkles[5]	1	3500	ND	7.9	"	NA	460	NA	ND	1900	8.0	8.1	10	200	110	NA	7.6	5.0
	Winkles[6]	4	1900	0.9	26	"	"	120	"	2.9	1300	20	3.3	8.1	140	29	"	2.0	2.2
	Winkles[7]	4	910	ND	8.5	"	"	120	"	ND	630	12	1.0	2.6	64	6.8	"	ND	ND
	Winkles[8]	2	690	"	12	"	"	3.2	"	"	450	15	2.1	4.4	66	8.7	"	"	"
	Mussels[4]	6	3200	"	16	"	"	420	"	9.4	2500	5.7	ND	2.8	60	31	"	5.1	4.3
	Limpets[4]	6	1600	"	9.2	"	"	200	"	2.3	880	9.6	5.7	5.4	120	21	"	3.0	3.8
	Limpets[7]	4	NA	"	7.0	"	"	230	"	4.8	840	12	4.1	5.8	130	19	"	1.4	2.0
St Bees[1]	Winkles	11	970	"	10	"	23	85	29	1.9	670	12	2.7	3.2	68	9.5	30	0.4	0.4
	Mussels	4	1600	"	9.3	"	NA	240	NA	4.8	1300	13	ND	1.7	37	13	NA	1.3	1.5
	Limpets	4	1700	"	7.2	"	"	110	"	1.5	1000	14	8.4	6.7	120	18	"	2.4	3.3
Nethertown[1]	Winkles	11	1300	"	17	"	41	94	33	1.2	940	17	3.4	4.3	84	14	63	0.8	0.8
Drigg[1]	Winkles	11	1600	"	24	"	31	110	33	1.6	1200	18	2.1	4.2	81	21	58	0.2	1.8
Ravenglass[1]	Cockles	4	1300	"	40	"	NA	110	NA	1.4	810	2.3	ND	4.3	75	31	NA	6.0	5.0
	Mussels	11	1000	0.1	11	"	"	44	"	0.7	790	ND	0.2	1.5	31	9.4	"	4.6	3.1
Tarn Bay[1]	Winkles	4	990	ND	9.7	"	"	84	"	ND	690	12	0.5	4.5	68	12	"	0.6	1.0
Ravenglass[2]	Crabs	6	210	"	3.3	"	"	ND	"	"	50	4.8	ND	2.1	41	0.6	"	0.1	0.1
	Lobsters	3	480	"	2.8	"	"	"	"	"	49	10	"	5.5	110	1.4	"	ND	ND
	Whelks	4	600	"	6.6	0.6	"	2.1	"	"	440	18	"	3.0	40	1.1	"	"	"
Parton[1]	*Nephrops*	4	650	"	4.4	ND	"	32	"	"	420	4.7	"	2.3	63	1.8	"	"	"
Whitehaven[2]	*Nephrops*	4	160	"	0.04	"	"	ND	"	"	0.4	ND	"	2.0	50	ND	"	"	"
Roosebeck[1]	Oysters	4	110	"	0.2	0.4	"	"	"	"	38	6.7	"	0.5	19	"	"	"	"
Morecambe Bay[1]	Shrimps	4	130	"	ND	ND	1.7	"	"	"	2.4	ND	"	2.3	63	"	"	"	"
	Cockles	4	180	"	3.2	"	3.6	"	"	"	46	"	"	0.6	36	"	"	"	"
Isle of Man[2]	Scallops	12	120	"	ND	"	NA	"	"	"	ND	"	"	0.1	5.2	"	"	"	"
Inner Solway[1]	Shrimps	4	130	"	"	"	"	"	"	"	1.4	"	"	2.2	60	"	"	"	"
Southerness[1]	Winkles	4	NA	ND	0.6	ND	NA	ND	NA	ND	39	ND	ND	1.5	36	ND	NA	ND	ND
Kirkcudbright[2]	Scallops	4	58	"	0.2	"	"	"	"	"	0.3	"	"	0.1	4.0	"	"	"	"
	Queens	4	78	"	0.2	"	"	"	"	"	1.1	0.2	"	0.2	6.0	"	"	"	"
North Solway coast[1]	Winkles	4	200	"	2.1	"	"	"	"	"	60	ND	"	1.7	27	"	"	"	"
Loch Ryan[1]	Oysters	1	56	"	ND	"	"	"	"	"	ND	"	"	ND	4.3	"	"	"	"
Wirral[1]	Shrimps	2	73	"	"	"	"	"	0.3	"	"	"	"	0.7	20	"	"	"	"
	Cockles	2	100	"	"	"	"	"	1.4	"	12	"	"	0.4	18	"	"	"	"
Conwy[2]	Mussels	3	100	"	0.1	"	"	"	NA	"	6.6	"	"	0.1	8.9	"	"	"	"
North Anglesey[1]	Crabs	2	NA	"	ND	"	"	"	"	"	ND	"	"	ND	7.3	"	"	"	"
	Lobsters	2	"	"	"	"	"	"	"	"	"	"	"	"	7.1	"	"	"	"
	Winkles	2	76	"	"	"	"	"	"	"	"	"	"	"	4.4	"	"	"	"
Northern Ireland[2]	*Nephrops*	3	110	"	"	"	"	"	"	"	"	"	"	0.2	8.9	"	"	"	"
Northern North Sea[1]	*Nephrops*	4	110	"	"	"	"	"	"	"	"	"	"	ND	3.8	"	"	"	"
Mid North Sea[1]	Mussels	2	48	"	"	"	"	"	"	"	"	"	"	"	1.2	"	"	"	"
	Mussels[9]	4	31	"	0.04	"	"	"	"	"	0.4	"	"	"	0.3	"	"	"	"
	Queens	1	NA	"	ND	"	"	"	"	"	ND	"	"	"	1.1	"	"	"	"
Southern North Sea[1]	Cockles	4	16	"	1.1	"	"	"	"	"	"	"	"	"	0.1	"	"	"	"
	Cockles[10]	4	41	"	0.3	"	"	"	"	"	0.4	"	"	"	0.4	"	"	"	"
	Mussels	4	35	"	ND	"	"	"	"	"	ND	"	"	"	0.8	"	"	"	"

NA = not analysed; ND = not detected.
[1]Sampling area; [2]Landing point; [3]See section 3.3 for definition; [4]Samples collected by Consumer 116; [5]Samples collected by Consumer 277; [6]Samples collected by Consumer 460; [7]Samples collected by Consumer 311; [8]Samples collected by Consumer 471; [9]Landed in Denmark; [10]Landed in Holland.

Public radiation exposure from transuranic nuclides in fish is lower than from radiocaesium. Analyses for transuranics are also particularly labour-intensive. Therefore, a selection of samples of fish and shellfish chosen mainly on the basis of potential radiological significance were analysed for transuranic nuclides; the number of transuranic analyses was further increased in 1985. Analyses were often carried out on bulked samples (sub-section 3.3). The data for 1985 are presented in Table 6. Transuranics are less conservative to sea water than is radiocaesium; this is reflected in higher concentrations of transuranics in shellfish as compared with fish, and a rapid reduction with distance in concentrations of transuranics, particularly in shellfish.

Concentrations of transuranics in fish and shellfish from the Irish Sea showed general reductions in 1985 as compared with 1984, particularly for plutonium and in areas close to Sellafield. The reductions in concentrations of plutonium isotopes were not generally as great in proportion to the decreases in discharges between 1984 and 1985. This was because the non-conservative nature of these nuclides causes a delayed effect in the environment (Hunt, 1985b), such that a contribution to present levels is provided by discharges in earlier years; further reductions in concentrations may be expected in the next few years even though discharges themselves may vary due to operational factors prior to introduction of the enhanced actinide removal plant, planned for 1992.

Table 6 Transuranic radioactivity in fish and shellfish from the Irish Sea vicinity and further afield, 1985

Sampling area/ landing point	Sample	No. of sampling observations[3]	Mean radioactivity concentration (wet), Bq kg^{-1}						
			^{237}Np	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm
Sellafield coastal area[1]	Cod	1	0.00080	0.028	0.11	2.5	0.11	0.0012	0.00046
	Crabs	4	0.047	0.41	1.6	42	4.3	0.025	0.021
	Lobsters	2	NA	0.23	0.91	NA	8.9	0.013	0.030
	Winkles[4]	2	0.20	12	47	1300	58	0.52	0.24
	Winkles[5]	1	NA	4.4	18	NA	27	0.19	0.10
	Winkles[6]	1	"	5.7	21	"	25	0.18	0.10
	Winkles[7]	2	"	11	41	1100	56	0.38	0.27
	Mussels[4]	1	"	14	55	NA	73	0.33	0.30
	Limpets[4]	1	"	7.8	31	"	44	0.39	0.22
	Limpets[6]	1	"	11	37	"	43	0.50	0.21
Sellafield offshore area[1]	Plaice	1	"	0.0039	0.014	"	0.020	ND	0.000080
	Cod	1	"	0.0027	0.011	"	0.020	0.00017	0.00007
	Skate	1	"	0.0023	0.011	"	0.015	ND	0.000096
St Bees[1]	Winkles	4	0.085	5.0	20	540	25	0.22	0.13
	Mussels	2	NA	10	40	NA	46	0.22	0.15
	Limpets	1	"	8.8	36	"	48	0.23	0.23
Nethertown[1]	Winkles	4	0.12	7.8	31	830	42	0.22	0.20
Drigg[1]	Winkles	4	0.15	8.9	34	920	50	0.38	0.26
Ravenglass[1]	Cockles	1	NA	11	41	1100	76	0.48	0.36
	Mussels	4	"	11	46	1100	72	0.16	0.28
	Whitebait	1	"	0.20	0.80	21	0.97	0.0086	0.0090
Tarn Bay[1]	Winkles	2	"	4.8	19	NA	22	0.23	0.12
Ravenglass[2]	Plaice[8]	1	0.00065	0.0042	0.016	"	0.024	ND	0.00015
	Cod[8]	1	0.00015	0.0059	0.026	"	0.027	0.00019	0.00011
	Cod[9]	1	NA	0.0044	0.018	"	0.024	0.00054	0.00015
	Crabs[9]	1	"	0.41	1.6	"	4.4	0.029	0.029
	Lobsters[9]	1	"	0.36	1.4	"	9.9	0.029	0.042
	Whelks[9]	1	"	1.1	4.3	100	8.0	0.032	0.049
Parton[1]	Winkles	2	NA	2.8	12	300	15	0.040	0.074
Whitehaven[2]	Plaice	1	"	0.0030	0.013	NA	0.015	0.000079	0.000060
	Cod	1	"	0.0018	0.0081	"	0.012	ND	0.000074
	Nephrops	1	"	0.042	0.19	"	0.61	0.0030	0.0026
Roosebeck	Oysters	1	"	0.45	1.8	"	1.3	ND	0.0039
Morecambe Bay[1]	Shrimps	1	"	0.0088	0.044	"	0.057	0.0003	0.0002
	Cockles	1	"	0.76	3.4	"	7.5	ND	0.028
Fleetwood[2]	Cod	1	"	0.00028	0.0014	"	0.00031	"	ND
	Plaice	1	"	0.00065	0.0031	"	0.00048	"	"
Isle of Man[2]	Cod	1	NA	0.00023	0.0011	NA	0.0013	ND	ND
	Plaice	1	"	0.00069	0.0034	"	0.0043	0.00010	0.000033
	Herring	1	"	0.00021	0.00096	"	0.0010	ND	ND
	Scallops	3	"	0.025	0.12	"	0.031	0.0003	0.00008
Inner Solway[1]	Sea trout	1	"	0.00011	0.00047	"	0.00048	ND	ND
Southerness[1]	Winkles	1	"	0.61	2.8	"	3.7	0.0073	0.021
Kirkcudbright[2]	Plaice	1	"	0.0017	0.0072	"	0.015	ND	0.000042
	Scallops	1	"	0.056	0.25	"	0.076	"	0.00022
	Queens	1	"	0.036	0.16	"	0.16	0.0004	0.0007
North Solway coast[1]	Winkles	1	"	1.3	5.6	"	7.6	0.018	0.021
Ayr[2]	Cod	1	"	0.00012	0.00057	"	0.00047	ND	ND
	Plaice	1	"	0.00024	0.0011	"	0.0012	"	"
Wirral[1]	Cockles	1	"	0.57	2.8	"	5.4	"	0.018
Conwy[2]	Mussels	1	"	0.026	0.12	"	0.31	"	0.0010
North Anglesey[1]	Winkles	1	"	0.065	0.31	"	0.38	"	0.0013
Northern Ireland[2]	Whiting	1	"	0.00032	0.0018	"	0.0018	0.000020	ND
	Nephrops	1	"	0.0028	0.015	"	0.028	ND	0.00012
Minch[1]	Cod	1	"	0.00027	0.0014	"	0.0012	"	ND
Shetland[1]	Fish meal[10]	1	"	0.0013	0.0084	"	0.0023	"	"
Northern North Sea[1]	Cod	1	"	0.000082	0.00039	"	0.00054	"	"
	Nephrops	1	"	0.0014	0.0061	"	0.0098	0.00019	0.00020
Mid North Sea[1]	Mussels	1	"	0.0048	0.024	"	0.0086	"	ND
	Mussels[11]	1	"	0.00032	0.0041	"	0.0016	"	0.000022
Southern North Sea[1]	Mussels	1	"	0.0037	0.019	"	0.0076	"	ND
	Cockles	1	"	0.0012	0.0052	"	0.0050	"	0.00050
	Cockles[12]	1	"	0.0028	0.012	"	0.0072	"	0.00043
Icelandic processed	Cod	1	"	0.000054	0.00024	"	0.00023	"	ND

ND = not detected.
NA = not analysed.

[1]Sampling area; [2]Landing point; [3]See section 3.3 for definition; [4]Samples collected by Consumer 116; [5]Samples collected by Consumer 471; [6]Samples collected by Consumer 311; [7]Samples collected by consumer 460; [8]Samples provided by Fisherman A; [9]Samples provided by Fisherman B; [10]Concentrations refer to weight as supplied; [11]Landed in Denmark; [12]Landed in Holland.

The radiation dose to consumers of fish and shellfish depends upon the product of the mass of foodstuff consumed and its radioactivity concentration. Because of variations in these two quantities between individual consumers, a wide range of annual doses is to be expected. The critical group approach, which is well established in the UK and recommended by the ICRP for control purposes, is based on identifying groups of individuals in exposed populations subject to the highest radiation exposures. Of the two main variables, radioactivity concentrations in fish and shellfish are highest in the coastal area in the vicinity of the pipeline. Hence, eaters of fish and shellfish within the local community represent one exposed population whose consumption rates we have studied and kept under review. As regards the other main variable, consumption rates, surveys have shown that, in addition to the Cumbrian coastal community, the larger population in Cumbria and north Lancashire of those associated with commercial fisheries based primarily at Whitehaven, Fleetwood and in the Morecambe Bay area contains consumers of large quantities of fish and shellfish. This therefore represents a second exposed population which is kept under review, even though, in general, the relevant fishing grounds are further afield than the Cumbrian coastal area and concentrations of radioactivity in fish landed are lower.

The consumption rates of the Cumbrian coastal community described above were kept under review in 1985. Techniques used in the collection of data have continued to include the use of consumption logging sheets particularly by members of critical groups (Leonard *et al.*, 1982; Leonard, 1984). Consumption rate data have been interpreted using techniques based upon ICRP recommendations (Hunt *et al.*, 1982) to select appropriate critical groups of higher-rate consumers. We have included consideration of children's consumption rates in this selection process (Leonard and Hunt, 1985).

Radioactivity concentrations in fish and shellfish vary with the species involved, so in estimation of doses to consumers it is not sufficient to determine only the total consumption rates of fish and shellfish together. Our experience (illustrated by Tables 4-6) has shown, however, that for a given area, within each of the classes, fish, crustaceans and molluscs, the concentrations of given nuclides in representative samples are relatively constant. For each of the two exposed populations, therefore, sub-groups of persons were identified who were likely to have received the greatest exposures from eating each class of foodstuff, and mean consumption rates for the sub-groups were determined. For the Cumbrian coastal community these consumption rates of fish and crustaceans in 1985 were 36.5 kg year^{-1} (100 g d^{-1}) and 6.6 kg year^{-1} (18 g d^{-1}) respectively, as for 1984 (Hunt, 1985a). Our surveys revealed, however, an increase in consumption of molluscs, from 5.8 kg year^{-1} (16 g d^{-1}) in 1984 to 9.5 kg year^{-1} (26 g d^{-1}) in 1985. This consumption rate is still less than the maximum of 16.4 kg year^{-1} (45 g d^{-1}) observed for 1981-83. We believe that the habits of local mollusc consumers are partly a repercussion of the Sellafield incident in November 1983. Following this incident the Government issued advice to the public to avoid unnecessary use of local beaches. This advice was later modified and finally withdrawn in July 1984. The effect of this and other factors in 1984 was a reduction in use of the intertidal areas by mollusc collectors, with a partial recovery in 1985. In this report, exposures due to mollusc consumption have been assessed on the basis of the 1985 consumption rate of 9.5 kg year^{-1} (26 g d^{-1}). For comparison with previous years, and because consumption rates may increase again in the future, a summarised assessment is also presented on the basis of the consumption rate for 1981-83 of 16.4 kg year^{-1} (45 g d^{-1}).

The habits survey data obtained show that above-average consumers in each of the component sub-groups are not generally members of another component sub-group. However, members of more than one sub-group do exist, so that to avoid underestimating the exposure of the overall critical group, this exposure is derived by adding together the exposures of each sub-group. Comparison based on individual critical group members' exposures shows that this procedure is not excessively conservative (Leonard and Hunt, 1985). Plaice and cod are overwhelmingly the most popular fish eaten by the high-rate consumers, and the assessment of exposure of the critical group is based upon an equal mix of these species taken from the Sellafield Offshore Area and from landings at Ravenglass, typical sources of most of the local commercial supplies. The exposure due to consumption of crustaceans is based on an equal mix of crabs and lobsters from the Coastal Area, whilst the exposure from consumption of molluscs is based upon averaged radionuclide concentrations in winkles from the Coastal Area, including data from both our own sampling at specific locations within this Area and from samples collected by local consumers.

Table 7 summarises exposures in 1985. For each exposed group considered the committed effective dose equivalent (sub-section 3.4) is given together with the contributions of individual radionuclides. For simplicity, only the more important of these are listed; hence it is not to be expected that the sums of the listed contributions will necessarily equal the totals presented. The effect of applying different gut transfer factors for plutonium is shown in the last two columns. Recent work at this laboratory (Hunt *et al.*, in press) has provided evidence that the gut transfer factor used in ICRP Publication 30 (ICRP, 1979) provides a

Table 7 Individual radiation exposures due to consumption of Irish Sea fish and shellfish, 1985

Exposed population	Consumption rate used in assessment (see text)			Nuclide	Committed effective dose equivalent, mSv year^{-1}	
		kg year^{-1}	(g d^{-1})		On basis of current ICRP recommendations	Effect of Pu enhanced by a factor of 5 (see text)
Consumers in local fishing community	fish:	36.5	(100)	^{90}Sr	0.02	0.02
	crustaceans:	6.6	(18)	^{106}Ru	0.06	0.06
	molluscs:	9.5	(26)	^{134}Cs	0.01	0.01
				^{137}Cs	0.10	0.10
				^{238}Pu	0.01	0.04
				^{239}Pu + ^{240}Pu	0.03	0.17
				^{241}Pu	0.02	0.11
				^{241}Am	0.24	0.24
				Total	0.49	0.73
Consumers associated with commercial fisheries (Whitehaven, Fleetwood, Morecambe Bay)	fish:	131	(360)	^{90}Sr	0.005	0.005
	crustaceans:	18	(50)	^{106}Ru	0.004	0.004
	molluscs:	15	(40)	^{134}Cs	0.01	0.01
				^{137}Cs	0.16	0.16
				^{238}Pu	0.001	0.006
				^{239}Pu + ^{240}Pu	0.006	0.03
				^{241}Pu	0.004	0.02
				^{241}Am	0.07	0.07
				Total	0.26	0.30
Typical member of the fish-eating public consuming fish landed at Whitehaven/Fleetwood	fish:	15	(40)	^{134}Cs	0.001	0.001
				^{137}Cs	0.016	0.016
				Total	0.02	0.02

realistic basis for assessments of dose from eating winkles from near Sellafield. On this basis the committed effective dose equivalent to the local critical group in 1985 would have been 0.49 mSv. This result is less than the dose of 0.54 mSv reported for 1984 using the same transfer factor; reductions in concentrations of radionuclides (particularly radiocaesium and ruthenium-106) in fish and shellfish have outweighed the effect of the increase in mollusc consumption. The effect of applying the enhanced gut transfer factor for plutonium, following NRPB's advice (sub-section 3.4), is shown in the last column of Table 7. Using this advice the committed effective dose equivalent to the critical group of local consumers in 1985 would have been at most 0.73 mSv, a decrease from 0.84 mSv reported in 1984. All these results are within the ICRP-recommended principal dose limit for members of the public of 1 mSv year^{-1}.

For comparison with the doses reported in previous years and because consumption rates of molluscs could possibly increase again in the future, an assessment has also been carried out using the local critical group consumption rates which obtained in 1981-83 (i.e. 36.5 kg year^{-1} (100 g d^{-1}) fish, 6.6 kg year^{-1} (18 g d^{-1}) crustaceans and 16.4 kg year^{-1} (45 g d^{-1}) molluscs). If these consumption rates had applied in 1985, the dose to the critical group would have been 0.75 mSv on the basis of the gut transfer factor used in ICRP Publication 30. Using the enhanced factor recommended by the NRPB, the dose would have been 1.2 mSv. These results show significant decreases as compared with previous years, due to lower concentrations in fish and shellfish of transuranics, ruthenium-106 and radiocaesium. They are also in good agreement with our earlier predictions of dose to the critical group on the basis of likely future discharges from Sellafield (Hunt, in press).

The exposure of the critical group has been considered in comparison with the ICRP-recommended dose limits including the recommendation on lifetime exposure (sub-section 3.4). In 1985, as for 1984, realistically-assessed exposures were within the principal dose limit of 1 mSv year^{-1}. For a few previous years, exposures were in excess of 1 mSv year^{-1} but within the ICRP-recommended subsidiary dose limit of 5 mSv year^{-1}. Concentrations of radiologically significant nuclides in environmental materials are declining as a result of reduced discharges, and consumption rates of shellfish would need to increase substantially in the next few years for exposures, calculated using realistic parameters, to exceed the principal dose limit. These exposures are now considered likely to be permanently below the 1 mSv year^{-1} level, and dose rates above this level have not occurred for long enough for lifetime exposures to have exceeded, on average, 1 mSv year^{-1}. This statement takes account of predicted exposures from future discharges (Hunt, in press). Having demonstrated compliance with the ICRP's lifetime dose objectives, it follows (sub-section 3.4) that non-stochastic effects will also be avoided.

Habits surveys carried out in relation to the consumers associated with commercial fisheries based mainly on Whitehaven, Fleetwood and the Morecambe Bay area indicate critical sub-group consumption rates for fish, crustaceans and molluscs to be 131 kg year^{-1} (360 g d^{-1}), 18 kg year^{-1} (50 g d^{-1}) and 15 kg year^{-1} (40 g d^{-1}) respectively. As for the Cumbrian coastal community, the overall critical group has been defined by the maximising procedure of summing exposures due to these component consumption rates. The dose rate due to intake of fish has been assessed using activity concentrations of an equal mix of plaice and cod landed at Whitehaven and Fleetwood. Consumption of crustaceans has been based on shrimps from Morcambe Bay, and consumption of molluscs has been based on Morecambe Bay cockles. The effective dose equivalent to members of this critical group in 1985 is given in Table 7. The total of 0.26 mSv, on the basis of the gut transfer factor for plutonium used in ICRP Publication 30, represents a decrease from 0.41 mSv reported for 1984 (Hunt, 1985a). The decrease was mainly due to the lower concentrations of radiocaesium in Irish Sea fish.

The effective dose appropriate to a consumption rate of 15 kg year^{-1} (40 g d^{-1}) of fish from landings at Whitehaven and Fleetwood is also given in Table 7. This consumption rate represents an average for typical fish-eating members of the public. The effective dose in 1985 was 0.02 mSv, which represents a decrease from 0.03 mSv reported for 1984 (Hunt, 1985a), due to the reduced concentrations of radiocaesium in Irish Sea fish.

Collective doses from consumption of fish and shellfish during 1985 have been estimated for the UK and other European countries. In general, the method used has been to combine data on fish and shellfish landings from relevant sea areas with average radioactivity concentrations in fish and shellfish caught in these areas. Sea areas considered included the Irish Sea, Scottish waters, the North Sea, Baltic Sea, Norwegian Sea, Spitzbergen/Bear Island area and Barents Sea. Corrections were made for the fraction of fish or shellfish consumed. The contribution for weapons-test fallout to the radioactivity concentrations was subtracted. Consideration has been given to the pathway due to fish offal and industrial fisheries, the product of both of which is fish meal which is fed to pigs and poultry. Consumption of food products from these animals gives rise to a small contribution to the collective dose, and this has been included. The results are presented in Table 8. The results for 1985 are preliminary, being based on landings statistics provided by the International Council for the Exploration of the Sea (ICES) for 1984; data for 1985 are not yet available. Collective doses will be revised as new statistics are received and the results included in future reports. The results for 1984, given as provisional in the previous report (Hunt, 1985a), are now confirmed.

Table 8 Collective doses from fish and shellfish, 1984 and 1985

Population	Size of population	Collective effective dose equivalent, man-Sv	
		1984	1985 (preliminary)
UK	5.6×10^7	70	30
Other European countries	7.0×10^8	100	50

Liquid radioactive discharges from Sellafield are the main source of collective dose reported here; by comparison the effect of liquid discharges from other establishments is very small. Most of the collective dose is due to radiocaesium in edible fish; the contribution due to shellfish is minor. Also relatively small is the contribution, again mainly from radiocaesium, due to fish offal and industrial fisheries (Hunt and Jefferies, 1981). Other radionuclides which contribute to the collective dose, but in even smaller proportions, are strontium-90, through both fish and shellfish, and ruthenium-106 and the transuranics, mainly through shellfish. It should be noted that for transuranics the doses per unit intake allow for the long body half-times, so that the small contributions estimated for the transuranics are committed in the future rather than already received (sub-section 3.4). The contribution of pathways other than fish and shellfish consumption, e.g. external exposure, to the collective dose from Sellafield liquid discharges is relatively small (Hunt and Jefferies, 1981).

The preliminary result of 30 man-Sv for the UK in 1985 is significantly less than the result for 1984 (70 man-Sv). This is due to the lower radiocaesium concentrations, noted above, in fish and shellfish from the Irish Sea and further afield. The preliminary result of 50 man-Sv for the collective dose to inhabitants of other countries in 1985 was also much less than in 1984 (100 man-Sv), reflecting the same reductions.

The collective dose for the UK given in Table 8 may be compared with the annual dose equivalent averaged over the population of 0.05 mSv considered unlikely to be exceeded (NRPB, 1978) (see sub-section 3.4) as a result of all waste management practices. In 1985 the UK collective dose through the fish and shellfish pathway as a result of liquid radioactive waste disposal operations amounted to only about 1% of this value.

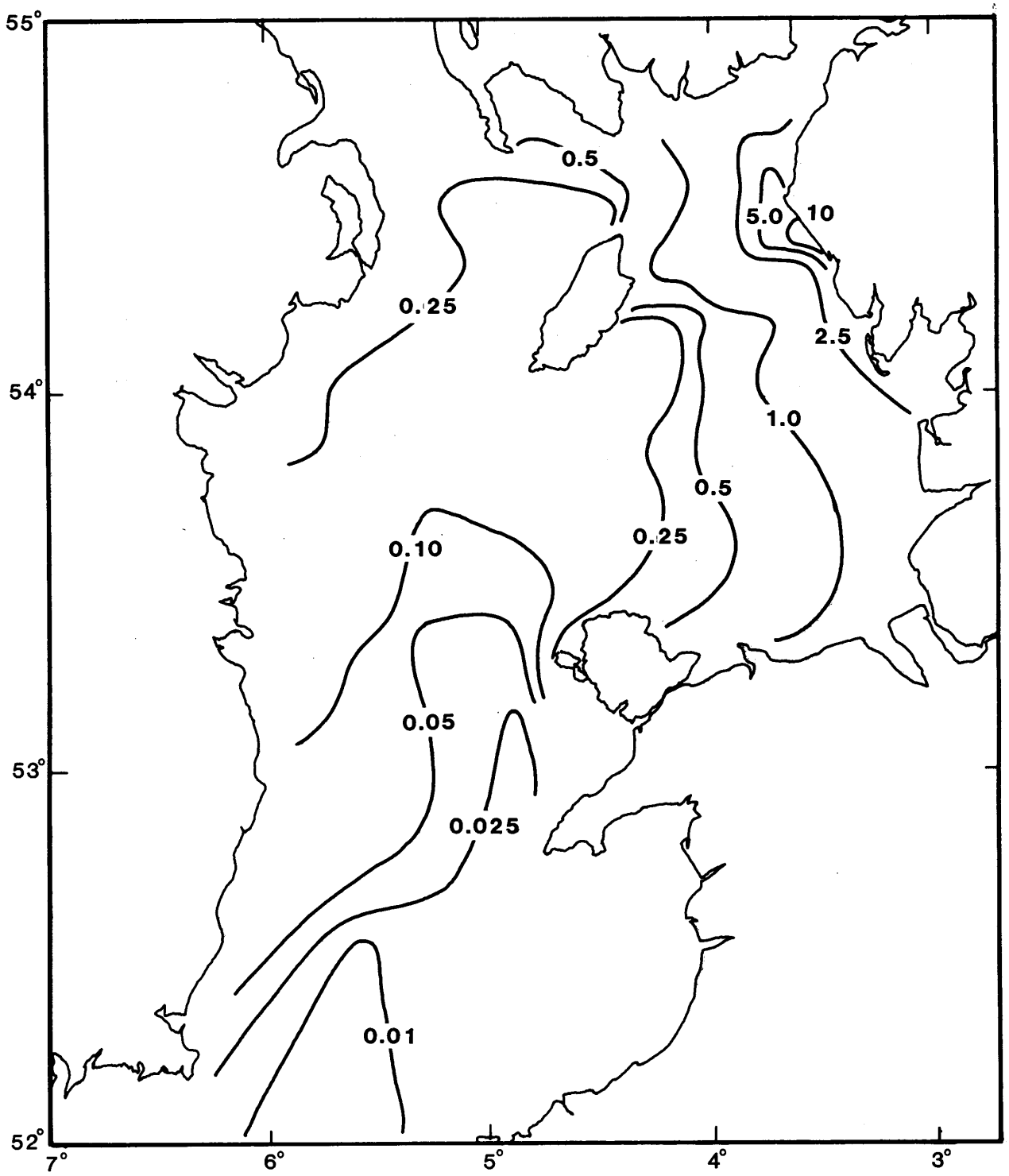

Figure 2 Concentration (Bq kg^{-1}) of caesium-137 in filtered water from the Irish Sea, March-April 1985

It is clear from the statements above which compare the 1984 and 1985 results for both critical group and collective dose rates that an important factor determining exposures is the distribution of radioactivity in the marine environment. We maintain a continuing programme of research on marine behaviour and distribution (including budget assessments) of significant radionuclides. Data on the distribution of caesium-137 in sea water are regularly collected by research vessel cruises; the distribution observed in the Irish Sea in March-April 1985 is shown in Figure 2. Comparison with the data for November 1984 (Hunt, 1985a) shows that concentrations of caesium-137 in sea water of the western Irish Sea reduced significantly, reflecting the period of increased flushing during the winter and the decreased discharges from Sellafield during 1984. In the area immediately offshore from Sellafield, concentrations of caesium-137 in March-April 1985 increased slightly because of greater discharges from Sellafield during the few months before SIXEP became operational; for the whole of 1985, there was an overall decrease in

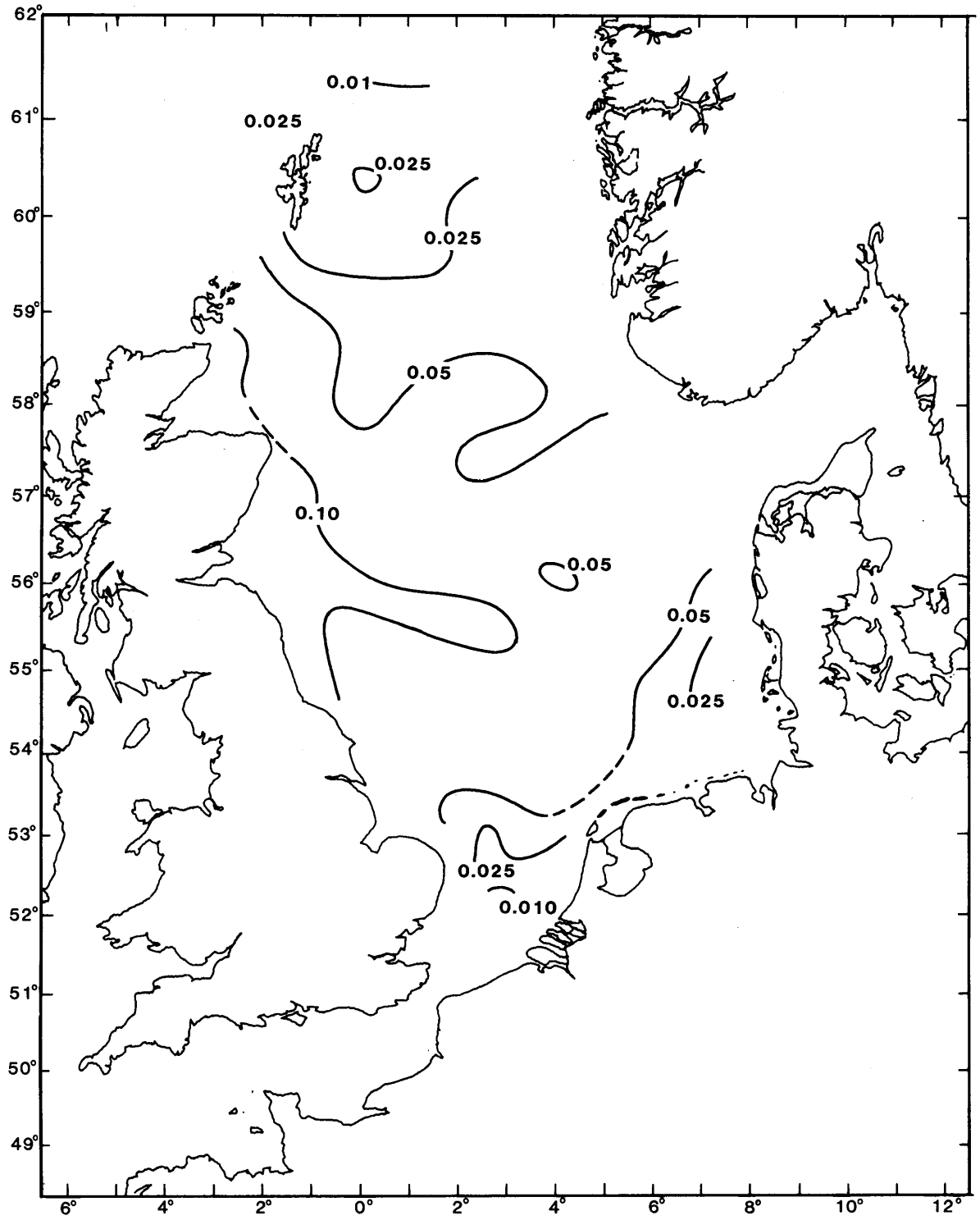

Figure 3 Concentration (Bq kg^{-1}) of caesium-137 in filtered water from the North Sea, August-September 1985

radiocaesium discharges. The decline in concentrations of radiocaesium in fish from the Irish Sea in 1985 occurred to a rather greater proportion than did the discharges. This is likely to be due to the lag period for dispersion and biological uptake; continuing reductions in radiocaesium concentrations in fish following the significant decrease in discharges from 1983 to 1984 were predicted in the previous report (Hunt, 1985a). Further reductions are also likely to occur in 1986. The distribution of caesium-137 in sea water of the North Sea during August and September 1985 is shown in Figure 3. Comparison with the distribution observed in August and September 1984 (Hunt, 1985a) shows a general reduction in concentrations. This was reflected in general decreases in concentrations of radiocaesium in fish and shellfish from the North Sea. Overall, there is a reducing trend in radiocaesium concentrations in sea water and fish from all areas, reflecting the decreases in radiocaesium discharges from Sellafield since 1975.

Table 9 Gamma radiation dose rates over intertidal areas of the Cumbrian coast and further afield, 1985

Location	Ground type	No. of sampling observa-tions†	Mean gamma dose rate in air at 1 m, μGy h^{-1}
Burgh Marsh	Salt marsh	4	0.12
Greenend	" "	4	0.13
"	Sand	4	0.10
Maryport harbour	Silt	4	0.28
" "	Dried silt	4	0.15
Workington harbour	Silt	4	0.29
Harrington harbour	"	2	0.38
Whitehaven outer harbour	"	12	0.35
" " "	Coal/sand	12	0.25
Whitehaven yacht basin	Silt	12	0.54
St Bees	Sand	4	0.096
Coulderton winkle beds	Rock	4	0.16
Sellafield	Sand	12	0.13
Seascale	"	4	0.12
Drigg	"	4	0.11
"	Mussel bed	3	0.22
Ravenglass - Salmon Garth	Sand	12	0.16
" "	Silt	12	0.28
" "	Mussel bed	12	0.33
Ravenglass - boats area	Sand	12	0.14
" " "	Silt	5	0.14
Ravenglass - ford area	"	4	0.34
Ravenglass - Ravenvilla	"	12	0.41
" "	Salt marsh	12	0.66
Newbiggin	Silt	12	0.54
Newbiggin - west of bridge	Sand/silt	4	0.36
" " " "	Salt marsh	4	0.72
Haverigg	Sand	4	0.18
"	Silt	4	0.41
Millom	Sand	4	0.17
"	Silt	5	0.25
Walney Channel	Sand	4	0.16
" "	Silt	4	0.22
" west shore	Sand	4	0.086
Low Shaw	Salt marsh	4	0.19
Flookburgh	Sand	4	0.12
Skipool Creek	Silt	2	0.23
Fleetwood	Sand	4	0.086
Blackpool	"	4	0.073
Ainsdale	"	5	0.068
New Brighton	"	4	0.076
Mersey (Rock Ferry)	Silt	4	0.13
Llandudno	Sand	4	0.082
Prestatyn	"	4	0.066
Garlieston	Silt	4	0.12
Kippford - slipway	"	4	0.15
" - jetty	"	4	0.14
" - merse	Salt marsh	4	0.23

†See section 3.3 for definition.

4.1.2 External exposure

A further important pathway leading to radiation exposure as a result of Sellafield discharges derives from uptake of gamma-emitting radionuclides by intertidal sediments in areas frequented by the public. In general, it is the fine-grained muds and silts prevalent in estuaries and harbours, rather than the coarser-grained sands to be found on open beaches, which adsorb the radioactivity more readily. Gamma dose rates currently observed are mainly due to radiocaesium.

We regularly monitor a range of coastal locations both in the Sellafield vicinity and further afield using portable gamma-radiation dosemeters. Locations are chosen on account of both dose rates themselves and levels of occupancy by members of the public. Table 9 lists the locations monitored together with the dose rates in air at 1 m above ground level. Monitoring in Scotland is carried out on behalf of the departments of the Scottish Office. Dose rates on Irish Sea shorelines near other nuclear establishments which reflect Sellafield discharges are given later in this report (see sub-sections 4.2, 4.3, 4.4, 6.5, 6.11). Variations in

Table 10 Radioactivity in sediment from the Cumbrian coast and further afield, 1985

Sampling point and sediment type		No. of sampling observations†	Mean radioactivity concentration (dry), Bq kg^{-1}							
			Total beta	^{60}Co	^{95}Zr + ^{95}Nb	^{103}Ru	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce
Maryport	(silt)	4	11 000	26	2 700	29	8 400	27	90	2 300	260
Harrington	(")	2	12 000	43	1 500	14	7 000	32	91	2 900	250
Whitehaven	(")	4	15 000	31	1 800	12	6 200	19	130	4 100	190
Newbiggin	(silt)	4	12 000	60	1 100	13	7 500	78	77	2 500	310
Walney Island	(")	4	2 500	12	160	ND	1 200	12	28	850	56
Flookburgh	(sand)	4	1 400	2.6	14	ND	230	ND	13	530	3.0
Heysham	(silt)	4	1 300	4.9	26	"	360	"	17	650	5.6
Sunderland Pt	(")	4	2 000	6.3	31	"	520	"	26	960	11
Skipool Creek	(")	2	4 200	13	62	"	1 100	14	72	2 900	18
Fleetwood	(sand)	4	380	ND	ND	"	8.9	ND	2.2	85	ND
Blackpool	(")	4	300	"	"	"	2.0	"	1.7	62	"
New Brighton	(")	4	400	0.2	"	"	18	"	2.4	100	"
Rock Ferry	(silt)	4	2 300	3.4	"	"	250	"	25	1 300	"
Garlieston	(sand)	3	540	0.2	ND	"	6.9	"	2.7	110	ND
"	(silt)	5	1 300	3.6	24	"	290	"	13	510	5.7
Kippford slipway	(")	4	3 000	15	150	"	1 100	9.6	28	1 200	35
" merse	(")	2	3 600	12	170	"	1 100	8.1	33	1 500	52
" "	(marsh)	2	4 000	15	31	"	840	12	34	1 800	29
" jetty	(silt)	4	2 400	12	130	"	860	ND	22	940	25
Palnackie	(")	4	3 300	16	170	"	1 300	2.3	35	1 500	40

Sampling point and sediment type		No. of sampling observations†	Mean radioactivity concentration (dry), Bq kg^{-1}							
			^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm
Maryport	(silt)	4	47	39	180	780	NA	840	ND	3.5
Harrington	(")	2	62	38	NA	NA	"	1 200	NA	NA
Whitehaven	(")	4	68	46	250	1 100	"	1 200	5.5	5.3
Newbiggin	(silt)	4	99	72	410	1 700	41 000	1 900	ND	11
Walney Island	(")	4	20	15	NA	NA	NA	330	NA	NA
Flookburgh	(sand)	4	2.3	1.8	"	"	"	92	"	"
Heysham	(silt)	4	2.9	ND	21	99	"	130	0.20	0.41
Sunderland Pt	(")	4	4.3	4.5	NA	NA	"	140	NA	NA
Skipool Creek	(")	2	22	15	"	"	"	410	"	"
Fleetwood	(sand)	4	ND	ND	"	"	"	10	"	"
Blackpool	(")	4	"	"	"	"	"	4.3	"	"
New Brighton	(")	4	"	"	"	"	"	9.2	"	"
Rock Ferry	(silt)	4	4.6	5.0	"	"	"	180	"	"
Garlieston	(sand)	3	ND	ND	"	"	"	24	"	"
"	(silt)	5	5.3	5.1	25	110	"	150	0.28	0.47
Kippford slipway	(")	4	17	13	76	360	"	430	0.62	1.7
" merse	(")	2	24	20	80	380	"	460	0.32	1.7
" "	(marsh)	2	28	18	170	780	"	600	0.35	1.7
" jetty	(silt)	4	9.0	7.4	65	290	"	330	0.62	1.0
Palnackie	(")	4	21	18	87	390	"	480	1.0	1.6

NA = not analysed.
ND = not detected.
†See section 3.3 for definition.

sediment type account for the quite marked fluctuations in dose rate, superimposed on a general decrease with increasing distance from Sellafield. Dose rates over intertidal areas in 1985 showed general reductions as compared with 1984 (Hunt, 1985a).

We also regularly monitor radioactivity concentrations in sediments. This is both because of relevance to dose rates and in order to keep under review distributions of adsorbed radioactivity. Concentrations of beta/gamma radioactivity and transuranics, in most cases at the same locations as the dose rate measurements, are given in Table 10. Variations similar in cause to those of the dose rates are observed, and comparison with results for 1984 (Hunt, 1985a) shows general reductions, in line with the behaviour of dose rates. It is to be noted that these levels of radionuclide concentrations give rise to negligible exposure following inhalation of resuspended sediment (Pattenden *et al.*, 1981).

To identify those members of the public subject to the highest external exposures, occupancies of different locations need to be considered. We keep under review the amounts of time spent by members of the public on intertidal areas of coastline bordering the north-east

Irish Sea. This includes a review of exposure at the Ravenglass salmon garth which was fished during the 1985 season; however, it is still considered that, combining dose rates and occupancy times, persons who may live on board boats in Whitehaven harbour are representative of those who receive the highest external exposures. Taking account of the time the boats are shielded from the mud by tidal effects and the shielding afforded by the boats themselves, their exposure in 1985 was equivalent to that from spending 650 h year^{-1} over unshielded mud. From Table 9, making an allowance for natural background, their external exposure in 1985 was 0.26 mSv. This result makes use (sub-section 3.4) of the factor of 0.87 Sv Gy^{-1} to convert absorbed dose rate 'free-in-air' to effective dose equivalent rate (Spiers *et al.*, 1981). These persons also consume fish and shellfish, and an addition is necessary to derive their total exposure related to Sellafield liquid discharges; other exposure pathways, such as handling of fishing gear, are negligible by comparison (sub-section 4.1.3). This addition is estimated to be 0.09 mSv for 1985 on the basis of the enhanced value of gut transfer factor for plutonium described in sub-section 3.4. Total exposure of the externally exposed critical group in 1985 is thus estimated to be 0.35 mSv, as compared with 0.43 mSv in 1984 (Hunt, 1985a). This exposure is less than that of the critical group of fish and shellfish consumers given earlier, and within the ICRP-recommended principal dose limit of 1 mSv year^{-1} for members of the public.

The converse situation, of the critical group of fish and shellfish consumers receiving exposure from external pathways, also needs to be considered. Habits survey data indicate, however, that the external component is too small to make a significant difference to the result for their exposure already given in sub-section 4.1.1; additions of this small order are considered to be adequately taken into account by the maximising process of summing exposures from the consumption of fish, crustaceans and molluscs.

4.1.3 Fishing gear

During immersion in sea water, fishing gear may entrain particles of sediment on which radioactivity is adsorbed. Fishermen handling this gear may be exposed to external radiation, mainly to their skin from beta particles. We regularly monitor fishing gear using portable beta dosemeters. Results for 1985 are presented in Table 11. Our habits surveys keep under review the amounts of time spent by fishermen handling their gear; for those most exposed, 500 h year^{-1} is appropriate. The maximum exposure from handling of fishing gear in 1985 would have been 0.3 mSv, less than 1% of the ICRP-recommended dose limit appropriate for exposures to skin of members of the public, based on non-stochastic effects (sub-section 3.4). Handling of fishing gear therefore continues to be a minor radiation exposure pathway.

Table 11 Beta radiation dose rates on contact with fishing gear on vessels operating off Sellafield, 1985

Vessel	Type of gear	No. of sampling observations†	Mean beta dose rate in tissue, μGy h^{-1}
B	Nets	15	0.14
	Ropes	13	0.65
D	Nets	7	0.25
	Pots	1	0.34
E	Nets	6	0.37
F	Nets	4	0.03
G	Nets	4	0.17
	Ropes	4	0.24
H	Nets	3	0.10
	Ropes	1	0.04
I	Nets	5	0.03

†See section 3.3 for definition.

4.1.4 Porphyra/laverbread pathway

No harvesting of *Porphyra* in the Sellafield vicinity for consumption as laverbread was reported in 1985; this pathway has therefore remained essentially dormant. However, monitoring has continued in view of its potential importance and the value of *Porphyra* as an indicator. Samples of *Porphyra* are regularly collected from selected locations along the Cumbrian coast. Results of analyses for 1985 are presented in Table 12, and showed similar reductions to those observed in other materials as compared with results for 1984. Samples of laverbread from the major manufacturers are regularly collected from markets in South Wales and analysed. Results for 1985 are presented in Table 13. The exposure of critical laverbread consumers was less than 0.01 mSv, confirming the virtual abeyance of this pathway.

4.1.5 Contact beta dose-rate monitoring of intertidal areas

We regularly monitor contact beta dose rates in intertidal areas to locate and remove any material with unusual levels of contamination. A summary of items detected during 1985 is presented in Table 14. The rate of detection declined in the latter part of 1984 following the incident in November 1983 and has remained relatively low in 1985. The presence of contaminated items only represents a pathway for exposure of the public in the unlikely event of prolonged contact with

Table 12 Radioactivity in *Porphyra* from the Cumbrian coast, 1985

Sampling point	No. of sampling observations†	Mean radioactivity concentration (wet), Bq kg^{-1}									
		Total beta	^{54}Mn	^{60}Co	^{90}Sr	^{95}Zr + ^{95}Nb	^{99}Tc	^{103}Ru	^{106}Ru	^{110m}Ag	^{125}Sb
Braystones South	12	1 100	ND	3.3	NA	58	NA	1.9	910	ND	3.3
Seascale	51*	NA	0.01	2.6	"	24	"	1.8	510	0.3	2.0
St Bees	5	880	ND	1.8	1.7	33	1.5	3.4	720	ND	2.6

Sampling point	No. of sampling observations†	Mean radioactivity concentration (wet), Bq kg^{-1}								
		^{134}Cs	^{137}Cs	^{144}Ce	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm
Braystones South	12	2.3	42	5.2	3.5	14	370	21	0.20	0.085
Seascale	51*	2.0	41	2.7	NA	NA	NA	15	NA	NA
St Bees	5	1.4	25	2.7	"	"	"	11	"	"

NA = not analysed.
ND = not detected.
†See section 3.3 for definition.
*These samples are counted wet to provide a rapid result.

Table 13 Radioactivity in laverbread from South Wales, 1985

Manufacturer	No. of sampling observations†	Mean radioactivity concentration (wet), Bq kg^{-1}			
		Total beta	^{106}Ru	^{137}Cs	^{241}Am
A	3	78	ND	1.7	0.07
C	3	59	1.6	0.8	ND
D	4	92	2.9	1.2	"

ND = not detected.
†See section 3.3 for definition.

Table 14 Summary of contact beta dose rate monitoring of intertidal areas of Cumbria, 1985

Month	No. of items detected (> 0.01 mGy h^{-1}) but below 0.1 mGy h^{-1}	Locations and dose rates (mGy h^{-1}) of items 0.1 mGy h^{-1} and above	
January	25	St Bees:	0.37
February	33	Sellafield:	0.90
		Braystones:	0.36
		Seascale:	0.17
		Ravenvilla:	0.48
March	51		
April	15	Seascale:	0.15
May	15	Drigg:	0.31
		Eskmeals:	0.25
June	19	Sellafield:	0.46
July	20	Seascale:	0.13, 0.13, 0.15
August	8	Low Shaw:	0.14
September	4	Coulderton:	0.11
October	5	Sellafield:	0.11
November	2		
December	8	St Bees:	0.16
		Coulderton:	0.17

them. The appropriate standard with which to compare the dose rates is the ICRP-recommended dose limit of 50 mSv year^{-1} for exposures to skin of members of the public (sub-section 3.4). It is not considered likely that anybody has received a dose to skin in excess of this.

4.1.6 Other surveys

In addition to the monitoring described above which is related to the more (or potentially more) significant radiation exposure pathways as a consequence of Sellafield discharges, we undertake a number of further investigations. Some of these are of a research nature; however, they also enable pathways of lower current importance to be kept under review.

Seaweeds are useful indicator materials; they may concentrate certain radionuclides so that they greatly facilitate measurement and assist in the tracing of these radionuclides in the environment. Table 15 presents the results of measurements in 1985 on marine plants from shorelines of the Irish Sea. Although small quantities of samphire and *Rhodymenia* may be eaten, radioactivity concentrations are of negligible radiological significance. *Fucus* seaweeds are useful indicators particularly of fission product radioactivity other than from ruthenium-106; samples of *Fucus vesiculosus* are collected both in the Sellafield vicinity and further afield, and the results are presented here. Monitoring in Scotland is carried out on behalf of departments of the Scottish Office. Analyses of samples collected in Northern Ireland are carried out on behalf of the DOE(NI).

Table 15 Radioactivity in marine plants from shorelines of the Irish Sea, 1985

Type of seaweed and sampling point	No. of sampling observations†	Mean radioactivity concentration (wet), Bq kg^{-1}									
		Total beta	^{54}Mn	^{60}Co	^{90}Sr	^{95}Zr + ^{95}Nb	^{99}Tc	^{103}Ru	^{106}Ru	^{110m}Ag	^{125}Sb
Fucus vesiculosus											
Sellafield	12	1 600	0.7	24	5.9	42	750	0.3	140	7.1	1.3
St Bees	4	1 000	0.1	11	12	24	710	ND	83	3.2	ND
Heysham	4	600	ND	1.1	NA	0.6	NA	"	10	ND	0.4
Port William	4	320	"	0.2	"	ND	"	"	ND	"	ND
Garlieston	4	400	"	1.2	"	1.5	"	"	6.2	"	0.4
Auchencairn	4	490	"	1.4	"	3.3	"	"	9.1	"	ND
Ardglass	2	370	"	ND	"	ND	"	"	ND	"	"
Portrush	4	270	"	"	"	"	"	"	"	"	"
Fucus spiralis											
St Bees	4	590	0.03	6.9	13	24	220	"	62	1.5	0.9
Fucus serratus											
St Bees	4	870	0.1	18	9.4	23	330	"	170	2.0	0.2
Douglas	1	270	ND	0.8	NA	ND	NA	"	3.4	ND	ND
Laminaria											
St Bees	3	740	"	0.6	8.2	19	140	"	150	1.6	0.4
Samphire											
Ravenglass	2	64	0.02	0.5	NA	0.9	NA	"	11	ND	0.1
Heysham	1	92	ND	0.2	"	ND	"	"	5.4	"	ND
Rhodymenia spp.											
St Bees	2	2 100	"	4.7	7.7	100	1.0	4.0	900	3.0	"
Millisle	3	990	"	ND	NA	ND	NA	ND	2.2	ND	"
Ascophyllum nodosum											
St Bees	4	1 600	"	6.1	7.5	22	1 700	"	79	1.3	1.9
Ardglass	1	700	"	ND	NA	ND	NA	"	ND	ND	ND

Table 15 Continued

Type of seaweed and sampling point	No. of sampling observations†	Mean radioactivity concentration (wet), Bq kg^{-1}										
		^{134}Cs	^{137}Cs	^{144}Ce	^{147}Pm	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm
Fucus vesiculosus												
Sellafield	12	10	170	3.4	4.0	0.3	0.2	7.6	29	12	0.11	0.077
St Bees	4	6.3	100	ND	NA	ND	ND	NA	NA	4.2	NA	NA
Heysham	4	3.9	95	"	"	"	"	1.0	4.6	1.9	ND	0.0090
Port William	4	1.2	29	"	"	"	"	NA	NA	0.7	NA	NA
Garlieston	4	2.0	47	"	"	"	"	"	"	2.4	"	"
Auchencairn	4	3.0	74	"	"	"	"	"	"	3.6	"	"
Ardglass	2	0.9	17	"	"	"	"	"	"	ND	"	"
Portrush	4	0.06	4.1	"	"	"	"	"	"	"	"	"
Fucus spiralis												
St Bees	4	4.7	85	"	"	"	"	"	"	6.3	"	"
Fucus serratus												
St Bees	4	4.7	80	0.5	"	0.2	"	"	"	6.4	"	"
Douglas	1	0.6	13	ND	"	ND	"	"	"	ND	"	"
Laminaria												
St Bees	3	5.8	95	"	"	"	"	"	"	3.8	"	"
Samphire												
Ravenglass	2	0.3	9.8	0.6	"	0.1	0.1	"	"	3.6	"	"
Heysham	1	0.6	17	ND	"	ND	ND	"	"	2.6	"	"
Rhodymenia spp.												
St Bees	2	10	190	16	"	3.0	3.0	"	"	35	"	"
Millisle	3	0.7	21	ND	"	ND	ND	"	"	ND	"	"
Ascophyllum nodosum												
St Bees	4	4.4	76	1.2	"	"	"	"	"	5.5	"	"
Ardglass	1	0.5	20	ND	"	"	"	"	"	ND	"	"

NA = not analysed.
ND = not detected.
†See section 3.3 for definition.

Table 16(a) Radioactivity in environmental materials near Springfields, 1985

Material	Sampling point	No. of sampling observations†	Mean radioactivity concentration (dry), Bq kg^{-1}										
			Total beta	^{60}Co	^{95}Zr + ^{95}Nb	^{106}Ru	^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	^{155}Eu
Bass	Ribble estuary	1	300	ND	ND	ND	ND	ND	7.3	270	ND	ND	ND
Grey mullet	" "	1	180	"	"	"	"	"	3.5	110	"	"	"
Cockles	Lytham	1	200	"	"	27	"	"	1.1	32	"	"	"
Silt	Pipeline outlet	4	17 000	6.7	18	580	2.2	1.1	35	1 300	32	7.4	ND
	Becconsall	4	18 000	7.3	20	660	ND	1.7	41	1 800	34	15	1.3
Sand	Lytham	1	610	1.1	ND	48	"	ND	4.1	180	ND	ND	1.8
	Blackpool	4	300	ND	"	8.9	"	"	1.7	62	"	"	ND

Material	Sampling point	No. of sampling observations†	Mean radioactivity concentration (dry), Bq kg^{-1}								
			^{228}Th	^{230}Th	^{232}Th	^{234m}Pa	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm
Bass	Ribble estuary	1	0.0012	0.0013	0.00061	ND	NA	NA	ND	NA	NA
Grey mullet	" "	1	0.0021	0.00078	0.00033	"	"	"	"	"	"
Cockles	Lytham	1	0.39	1.1	0.23	360	"	"	5.2	"	"
Silt	Pipeline outlet	4	75	630	87	36 000	38	180	230	ND	0.86
	Becconsall	4	NA	NA	NA	45 000	NA	NA	420	NA	NA
Sand	Lytham	1	16	29	17	260	"	"	25	"	"
	Blackpool	4	14	17	15	ND	"	"	10	"	"

†See section 3.3 for definition.
NA = not analysed.
ND = not detected.

4.2 Springfields, Lancashire

This establishment is mainly concerned with manufacture of fuel elements for nuclear reactors and production of uranium hexafluoride. Radioactive waste arisings are small and consist mainly of uranium and thorium and their decay products; liquid discharges are made by pipeline to the Ribble Estuary. Public radiation exposure in this vicinity as a result of these discharges is very low; there is, however, a greater contribution due to Sellafield discharges. The critical pathway is external exposure, due to adsorption of radioactivity on the muddy areas of river banks. The amounts of time for which members of the public are subject to such exposure is kept under review. The critical group consists of people who live on houseboats moored in muddy creeks of the Ribble Estuary. We regularly monitor dose rates in relevant areas including muddy creeks where houseboats are moored, and some of these measurements are supported by analyses of sediment. In 1985 we also investigated the fish and shellfish consumption pathway by analysing locally-obtained samples, including analyses for isotopes of thorium.

Results for 1985 are shown in Table 16(a) and (b). The only radionuclides detected which were due to Springfields discharges were isotopes of thorium and protactinium-234m; other radionuclides present were mainly from Sellafield. Exposure of the critical group of houseboat dwellers in 1985, including the Sellafield component, was about 0.3mSv, within the ICRP-recommended principal dose limit of 1 mSv year^{-1} for members of the public. This exposure was mainly due to Sellafield discharges; the contribution due to Springfields would have been a small fraction of the total. Concentrations of thorium in fish from the Ribble Estuary were not significantly different from those to be expected from natural sources. Any exposures due to Springfields-derived radionuclides in shellfish would be a small fraction of the total, most of which would be due to Sellafield discharges, as considered in sub-section 4.1.1. Also consistent with natural sources of thorium were the concentrations in sand from Blackpool, by reference to which only trace levels of Springfields-derived activity was detected in sand from the Ribble Estuary.

Table 16(b) Gamma dose rates in air at 1 m over intertidal areas near Springfields, 1985

Location	No. of sampling observations†	μGy h^{-1}
Pipeline outlet	4	0.21
Freckleton	3	0.23
Becconsall	4	0.21
Lytham	4	0.21

†See section 3.3 for definition.

Table 17 Radioactivity in environmental materials in the vicinity of the Wirral, 1985

Material	Sampling point	No. of sampling observations†	Mean radioactivity concentration (wet)*, Bq kg^{-1}						
			Total beta	^{60}Co	^{99}Tc	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs
Shrimps	Hoylake	2	73	ND	0.30	ND	ND	0.7	20
Cockles	Dee Estuary	2	100	"	1.4	12	"	0.4	18
Fucus spiralis	Hoylake	2	250	"	27	1.2	"	1.4	38
" "	Little Orme	1	330	"	90	ND	"	ND	10
Fucus vesiculosus	Little Orme	1	210	0.1	120	"	"	0.4	12
Silt	Hoylake	2	1800	4.3	2.5	280	8.5	22	960
Sand	Hoylake	1	360	ND	ND	6.0	"	1.5	68

Material	Sampling point	No. of sampling observations†	Mean radioactivity concentration (wet)*, Bq kg^{-1}					
			^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{243}Cm + ^{244}Cm
Shrimps	Hoylake	2	ND	ND	NA	NA	ND	NA
Cockles	Dee Estuary	2	"	"	0.57	2.8	5.4	0.018
Fucus spiralis	Hoylake	2	"	"	NA	NA	1.3	NA
" "	Little Orme	1	"	"	"	"	ND	"
Fucus vesiculosus	Little Orme	1	"	"	"	"	ND	NA
Silt	Hoylake	2	6.8	5.5	"	"	130	"
Sand	Hoylake	1	ND	ND	0.86	4.1	4.7	0.0106

ND = not detected.
NA = not analysed.
*Except for sand where dry concentrations apply.
†See section 3.3 for definition.

4.3 Capenhurst, Cheshire

The main function of the Capenhurst Works is enrichment of uranium. Radioactive waste arisings, mainly of uranium and its daughter products, are very small; the Works have an authorisation to dispose of liquid wastes to the Rivacre Brook. Uranium recovered from irradiated fuel is also recycled; this may contain small quantities of fission products, of which technetium-99 is the only component of potential significance. Waste arisings in this second category are again very low; their disposal to Liverpool Bay from the North Wirral outfall at Meols is regulated by authorisation. It is not expected that the environmental consequences of these small disposals would be detectable above background levels due both to natural sources of radioactivity and to Sellafield discharges. However, we have established an environmental monitoring programme related to the potentially critical pathway due to consumption of locally-caught shellfish. *Fucus* seaweed is also sampled, being a good indicator for technetium-99. It is to be noted that the programme is much more extensive than is technically justified by the potential radiological hazard from Capenhurst discharges.

Results for 1985 are presented in Table 17. The concentrations of artificial radioactivity are mainly due to Sellafield discharges and are consistent with values to be expected at this distance from Sellafield. Technetium-99 concentrations continued to be low, reflecting the much reduced discharges of technetium-99 from Sellafield because decay-stored liquors were not being released. Discharges of technetium-99 from Meols which were at a low percentage of the authorised limit in 1984 decreased to an even lower level in 1985. Exposure of critical shellfish consumers in the vicinity of the Wirral in 1985 amounted to less than 0.1 mSv, within the ICRP-recommended principal dose limit of 1 mSv year^{-1} for members of the public. This exposure was mainly due to radiocaesium and transuranic nuclides from Sellafield; only a tiny fraction was due to technetium-99, which was almost entirely from Sellafield discharges.

Table 18(a) Radioactivity in environmental materials in the vicinity of Chapelcross, 1985

Material	Sampling point	No. of sampling observations†	Mean radioactivity concentration (wet)*, Bq kg^{-1}							
			Total beta	^{60}Co	^{95}Zr + ^{95}Nb	^{106}Ru	^{134}Cs	^{137}Cs	^{154}Eu	^{155}Eu
Flounder	Seafield	4	250	ND	ND	ND	4.4	190	ND	ND
Salmon	"	1	140	"	"	"	ND	3.1	"	"
Sea trout	"	1	180	"	"	"	3.2	96	"	"
Shrimps	"	4	130	"	"	1.4	2.2	60	"	"
Fucus vesiculosus	"	4	460	1.0	0.3	6.5	2.7	100	"	"
Silt	"	5	1900	3.6	53	320	22	1100	4.4	1.8
Sand	"	3	1100	1.4	8.2	75	10	540	1.2	ND

Material	Sampling point	No. of sampling observations†	Mean radioactivity concentration (wet)*, Bq kg^{-1}				
			^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm
Flounder	Seafield	4	NA	NA	ND	NA	NA
Salmon	"	1	"	"	"	"	"
Sea trout	"	1	0.00011	0.00047	0.00048	ND	ND
Shrimps	"	4	NA	NA	ND	NA	NA
Fucus vesiculosus	"	4	0.66	3.1	2.9	0.0092	ND
Silt	"	5	29	130	160	ND	0.39
Sand	"	3	6.2	30	38	ND	0.14

ND = not detected.
NA = not analysed.
*Except for sediment where dry concentrations apply.
†See section 3.3 for definition.

4.4 Chapelcross, Dumfriesshire

At this establishment BNFL operates a magnox-type nuclear power station. Liquid waste arisings are discharged to the Solway Firth under authorisation of the Scottish Development Department. Discharges in 1985 were greater than in 1984 because of continuing pond cleaning operations, but were still well within authorised limits. There are two pathways leading to public radiation exposures which are of potential importance. These are internal irradiation from consumption of locally-caught fish and shellfish and external exposure from use of intertidal areas by fishermen and turf cutters; fishermen continue to constitute the critical group in view of their regular occupancy of intertidal areas and consumption of local seafood. Our monitoring, which is carried out on behalf of departments of the Scottish Office, continued to reflect these pathways. Samples of *Fucus vesiculosus,* as a useful indicator, are also analysed. The results of monitoring in 1985 are presented in Table 18(a) and (b).

Concentrations of artificial radionuclides in the Chapelcross vicinity are mostly due to Sellafield discharges, and the general levels given in Table 18(a) are consistent with values to be expected at this distance from Sellafield. Radiocaesium concentrations in 1985 were generally less than those in 1984, reflecting reductions in Sellafield discharges. Exposure of the critical group in 1985, making the maximising assumption of additivity of the two pathways, amounted to about 0.2 mSv, within the ICRP-recommended principal dose limit of 1 mSv year^{-1} for members of the public. The magnitude of the Chapelcross discharges indicate that the local contribution would have been a tiny fraction of this exposure; most of it is due to Sellafield discharges.

Table 18(b) Gamma dose rates in air at 1 m over intertidal areas in the vicinity of Chapelcross, 1985

Location and sediment type	No. of sampling observations†	μGy h^{-1}
Seafield (silt)	4	0.16
Seafield (merse)	4	0.16
Torduff Point (silt)	4	0.14
Dornoch Brow (silt)	4	0.11
Dornoch Brow (merse)	4	0.15

†See section 3.3 for definition.

5. United Kingdom Atomic Energy Authority

We regularly monitor the environmental impact of liquid radioactive discharges from two UKAEA sites. These are the Atomic Energy Establishment, Winfrith and the Dounreay Nuclear Power Development Establishment. Liquid radioactive wastes also arise at the Atomic Energy Research Establishment, Harwell. In common with such wastes from other nuclear establishments in the Thames Valley area, these are discharged into the River Thames, and the critical exposure pathway is from drinking water. Monitoring in respect of these discharges is therefore carried out by the DOE rather than by this Ministry.

5.1 Atomic Energy Establishment, Winfrith, Dorset

The principal source of liquid radioactive wastes at this establishment is the Steam Generating Heavy Water Reactor. Most of the activity is due to tritium from the moderator and coolant, but small amounts of activation products, including manganese-54, cobalt-60 and zinc-65, are removed during decontamination of the reactor pressure circuit. These wastes are disposed of under authorisation to deep water in Weymouth Bay. It is the activation products rather than tritium which are of greater, but still small, environmental significance. Reconcentration of activation products by shellfish, followed by local consumption, constitutes the critical exposure pathway; this is reflected in our monitoring programme. External gamma radiation dose rates are monitored in Poole Harbour where the fine silt has the potential to adsorb radioactivity. Monitoring of the indicator material *Fucus serratus* and of sediments from a number of locations along the south coast provides additional information on the distribution of activation products. Data are presented in Table 19.

The impact of Winfrith discharges was, as in previous years, mainly observed in the concentrations of activation products. In 1985 the total radiation dose to the critical group of fish and shellfish consumers near this establishment was low, at less than 0.03 mSv, or less than 3% of the ICRP-recommended principal dose limit of 1 mSv year^{-1}. External gamma radiation dose rates continued to be indistinguishable from natural background.

5.2 Dounreay Nuclear Power Development Establishment (DNPDE), Caithness

Liquid radioactive waste discharges from this establishment are made to the Pentland Firth under authorisation of the Scottish Development Department. Discharges include a minor contribution from the adjoining reactor site (Vulcan Naval Reactor Test Establishment) operated by the Ministry of Defence (Procurement Executive). In 1985, discharges from DNPDE were less than in 1984 following a period of plant refurbishment. Work carried out at the Vulcan site in 1985 necessitated greater discharges than in previous years, mainly of cobalt-60, but they were well within agreed limits. Our surveys near Dounreay are carried out on behalf of departments of the Scottish Office. Monitoring in 1985 was extended to include samples from Brims Ness, east of Dounreay, as well as from Sandside Bay which lies to the west.

A further survey of habits and consumption rates was carried out near Dounreay in 1985. This confirmed the existence of three potentially critical exposure pathways, two of which involve external radiation. The first of these is due to radioactivity adsorbed mainly on fine particulate matter becoming entrained on fishing gear which is regularly handled. This results in skin dose, mainly from beta particles, to the hands and forearms of fishermen. The most exposed group is represented by a small number of people who operate a salmon fishery from Sandside Bay, close to Dounreay. Our regular measurements in previous years have shown that at current rates of discharge the average dose rates on nets will be low. Monitoring by the UKAEA in 1985 has confirmed that the exposure of these fishermen remained low, at less than 0.01 mSv or less than 1% of the ICRP-recommended dose limit of 50 mSv year^{-1} for skin exposures (see sub-section 3.4).

The second potentially critical pathway arises also from the uptake of radioactivity by particulate material which accumulates in rocky areas of the foreshore and presents a potential source of exposure mainly to gamma radiation of those who visit these areas. Monitoring of the foreshore dose rates is also carried out by the UKAEA. Public radiation exposure via this pathway also remained low, at less than 0.01 mSv or less than 1% of the ICRP-recommended principal dose limit of 1 mSv year^{-1}.

The third potentially critical pathway involves internal exposure of consumers of locally-collected shellfish, particularly winkles; we sample winkles from Sandside Bay to enable this pathway to be kept under review. Additionally, as in previous years, limpets and seaweed were sampled as indicator materials. Results are presented in Table 20. Radiocaesium concentrations are mostly due to discharges from Sellafield. Other radionuclides detected, including transuranics, mainly reflect Dounreay discharges. Concentrations of radionuclides except for cobalt-60 were generally less than in 1984 reflecting the changes in discharges noted above. The radiological significance of shellfish consumption continued to be low; for high-rate winkle consumers the radiation dose was less than 0.05 mSv or 5% of the ICRP-recommended principal dose limit of 1 mSv year^{-1}.

Table 19 Radioactivity in environmental materials from the vicinity of Winfrith, 1985

Material	Sampling point	No. of sampling observations†	Mean radioactivity concentration (wet)*, Bq kg^{-1}						
			Total beta	^{54}Mn	^{58}Co	^{60}Co	^{65}Zn	^{106}Ru	^{137}Cs	^{144}Ce
Plaice	Weymouth Bay	2	93	0.1	ND	0.5	4.3	ND	0.2	ND
Flounder	Poole	1	94	ND	"	ND	ND	"	0.4	"
Crabs	Weymouth Bay	5	99	2.5	0.2	48	93	"	ND	"
Oysters	Poole	4	67	0.5	ND	2.2	72	"	"	"
Cockles	Poole	1	84	ND	"	32	ND	"	"	"
Scallops	Weymouth Bay	2	120	6.3	"	6.4	26	"	0.1	"
Fucus serratus	Arish Mell	1	260	27	16	170	62	"	0.9	"
	Kimmeridge	2	210	20	10	110	35	"	0.2	"
	Swanage	2	330	16	14	148	39	"	ND	"
	Hengistbury Head	2	280	9.1	12	130	23	"	0.1	"
	Bognor Regis	2	200	0.4	ND	15	1.0	"	0.3	"
	Sandgate	2	350	0.3	"	19	1.0	1.4	0.7	"
	Weymouth	2	230	8.2	2.6	57	14	ND	ND	"
	Chesil	2	190	0.1	ND	3.2	0.5	"	0.2	"
	Lyme Regis	2	210	ND	"	1.6	ND	"	0.2	"
Silt	Kimmeridge	1	760	9.4	4.4	100	38	"	5.3	13
	Poole Harbour	5	570	5.4	0.5	46	1.9	"	7.3	ND
	Calshot	2	810	3.5	ND	53	7.0	"	9.0	"
	Hardway	2	720	3.8	"	46	2.5	"	5.9	"
	Littlehampton	2	520	0.5	"	17	ND	"	6.0	"
	Rye Harbour	2	650	1.8	"	20	"	7.1	4.3	"
Sand	Arish Mell	1	32	0.8	"	12	3.0	ND	ND	"
	Kimmeridge	2	120	1.4	"	17	15	"	0.8	1.8

Table 19 Continued

Material	Sampling point	No. of sampling observations†	Mean radioactivity concentration (wet)*, Bq kg^{-1}					
			^{155}Eu	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm
Plaice	Weymouth Bay	2	ND	NA	NA	ND	NA	NA
Flounder	Poole	1	"	"	"	"	"	"
Crabs	Weymouth Bay	5	"	"	"	"	"	"
Oysters	Poole	4	"	"	"	"	"	"
Cockles	Poole	1	"	"	"	"	"	"
Scallops	Weymouth Bay	2	"	0.0046	0.016	0.0049	0.00052	0.00052
Fucus serratus	Arish Mell	1	"	NA	NA	ND	NA	NA
	Kimmeridge	2	"	"	"	"	"	"
	Swanage	2	"	"	"	"	"	"
	Hengistbury Head	2	"	"	"	"	"	"
	Bognor Regis	2	"	"	"	"	"	"
	Sandgate	2	"	"	"	"	"	"
	Weymouth	2	"	"	"	"	"	"
	Chesil	2	"	"	"	"	"	"
	Lyme Regis	2	"	"	"	"	"	"
Silt	Kimmeridge	1	1.9	"	"	"	"	"
	Poole Harbour	5	ND	0.22	0.95	0.58	0.015	0.015
	Calshot	2	"	NA	NA	ND	NA	NA
	Hardway	2	1.2	"	"	"	"	"
	Littlehampton	2	ND	"	"	"	"	"
	Rye Harbour	2	"	"	"	"	"	"
Sand	Arish Mell	1	"	"	"	"	"	"
	Kimmeridge	2	0.5	"	"	"	"	"

Mean gamma dose rate in air at 1 m over intertidal sediments in Poole Harbour (2 sampling observations†): 0.076 μGy h^{-1}

ND = not detected.
NA = not analysed.
*Except for sediment where dry concentrations apply.
†See section 3.3 for definition.

Table 20 Radioactivity in environmental materials from the vicinity of Dounreay, 1985

Sampling point and material	No. of sampling observations†	Mean radioactivity concentration (wet), Bq kg^{-1}									
		Total beta	^{54}Mn	^{58}Co	^{60}Co	^{95}Zr + ^{95}Nb	^{106}Ru	^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs
Sandside Bay											
Winkles	4	130	ND	ND	14	ND	24	50	ND	ND	1.7
Limpets	2	310	0.5	"	6.2	"	48	24	0.6	"	4.0
Fucus vesiculosus	3	390	4.6	0.3	89	0.7	3.2	4.8	ND	0.1	7.4
Fucus serratus	3	360	3.8	0.3	55	ND	3.5	4.5	"	ND	6.6
Shell sand	4	380	ND	ND	1.6	"	8.8	ND	ND	"	11
Brims Ness											
Limpets	3	130	0.2	"	21	"	33	25	"	"	2.4
Fucus vesiculosus	1	300	2.6	"	12	"	6.1	6.8	"	"	5.4
Fucus spiralis	1	320	3.8	"	80	"	ND	3.6	"	"	ND

Sampling point and material	No. of sampling observations†	Mean radioactivity concentration (wet), Bq kg^{-1}								
		^{144}Ce	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm
Sandside Bay										
Winkles	4	7.2	ND	ND	0.36	1.1	21	2.2	0.30	0.16
Limpets	2	27	"	0.9	0.80	2.5	51	6.0	1.1	0.041
Fucus vesiculosus	3	4.3	"	0.7	NA	NA	NA	1.6	NA	NA
Fucus serratus	3	6.8	"	0.4	"	"	"	1.5	"	"
Shell sand	4	25	5.1	6.8	5.7	20	250	25	0.75	0.39
Brims Ness										
Limpets	3	19	ND	0.9	0.47	1.4	26	7.1	0.85	0.63
Fucus vesiculosus	1	15	"	ND	NA	NA	NA	4.6	NA	NA
Fucus spiralis	1	ND	"	"	"	"	"	ND	"	"

ND = not detected.
NA = not analysed.
†See section 3.3 for definition.

6. Nuclear power stations operated by the electricity boards

All but two of these power stations are in England or Wales and are operated by the Central Electricity Generating Board. The power station at Hunterston is operated by the South of Scotland Electricity Board. Results are also presented for measurements made near the second Scottish nuclear power station which is presently under construction at Torness.

6.1 Berkeley, Gloucestershire and Oldbury, Avon

Liquid radioactive wastes from both of these stations are generally similar in composition and are discharged to the same stretch of the Severn Estuary. The stations are therefore considered together for the purpose of our environmental monitoring. The two potentially critical pathways for public radiation exposure are internal irradiation following consumption of locally-caught fish and shellfish, and external exposure from occupancy of muddy intertidal areas. We therefore analyse samples of fish and shellfish and monitor gamma dose rates over silt and sand. In addition, measurements of external exposure are supported by analyses of intertidal mud, and *Fucus vesiculosus* is collected as an indicator material.

Data for 1985 are presented in Table 21. The only artificial radioactivity detected in fish and shellfish was due to radiocaesium. Concentrations of radiocaesium represent the combined effect of discharges from the stations and fallout, and possibly include a small Sellafield-derived component, but apportionment is difficult at the low levels detected. Radiation exposure of the critical group of fish and shellfish consumers was very low, at less than 0.002 mSv or 0.2% of the ICRP-recommended principal dose limit of 1 mSv year^{-1}. Very small concentrations of other artificial radionuclides, in addition to radiocaesium, were detected in mud and seaweed but taken together were of negligible radiological significance. Directly-measured gamma dose rates over intertidal mud continued to be indistinguishable from the natural background.

Table 21 Radioactivity in environmental materials and gamma dose rates near Berkeley and Oldbury nuclear power stations, 1985

Material	No. of sampling observations†	Mean radioactivity concentration (wet)*, Bq kg^{-1}						
		Total beta	^{54}Mn	^{60}Co	^{65}Zn	^{134}Cs	^{137}Cs	^{155}Eu
Flounders	3	59	ND	ND	ND	ND	2.4	ND
Grey mullet	1	118	"	"	"	"	1.9	"
Eels	1	63	"	"	"	"	0.3	"
Shrimps	1	120	"	"	"	"	2.1	"
Fucus vesiculosus	2	240	1.3	4.3	1.2	1.7	24	"
Mud: area of outfalls	4	790	ND	ND	ND	1.5	55	0.7
Guscar rock	2	970	"	"	"	2.7	76	4.0

Mean gamma dose rate in air at 1 m over intertidal mud (10 sampling observations†): 0.093 μGy h^{-1}

ND = not detected.
*Except for mud where dry concentrations apply.
†See section 3.3 for definition.

Table 22 Radioactivity in environmental materials and gamma dose rates near Bradwell nuclear power station, 1985

Material	No. of sampling observations†	Mean radioactivity concentration (wet)*, Bq kg^{-1}						
		Total beta	^{54}Mn	^{60}Co	^{65}Zn	^{106}Ru	^{134}Cs	^{137}Cs
Mixed fish	7	105	ND	ND	ND	ND	0.06	4.3
Oysters	2	99	"	"	7.5	"	ND	1.2
Fucus vesiculosus	2	260	"	1.5	ND	"	0.2	6.9
Sediment	4	860	1.0	7.9	"	6.3	4.0	62

Material	No. of sampling observations†	Mean radioactivity concentration (wet)*, Bq kg^{-1}					
		^{155}Eu	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm
Mixed fish	7	ND	NA	NA	ND	NA	NA
Oysters	2	"	0.00048	0.0021	0.0050	0.00020	0.00018
Fucus vesiculosus	2	0.2	NA	NA	ND	NA	NA
Sediment	4	3.1	"	"	"	"	"

Mean gamma dose rate in air at 1 m over intertidal sediments (6 sampling observations†): 0.080 μGy h^{-1}

ND = not detected.
NA = not analysed.
*Except for sediment where dry concentrations apply.
†See section 3.3 for definition.

6.2 Bradwell, Essex

Radioactive liquid effluent from this power station is discharged to the estuary of the River Blackwater. There are two potentially critical pathways, via consumption of locally-caught fish and shellfish, and external exposure of people who live in houseboats moored in muddy areas of the estuary. Our environmental monitoring reflects these pathways. Gamma dose rate measurements are supported by analyses of intertidal sediment, and *Fucus vesiculosus* is analysed as an indicator material.

Measurements for 1985 are summarised in Table 22. In fish, the only artificial radioactivity detected was due to radiocaesium, for which concentrations given represent the combined effects of discharges from the station, Sellafield discharges and fallout. Apportionment is difficult because of the low levels detected. The dose to members of the critical group of fish and shellfish consumers, however, was low, totalling less than 0.01 mSv or 1% of the ICRP-recommended principal dose limit of 1 mSv year^{-1}. The concentrations of zinc-65 and transuranic nuclides in oysters were low, such that the contributions to dose from these nuclides remained small. Concentrations of artificial radionuclides detected in mud and seaweed were also low and of negligible radiological significance. Gamma dose rates, as directly measured, were indistinguishable from the natural background.

6.3 Dungeness, Kent

There are two, essentially separate, "A" and "B" nuclear power stations on this site: the "A" station is powered by magnox-type reactors and the "B" station by AGRs. Discharges from both "A" and "B" stations are made via the same outfall and for the purposes of our environmental monitoring are considered together. There are two potentially critical radiation exposure pathways as a result of liquid radioactive waste discharges: internal irradiation due to consumption of locally-caught fish, and external exposure from occupancy of the foreshore. Our monitoring programme therefore includes analyses of fish and shellfish and gamma dose rate surveys of the intertidal areas. Samples of sediment are also collected and analysed. Local whelks and seaweed have been analysed mainly for their value as indicator materials. The results for 1985 are given in Table 23.

Concentrations of caesium-137 in fish are attributable to discharges from the station and from Sellafield, with a small contribution due to fallout. Apportionment is difficult at these low levels. Trace levels of cobalt-60 and zinc-65 in some materials are likely to be due to discharges from AEE Winfrith rather than Dungeness, as demonstrated by the indicator sampling programme described in sub-section 5.1. Trace amounts of ruthenium-106 were also detected in silt and seaweed. The results of our monitoring in the Channel Islands (section 9) shows that the French reprocessing plant at Cap de la Hague may be the source of this nuclide. However, the radiation dose to members of the critical group of fish consumers near Dungeness was very low, at less than 0.002 mSv or 0.2% of the ICRP-recommended principal dose limit of 1 mSv year^{-1}. Gamma dose rates over sand were indistinguishable from natural background.

Table 23 Radioactivity in environmental materials and gamma dose rates near Dungeness nuclear power station, 1985

Material	No. of sampling observations†	Mean radioactivity concentration (wet)*, Bq kg^{-1}						
		Total beta	^{54}Mn	^{60}Co	^{65}Zn	^{106}Ru	^{134}Cs	^{137}Cs
Plaice	2	110	ND	ND	ND	ND	ND	1.1
Whelks	1	91	"	2.2	2.0	"	"	0.5
Fucus serratus	2	350	0.3	19	1.0	1.4	"	0.7
Sand	2	270	0.4	4.2	ND	ND	0.3	1.6
Silt	2	650	1.8	20	"	7.1	ND	4.3

Mean gamma dose rate in air at 1 m over intertidal sand (7 sampling observations†): 0.072 μGy h^{-1}

Mean gamma dose rate in air at 1 m over intertidal silt in Rye Harbour (2 sampling observations†): 0.074 μGy h^{-1}

ND = not detected.
*Except for sediment where dry concentrations apply.
†See section 3.3 for definition.

6.4 Hartlepool, Cleveland

This twin-AGR station came into operation in 1983 and discharges of liquid radioactive wastes were still small in 1985 (Table 1). Potentially critical pathways of radiation exposure for the public near this station are internal irradiation following consumption of local fish and shellfish and external exposure from occupancy of intertidal areas. Collectors of small coal, which is washed ashore along this stretch of coast, account for the highest beach occupancies, but the highest external exposures are likely to be to fishermen who operate in muddy areas near the mouth of the Tees.

Results of our monitoring programme carried out in 1985 are shown in Table 24. Concentrations of radiocaesium and transuranics were mainly due to discharges from Sellafield and to fallout; any effects of station operation were not detectable above the background due to these sources. The radiation exposure of the critical group of local fish and shellfish consumers was low, at less than 0.02 mSv or 2% of the ICRP-recommended principal dose limit of 1 mSv year^{-1}. Gamma radiation dose rates over intertidal sediments continued to be indistinguishable from natural background.

6.5 Heysham, Lancashire

This establishment will comprise two, essentially separate, nuclear power stations both powered by AGRs. The first station came into operation in 1983; the second is still under construction. Discharges of liquid radioactive waste in 1985 were still small (Table 1) and of negligible radiological significance. The potentially critical radiation exposure pathways are due to internal irradiation following consumption of locally-caught fish and shellfish and external exposure from occupancy of intertidal areas. Our monitoring programme includes analyses of fish and shellfish and measurements of beach gamma dose rates. Samples of sediment are also analysed, and *Fucus vesiculosus* is monitored as an indicator material. Samphire is also collected and analysed because of its potential use as a foodstuff.

The results for 1985 are given in Table 25. These almost entirely reflect discharges from Sellafield; the magnitude of discharges from the station indicate that its contribution would have been but a small fraction of the measured levels and undetectable above the Sellafield-derived background. Estimates of the radiation exposure in 1985 of members of the critical group of fish and shellfish consumers associated with commercial fisheries (which include the Morecambe Bay area) are given in sub-section 4.1.1. External exposure of members of the public was at most about 0.1 mSv, within the ICRP-recommended principal dose limit of 1 mSv year^{-1}. Concentrations of radioactivity in samphire were of negligible radiological significance.

6.6 Hinkley Point, Somerset

At this establishment there are two essentially separate "A" and "B" nuclear power stations; the "A" station is powered by magnox-type reactors and the "B" station by AGRs. Tritium discharges from the "A" station increased in 1985 (Table 1) as a result of use of oxygen in the coolant circuit to remove corrosion products, but

Table 24 Radioactivity in environmental materials and gamma dose rates near Hartlepool nuclear power station, 1985

Material	No. of sampling observations†	Mean radioactivity concentration (wet)*, Bq kg^{-1}						
		Total beta	^{134}Cs	^{137}Cs	^{155}Eu	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am
Cod	2	120	0.1	11	ND	NA	NA	ND
Plaice	2	88	ND	3.0	"	"	"	"
Shrimps	3	96	"	2.5	"	0.00052	0.0024	0.0032
Crabs	3	80	"	1.3	"	0.00044	0.0022	0.0015
Winkles	3	95	"	1.5	"	NA	NA	ND
Fucus spp.	3	220	"	2.7	"	"	"	"
Sand/coal	4	220	"	7.1	"	"	"	"
Silt	4	790	1.1	70	1.2	"	"	"

Mean gamma dose rate in air at 1 m over intertidal sediment (12 sampling observations†): 0.089 μGy h^{-1}

NA = not analysed.
ND = not detected.
*Except for sand and silt where dry concentrations apply.
†See section 3.3 for definition.

Table 25 Radioactivity in environmental materials and gamma dose rates near Heysham nuclear power station, 1985

Material	No. of sampling observations†	Mean radioactivity concentration (wet)*, Bq kg^{-1}							
		Total beta	^{60}Co	^{95}Zr + ^{95}Nb	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce
Plaice	4	130	ND	ND	ND	ND	1.8	55	ND
Whitebait	1	180	"	"	"	"	1.6	55	"
Shrimps	4	130	"	"	2.4	"	2.3	63	"
Cockles	4	241	4.5	"	69	"	0.4	32	"
Mussels	4	125	0.5	"	43	"	0.4	19	"
Fucus vesiculosus	4	600	1.1	0.6	10	0.4	3.9	95	"
Samphire	1	92	0.2	ND	5.4	ND	0.6	17	"
Sediment:									
Sunderland Point	4	2000	6.3	31	520	"	26	960	11
Half Moon Bay	4	1300	4.9	26	360	"	17	650	5.6
Morecambe Pier	4	680	0.9	13	120	"	7.5	270	4.7

Material	No. of sampling observations†	Mean radioactivity concentration (wet)*, Bq kg^{-1}						
		^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm
Plaice	4	ND	ND	NA	NA	ND	NA	NA
Whitebait	1	"	"	0.086	0.40	0.50	ND	0.0016
Shrimps	4	"	"	0.0088	0.044	0.057	"	0.00018
Cockles	4	"	"	1.4	6.1	13	"	0.051
Mussels	4	"	"	0.32	1.5	2.1	"	0.0076
Fucus vesiculosus	4	"	"	1.0	4.6	1.9	"	0.0090
Samphire	1	"	"	NA	NA	2.6	NA	NA
Sediment:								
Sunderland Point	4	4.3	4.5	"	"	140	"	"
Half Moon Bay	4	2.9	ND	21	99	130	0.20	0.41
Morecambe Pier	4	ND	"	NA	NA	31	NA	NA

Mean gamma dose rate in air at 1 m over intertidal sediment:
Heysham vicinity (20 sampling observations†): 0.11 μGy h^{-1}
Sunderland Point (8 sampling observations†): 0.15 μGy h^{-1}

NA = not analysed.
ND = not detected.
*Except for sediments for which dry concentrations apply.
†See section 3.3 for definition.

Table 26 Radioactivity in environmental materials and gamma dose rates near Hinkley Point nuclear power station, 1985

Material	No. of sampling observations†	Mean radioactivity concentration (wet)*, Bq kg^{-1}									
		Total beta	^{54}Mn	^{60}Co	^{65}Zn	^{90}Sr	^{134}Cs	^{137}Cs	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am
Flounders	2	130	ND	ND	ND	NA	0.1	3.9	NA	NA	ND
Eels	1	68	"	"	"	"	ND	3.0	"	"	"
Shrimps	2	110	"	"	"	0.2	"	2.4	0.00041	0.0015	0.0015
Fucus vesiculosus	2	300	3.5	0.6	1.7	NA	1.4	21	NA	NA	ND
Sediment	2	730	1.8	0.5	ND	"	3.8	71	"	"	"

Mean gamma dose rate in air at 1 m over intertidal sediment (8 sampling observations†): 0.11 μGy h^{-1}

NA = not analysed.
ND = not detected.
*Except for sediment where dry concentrations apply.
†See section 3.3 for definition.

the increased discharges were of negligible radiological significance. Liquid radioactive waste discharges from both "A" and "B" stations are made via the same outfall and for the purposes of our environmental monitoring they are considered together. There are two potentially critical radiation exposure pathways associated with these discharges: consumption of locally-caught fish and shrimps gives rise to internal irradiation, while external exposure results from occupancy of the foreshore. Our monitoring programme includes analyses of locally-caught fish and shrimps. External exposure is monitored by means of gamma dose rate measurements, supported by analyses of sediment. In addition, *Fucus vesiculosus* is monitored as an indicator.

The results for 1985, presented in Table 26, indicate concentrations of radiocaesium representing the combined effect of discharges from the station and from Sellafield, in addition to fallout. Apportionment is difficult in view of the low levels detected. The radiation exposure of high-rate fish and shellfish consumers was low, at less than 0.01 mSv or less than 1% of the ICRP-recommended principal dose limit of 1 mSv year^{-1}. The concentrations in shrimps of transuranic nuclides from the station and from Sellafield were of negligible radiological significance. Gamma radiation dose rates over intertidal sediment close to the station were indistinguishable from the natural background.

6.7 Hunterston, Ayrshire

This establishment also comprises "A" and "B" stations, the latter being powered by AGRs. Liquid radioactive waste discharges are made to the Firth of Clyde under authorisation of the Scottish Development Department. There are two potentially critical radiation exposure pathways: fish and shellfish consumption leading to internal irradiation, and occupancy of intertidal areas leading to external exposure. We regularly monitor, on behalf of departments of the the Scottish Office, samples of fish and shellfish and carry out gamma dose rate measurements on the foreshore. Samples of sand are analysed together with *Fucus* seaweed as indicators. The results of monitoring in 1985 are shown in Table 27.

Table 27 Radioactivity in environmental materials and gamma dose rates near Hunterston nuclear power station, 1985

Material	No. of sampling observations†	Mean radioactivity concentration (wet)*, Bq kg^{-1}								
		Total beta	^{54}Mn	^{58}Co	^{59}Fe	^{60}Co	^{65}Zn	^{106}Ru	^{110m}Ag	^{134}Cs	^{137}Cs
Cod	4	150	ND	ND	ND	ND	ND	ND	ND	1.2	32
Grey mullet	1	130	"	"	"	"	"	"	"	1.7	32
Turbot (fish farm)	4	110	"	"	"	"	"	"	"	0.9	15
Cockles	4	46	"	"	"	6.7	0.5	1.6	"	ND	3.8
Winkles	4	130	4.7	"	"	8.7	9.3	7.4	1.1	1.2	11
Fucus spp.	4	340	12	0.1	0.3	8.6	9.0	8.8	0.2	5.7	34
Sand	4	300	2.7	ND	ND	3.0	0.4	2.5	ND	6.4	99

Material	No. of sampling observations†	Mean radioactivity concentration (wet)*, Bq kg^{-1}							
		^{144}Ce	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm
Cod	4	ND	ND	ND	NA	NA	ND	NA	NA
Grey mullet	1	"	"	"	"	"	"	"	"
Turbot (fish farm)	4	"	"	"	"	"	"	"	"
Cockles	4	"	"	"	0.094	0.27	0.33	0.019	0.049
Winkles	4	2.5	"	"	0.12	0.27	0.16	0.023	0.17
Fucus spp.	4	2.5	"	0.1	0.24	0.63	0.22	0.029	0.27
Sand	4	4.3	0.7	0.3	NA	NA	ND	NA	NA

Mean gamma dose rate in air at 1 m over intertidal sediment (12 sampling observations†): 0.12 μGy h^{-1}

NA = not analysed.
ND = not detected.
*Except for sand where dry concentrations apply.
†See section 3.3 for definition.

The concentrations of artificial radioactivity in this area are predominantly due to Sellafield discharges, the general values being consistent with those to be expected at this distance from Sellafield. Concentrations of radiocaesium declined in 1985 in line with the reducing trend in Sellafield discharges. The resulting exposure of members of the critical group of fish and shellfish consumers near Hunterston in 1985 was low, at about 0.03 mSv or 3% of the principal ICRP-recommended dose limit of 1 mSv year^{-1}. Radiocaesium concentrations detected in fish from farms which are supplied by station cooling water were lower than in fish caught in the open sea; this is because the farmed fish are fed on manufactured food which has a lower radioactivity concentration. The concentrations of activation products observed in molluscs, seaweed and sand were due to discharges from the "B" station. However, they gave rise to but a small fraction of the above exposure and their radiological significance was negligible.

Table 28 Radioactivity in environmental materials and gamma dose rates near Sizewell nuclear power station, 1985

	No. of sampling observations†	Mean radioactivity concentration (wet)*, Bq kg^{-1}			
		Total beta	^{60}Co	^{106}Ru	^{137}Cs
Plaice	1	100	ND	ND	1.4
Shrimps	1	110	"	"	2.7
Mussels	2	42	0.3	"	0.7
Oysters	2	90	ND	"	0.9
Silt	2	740	4.9	4.2	49

Mean gamma dose rate in air at 1 m over intertidal sand/shingle (10 sampling observations†): 0.061 μGy h^{-1}

Mean gamma dose rate in air at 1 m over intertidal silt in Southwold harbour (2 sampling observations†): 0.082 μGy h^{-1}

ND = not detected.
*Except for silt where dry concentrations apply.
†See section 3.3 for definition.

6.8 Sizewell, Suffolk

Radioactive liquid effluent from this station is discharged to the North Sea. Increased discharges of tritium in 1985 (Table 1) were due to leakage of boiler water to the coolant circuit, but were of negligible radiological significance. Our monitoring near Sizewell reflects the two potentially critical radiation exposure pathways of fish and shellfish consumption leading to internal irradiation, and occupancy of intertidal areas giving rise to external exposure (Leonard and Smith, 1982). The results of this monitoring in 1985 are shown in Table 28.

The radiocaesium concentrations in fish and shellfish represent the combined effect of discharges from the station and from Sellafield, as well as of fallout. Apportionment is difficult at the low levels detected. Trace levels of cobalt-60 and ruthenium-106 in some shellfish and silt are likely to have been due to discharges from the station, but their radiological significance was negligible. the total radiation exposure of local fish and shellfish consumers was low, at less than 0.01 mSv or 1% of the ICRP-recommended principal dose limit of 1 mSv year^{-1}. Gamma dose rates, as in previous years, were indistinguishable from the natural background.

6.9 Torness, East Lothian

This station, which will be powered by two AGRs, is not yet in operation. Our investigations have shown that potential critical pathways for radiation exposure of the public, likely to be associated with future liquid discharges, are internal irradiation from consumption of local fish and shellfish and external exposure from occupancy of inertidal areas. These pathways form the basis of our regular monitoring programme, which has commenced prior to station operation in order to establish background levels and reliable sources of

Table 29 Radioactivity in environmental materials and gamma dose rates near Torness nuclear power station, 1985

Material	No. of sampling observations†	Mean radioactivity concentration (wet)*, Bq kg^{-1}							
		Total beta	^{134}Cs	^{137}Cs	^{155}Eu	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{243}Cm + ^{244}Cm
Cod	1	110	ND	5.8	ND	NA	NA	ND	NA
Haddock	1	120	"	5.3	"	"	"	"	"
Whiting	1	110	0.3	7.8	"	"	"	"	"
Crabs	2	68	ND	1.4	"	"	"	"	"
Nephrops	2	99	"	4.3	"	0.00064	0.0031	0.0036	0.00002
Lobster	1	62	"	1.7	"	NA	NA	ND	NA
Winkles	2	93	"	1.6	"	"	"	"	"
Fucus spiralis	2	210	"	2.9	"	"	"	"	"
Fucus serratus	1	180	"	2.6	"	"	"	"	"
Silt	5	500	0.6	51	0.6	"	"	"	"
Fine sand	2	210	ND	7.6	ND	"	"	"	"

Mean gamma dose rate in air at 1 m over intertidal sediment (21 sampling observations†): 0.067 μGy h^{-1}

*Except for sediment where dry concentrations apply.
†See section 3.3 for definition.

supply of environmental materials. In 1985, samples of fish and shellfish were collected and analysed, and samples of seaweed and sediment were monitored as indicator materials. Measurements were also made of gamma dose rates over intertidal areas.

Results of this monitoring are shown in Table 29. The very low concentrations of artificial radionuclides are due to fallout and the distant effects of Sellafield discharges. The measured gamma dose rate is consistent with that to be expected from natural background.

6.10 Trawsfynydd, Gwynedd

Discharges from this station are made to the freshwater Lake Trawsfynydd under authorisation of the Welsh Office. Because of the limited volume of water available for dispersion they are of greater radiological significance than those from other UK nuclear power stations which discharge to estuarine or coastal waters. The critical radiation exposure pathway is due to consumption of fish caught in the lake, leading to internal irradiation; the important radionuclides are those of caesium and, to a lesser extent, strontium-90.

Table 30 Radioactivity in environmental materials near Trawsfynydd nuclear power station, 1985

Material	No. of sampling observations†	Mean radioactivity concentration (wet)*, Bq kg^{-1}							
		Total beta	^{54}Mn	^{60}Co	^{90}Sr	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce
Brown trout	6	350	ND	ND	3.5	ND	33	260	ND
Rainbow trout	7	120	"	"	1.9	"	2.9	24	"
Rainbow trout (hatchery)	1	120	NA	NA	NA	NA	ND	6.1	NA
Perch	2	880	ND	ND	15	ND	81	730	ND
Mud	2	8200	"	37	NA	480	59	7800	"
Peat	2	2400	"	7.5	"	160	17	1500	"
Fontinalis									
Afon Prysor	2	170	"	ND	"	ND	ND	3.3	"
Gwylan Stream	2	410	3.4	24	"	54	2.4	54	9.4
Water									
Hot Lagoon	4	NA	NA	NA	0.21	NA	0.035	0.21	NA
Cold Lagoon	4	"	"	"	0.14	"	0.028	0.18	"

Material	No. of sampling observations†	Mean radioactivity concentration (wet)*, Bq kg^{-1}						
		^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm
Brown trout	6	ND	ND	0.00011	0.00041	0.00044	0.000029	0.000005
Rainbow trout	7	"	"	0.00027	0.0012	0.0013	0.000045	0.000017
Rainbow trout (hatchery)	1	NA	NA	NA	NA	ND	NA	NA
Perch	2	ND	ND	0.00012	0.00049	0.00063	0.00005	0.00001
Mud	2	24	16	0.020	0.082	0.12	0.0015	0.0024
Peat	2	ND	4.1	0.0051	0.026	0.033	0.0003	0.00062
Fontinalis								
Afon Prysor	2	"	1.1	NA	NA	ND	NA	NA
Gwylan Stream	2	"	1.2	"	"	"	"	"
Water								
Hot Lagoon	4	NA	NA	"	"	NA	"	"
Cold Lagoon	4	"	"	"	"	"	"	"

Mean gamma dose rate in air at 1 m over areas near lake shoreline (6 sampling observations†): 0.097 μGy h^{-1}

NA = not analysed.
ND = not detected.
*Except for mud and peat where dry concentrations apply.
†See section 3.3 for definition.

Species of fish consumed are brown trout, rainbow trout and, in very small amounts, perch. Perch and some brown trout are indigenous to the lake but rainbow trout and a smaller number of brown trout are regularly introduced from a hatchery. Because of the limited period which they spend in the lake, introduced fish generally exhibit lower radiocaesium concentrations than do indigenous fish.

Our monitoring programme reflects the exposure pathways. Samples of rainbow trout, brown trout and perch are regularly analysed. As part of our research programme, mud and peat from the lake bed are also analysed; these materials contribute radioactivity to the fishes's diet. Additional information is gained from analyses of the moss *Fontinalis* which is a sensitive indicator for a number of radionuclides, and from analyses of lake water. Gamma dose rates over lake shoreline areas are also kept under review. The results of these measurements for 1985 are shown in Table 30.

Radiocaesium discharges increased in 1985 as compared with 1984 (Table 1). However, there were only small increases in concentrations of radiocaesium in lake water, and concentrations in trout were less than in 1984 (Hunt, 1985a). This is thought to be due to improved dispersion conditions and shorter residence times of fish in the lake after stocking. Radiocaesium concentrations in the indigenous perch increased slightly in 1985 in line with the behaviour of the concentrations in lake water, but the amounts of perch eaten are so small that they are of much lower radiological significance than trout. As in previous years, low concentrations of transuranic nuclides from station operations were observed in fish; these continued to be of negligible radiological significance.

It is estimated that in 1985 members of the critical group of fish consumers received at most about 0.21 mSv, within the ICRP-recommended principal dose limit of 1 mSv year^{-1}. This reduced exposure as compared with 1984 (Hunt, 1985a) reflects the lower radiocaesium concentrations in trout noted above. Gamma dose rates were consistent with those to be expected from natural background.

Table 31 Radioactivity in environmental materials and gamma dose rates near Wylfa nuclear power station, 1985

Material	No. of sampling observations†	Mean radioactivity concentration (wet)*, Bq kg^{-1}					
		Total beta	^{60}Co	^{106}Ru	^{134}Cs	^{137}Cs	^{154}Eu
Crabs	2	73	ND	ND	ND	7.3	ND
Lobsters	2	120	"	"	"	7.1	"
Mussels	3	100	0.1	6.6	0.1	8.9	"
Winkles	2	76	ND	ND	ND	4.4	"
Fucus vesiculosus	4	250	"	0.4	0.2	9.3	"
Sediment: Cemlyn Bay	4	1700	1.1	58	10	700	1.2

Material	No. of sampling observations†	Mean radioactivity concentration (wet)*, Bq kg^{-1}					
		^{155}Eu	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm
Crabs	2	ND	NA	NA	ND	NA	NA
Lobsters	2	"	"	"	0.29	"	"
Mussels	3	"	0.026	0.12	0.31	ND	0.0010
Winkles	2	"	0.065	0.31	0.38	"	0.0013
Fucus vesiculosus	4	"	NA	NA	0.17	NA	NA
Sediment: Cemlyn Bay	4	2.7	13	58	76	0.24	0.17

Mean gamma dose rate in air at 1 m over intertidal sediment (11 sampling observations†): 0.088 μGy h^{-1}

NA = not analysed.
ND = not detected.
*Except for sediments where dry concentrations apply.
†See section 3.3 for definition.

6.11 Wylfa, Gwynedd

Liquid radioactive wastes from this station are discharged to the Irish Sea under authorisation of the Welsh Office. The two potentially critical pathways are due to consumption of local fish and shellfish and to occupancy of intertidal areas. Monitoring is carried out in respect of these pathways. Samples of sediment are analysed in support of the gamma dose rate measurements, and the indicator seaweed *Fucus vesiculosus* is also sampled. The results of monitoring in 1985 are presented in Table 31.

Any effects of discharges from this station are masked by Sellafield-derived radioactivity. Concentrations of artificial radionuclides in environmental materials were consistent with those to be expected at this distance from Sellafield, and generally decreased in 1985, particularly for radiocaesium, in line with the reducing trend in Sellafield discharges. The total radiation exposure of members of the critical group in 1985 was less than 0.1 mSv, within the ICRP-recommended principal dose limit of 1 mSv year^{-1}. The magnitude of discharges from the station indicate that the local contribution would have been a small fraction of this exposure. Gamma dose rates continued to be indistinguishable from the natural background.

7. Naval establishments

Liquid wastes containing small quantities of radioactivity are discharged from the establishments at Devonport, Faslane and Rosyth, all of which are operated by the Ministry of Defence (Navy Department). There were only small discharges from Chatham during 1985 as a result of decommissioning; discharges due to routine operations had ceased in 1983 prior to closure of this establishment. The US naval base at Holy Loch discharges small quantities of radioactive waste. We carry out monitoring programmes near all these establishments, in the case of Faslane and Rosyth on behalf of departments of the Scottish Office.

The critical pathway for public radiation exposure near these establishments is via external exposure from occupancy of intertidal areas, the nuclide of main importance being cobalt-60. We therefore regularly carry out measurements of gamma dose rates: these are supported by analyses of sediments. Indicator shellfish and seaweed are also analysed where appropriate.

Results of monitoring in 1985 are presented in Table 32. The small concentrations of cobalt-60 mainly reflect discharges from the establishments; levels of other artificial nuclides are due to fallout and to discharges from Sellafield. Gamma dose rates over intertidal sediments remained indistinguishable from the natural background, such that public radiation exposure was very low, at less than 0.01 mSv year^{-1}. This represents less than 1% of the ICRP-recommended principal dose limit of 1 mSv year^{-1}.

Table 32 Radioactivity in environmental materials and gamma dose rates near naval establishments, 1985

Establishment	Material	No. of sampling observations†	Mean radioactivity concentration (wet)*, Bq kg^{-1}				Mean gamma dose rate in air at 1 m	
			^{60}Co	^{134}Cs	^{137}Cs	^{155}Eu	No. of sampling observations†	μGy h^{-1}
Chatham	Sediment	4	7.1	0.5	40	ND	10	0.076
Devonport	Mussels	2	0.1	ND	ND	"	NP	NP
	Fucus vesiculosus	2	0.5	"	0.2	"	"	"
	Sediment	6	1.1	"	6.5	1.0	12	0.087
Faslane	Sediment	4	36	2.2	110	ND	10	0.082
Rosyth	Sediment	2	2.5	0.7	39	1.8	4	0.076
Holy Loch	Sediment	2	1.6	1.5	77	ND	12	0.080

ND = not detected.
NP = not applicable.
*Except for sediment where dry concentrations apply.
†See section 3.3 for definition.

8. Amersham International plc

Amersham International plc is engaged in the manufacture of radioactive materials for use in medicine, research and industry. The company's parent establishment is located in Amersham, Buckinghamshire, from which radioactive discharges are made into the catchment of the River Thames. As explained in section 5, environmental monitoring in respect of these discharges is carried out by the DOE. A further laboratory, situated near Cardiff, is engaged in the production of labelled compounds used in research and of diagnostic kits used in medicine for the *in vitro* testing of clinical samples. An authorisation issued by the Welsh Office regulates disposals of liquid radioactive wastes from this establishment to a sewer discharging into the Severn Estuary.

Our monitoring programme, carried out on behalf of the Welsh Office, reflects the two potentially critical pathways due to consumption of fish and shellfish and to external exposure over muddy intertidal areas. Measurements of external exposure are supported by analyses of intertidal sediment, and *Fucus* seaweed is collected as an indicator material. The radiological consequences of discharges from this establishment are small and mainly due to carbon-14. Additional artificial radionuclides detected are due to fallout, other nuclear facilities which discharge small amounts of radioactive wastes to the Severn Estuary and the Bristol Channel, and possibly to Sellafield.

The results of monitoring in 1985 are presented in Table 33. None of the separate nuclides listed was processed or discharged by this establishment in 1985:

Table 33 Radioactivity in environmental materials and gamma dose rates near the outfall of the sewer serving Amersham International plc, Cardiff, 1985

Material	No. of sampling observations†	Mean radioactivity concentration (wet)*, Bq kg^{-1}			
		Total beta	^{131}I	^{134}Cs	^{137}Cs
Flounders	2	650	ND	ND	1.1
Mussels	1	290	"	"	1.1
Fucus spiralis	4	180	8.7	"	0.9
Sediment	4	1 000	ND	1.7	62

Mean gamma dose rate in air at 1 m over intertidal sediment (4 sampling observations†): 0.093 μGy h^{-1}

ND = not detected.
*Except for sediment where dry concentrations apply.
†See section 3.3 for definition.

Table 34 Radioactivity in marine environmental materials from the Channel Islands, 1985

Material	Sampling area	No. of sampling observations†	Mean radioactivity concentration (wet)*, Bq kg^{-1}							
			Total beta	^{60}Co	^{65}Zn	^{90}Sr	^{106}Ru	^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs
Ray	Guernsey	1	120	ND	ND	NA	ND	ND	ND	0.2	3.5
Sandeel	Guernsey	2	140	0.5	0.2	"	0.5	"	"	ND	0.6
Crabs	Guernsey	1	110	0.6	3.2	"	ND	"	"	"	0.6
	Jersey	1	74	1.7	0.8	"	2.5	1.1	"	"	0.3
Oysters	Jersey	1	89	1.7	5.4	"	10	1.4	"	"	ND
Limpets	Jersey	1	81	1.4	0.2	"	6.0	0.4	"	"	0.2
	Guernsey	1	75	1.0	ND	"	ND	ND	"	"	0.4
	Alderney	1	140	2.9	"	"	28	"	"	"	0.6
Porphyra	Jersey										
	Greve de Lecq	4	340	3.0	ND	"	25	"	"	"	ND
	La Rozel	4	200	1.2	"	"	17	"	"	"	0.2
	Guernsey										
	Fermain Bay	4	190	0.5	"	"	7.7	"	"	"	0.1
	Alderney										
	Quenard Point	4	260	2.4	"	"	78	"	"	"	0.4
Fucus serratus	Jersey										
	La Rozel	4	360	9.6	"	0.9	4.5	"	"	"	0.3
	Guernsey										
	Fermain Bay	4	370	5.5	"	0.5	5.6	"	"	"	0.4
	Alderney										
	Quenard Point	4	410	18	0.9	1.2	26	"	0.3	"	0.5
Sediment	Jersey										
	St Helier Harbour	1	830	12	ND	NA	85	"	4.4	1.9	15
	Guernsey										
	Bordeaux Harbour	1	440	0.6	"	"	ND	"	1.5	ND	3.3
	Alderney										
	Crabbe Harbour	1	480	1.6	"	"	18	"	5.4	0.8	5.2

Table 34 Continued

Material	Sampling area	No. of sampling observations†	Mean radioactivity concentration (wet)*, Bq kg^{-1}					
			^{144}Ce	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm
Ray	Guernsey	1	ND	0.00002	0.00011	0.0002	ND	ND
Sandeel	Guernsey	2	"	NA	NA	ND	NA	ND
Crabs	Guernsey	1	"	0.0006	0.0012	0.020	0.0012	0.012
	Jersey	1	"	0.0017	0.0051	0.013	0.0005	0.0071
Oysters	Jersey	1	"	0.010	0.021	0.019	0.0010	0.011
Limpets	Jersey	1	"	0.010	0.024	0.028	0.0010	0.012
	Guernsey	1	"	0.0040	0.011	0.012	0.0004	0.0050
	Alderney	1	"	0.016	0.022	0.070	0.0043	0.044
Porphyra	Jersey							
	Greve de Lecq	4	"	NA	NA	ND	NA	NA
	La Rozel	3	"	"	"	"	"	"
	Guernsey							
	Fermain Bay	4	"	"	"	"	"	"
	Alderney							
	Quenard Point	4	"	"	"	"	"	"
Fucus serratus	Jersey							
	La Rozel	4	"	0.029	0.057	0.032	0.0020	0.015
	Guernsey							
	Fermain Bay	4	"	0.027	0.060	0.032	0.0010	0.017
	Alderney							
	Quenard Point	4	0.3	0.072	0.10	0.096	0.0063	0.049
Sediment	Jersey							
	St Helier Harbour	1	19	1.4	3.4	3.9	0.12	1.7
	Guernsey							
	Bordeaux Harbour	1	ND	0.10	0.35	0.28	0.008	0.095
	Alderney							
	Crabbe Harbour	1	5.5	NA	NA	ND	NA	NA

NA = not analysed.
ND = not detected.
*Except for sediment where dry concentrations apply.
†See section 3.3 for definition.

their presence was therefore due to the combined background effects noted above. Small amounts of iodine-131 detected in seaweed are likely to have been due to discharges from a local hospital. Approximate concentrations of carbon-14 may be derived from the total beta concentrations after subtracting the contribution due to natural radionuclides (see Table 3) and the small effect of the separate artificial beta-emitting radionuclides. The exposure of the critical group of fish consumers in 1985 was low, at about 0.05 mSv, or 5% of the ICRP-recommended principal dose limit of 1 mSv year^{-1}. Gamma dose rates over sediment were indistinguishable from those to be expected from natural background.

9. Channel Islands monitoring

We have continued to analyse marine environmental samples provided by the Channel Islands States in surveillance of the effects of radioactive liquid discharges from the French reprocessing plant at Cap de la Hague. Fish and shellfish are monitored in relation to the internal irradiation pathway; sediment is analysed with relevance to external exposures. Seaweeds are sampled as indicator materials.

The results for 1985 are given in Table 34. Concentrations of caesium-137 in fish and shellfish were not significantly in excess of those to be expected from other sources, including fallout. The presence of transuranics and ruthenium-106 in environmental materials may be attributed to discharges from the plant at Cap de la Hague. However, the concentrations of artificial radionuclides in each of these materials were of negligible radiological significance.

Table 35 Summarised estimates of public radiation exposure from discharges of liquid radioactive waste in the UK, 1985

Establishment	Radiation exposure pathway	Critical group	Exposure[+], mSv
BRITISH NUCLEAR FUELS LIMITED			
Sellafield	Fish and shellfish consumption	Local fishing community	0.49 (0.73)*
		Commercial fishing community	0.26 (0.30)*
	External	Whitehaven boat dwellers	0.35
	Handling of fishing gear	Local fishing community	<0.3[‡]
	Porphyra/laverbread consumption	Consumers in South Wales	<0.01
Springfields	External	Houseboat dwellers	0.3[a]
Capenhurst (Meols outfall)	Shellfish consumption	Local fishing community	<0.1[a]
Chapelcross	Fish and shellfish consumption External	Local fishermen	0.2[a]
UNITED KINGDOM ATOMIC ENERGY AUTHORITY			
Winfrith	Fish and shellfish consumption	Local fishing community	<0.03
Dounreay	Handling of fishing gear	Local fishermen	<0.01[‡b]
	External	Local community	<0.01[b]
	Shellfish consumption	Local fishing community	<0.05[b]
NUCLEAR POWER STATIONS OPERATED BY THE ELECTRICITY BOARDS			
Berkeley and Oldbury	Fish and shellfish consumption External	Local fishing community	<0.002[b]
Bradwell	Fish and shellfish consumption	Local fishing community	<0.01[b]
	External	Houseboat dwellers	
Dungeness	Fish consumption External	Local fishing community	<0.002
Hartlepool	Fish and shellfish consumption	Local fishing community	<0.02[a]
	External	Coal collectors	<0.01[a]
Heysham	Fish and shellfish consumption	Local fishing community	0.26 (0.30)*[a]
	External		0.1[a]
Hinkley Point	Fish and shellfish consumption External	Local fishing community	<0.01[b]
Hunterston	Fish and shellfish consumption External	Local fishing community	0.03[a]
Sizewell	Fish and shellfish consumption External	Local fishing community	<0.01[b]
Trawsfynydd	Fish consumption	Local fishing community	0.21
Wylfa	Fish and shellfish consumption External	Local community	<0.1[a]
NAVAL ESTABLISHMENTS			
Chatham	External	Houseboat dwellers	<0.01
Devonport	External	Bait diggers	<0.01
Faslane	External	Boatyard workers	<0.01[b]
Rosyth	External	Dredgermen	<0.01[b]
Holy Loch	External	Local community	<0.01[b]
AMERSHAM INTERNATIONAL plc			
Cardiff	Fish and shellfish consumption External	Local fishing community	0.05

[+]Unless otherwise stated represents the committed effective dose equivalent, to be compared with the ICRP-recommended principal dose limit of 1 mSv year^{-1} or with the subsidiary limit of 5 mSv year^{-1} provided the lifetime average does not exceed 1 mSv year^{-1} (see section 3.4).

*See section 4.1.1. The first value is based on the gut transfer factor for plutonium used in ICRP Publication 30 (ICRP, 1979); the value using the enhanced factor follows in parentheses.

[‡]Exposure to skin, to be compared with the ICRP-recommended dose limit of 50 mSv year^{-1} (see section 3.4).

[a]Mainly due to discharges from Sellafield.

[b]Partly due to discharges from Sellafield.

10. Summary and conclusions

A summary of estimated public radiation exposures in 1985 resulting from liquid radioactive waste discharges from nuclear establishments which we monitor is presented in Table 35. The exposures are expressed in terms of the committed effective dose equivalents to, or as doses to skin of, members of the critical groups. Results for internal exposures incorporate the enhanced gut transfer factor for plutonium except where a more appropriate value is justified (sub-section 3.4).

Committed effective dose equivalents were all within the ICRP-recommended principal dose limit of 1 mSv $year^{-1}$ to members of the public. Discharges from Sellafield have, as in previous years, given rise to the highest exposures. The most important contributions to these exposures were due to transuranic radionuclides and ruthenium-106 from the reprocessing operations; a further contribution was from radiocaesium which is discharged mainly from the fuel element storage ponds. Details are given in sub-section 4.1.1. Exposures near Sellafield decreased in 1985 as compared with 1984, due to the reducing trend in discharges, despite an increase in consumption of locally-caught molluscan shellfish. This increase reflected a partial recovery in use of intertidal areas by shellfish collectors following the effect of Government advice after the Sellafield incident of November 1983. It should be noted that consumption rates could increase again in the next year or so, but it is considered unlikely that exposures, calculated using realistic parameters, will again exceed the 1 mSv $year^{-1}$ level. It is expected that the trend of reductions in discharges will continue in 1986 following the commissioning in 1985 of the site ion-exchange effluent plant (SIXEP) and the salt evaporator, but that thereafter discharges may fluctuate about these lower levels because of operational factors. The enhanced actinide removal plant will reduce discharges even further upon fulfilment of plans for its introduction in 1992. It is expected that exposures resulting from these discharges will continue to decline in line with predictions (Hunt, in press). Dose rates which were above the 1 mSv $year^{-1}$ level in the recent past have not occurred for long enough for lifetime exposure to have exceeded 1 mSv $year^{-1}$ on average, and thus the dose limitation objectives of ICRP will be met.

Radioactivity from Sellafield also contributed to exposures near many other nuclear establishments. Since apportionment of exposure to radioactivity of local origin is often difficult, the exposures from all sources (including the small contribution due to fallout) are quoted in Table 35, with appropriate footnotes.

As in previous years, collective doses from UK liquid radioactive discharges have also been considered. The most significant discharges giving rise to collective dose, compared with which all other discharges may be disregarded, were those from Sellafield, radiocaesium being the most significant component. Details are given in sub-section 4.1.1. The preliminary collective effective dose equivalent to the UK population in 1985 was 30 man-Sv, significantly less than for 1984 (70 man-Sv), due to lower radiocaesium concentrations in fish and shellfish from the Irish Sea and further afield. For the population of other European countries the preliminary collective effective dose equivalent was 50 man-Sv in 1985, less than in 1984 (100 man-Sv), also reflecting these reductions. There is an overall reducing trend in concentrations of radiocaesium and other radiologically significant nuclides in all areas affected by discharges from Sellafield, and this trend is likely to continue.

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