ISSN 0142-2499

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD

DIRECTORATE OF FISHERIES RESEARCH

AQUATIC ENVIRONMENT MONITORING REPORT

NUMBER 6

RADIOACTIVITY IN SURFACE AND COASTAL WATERS OF THE BRITISH ISLES, 1979

G J HUNT

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Aquat. Environ. Monit. Rep., MAFF Direct. Fish. Res., Lowestoft, (6) 32 pp.

CONTENTS

Page

1. **Introduction** 1

2. **Discharges of radioactive waste** 1

2.1 Liquid radioactive waste 1

2.2 Solid radioactive waste 1

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

3.1 SI units 3

3.2 Summary of analytical methods 3

3.3 Methods of presentation of measurements 4

3.4 Methods of interpretation 4

4. **British Nuclear Fuels Limited** 6

4.1 Sellafield, Cumbria 6

4.1.1 The fish and shellfish consumption pathway 6
4.1.2 External exposure 12
4.1.3 *Porphyra* /laverbread pathway 15
4.1.4 Other surveys 17

4.2 Springfields, Lancashire 17

4.3 Capenhurst, Cheshire 17

4.4 Chapelcross, Dumfriesshire 18

5. **United Kingdom Atomic Energy Authority** 18

5.1 Atomic Energy Establishment, Winfrith, Dorset 19

5.2 Dounreay Nuclear Power Development Establishment, Caithness 20

6. **Nuclear power stations operated by the electricity boards** 20

6.1 Berkeley, Gloucestershire and Oldbury, Avon 22

6.2 Bradwell, Essex 22

6.3 Dungeness, Kent 22

6.4 Hartlepool, Cleveland 22

6.5 Heysham, Lancashire 23

6.6 Hinkley Point, Somerset 23

6.7 Hunterston, Ayrshire 23

6.8 Sizewell, Suffolk 25

6.9 Trawsfynydd, Gwynedd 26

6.10 Wylfa, Gwynedd 27

7. **Naval establishments** 27

8. **Amersham International Limited** 27

9. **Channel Islands monitoring** 29

10. **Summary and conclusions** 31

11. **References** 31

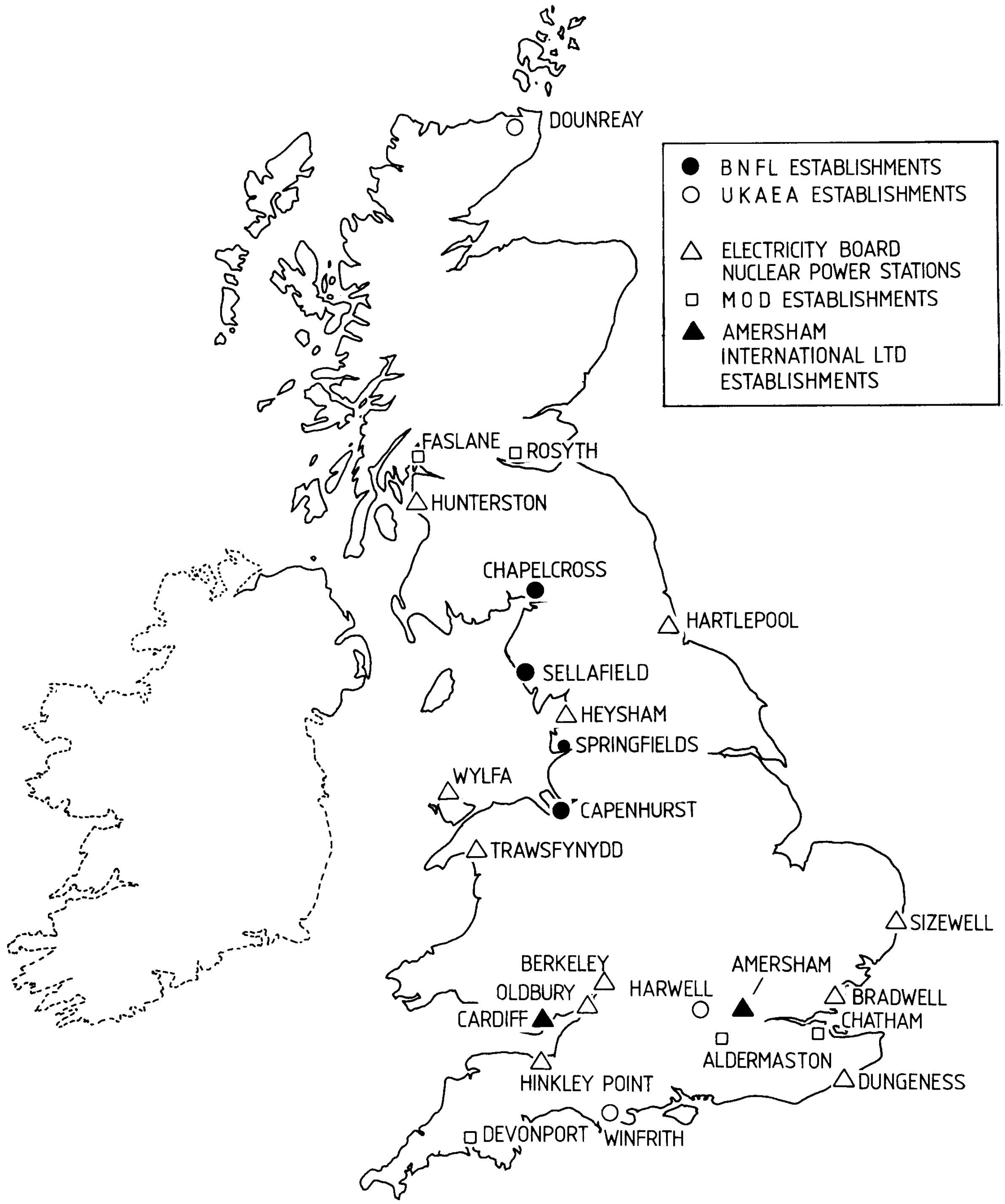

Figure 1 UK nuclear establishments giving rise to principal discharges of liquid radioactive waste.

1. Introduction

This report presents the results of the environmental monitoring programme carried out during 1979 by staff of the Directorate's Aquatic Environment Protection Division Section 1, at the Fisheries Radiobiological Laboratory (FRL). The monitoring programme is part of this Ministry's responsibilities under the Radioactive Substances Act, 1960 (Great Britain – Parliament, 1960). This 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 often 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 Department of the Environment for Northern Ireland, the Channel Islands States and the Republic of Ireland. Where appropriate, the information presented is supplemented by results from FRL's 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 1979 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

Following the Government's response (Great Britain – Parliament, 1977) to the 6th Report of the Royal Commission on Environmental Pollution (1976), an annual survey of radioactive discharges is now published by the Environment Departments. The survey for 1979 has been published (DOE, Scottish Office & Welsh Office, 1980) but to enable the data on environmental levels presented in this report readily to be considered 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 1979. The locations of these establishments are shown in Figure 1. Discharge data are derived from the operators' returns. 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 Section 3.1) and curies. The limits are given only in curies since it is in these units that the limits are currently specified. 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 lower (often 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, 1959). For each discharge the percentage of the authorised (or agreed) limit taken up in 1979 is also stated in Table l.

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 1979 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 (l 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 also receives low specific activity packaged solid waste. This is not disposed of in coastal waters, but in an area of the deep Atlantic Ocean. Solid radioactive waste from some other West European countries is also disposed of in the same area. The current disposals conform to the requirements of the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (The London Convention) and are organised within the Multilateral Consultation and Surveillance Mechanism operated by the Nuclear Energy Agency (NEA) of the Organisation for Economic Cooperation and Development (OECD). This Mechanism makes provision for consultation between member states before a disposal operation takes place, and the operation itself is subject to surveillance by a representative of the OECD(NEA). In 1979 the waste was disposed of within an area defined by the two lines of longitude 16°W and 17°30'W and two lines of latitude 10 nautical miles north and 10 nautical miles south respectively of latitude 46°N. The continued suitability of this site has recently been reviewed OECD (NEA) 1980). Following previous practice, the 1979 UK disposal operation was carried out by the Atomic Energy Research Establishment (AERE) Harwell according to the conditions laid down by this Ministry and the Department of the Environment (DOE). These conditions embody internationally-agreed safeguards. The operation was observed by a representative of the OECD(NEA). The waste was from several establishments and totalled 2,522 packages of 2,014 tonnes gross weight (219 tonnes net) containing 51 TBq (1,381 Ci) of alpha activity and 3,000 TBq (81,080 Ci) of beta/gamma activity, including 1,517 TBq (40,991 Ci) tritium. Routine environmental monitoring does not provide an effective means of assessing public radiation exposure from these disposals. Their environmental impact, as indicated by calculations using appropriate models, is negligible (OECD (NEA) 1980).

Table 1 Principal discharges of liquid radioactive waste from UK nuclear establishments, 1979

Establishment	Radioactivity	Discharge limit (annual equivalent), Ci	Discharges during 1979		
			TBq	Ci	% of limit utilised
BRITISH NUCLEAR FUELS LIMITED					
Sellafield					
Sea pipeline	Total beta	300 000	4 058	109 678	37
	Ruthenium-106	60 000	393	10 615	18
	Strontium-90	30 000	252	6 810	23
	Total alpha	6 000	62	1 675	28
Seaburn sewer	Total activity	4	0.011	0.31	7.8
Springfields	Total alpha	360	1.8	48	13
	Total beta	12 000	135	3 660	31
Chapelcross	Total activity[1]	700	9.1	246	35
	Tritium	150	2.8	76	51
Capenhurst					
Rivacre Brook	Total activity[2]	0.04	0.00049	0.0132	33
Meols outfall	Technetium-99	4	0.0118	0.32	8.0
UNITED KINGDOM ATOMIC ENERGY AUTHORITY					
Winfrith	Total activity	30 000	117	3 153	11
	Ruthenium-106	9 000	0.078	2.11	<1
	Strontium-90	1 200	0.054	1.45	<1
	Total alpha	1 200	0.021	0.58	<1
Harwell	Total activity[1,3]	240	1.8	48	20
	Tritium	240	1.8	48	20
Dounreay	Total activity	24 000	32	857	3.6
	Strontium-90	2 400	7.9	213	8.9
	Total alpha	240	0.48	13	5.4
CENTRAL ELECTRICITY GENERATING BOARD					
Berkeley	Total activity[1]	200	1.7	46	23
	Tritium	1 500	1.6	43	2.9
Bradwell	Total activity[1]	200	1.6	43	22
	Zinc-65	5	0.011	0.3	6.0
	Tritium	1 500	4.4	119	7.9
Dungeness	Total activity[1]	200	1.1	30	15
	Tritium	2 000	0.78	21	1.1
Hinkley Point[4]					
"A" Station	Total activity[1]	200	2.3	62	31
	Tritium	2 000	3.6	96	4.8
"B" Station	Total activity[1,5]	100	0.52	14	14
	Sulphur-35	700	0.081	2.2	<1
	Tritium	18 000	160	4 320	24
Oldbury	Total activity[1]	100	0.70	19	19
	Tritium	2 000	0.22	6	<1
Sizewell	Total activity[1]	200	1.4	38	19
	Tritium	3 000	1.6	43	1.4
Trawsfynydd	Total activity[1]	40	0.22	6	15
	Caesium-137	7	0.056	1.5	21
	Tritium	2 000	2.1	56	2.8
Wylfa	Total activity[1]	65	0.59	16	25
	Tritium	4 000	4.6	123	3.1
SOUTH OF SCOTLAND ELECTRICITY BOARD					
Hunterston					
"A" Station	Total activity[1]	200	4.2	113	57
	Tritium	1 200	3.3	89	7.4
"B" Station	Total activity[1,5]	100	0.074	2	2.0
	Sulphur-35	700	0.017	0.45	<1
	Tritium	40 000	75	2 025	5.1

Table 1 (continued)

Establishment	Radioactivity	Discharge limit (annual equivalent), Ci	Discharges during 1979		
			TBq	Ci	% of limit utilised
MINISTRY OF DEFENCE (PROCUREMENT EXECUTIVE)					
Aldermaston	Total activity[1,3]	156	0.14	3.9	2.5
	Tritium	156	0.051	1.4	<1
MINISTRY OF DEFENCE (NAVY DEPARTMENT)					
Chatham	Total activity[1]	20	0.00093	0.025	<1
	Cobalt-60	10	0.00093	0.025	<1
	Tritium	20	0.0015	0.041	<1
Devonport	Total activity[1]	4	0.00064	0.017	<1
	Cobalt-60	1	0.00064	0.017	1.7
	Tritium	10	0.015	0.408	4.1
Faslane	Total activity[1]	1	0.000012	0.00033	<1
Rosyth	Total activity[1]	30	0.0038	0.105	<1
AMERSHAM INTERNATIONAL LIMITED					
Amersham	Total activity[1,3]	72	0.95	26	36
	Tritium	400	7.9	214	54
Cardiff[6]	Beta/gamma activity[7]	2.4	0.00002	0.0006	<1
	Carbon-14	20	0	0	0
	Tritium	36 000	0	0	0

[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]A single site authorisation applies at Hinkley Point. The format above represents the way in which it has been agreed that the authorisation should be apportioned in practice.
[5]Excluding sulphur-35.
[6]Discharges began in December 1979.
[7]Excluding tritium, carbon-14 and radioisotopes of calcium and strontium.

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 = 100 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. Methods of analysis and of presentation and interpretation of results

3.1 SI units

In this report data are presented using the SI (Systeme Internationale) 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.

3.2 Summary of analytical methods

Although some of the analytical methods used by FRL 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. 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.

Except for ruthenium-106 in laverbread, which is analysed using this nuclide's energetic beta particles (Dutton, 1968), gamma-emitting nuclides are analysed by gamma spectrometry. This is carried out using both NaI(Tl) and Ge(Li) 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 and technetium-99, are chemically separated from samples before beta counting.

Transuranic nuclides are chemically separated and analysed by alpha spectrometry using silicon surface-barrier detectors. 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 (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 section 3.4. The appropriate integration period for comparison with recommended limits is one year; standard practice is to combine annual rates of consumption or occupancy of members of the public more highly exposed (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 which already embody a number of maximising assumptions. Therefore, the tables present the arithmetic means of observations made during the year. The frequency of sampling reflects the resolution (implying the accuracy) judged to be necessary in the assessment, or, as is largely self-evident, its radiological importance. The number of observations during the year is therefore also given.

Measurements on biota are given in terms of concentrations in wet material as collected. For fish and shellfish, because the purpose is assessment of internal exposure of the consumer, the concentrations apply to the edible fractions. For sediments, whose water content is more variable, dry concentrations are given. Analyses are carried out on samples consisting of a suitably large mass of material; for fish and shellfish these contain a number of individuals of the given species to compensate for statistical variations. Analyses requiring radiochemical separation may be carried out on these samples directly, or on bulks of samples for an appropriate period; in tables combining the results of gamma spectrometry and radiochemical analyses, unless otherwise stated, an annual bulk applies to the latter. 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.

At many locations monitored by FRL the results for certain measurements, particularly total beta radioactivity concentrations and gamma dose rates, may be comparable with levels due to natural radioactivity. Further analysis of samples (usually by gamma spectrometry) can indicate the component of total beta radioactivity which may be 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.

3.4 Methods of interpretation

The monitoring results in this report are interpreted in terms of radiation exposures of the public. The bases against which these exposures are judged are the recommendations of the International Commission on Radiological Protection (ICRP). For many years these recommendations have been endorsed for use in the UK by appropriate advisory bodies. UK practice relevant to the general public is now mainly based on the recent recommendations of ICRP as set out in ICRP Publication 26 (ICRP, 1977). The dose limitation system therein embodied has been endorsed by the National Radiological Protection Board (NRPB, 1978a) as a satisfactory basis for control of

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:	$\mu Gy\ h^{-1}$
Sand, shingle	0.03 to 0.05
Mud	0.05 to 0.1

*Except sediments for which dry concentrations apply.

radiation exposures. UK legislation will comply with the Euratom Directive on basic radiation safety standards, the current version of which (Commission of the European Communities, 1980) is based on the recommendations of ICRP Publication 26. In this report, results have been interpreted also on the basis of these recommendations.

The effect of these recommendations on the interpretation of the results will be briefly described. Most of the concepts forming the basis of the ICRP Publication 26 dose limitation system are not new. Greater weight than in previous recommendations is given to the principle that "all exposures shall be kept As Low as Reasonably Achievable ....." (ALARA). This principle was recognised for the purposes of radioactive waste disposal in the UK policy statement of 1959 (Great Britain – Parliament, 1959) which has recently been reviewed (Department of the Environment *et al.*, 1979). The recommendations of ICRP Publication 26 re-emphasise the importance of consideration of collective 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 0.5mSv. The NRPB considers (NRPB, 1978b) 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 from radioactive waste discharges. By comparison, the annual average dose equivalent in the UK from natural radiation is approximately 1 mSv (Taylor and Webb, 1978).

ICRP Publication 26 recommends that doses should meet the ALARA objectives, subject to compliance with appropriate individual dose limits. Control of individual exposures is intended to prevent non-stochastic (threshold) effects and to limit stochastic effects (i.e., those whose probability depends on the dose) to an acceptable level. To prevent non-stochastic effects, a dose equivalent limit for the public of 50 mSv $year^{-1}$ to any one organ or tissue is prescribed. 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 is called the effective dose equivalent, and the ICRP-recommended limit for members of the public is 5 mSv $year^{-1}$.

The ICRP also recommends secondary limits for internal and external irradiation. For internal irradiation, the limits are expressed as Annual Limits of Intake (ALIs). Values for radiation workers for a number of elements have been published in ICRP Publication 30 (ICRP, 1979a, 1980). In this report environmental monitoring results are interpreted in terms of doses to members of the public. Thus the data on doses per unit intake, published in supplements to ICRP Publication 30 (ICRP, 1979b, 1981), have been used. The following points should be noted. First, metabolic differences may exist between certain age groups of the public and radiation workers. However, for the nuclides of main radiological importance in this report, the use of doses per unit intake for workers is unlikely to underestimate significantly doses to the public. Secondly, for nuclides with long body retention times, such as the transuranics, the dose per unit intake is only reached on an annual basis after steady intake for a period of 50 years, taken by the ICRP as a working lifetime. Thirdly, in addition to the estimation of the effective dose equivalent for comparison with the ICRP-recommended dose limit based on stochastic effects, non-stochastic effects also require consideration, and this has been given in this report. However, in a given situation, provided the dose equivalent to each tissue from all nuclides is below the non-stochastic limit, the significance of the exposure is in the effective dose equivalent.

In the case of external exposure to penetrating radiation, uniform whole body exposure has been assumed. The measured quantity is absorbed dose in air; the resulting whole body dose equivalent (in consistent units) is in practice very nearly equal to this measured quantity and has been taken to be equal to it.

In order to interpret monitoring results in terms of the recommendations of the ICRP, the remaining data required are, as appropriate, rates of food consumption or occupancy of areas relevant to external exposure. These are obtained by FRL 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 a group (the critical group) of persons more highly exposed through a particular pathway or pathways. The critical pathway approach has been in use for many years, and is still embodied in the recommendations of the ICRP. 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 annual dose to the critical group. This is then expressed as a percentage of the appropriate ICRP-recommended dose limit for members of the public.

4. British Nuclear Fuels Limited

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. FRL regularly monitors the environmental consequences of discharges of liquid radioactive waste from four BNFL sites, namely Sellafield (until 1981, known as Windscale and Calder), Springfields, Capenhurst and, on behalf of Scottish Departments, Chapelcross.

4.1 Sellafield, Cumbria

Operations and facilities at this establishment include fuel element storage and decanning, the Windscale nuclear fuel reprocessing plant, the Calder Hall magnox-type nuclear power station and the Windscale Advanced Gas-cooled Reactor (AGR) development. The most significant liquid radioactive waste discharges are from the fuel element storage ponds and the reprocessing plant, through which pass all the irradiated fuel from the UK nuclear power programme. 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 twin pipelines which terminate 2.1 km beyond low-water mark. Discharges during 1979 are summarised in Table 1, and were within the limits set by the authorising departments. Discharges of total beta activity, at 37% of the authorised limit, were less than in 1978 (64%). Total beta discharges are substantially dependent upon releases of radiocaesium which mainly originate from the fuel element storage ponds. In 1979 caesium-137 pipeline discharges totalled 2562 TBq, a lower total than in 1978 (4088 TBq), due mainly to increased use of zeolite, a material employed to absorb caesium, in the ponds. The discharge of ruthenium-106 in 1979 was also less than in 1978, as were discharges of strontium-90 and alpha emitters, which consist mainly of plutonium isotopes and americium-241.

A substantial monitoring effort was maintained by FRL during 1979. The two critical radiation exposure pathways continued to be from consumption of fish and shellfish and from external exposure. Following established practice, the largest monitoring effort has been expended on these pathways. In 1979, as in previous recent years, there was no harvesting of *Porphyra* in the immediate Sellafield vicinity for manufacture of laverbread but 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 radionuclides 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. Some of the research was supported by contract with the Commission of the European Communities. Results from the FRL research programme are included where relevant.

4.1.1 The fish and shellfish consumption pathway

Public radiation exposure from Sellafield discharges by consumption of fish is 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. 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, specific surveys are also carried out by FRL, sampling fish and shellfish from the Sellafield vicinity. The location "Sellafield Shoreline Area" is close inshore in this vicinity. "Sellafield Offshore Area" is defined by a rectangle, one nautical mile wide and two nautical miles long, situated south of the pipeline with the long side parallel to the shoreline; the Area averages about 5 km from the pipeline outlet. Table 4 includes the results of analyses by FRL of samples collected by authorities in Northern Ireland and the Irish Republic.

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 cod, measurements remote from land run-off indicate a value of about 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. Because the purpose of the result is dose estimation, results are based on observations which include large numbers of individual fish.

Concentrations of radiocaesium in fish from areas of the Irish Sea and Scottish waters for 1979 were generally slightly lower than in 1978, mainly because of the reduction in radiocaesium discharges. The percentage reduction in radiocaesium concentrations was not as great as that in the discharges because of the delay, explainable in terms of water movements and fish uptake rates, between cause and effect. In contrast with the Irish Sea, radiocaesium concentrations in fish from the North Sea and further afield were generally higher in 1979 than in 1978. This is probably the continued effect (Hunt, 1980) of the increased levels of radiocaesium discharges from Sellafield since 1974, and the rapid flushing of the Irish Sea reported for 1977 (Hunt, 1979).

Radiation exposure from consumption of shellfish is due in part to radiocaesium, but other nuclides also make significant contributions owing to higher concentration factors in these foods than in fish. Table 5 lists concentrations of total beta activity and beta/gamma emitting nuclides in shellfish from the Irish Sea. As with fish, concentrations 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, whilst in contrast the concentrations of radiocaesium are similar in both classes of shellfish as well as in fish.

As with fish, radiocaesium concentrations in Irish Sea shellfish in 1979 were generally slightly lower than those in 1978. The concentrations of other beta/gamma emitting radionuclides also decreased following reduced discharges of these radionuclides in 1979.

Public radiation exposure from transuranic nuclides in fish and shellfish is lower than from radiocaesium. Analyses for transuranics are also labour-intensive. Therefore, only a selection of samples of fish and shellfish chosen mainly, but not exclusively, on the basis of potential radiological significance have been analysed for transuranic nuclides. The data are presented in Table 6. Concentrations reduce rapidly with distance, consistent with lower retention of transuranics in sea water. Non-conservatism to sea water is also reflected in higher concentrations of transuranics in shellfish as compared with fish. Concentrations of transuranics in fish and shellfish from the Irish Sea were in 1979 generally lower than in 1978.

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 ICRP for control purposes, is based on identifying groups of individuals in exposed populations subject to the highest radiation dose rates. 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 fishing community represent one exposed population whose consumption rates have been studied, and kept under review, by FRL. The other main variable is that of consumption rates. Surveys by FRL 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 kept under review by FRL, 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.

Table 4 Beta/gamma radioactivity in fish from the Irish Sea vicinity and further afield, 1979

Sampling area/landing point	Sample	No. of observations	Mean radioactivity concentration (wet), Bq kg^{-1}		
			Total beta	^{134}Cs	^{137}Cs
Sellafield shoreline area[1,3]	Plaice	2	1900	140	2000
	Cod	12	2700	220	2600
	Pollack	5	2000	160	2100
	Flounder	1	2200	200	2600
Sellafield offshore area[1,3]	Plaice	4	900	63	820
	Dab	4	610	42	560
	Cod	3	670	46	570
	Whiting	2	1500	120	1500
	Flounder	1	560	43	560
	Brill	1	630	44	580
	Ray	3	730	58	610
	Gurnard	1	480	23	390
Ravenglass[2]	Plaice	7	470	25	380
	Cod	5	810	50	760
	Sole	1	450	28	400
	Lemon sole	1	1400	110	1300
Whitehaven[2]	Plaice	12	360	17	270
	Cod	12	400	18	260
	Herring	2	270	14	180
Morecambe Bay[1]	Flounder	3	590	35	580
Fleetwood[2]	Plaice	4	340	19	270
	Cod	4	320	17	200
Cumbrian rivers[4]	Sea trout	2	530	34	480
Isle of Man[2]	Plaice	3	190	3.6	88
	Cod	3	230	2.7	99
	Herring	3	240	12	130
Solway[1]	Salmon	1	100	ND	5.8
North Anglesey[1]	Plaice	2	160	1.6	30
Northern Ireland[2]	Whiting	3	310	9.5	210
	Herring	2	160	4.8	96
Republic of Ireland[2]	Plaice	5	160	3.8	53
	Cod	6	190	3.6	74
	Whiting	4	220	6.1	100
Minch[1]	Plaice	4	140	2.0	33
	Cod	4	170	2.6	42
	Herring	1	92	0.5	8.9
Northern North Sea[1]	Plaice	8	120	0.3	8.6
	Cod	10	130	0.2	10
	Haddock	3	140	0.5	8.8
	Herring	1	120	ND	4.6
	Saithe	1	140	"	7.1
Mid-North Sea[1]	Plaice	8	110	0.2	7.1
	Cod	10	140	0.4	15
	Haddock	4	130	0.1	13
	Whiting	1	120	0.5	7.8
Southern North Sea[1]	Plaice	4	110	0.1	4.3
	Cod	4	120	0.2	7.5
	Whiting	2	130	0.3	8.8
Iceland area[1]	Plaice	1	85	ND	0.3
	Cod	1	100	"	0.4
Norwegian Sea[1]	Cod	1	130	"	1.0

ND = not detected.

[1] Sampling area.
[2] Landing point.
[3] See text for definition.
[4] Samples collected from a number of rivers by the North West Water Authority.

Table 5 Beta/gamma radioactivity in shellfish from the Irish Sea, 1979

Sampling area/landing point	Sample	No. of observations	Mean radioactivity concentration (wet), Bq kg^{-1}							
			Total beta	^{60}Co	$^{95}Zr + ^{95}Nb$	^{106}Ru	^{110m}Ag	^{134}Cs	^{137}Cs	^{144}Ce
Sellafield shoreline area[1,3]	Crabs	3	1200	3.5	10	480	ND	30	380	28
	Lobsters	1	2500	ND	21	46	"	71	1000	48
	Winkles	8	5200	7.9	160	3000	38	35	390	59
St Bees[1]	Limpets	4	2600	3.1	110	1300	9.8	28	320	120
	Mussels	4	4100	8.2	510	3900	4.1	34	320	28
Whitehaven[2]	*Nephrops*	4	680	ND	ND	ND	ND	24	320	ND
	Queens	2	270	"	"	99	3.9	1.2	38	"
Morecambe Bay[1]	Shrimps	4	340	"	"	16	ND	18	130	"
	Cockles	2	350	0.8	"	97	"	14	130	4.1
Isle of Man[2]	Scallops	1	120	ND	"	ND	"	ND	9.7	ND
	Queens	2	86	"	"	"	"	"	11	"
Kirkcudbright[2]	Queens	4	69	"	"	"	"	0.5	9.6	"
	Winkles	4	600	"	"	160	"	3.5	78	"
Solway[1]	Shrimps	3	280	"	"	4.9	"	7.8	130	"
Wirral[1]	Shrimps	1	300	"	"	ND	"	8.6	140	"
	Cockles	1	150	"	"	16	"	2.6	43	"
Conwy[2]	Mussels	2	140	"	"	"	"	1.6	16	"
North Anglesey[1]	Crabs	1	110	"	"	ND	"	ND	14	"
	Winkles	3	150	"	"	"	"	ND	12	"
Northern Ireland[2]	*Nephrops*	3	130	"	"	"	"	"	23	"
Republic of Ireland[2]	*Nephrops*	4	130	"	"	"	"	0.6	27	"

ND = not detected.

[1] Sampling area.
[2] Landing point.
[3] See text for definition.

Table 6 Transuranic radioactivity in fish and shellfish from the Irish Sea vicinity and further afield, 1979

Sampling area/landing point	Sample	No. of observations	Mean radioactivity concentration (wet), Bq kg^{-1}				
			^{238}Pu	$^{239}Pu + ^{240}Pu$	^{241}Am	^{242}Cm	$^{243}Cm + ^{244}Cm$
Sellafield shoreline area[1,3]	Plaice	2	0.089	0.37	0.16	0.0011	0.0010
	Cod	4	0.025	0.11	0.046	0.0022	0.0006
	Crabs	3	1.6	7.2	11	0.15	0.037
	Lobsters	5	0.45	1.8	14	0.08	0.08
	Winkles	3	17	70	48	1.5	0.32
	Mussels	1	30	120	81	NA	NA
Sellafield offshore area[1,3]	Plaice	3	0.016	0.066	0.051	0.0010	0.00038
	Rays	1	0.025	0.11	0.13	ND	ND
St Bees[1]	Limpets	1	13	55	43	NA	NA
Whitehaven[2]	Plaice	4	0.0055	0.023	0.019	0.00015	0.00014
	Cod	4	0.0036	0.015	0.012	0.00006	0.00007
	Herring	1	0.010	0.049	0.041	0.00048	0.00020
	Nephrops	4	0.23	1.0	2.0	0.010	0.014
Cumbrian rivers[4]	Sea trout	1	0.00042	0.0023	0.0014	ND	ND
Morecambe Bay[1]	Shrimps	1	0.25	1.1	0.95	0.0066	0.0059
	Cockles	1	2.6	10	7.1	0.044	0.031
Isle of Man[2]	Plaice	1	0.0014	0.0071	0.0045	ND	ND
	Cod	1	0.00025	0.0013	0.0010	"	"
	Herring	1	0.0017	0.0074	0.0026	"	"
	Scallops	1	0.033	0.18	0.045	"	0.0003
	Queens	1	0.0032	0.012	0.0057	"	0.0001
Solway[1]	Salmon	1	0.0043	0.019	0.019	0.0003	0.00012
Kirkcudbright[2]	Queens	1	0.019	0.091	0.055	ND	0.0007
	Winkles	1	0.99	4.3	4.4	"	0.020
Conwy[2]	Mussels	1	0.041	0.019	0.24	"	0.001
Minch[1]	Cod	1	0.0016	0.0058	0.0032	"	ND
Iceland area[1]	Cod	1	0.00015	0.00063	0.00050	"	"

ND = not detected.
NA = not analysed.

[1] Sampling area.
[2] Landing point.
[3] See text for definition.
[4] Samples collected by North West Water Authority.

The consumption rates of both of the two exposed populations described above have been recently re-assessed by FRL. Data have been reduced using techniques based upon ICRP recommendations (Hunt and Shepherd, 1980) to select appropriate critical groups of higher-rate consumers. This procedure is likely to lead to more reliable estimates of individual doses to these consumers than is the less reproducible procedure of using the maximum observation. A number of maximising assumptions are still present in the dose assessment, particularly in the way in which doses to critical groups are combined and in the maintenance of year-round consumption rates.

Radioactivity concentrations in fish and shellfish eaten by the two exposed populations will vary with the species involved, so to estimate doses it is not sufficient to determine only the total consumption rates of fish and shellfish together. FRL 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, critical sub-groups were identified for each class of foodstuff and the mean consumption rates of the sub-groups were determined. For the Cumbrian coastal community these consumption rates were estimated to be 170 g d^{-1} fish, 15 g d^{-1} crustaceans and 6 g d^{-1} molluscs. The data obtained show that above-average consumers in each of the component sub-groups are not generally members of another component sub-group. However, the sub-groups are not independent; hence the maximising assumption is made that the consumption rates appropriate to the overall critical group is represented by these component consumption rates combined additively. Plaice is overwhelmingly the fish most eaten by the high-rate consumers, hence the assessment of exposure of the critical group is based upon this species. A more fundamental assumption made here, erring on the conservative side, is that fish from this area represent the year-round intake of the critical group. During certain seasons of the year it is likely that fish consumed locally are supplemented by supplies from further afield. Consumption data indicate that it is certainly unreasonable to base the assessment on fish from the Shoreline Area. The exposure due to consumption of crustaceans is based upon an equal mix of crabs and lobsters from the Shoreline Area, whilst the exposure from consumption of molluscs is based upon winkles from the Shoreline Area.

Table 7 summarises doses in 1979. For each exposed population, the dose equivalent to each tissue from all nuclides is below the non-stochastic limit recommended for members of the public by the ICRP. Hence the significance of the exposures is in the effective dose equivalents, for which the doses per unit intake used are those determined by stochastic effects (see section 3.4). For each exposed population

Table 7 Individual radiation exposures due to consumption of Irish Sea fish and shellfish, 1979

Exposed population	Consumption rate used in assessment (see text)	Effective dose equivalent (as % of ICRP-recommended dose limit of 5 mSv $year^{-1}$ for members of the public)		
Consumers in local fishing community	170 g d^{-1} fish 15 g d^{-1} crustaceans 6 g d^{-1} molluscs	21	^{90}Sr ^{106}Ru ^{134}Cs ^{137}Cs $^{239}Pu + ^{240}Pu$ ^{241}Am	0.2 0.9 1.7 15.1 0.4 2.1
Consumers associated with commercial fisheries (Whitehaven, Fleetwood, Morecambe Bay)	360 g d^{-1} fish 70 g d^{-1} crustaceans 50 g d^{-1} molluscs	15	^{90}Sr ^{106}Ru ^{134}Cs ^{137}Cs $^{239}Pu + ^{240}Pu$ ^{241}Am	0.3 0.3 1.2 10.5 0.5 1.9
Typical member of the fish-eating public consuming fish landed at Whitehaven/Fleetwood	40 g d^{-1} fish	1.1	^{134}Cs ^{137}Cs	0.1 1.0

is given the effective dose together with the contributions of individual nuclides. For simplicity, only the more important nuclides are listed; hence it is not be be expected that the sums of the listed contributions will necessarily equal the totals presented. Comments in section 3.4 on the dose estimates for transuranics are relevant here.

The dose to the critical group of local consumers in 1979 was at most 21% of the ICRP-recommended limit for members of the public. The reduction from 26% estimated for 1978 (Hunt, 1980) was probably mainly due to decreases in discharges, particularly of radiocaesium.

Recent 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 360 g d^{-1}, 70 g d^{-1} and 50 g d^{-1} respectively. As for the Cumbrian coastal community, the overall critical group has been defined by the maximising procedure of combining these component consumption rates additively. 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 Morecambe Bay, and consumption of molluscs has been based on Morecambe Bay cockles. In 1979, analyses of these shellfish were carried out for transuranics; in previous years, estimates based on landings of comparable species at Whitehaven and Kirkcudbright had been used. The effective dose to members of this critical group is given in Table 7. Because of the change in the availability of analytical results for transuranics, comparison with the effective dose for 1978 is best made on the basis of the contribution from radiocaesium, which in 1978 was 13.5% of the ICRP-recommended dose limit for members of the public (Hunt, 1980). The contribution in 1979 was 11.7% of this limit, a small reduction from the 1978 contribution as a result of reduced radiocaesium discharges.

The effective dose appropriate to a consumption rate of 40 g d^{-1} 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 1979 was 1.1% of the ICRP-recommended dose limit for members of the public, a slight decrease as compared with the 1978 result of 1.2% (Hunt, 1980) because of reductions in discharges.

Collective doses from fish and shellfish have been estimated for 1979 for the UK and other European countries. In general, the method used is 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 include the Irish Sea, Scottish waters, the North Sea, Baltic Sea, Norwegian Sea, Spitzbergen/Bear Island area and Barents Sea. Corrections are made for the fraction of fish or shellfish consumed. The contribution of weapons-test fallout to the radioactivity concentrations is 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 for 1979. The results are presented in Table 8.

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 fish; the contribution due to shellfish is relatively minor. Also relatively small is the contribution, again mainly from radiocaesium, due to fish offal and industrial fisheries (Hunt and Jefferies, in press). 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

Table 8 Collective doses from fish and shellfish, 1979

Population	Size of population	Collective effective dose equivalent, man-Sv
UK	5.6×10^{7}	130
Other European countries	6.2×10^{8}	170

for the long body half-times, so that the small contributions estimated for the transuranics are committed in the future rather than already received (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, in press).

The results for 1979 include for the first time the contribution to the collective dose from landings from sea areas beyond the North Sea. They also include for the first time the contributions from fish offal and industrial fisheries. The result of 113 man-Sv for the UK in 1978 (Hunt, 1980) did not include these additional contributions but the appropriate corrections lead to a similar value to that now reported for 1979. Although radiocaesium concentrations in fish from the Irish Sea have been generally lower in 1979 as compared with 1978, as reported earlier in this section, the reduction in collective dose that this would have caused has been balanced by the effect of the generally higher concentrations in fish from the North Sea and further afield. These higher concentrations reflect concentrations in water of the North Sea reported for 1978 (Hunt, 1980) and are likely to have resulted from the increased radiocaesium discharges from Sellafield in the period 1974–1978 as compared with earlier years. The effect of reductions in discharges since 1978 has not yet become apparent in these more distant waters but should result in lower collective doses in due course.

The collective dose to inhabitants of other countries in 1979 includes for the first time the contributions due to landings from more distant sea areas than the North Sea (including the Baltic Sea), landings by Eastern European countries and the contributions due to fish offal and industrial fisheries. These contributions were not included in the result of 96 man-Sv reported for 1978 (Hunt, 1980) which would otherwise have been about 50% higher. After allowing for this correction, there has still been a small increase in collective dose to other countries in 1979 as compared with 1978, which reflects the generally higher radiocaesium concentrations found in fish in the North Sea and further afield.

The collective doses 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 b) (see section 3.4) as a result of all waste management practices. In 1979 the UK collective doses through the fish and shellfish pathways as a result of liquid radioactive waste disposal operations amounted to less than 5% of this value.

It is clear from the statements above which compare the 1978 and 1979 results for both critical group and collective dose rates that an important factor determining exposures is the distribution of radioactivity in the marine environment. A continuing programme of research is maintained by FRL on marine behaviour and distributions (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 April 1979 is shown in Figure 2. Comparison with the data for May 1978 (Hunt 1980) shows that contours of given concentration were in general somewhat closer to Sellafield in 1979, hence the caesium-137 inventory in the Irish Sea was less than in 1978. This is consistent with results presented earlier in this section of caesium-137 concentrations in fish from the Irish Sea in 1979 as compared with 1978.

4.1.2 External exposure

A further important pathway leading to radiation exposure as a result of Sellafield discharges arises 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, ruthenium-106 and zirconium-95 plus niobium-95.

FRL regularly monitors 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 1m above ground level. Monitoring in Scotland is carried out on behalf of 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 sections 4.2, 4.3, 4.4, 6.5, 6.10). Variations in sediment type account for the quite marked fluctuations in dose rate, superimposed on a general decrease with increasing distance from Sellafield.

FRL also regularly monitors radioactivity concentions 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

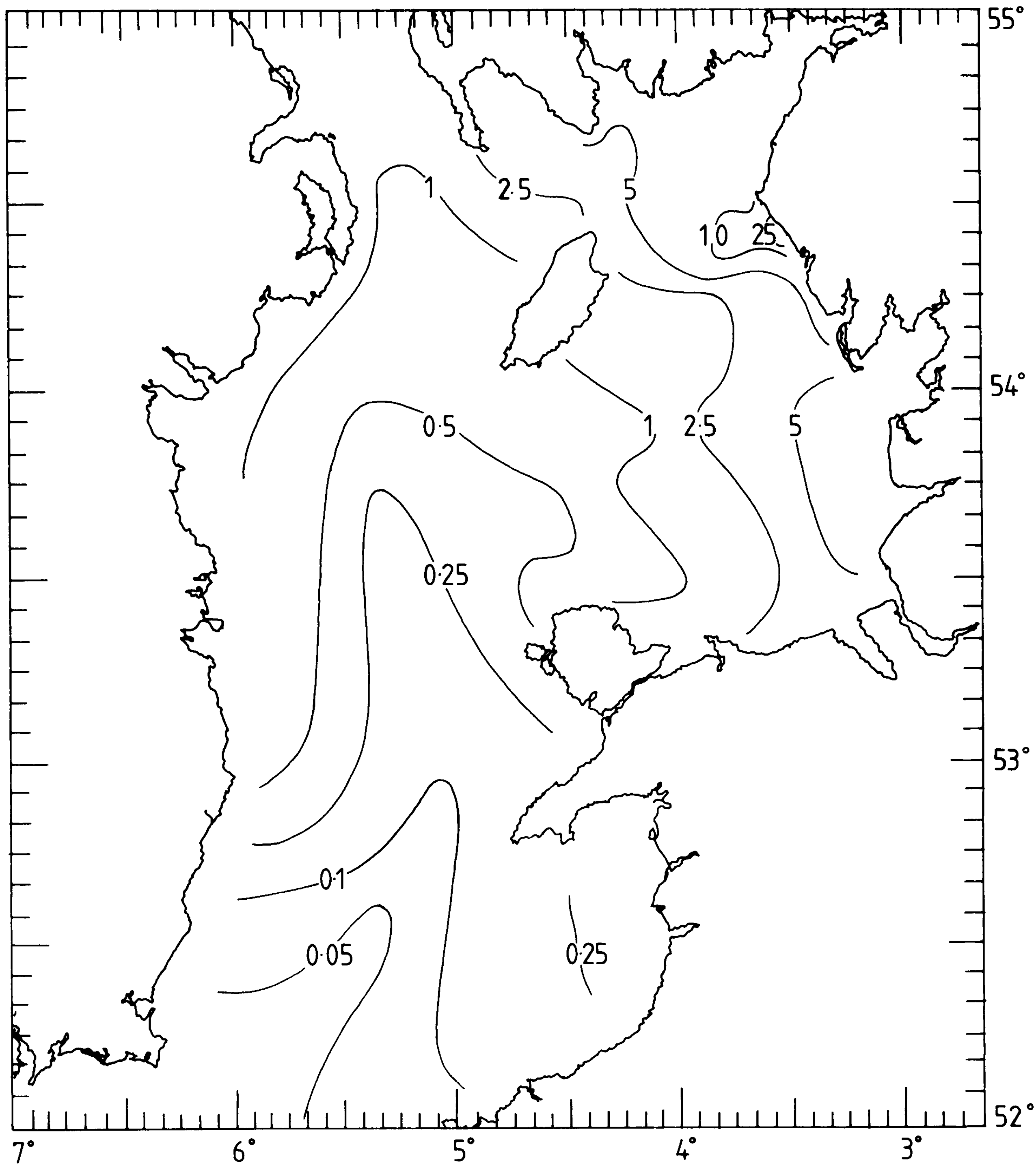

Figure 2 Concentration (Bq kg^{-1}) of caesium–137 in filtered water from the Irish Sea, April 1979.

Table 9 Gamma radiation dose rates over intertidal areas of the Cumbrian coast and further afield, 1979

Location	Type of sediment	No. of observations	Mean gamma dose rate in air at 1 m, $\mu Gy\ h^{-1}$
Maryport harbour	Silt	12	0.31
Workington harbour	"	12	0.37
Whitehaven harbour	"	12	0.94
St Bees	Sand	12	0.21
Braystones	"	12	0.28
Sellafield	"	12	0.29
Seascale	"	12	0.26
Ravenglass Salmon Garth	Silt/mussel bed	12	0.64
Ravenglass small boats area	Sand	12	0.28
Newbiggin	Silt	12	1.13
Haverigg	"	4	0.69
Millom	Sand	4	0.21
Walney Island	Silt	12	0.37
Heysham	"	16	0.15
Sunderland Point	Sand	4	0.17
Fleetwood	"	4	0.12
Blackpool	"	4	0.12
New Brighton	"	3	0.11
Mersey*	Silt	5	0.18
Kipford	"	4	0.34

*Results represent the means of levels observed at three points: Eastham Ferry, Rock Ferry, New Ferry.

Table 10 Radioactivity in sediment from the Cumbrian coast and further afield, 1979

Sampling point and sediment type		No. of observations	Mean radioactivity concentration (dry), Bq kg^{-1}				
			Total beta	^{60}Co	$^{95}Zr + {}^{95}Nb$	^{106}Ru	^{134}Cs
Maryport	(silt)	4	19 000	16	2 100	8 100	400
Whitehaven	(")	4	19 000	17	510	5 300	640
Newbiggin	(")	12	57 000	65	5 900	27 000	610
Walney Island	(")	4	9 300	21	480	4 400	170
Heysham	(")	4	3 300	3.7	ND	970	92
Sunderland Pt	(")	4	6 000	9.7	"	1 700	230
Fleetwood	(sand)	4	410	ND	"	17	1.3
New Brighton	(")	4	290	"	"	3.7	4.0
Rock Ferry	(silt)	4	3 600	1.9	"	500	120
Garlieston	(")	4	2 400	1.0	89	640	50
Kipford	(")	4	6 900	12	140	1 800	250

Sampling point and sediment type		No. of observations	Mean radioactivity concentration (dry), Bq kg^{-1}				
			^{137}Cs	^{144}Ce	^{238}Pu	$^{239}Pu + {}^{240}Pu$	^{241}Am
Maryport	(silt)	4	6 400	2 000	430	1 600	1 100
Whitehaven	(")	4	9 300	1 300	370	1 600	1 100
Newbiggin	(")	12	8 000	4 600	1 100	4 500	2 600
Walney Island	(")	4	2 600	1 200	NA	NA	750
Heysham	(")	4	1 300	190	41	180	170
Sunderland Pt	(")	4	3 600	310	80	360	270
Fleetwood	(sand)	4	150	12	NA	NA	ND
New Brighton	(")	4	83	7.9	"	"	"
Rock Ferry	(silt)	4	2 200	67	46	220	200
Garlieston	(")	4	1 100	81	41	170	260
Kipford	(")	4	3 100	360	120	540	310

NA = not analysed.
ND = not detected.

measurements, are given in Table 10. Variations similar in cause to those of the dose rates are observed.

To identify those members of the public subject to the highest external exposures, occupancies of different locations need to be considered. FRL keeps under review the amounts of time spent by members of the public on intertidal areas of coastline bordering the north-east Irish Sea; the longest times are often attributable to persons working in these areas. It is considered that, combining dose rates and occupancy times, the exposure of this critical group is represented by that of the salmon garth fisherman who works in muddy areas of the Ravenglass estuary. In 1979 his external exposure, after subtracting natural background, was about 3.2% of the ICRP-recommended dose limit. This exposure represents a small reduction from 3.7% reported for 1978 (Hunt, 1980).

The salmon garth fisherman is not a high-rate consumer of fish or shellfish, so his total exposure is less than the maximum calculated for fish and shellfish eaters. In principle, exposure through each of these pathways is additive, but combination of FRL data on external exposures and consumption rates for 1979 does not produce a higher dose rate than already given for the dose rate due to consumption of fish and shellfish.

4.1.3 *Porphyra*/laverbread pathway

No harvesting of *Porphyra* in the Sellafield vicinity for ultimate consumption was reported in 1979; this pathway has therefore remained essentially dormant. However, in view of its potential importance and the value of *Porphyra* as an indicator, monitoring by FRL has continued. Samples of *Porphyra* are regularly collected from selected locations along the Cumbrian coast and analysed for total beta activity and beta/gamma-emitting nuclides; samples from Braystones are also analysed for transuranics. Results for 1979 are presented in Table 11. Samples of laverbread from the product of both of the major manufacturers are regularly collected from markets in South Wales and analysed for ruthenium-106. Results for 1979 are presented in Table 12. The exposure of critical individuals was less than 0.1% of the ICRP-recommended dose limit, confirming the virtual abeyance of this pathway.

Table 11 Radioactivity in *Porphyra* from the Cumbrian coast, 1979

Sampling point	No. of observations	Mean radioactivity concentration (wet), Bq kg^{-1}					
		Total beta	^{60}Co	^{95}Zr + ^{95}Nb	^{103}Ru	^{106}Ru	^{134}Cs
Braystones South	12	7100	ND	750	51	5200	37
Seascale	53	5300	6.7	230	10	4000	28
Walney	4	910	ND	24	ND	770	11

Sampling point	No. of observations	Mean radioactivity concentration (wet), Bq kg^{-1}				
		^{137}Cs	^{144}Ce	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am
Braystones South	12	410	130	43	170	60
Seascale	53	320	35	NA	NA	43
Walney	4	99	3.3	"	"	5.2

NA = not analysed.
ND = not detected.

Table 12 Radioactivity in laverbread from South Wales, 1979

Manufacturer	No. of observations	^{106}Ru concentration (wet) Bq kg^{-1}
A	48	6.0
B	12	3.7
C	38	0.45

Table 13 Radioactivity in seaweeds from UK shorelines of the Irish Sea, 1979

Type of seaweed and sampling point	No. of observations	Mean radioactivity concentration (wet), Bq kg^{-1}							
		Total beta	^{60}Co	^{95}Zr + ^{95}Nb	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce	^{241}Am
Porphyra									
Larbrax	4	240	ND	ND	10	ND	7.5	ND	ND
Port William	4	260	"	"	34	"	17	"	"
Garlieston	4	320	"	"	62	1.7	30	"	"
Fucus vesiculosus									
Sellafield	12	10 000	13	420	800	180	2 000	55	27
Heysham	4	2 200	ND	ND	26	32	360	ND	ND
Port William	4	950	"	"	5.1	7.1	91	"	5.0
Garlieston	4	1 400	"	"	10	15	170	"	ND
Auchencairn	4	1 500	"	"	7.7	19	230	"	"
Portrush	4	530	"	"	ND	0.74	15	"	"
Ascophyllum nodosum									
Millisle	3	450	"	"	"	0.52	25	"	"

ND = not detected.

Table 14 Radioactivity in seaweeds from the coast of the Republic of Ireland, 1979

Type of seaweed and sampling point	No. of observations	Mean radioactivity concentration (dry), Bq kg^{-1}		
		Total beta	^{134}Cs	^{137}Cs
Porphyra				
Skerries	1	1200	16	ND
Colliemore	1	1300	16	"
Rosslare	1	1200	ND	"
Fucus spiralis				
Colliemore	1	2100	80	"
Fucus vesiculosus				
Carlingford	1	1700	120	5.7
Skerries	1	2600	100	ND
Dunmore	1	1000	ND	"
Rosslare	1	1100	"	"
Laminaria				
Skerries	1	4500	120	"
Rosslare	1	1300	ND	"

ND = not detected.

Table 15 Radioactivity in mud and gamma dose rates near the Springfields pipeline, 1979

Location	No. of observations	Mean radioactivity concentration (dry), Bq kg^{-1}								Mean gamma dose rate in air at 1 m, μGy h^{-1}
		Total beta	^{60}Co	^{106}Ru	^{134}Cs	^{137}Cs	^{234m}Pa	^{238}Pu	^{239}Pu + ^{240}Pu	
Pipeline outlet	4	11 000	ND	960	180	2 300	22 000	52	250	0.32
Upstream										
90 metres	4	13 000	5.0	730	160	2 200	29 000	57	230	0.32
460 metres	4	19 000	6.4	640	210	2 100	44 000	51	230	0.32
Downstream										
90 metres	4	20 000	11	1 200	290	2 900	45 000	80	350	0.30

ND = not detected.

4.1.4 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, FRL undertakes 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 13 presents the results of measurements in 1979 on seaweeds from UK shorelines of the Irish Sea. Radioactivity concentrations in *Porphyra* are reported in this section for areas relatively remote from Sellafield because of the value of this seaweed as an indicator, particularly for ruthenium-106. Although small quantities of *Porphyra* and *Ascophyllum nodosum* from these locations may be eaten, radioactivity concentrations are of negligible radiological significance. *Fucus* seaweeds are also 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 DOE(NI).

Samples of seaweed are also collected by authorities in the Republic of Ireland and analysed by FRL on their behalf. These results are presented in Table 14. Again, the programme serves an indicator purpose only; the concentrations reported are of no radiological significance.

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 its daughter products; liquid discharges are made by pipeline to the Ribble estuary. Public radiation exposure as a result of these discharges is very low. The critical pathway is by way of adsorption of the radioactivity on the muddy areas of river banks near the outfall; this gives rise to slightly increased dose rates in these areas, which are visited by members of the public. Dredgermen constitute the critical group. FRL regularly monitors dose rates near the outfall, and samples mud at the same points. The mud is analysed for total beta radioactivity, beta/gamma emitting nuclides and transuranics. Results for 1979 are presented in Table 15. The only detectable radionuclide due to Springfields discharges is protactinium-234m; other radionuclides present are mainly from Sellafield. Exposure of critical individuals in 1979, including the Sellafield component, amounted to less than 1% of the ICRP-recommended dose limit; the contribution due to Springfields discharges would have been but a small fraction of this.

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. Recently, uranium recovered from irradiated fuel has been 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; an authorisation was issued in September 1977 for their disposal to Liverpool Bay from the North Wirral outfall at Meols. Discharges commenced in August 1978. It is not expected that the

Table 16 Radioactivity in environmental materials in the vicinity of the Wirral, 1979

Material	Sampling point	No. of observations	Mean radioactivity concentration (wet)*, Bq kg^{-1}					
			Total beta	^{99}Tc	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce
Shrimps	Wirral	1	300	37	ND	8.6	140	ND
Cockles	Hoylake	1	150	17	16	2.6	43	"
Fucus spiralis	"	4	740	510	ND	12	150	"
" "	Little Orme	3	880	590	"	5.6	70	"
Sand	Hoylake	4	370	4.1	14	4.8	160	13

ND = not detected.
*Except for sand where dry concentrations apply.

environmental consequences of these small disposals would be detectable above background levels due both to natural sources of radioactivity and to Sellafield discharges. However, FRL have established an environmental monitoring programme which reflects the potentially critical pathway due to consumption of locally-caught shellfish. *Fucus*-type 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 1979 are presented in Table 16. 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 reflect the discharges of decay-stored liquors from Sellafield reported for 1978 (Hunt, 1980). Exposure of critical shellfish consumers in the vicinity of the Wirral in 1979 amounted to less than 2% of the ICRP-recommended dose limit; this was mainly due to radiocaesium from Sellafield. Only a tiny fraction of this exposure was due to technetium-99, which was almost entirely from Sellafield discharges.

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 within authorised limits increased in 1979 as compared with 1978 owing to cleaning operations in the fuel element storage ponds. There are two pathways of potential importance leading to public radiation exposure. Of these, external exposure from use of intertidal areas by fishermen is likely to be the more significant, owing to occupancy rates. The second pathway is internal irradiation following consumption of locally-caught fish and shellfish, mainly shrimps. Monitoring by FRL, on behalf of departments of the Scottish Office, reflects these pathways. Samples of ***Fucus vesiculosus***, as a useful indicator, are also analysed. The results of monitoring in 1979 are presented in Table 17.

Concentrations of artificial radionuclides in the Chapelcross vicinity are mostly due to Sellafield discharges, and the general levels given in Table 17(a) are consistent with values to be expected at this distance from Sellafield. Concentrations in 1979 were generally similar to those in 1978, with negligible long-term effect following the pond cleaning operations. Exposure of the critical group in 1979, making the maximising assumption of additivity of the two pathways, amounted to less than 2% of the ICRP-recommended dose limit. The magnitude of the Chapelcross discharges indicate that the local contribution would have been a tiny fraction of this exposure; most is due to Sellafield discharges.

Table 17(a) Radioactivity in environmental materials in the vicinity of Chapelcross, 1979

Material	Sampling point	No. of observations	Mean radioactivity concentration (wet)*, Bq kg^{-1}							
			Total beta	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce	^{238}Pu	$^{239}Pu + ^{240}Pu$	^{241}Am
Salmon	Seafield	1	100	ND	ND	5.8	ND	0.0043	0.019	0.019
Shrimps	"	2	220	"	12	170	"	NA	NA	NA
Fucus vesiculosus	Waterfoot	4	1400	"	17	220	"	"	"	"
" "	Seafield	4	1100	"	21	230	0.6	"	"	"
Sediment	"	4	3300	810	120	1700	180	42	180	130

ND = not detected.
NA = not analysed.
*Except for sediment where dry concentrations apply.

Table 17(b) Gamma dose rates in air at 1 m over intertidal areas in the vicinity of Chapelcross, 1979

Location	No. of observations	μGy h^{-1}
Seafield	4	0.18
Browhouses	4	0.12
Waterfoot	4	0.13
Torduff Point	4	0.13
Battle Hill	4	0.12

5. United Kingdom Atomic Energy Authority

FRL regularly monitors 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 Department of the Environment rather than this Ministry.

5.1 Atomic Energy Establishment, Winfrith, Dorset

The principal installation at which liquid radioactive wastes arise 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. Public radiation exposure pathways were reviewed in 1979. Reconcentration of activation products by shellfish, followed by local consumption, still constitutes the critical exposure pathway; this is reflected in the FRL monitoring programme. Monitoring of the indicator materials, limpets and *Fucus serratus*, provides additional information on the distribution of activation products; monitoring of *Fucus serratus* was extended further afield in 1979. Data are presented in Table 18. The impact of Winfrith discharges was, as in previous years, mainly observed in the activation product concentrations. Radiocaesium concentrations were similar to those to be expected from fallout; local discharges were likely to give rise to a negligible contribution. In 1979 the total radiation dose to critical consumers near this establishment was low, at about 1.1% of the ICRP-recommended dose limit.

Table 18 Radioactivity in environmental materials from the vicinity of Winfrith, 1979

Material	Sampling point	No. of observations	Mean radioactivity concentration (wet), Bq kg^{-1}					
			Total beta	^{54}Mn	^{60}Co	^{65}Zn	^{137}Cs	^{238}Pu
Mackerel	Weymouth	1	110	ND	0.44	2.3	1.7	NA
Crabs	Lulworth	4	100	1.8	53	82	ND	0.0012
Lobsters	Portland	2	66	1.1	11	70	"	NA
Oysters	Poole	2	65	ND	2.7	132	0.074	"
Scallops	Lulworth	1	110	150	100	410	1.4	0.037
	Poole	1	85	7.1	13	19	ND	NA
Limpets	Chapman's Pool	2	120	ND	49	64	0.83	"
	Osmington Mills	2	97	"	14	18	0.33	"
Fucus serratus	Chapman's Pool	2	420	46	360	50	ND	0.018
	Osmington Mills	2	350	17	190	ND	"	NA
	Weymouth	2	350	12	150	"	"	"
	Portland	2	360	5.4	53	4.3	0.31	"
	Swanage	2	510	26	370	150	ND	"
	Hengistbury Head	2	310	5.3	150	ND	"	"
	St Catherine's Point	1	320	ND	92	"	"	"
	Bognor Regis	1	260	"	14	"	"	"

Material	Sampling point	No. of observations	Mean radioactivity concentration (wet), Bq kg^{-1}			
			^{239}Pu + ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm
Mackerel	Weymouth	1	NA	NA	NA	NA
Crabs	Lulworth	4	0.0051	0.0024	ND	0.00010
Lobsters	Portland	2	NA	NA	NA	NA
Oysters	Poole	2	"	"	"	"
Scallops	Lulworth	1	0.14	0.052	0.0038	0.0027
	Poole	1	NA	NA	NA	NA
Limpets	Chapman's Pool	2	"	"	"	"
	Osmington Mills	2	"	"	"	"
Fucus serratus	Chapman's Pool	2	0.076	0.012	0.00055	0.00053
	Osmington Mills	2	NA	NA	NA	NA
	Weymouth	2	"	"	"	"
	Portland	2	"	"	"	"
	Swanage	2	"	"	"	"
	Hengistbury Head	2	"	"	"	"
	St Catherine's Point	1	"	"	"	"
	Bognor Regis	1	"	"	"	"

ND = not detected.
NA = not analysed.

5.2 Dounreay Nuclear Power Development Establishment, Caithness

Liquid radiactive 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 (HMS Vulcan) operated by the Ministry of Defence (Procurement Executive). Small quantities of fast reactor fuel were reprocessed at Dounreay in 1979. Monitoring by FRL near Dounreay is carried out on behalf of departments of the Scottish Office. There are two critical exposure pathways, both involving external radiation. The first pathways is due to radioactivity adsorbed mainly on fine sediments 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 critical group is a small number of people who operate a salmon fishery from Sandside Bay, close to Dounreay. Regular measurements throughout the 1979 fishing season (which ended before reprocessing operations began) showed that their exposure was low, at about 0.1% of the ICRP-recommended dose limit. The second critical pathway is due to adsorption of radioactivity on sediments trapped in rocky clefts on the foreshore. This leads to exposure mainly to gamma radiation of those who frequent these areas; winkle picking accounts for the highest occupancies. Monitoring of foreshore dose rates is not carried out by FRL; the UKAEA have published the results of their surveys of these areas in their 1979 monitoring report (Flew, 1980). Public radiation exposure via this pathway was also low, at less than 1% of the ICRP-recommended dose limit.

In 1979 FRL sampled winkles from Sandside Bay to enable the sub-critical pathway of shellfish consumption to be kept under direct review. In addition, limpets and *Fucus vesiculosus*, as in previous years, were sampled as indicator materials. Results for 1979 are presented in Table 19. Radiocaesium concentrations are mostly due to discharges from Sellafield. Other radionuclides detected, including transuranics, mainly reflect Dounreay discharges. Increased concentrations, as compared with 1978, of the short-lived fission products ruthenium-106 and cerium-144 were observed in all materials. These increases occurred in the latter part of the year following the reprocessing operations. However, the radiological significance of shellfish consumption was low; for high-rate winkle consumers the radiation dose was less than 0.1% of the ICRP-recommended dose limit. This pathway therefore remained of sub-critical importance in 1979.

6. Nuclear power stations operated by the electricity boards

All but one of these power stations are in England and Wales and are, or will be, operated by the Central Electricity Generating Board. The Scottish power station at Hunterston is operated by the South of Scotland Electricity Board. Results are presented for two power stations not yet operational, namely Hartlepool and Heysham, where monitoring by FRL has already commenced.

Table 19 Radioactivity in environmental materials from the vicinity of Dounreay, 1979

Sampling point and material	No. of observations	Mean radioactivity concentration (wet), Bq kg^{-1}						
		Total beta	^{60}Co	$^{95}Zr + ^{95}Nb$	^{106}Ru	^{125}Sb	^{137}Cs	^{144}Ce
Sandside Bay								
Winkles	4	170	1.0	ND	12	4.3	8.2	34
Limpets	12	300	0.6	"	28	3.4	5.9	58
Fucus vesiculosus	12	490	0.4	2.3	2.2	ND	15	49

Sampling point and material	No. of observations	Mean radioactivity concentration (wet), Bq kg^{-1}				
		^{238}Pu	$^{239}Pu + ^{240}Pu$	^{241}Am	^{242}Cm	$^{243}Cm + ^{244}Cm$
Sandside Bay						
Winkles	4	0.29	1.3	0.45	0.004	0.010
Limpets	12	0.69	2.9	1.1	0.015	0.017
Fucus vesiculosus	12	NA	NA	NA	NA	NA

ND = not detected.
NA = not analysed.

Table 20 Radioactivity in environmental materials and gamma dose rates near Berkeley and Oldbury nuclear power stations, 1979

Material	No. of observations	Mean radioactivity concentration, (wet)*, Bq kg^{-1}			
		Total beta	^{134}Cs	^{137}Cs	^{144}Ce
Mixed fish	3	98	ND	5.0	ND
Eels	1	62	"	2.7	"
Shrimps	6	93	0.14	3.0	1.4
Fucus vesiculosus	2	280	ND	4.9	ND
Mud: area of outfalls	4	780	5.4	69	"
area upstream	2	580	1.7	22	"

Mean gamma dose rate in air at 1 m over intertidal mud (6 observations): 0.056 μGy h^{-1}

ND = not detected.
*Except for mud where dry concentrations apply.

Table 21 Radioactivity in environmental materials and gamma dose rates near Bradwell nuclear power station, 1979

Material	No. of observations	Mean radioactivity concentration (wet)*, Bq kg^{-1}					
		Total beta	^{60}Co	^{65}Zn	^{134}Cs	^{137}Cs	^{238}Pu
Flounders	1	150	ND	ND	0.59	9.9	NA
Oysters	2	87	"	10	ND	2.9	0.0023
Fucus vesiculosus	2	230	0.86	ND	0.87	7.6	NA
Mud	6	990	1.6	"	4.7	70	"

Material	No. of observations	Mean radioactivity concentration (wet)*, Bq kg^{-1}			
		^{239}Pu + ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm
Flounders	1	NA	NA	NA	NA
Oysters	2	0.0098	0.015	0.00065	0.00074
Fucus vesiculosus	2	NA	NA	NA	NA
Mud	6	"	"	"	"

Mean gamma dose rate in air at 1 m over intertidal mud (4 observations): 0.075 μGy h^{-1}

NA = not analysed.
ND = not detected.
*Except for mud where dry concentrations apply.

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 environmental monitoring by FRL. The two 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. FRL therefore analyses samples of fish and shellfish and monitors beach gamma dose rates. In addition, measurements of external exposure are supported by analyses of intertidal mud, and ***Fucus vesiculosus*** is collected as an indicator material. Data for 1979 are presented in Table 20. The only artificial radioactivity detected was due to radiocaesium and cerium-144. 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. Public radiation exposure, however, was very low, at less than 0.1% of the ICRP-recommended limit to the critical group of fish and shellfish consumers. Directly measured gamma dose rates over intertidal mud continued to be indistinguishable from the natural background.

6.2 Bradwell, Essex

Radioactive liquid effluent from this power station is discharged to the estuary of the River Blackwater. Environmental monitoring by FRL reflects the critical internal radiation exposure pathway via consumption of locally-caught fish. Oysters also continue to be sampled and analysed, though their consumption no longer constitutes the critical pathway. Gamma dose rate measurements over intertidal mud are also carried out, as well as analyses of intertidal mud and the indicator ***Fucus vesiculosus.*** Measurements for 1979 are summarised in Table 21.

In fish, the only artificial radioactivity detected was due to radiocaesium, for which concentrations represent the combined effects of discharges from the station, of Sellafield discharges, and of fallout. Apportionment is difficult because of the low levels detected. The radiological significance of radiocaesium here, however, is low, totalling less than 0.3% of the ICRP-recommended dose limit to members of the critical group of fish consumers. The concentration of zinc-65 in oysters remained low in 1979, such that the exposure pathway involving this nuclide remained of small importance. The concentrations in oysters of transuranic nuclides, from local discharges and from Sellafield, were of negligible radiological significance. Gamma dose rates, as directly measured, were indistinguishable from the natural background.

6.3 Dungeness, Kent

The two critical radiation exposure pathways as a result of liquid radioactive waste discharges from this station are internal irradiation due to consumption of locally-caught fish, and external exposure from occupancy of the foreshore. The FRL monitoring programme therefore includes analyses of fish (of which plaice is the species most representative of consumption by the local critical group) and gamma dose rate surveys of the generally sandy beach. Samples of sand are also collected and analysed. Local whelks have been analysed mainly for their value as an indicator material. The results for 1979 are given in Table 22.

Table 22 Radioactivity in environmental materials and gamma dose rates near Dungeness nuclear power station, 1979

Material	No. of observations	Mean radioactivity concentration (wet)*, Bq kg^{-1}			
		Total beta	^{60}Co	^{134}Cs	^{137}Cs
Plaice	2	110	ND	0.20	0.9
Whiting	1	210	"	0.63	8.3
Whelks	2	120	1.2	ND	0.4
Sand	2	240	3.2	"	2.6

Mean gamma dose rate at 1 m over intertidal sand (10 observations): 0.060 $\mu Gy\ h^{-1}$

ND = not detected.
*Except for sand where dry concentrations apply.

Concentrations of caesium-137 in plaice were not significantly above the levels to be expected as a result of fallout. The concentration of caesium-137 in the sample of whiting taken in 1979, however, was more consistent with concentrations in the North Sea from Sellafield discharges (see Table 4) than those to be expected in the English Channel. The high result is likely, therefore, to be the result of fish migration. Even if the critical group consumed fish at this sustained concentration during 1979, however, their radiation dose would have been very low, at less than 0.2% of the ICRP-recommended dose limit. Gamma dose rates over sand were indistinguishable from natural background levels. Both whelks and sand samples, as in previous recent years, appeared to show trace levels of cobalt-60. The extended indicator sampling programme described in section 5.1 shows that AEE Winfrith rather than Dungeness may be the source of this nuclide; however, the concentrations here continued to be of negligible radiological significance.

6.4 Hartlepool, Cleveland

This station is not yet operational; its two Advanced Gas-cooled Reactors (AGRs) are under construction. However, monitoring by FRL has already begun in order to investigate background levels and to establish reliable sources of environmental materials. Potential critical pathways for radiation exposure of the public near this station likely to be associated with future liquid discharges 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 of fishermen who operate in muddy areas near the mouth of the Tees. Results of the FRL monitoring programme carried out in 1979 are shown in Table 23. Concentrations of radiocaesium were due to discharges from Sellafield and to fallout; the radiation exposure of the potentially critical group of local fish and shellfish consumers from these existing sources was low, at less than 0.6% of the ICRP-recommended dose limit for members of the public.

Table 23 Radioactivity in environmental materials and gamma dose rates near Hartlepool nuclear power station, 1979

Material	No. of observations	Mean radioactivity concentration (wet)*, Bq kg^{-1}		
		Total beta	^{134}Cs	^{137}Cs
Cod	3	130	0.45	20
Shrimps	2	110	0.33	7.3
Crabs	3	82	ND	3.8
Fucus vesiculosus	4	270	0.14	7.2
Sand	3	150	ND	5.8

Mean gamma dose rate in air at 1 m over intertidal sand (12 observations): 0.083 μGy h^{-1}

ND = not detected.
*Except for sand where dry concentrations apply.

6.5 Heysham, Lancashire

This establishment, which will comprise two, essentially separate, nuclear power stations both powered by AGRs, is under construction at present. Monitoring by FRL has begun for similar reasons as for the station at Hartlepool; in addition, information on radiation exposures and on the distribution of a range of radionuclides as a result of Sellafield discharges is to be gained. The potential critical radiation exposure pathways from future liquid radioactive discharges from Heysham are likely to be internal irradiation following consumption of locally-caught fish and shellfish (mainly shrimps and cockles), and external exposure from occupancy of intertidal areas. The FRL 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. The results for 1979 are given in Table 24. These mainly reflect discharges from Sellafield; it is unlikely that the effect of future discharges from Heysham will be detectable above the Sellafield-derived background. Estimates of the radiation exposure in 1979 of members of the critical group of fish and shellfish consumers associated with commercial fisheries (which include the Morecambe Bay area) were given in section 4.1.1. External exposure of members of the public was less than 1% of the ICRP-recommended dose limit.

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, which has been operational since 1976, by AGRs. Liquid radioactive discharges are made via the same outfall and for the purposes of FRL environmental monitoring are considered together. There are two critical radiation exposure pathways associated with liquid radioactive waste discharges: consumption of locally-caught fish and shrimps gives rise to internal irradiation, while external exposure results from occupancy of the foreshore. The FRL 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 1979, presented in Table 25, 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 total radiation exposure of members of the critical group through the fish and shellfish pathway was low, at less than 0.3% of the ICRP-recommended dose limit. 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, of which the latter is powered by AGRs. Liquid radioactive waste, discharges are made under authorisation of the Scottish Development Department to the Firth of Clyde. There are two critical radiation exposure pathways: fish and shellfish consumption leading to internal irradiation, and occupancy of intertidal areas leading to external exposure. FRL regularly monitors, on behalf of departments of the Scottish Office, samples of fish and shellfish and carries out gamma dose rate measurements on the foreshore. Samples of sand are analysed together with limpets and *Fucus spiralis* as indicators. The results of monitoring in 1979 are shown in Table 26.

The concentrations of artificial radioactivity in this area are predominantly due to Sellafield discharges, the general

Table 24 Radioactivity in environmental materials and gamma dose rates near Heysham nuclear power station, 1979

Material	No. of observations	Mean radioactivity concentration (wet)*, Bq kg^{-1}				
		Total beta	^{60}Co	^{106}Ru	^{134}Cs	^{137}Cs
Flounders	3	590	ND	ND	35	580
Plaice	1	330	"	"	19	280
Shrimps	4	340	"	16	18	130
Cockles	2	350	0.8	97	14	130
Fucus vesiculosus	4	2200	ND	26	32	360
Silt	4	3300	3.7	970	92	1300

Material	No. of observations	Mean radioactivity concentration (wet)*, Bq kg^{-1}			
		^{144}Ce	^{238}Pu	$^{239}Pu + ^{240}Pu$	^{241}Am
Flounders	3	ND	NA	NA	NA
Plaice	1	"	"	"	"
Shrimps	4	"	0.25	1.1	0.95
Cockles	2	4.1	2.6	10	7.1
Fucus vesiculosus	4	ND	NA	NA	NA
Silt	4	190	41	180	170

Mean gamma dose rate in air at 1 m over intertidal sediment (16 observations): 0.15 μGy h^{-1}

NA = not analysed.
ND = not detected.
*Except for silt for which dry concentrations apply.

Table 25 Radioactivity in environmental materials and gamma dose rates near Hinkley Point nuclear power station, 1979

Material	No. of observations	Mean radioactivity concentration (wet)*, Bq kg^{-1}						
		Total beta	^{110m}Ag	^{134}Cs	^{137}Cs	^{238}Pu	$^{239}Pu + ^{240}Pu$	^{241}Am
Flatfish	4	110	ND	0.45	4.2	NA	NA	NA
Shrimps	4	100	0.11	0.24	3.9	0.0027	0.014	0.0078
Fucus vesiculosus	2	320	ND	2.4	14	NA	NA	NA
Sediment	2	440	"	0.82	28	"	"	"

Mean gamma dose rate in air at 1 m over intertidal sediment (6 observations): 0.085 μGy h^{-1}

NA = not analysed.
ND = not detected.
*Except for sediment where dry concentrations apply.

Table 26 Radioactivity in environmental materials and gamma dose rates near Hunterston nuclear power station, 1979

Material	No. of observations	Mean radioactivity concentration (wet)*, Bq kg^{-1}					
		Total beta	^{60}Co	^{65}Zn	^{106}Ru	^{110m}Ag	^{134}Cs
Mixed fish	2	260	ND	ND	ND	ND	8.2
Cockles	2	76	2.7	"	"	"	ND
Winkles	4	210	22	2.2	18	1.4	6.2
Limpets	4	210	36	ND	15	ND	5.5
Fucus spiralis	4	630	230	"	16	"	15
Sand	4	290	11	"	9.0	"	17

Material	No. of observations	Mean radioactivity concentration (wet)*, Bq kg^{-1}				
		^{137}Cs	^{144}Ce	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am
Mixed fish	2	110	ND	0.00068	0.0037	0.0036
Cockles	2	11	"	NA	NA	NA
Winkles	4	34	6.1	"	"	"
Limpets	4	40	4.6	"	"	"
Fucus spiralis	4	75	ND	"	"	"
Sand	4	150	9.3	"	"	"

Mean gamma dose rate in air at 1 m over intertidal sand (4 observations): 0.11 μGy h^{-1}

NA = not analysed.
ND = not detected.
*Except for sand where dry concentrations apply.

values being consistent with those to be expected at this distance from Sellafield. However, the resulting public radiation exposure in 1979 was low, at less than 3% of the ICRP-recommended dose limit to members of the critical group of fish and shellfish consumers. The concentrations of cobalt-60 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.

6.8 Sizewell, Suffolk

FRL monitoring near this station reflects the two critical radiation exposure pathways of fish and shellfish consumption leading to internal irradiation, and of occupancy of intertidal areas giving rise to external exposure. Gamma dose rates are measured over sandy intertidal areas, where dose rates may be expected to be higher than on the rest of the beach which is mainly shingle. Results for 1979 are shown in Table 27.

The radiocaesium concentrations in fish represent the combined effect of discharges from the station and from Sellafield, as well as of fallout. Apportionment is difficult in view of the low levels detected. The total radiation exposure to local fish consumers was low, at less than 0.3% of the ICRP-recommended dose limit. Gamma dose rates continued to be indistinguishable above the natural background.

Table 27 Radioactivity in environmental materials and gamma dose rates near Sizewell nuclear power station, 1979

Material	No. of observations	Mean radioactivity, concentration (wet), Bq kg^{-1}	
		Total beta	^{137}Cs
Mixed fish	2	130	7.3
Crabs	1	120	2.4

Mean gamma dose rate in air at 1 m over intertidal sand (5 observations): 0.035 μGy h^{-1}

Table 28 Radioactivity in environmental materials near Trawsfynydd nuclear power station, 1979

Material	No. of observations	Mean radioactivity concentration (wet)*, Bq kg^{-1}					
		Total beta	^{60}Co	^{90}Sr	^{106}Ru	^{125}Sb	^{134}Cs
Rainbow trout	11	240	ND	17	ND	ND	10
Brown trout	4	870	"	17	"	"	89
Perch	4	1700	"	44	"	"	180
Rudd	4	1400	"	250	"	"	130
Mud	4	3400	11	NA	"	750	3.3
Peat	4	2200	9.8	"	"	270	4.9
Fontinalis							
Afon Prysor	4	280	ND	"	1.9	ND	ND
Gwylan Stream	4	1600	25	"	21	84	18
Water							
Hot Lagoon	12	NA	NA	0.58	NA	NA	0.040
Cold Lagoon	12	"	"	0.56	"	"	0.043

Material	No. of observa-	Mean radioactivity concentration (wet)*, Bq kg^{-1}				
		^{137}Cs	^{144}Ce	^{238}Pu	$^{239}Pu + ^{240}Pu$	^{241}Am
Rainbow trout	11	110	ND	0.00086	0.0048	0.0031
Brown trout	4	780	"	0.0016	0.0069	0.0069
Perch	4	1700	"	0.0042	0.017	0.0068
Rudd	4	1200	"	0.0020	0.0084	0.0095
Mud	4	1600	"	NA	NA	NA
Peat	4	630	"	"	"	"
Fontinalis						
Afon Prysor	4	10	10	"	"	"
Gwylan Stream	4	370	61	"	"	"
Water						
Hot Lagoon	12	0.32	NA	"	"	"
Cold Lagoon	12	0.34	"	"	"	"

NA = not analysed.
ND = not detected.
*Except for mud and peat where dry concentrations apply.

6.9 Trawsfynydd, Gwynedd

Discharges from this station are made under authorisation of the Welsh Office to the freshwater Lake Trawsfynydd. Because of the limited volume flow for dispersion they are of greater radiological significance than those from the other UK nuclear power stations which discharge to estuarine or coastal waters. The critical radiation exposure pathway here 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. Species of fish in the lake include the indigenous brown trout, perch and, more recently, rudd. The lake is also regularly stocked with rainbow trout reared in hatcheries containing lake water. Rainbow trout now account for the highest consumption rates but, because artificial radioactivity concentrations in rainbow trout are considerably lower than in indigenous fish as a result of the limited time spent in the lake, consumption of brown trout still accounts for a large proportion of the radiation exposure. Perch are also consumed, but at still lower rates; rudd are rarely eaten, if at all. FRL regularly analyses samples of each of these fish. As part of FRL's research programme, mud and peat from the lake bed are also analysed; these materials contribute to the fishes' 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. The results of these measurements for 1979 are shown in Table 28.

Radiocaesium concentrations in lake water were less than in 1978, following a decrease in discharges. Radiocaesium concentrations in fish in 1979 were, however, generally similar to those observed in 1978, reflecting the delay to be expected before equilibrium is established between caesium in lake water and in fish. Analyses of strontium-90 in fish were also carried out in 1979. In contrast with the behaviour of radiocaesium, concentrations of strontium-90 tend to be similar in both brown trout and rainbow trout. Strontium would therefore appear to be taken up into fish mainly via water, whilst caesium is taken up mainly via food. Low concentrations of transuranic nuclides from station operations were also observed in fish, as in previous years; the route of uptake would also appear to be via water. The concentrations of transuranics in fish continued to be of negligible radiological significance.

It is estimated that in 1979 members of the critical group of fish consumers received less than 2% of the ICRP-recommended dose limit. This result reflects the present low consumption rate of brown trout compared with rainbow trout. Consumption rate data will continue to be kept under review, however, in case the rates for indigenous fish should return to their former levels.

6.10 Wylfa, Gwynedd

Liquid radioactive wastes from this station are discharged to the Irish Sea under authorisation of the Welsh Office. Monitoring is carried out by FRL in respect of the two critical pathways, of local fish and shellfish consumption leading to internal irradiation and of occupancy of intertidal areas resulting in external exposure. Locally-caught fish and shellfish are sampled. Gamma dose rate measurements over intertidal mud are carried out and, in support, samples of mud are analysed. The indicator seaweed *Fucus vesiculosus* is also sampled. The results of monitoring in 1979 are presented in Table 29.

The 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. The total radiation exposure of members of the critical group in 1979 was less than 0.4% of the ICRP-recommended dose limit. The magnitude of discharges from the station indicate that the local contribution will have been a small fraction of this.

7. Naval establishments

Liquid wastes containing relatively small quantities of radioactivity are discharged from the following establishments: Chatham, Devonport, Faslane and Rosyth, all of which are operated by the Ministry of Defence (Navy Department). The US naval base at Holy Loch also discharges small quantities of radioactive waste. Monitoring of the effects of all these discharges is carried out by FRL, in the case of Faslane and Rosyth on behalf of departments of the Scottish Office.

The critical pathway for public radiation exposure due to these discharges is via external exposure from occupancy of intertidal areas, the nuclide of main importance being cobalt-60. FRL therefore regularly carries out measurements of gamma dose rates; these are supported by analyses of sediments. Indicator seaweeds are also analysed. Results of monitoring in 1979 are presented in Table 30. The small concentrations of activation product nuclides including cobalt-60 mainly reflect discharges from the establishments; levels of other artificial nuclides are largely due to fallout and to discharges from Sellafield. Gamma dose rates over intertidal sediments in 1979 remained indistinguishable from the natural background, such that public radiation exposure was very low, at less than 0.1% of the ICRP-recommended dose limit.

8. Amersham International Limited

Amersham International Limited (until 1981 known as The Radiochemical Centre Limited) are engaged in the manufacture of radioactive materials for use in industry, research and medicine. The company's parent establishment is located at 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 Department of the Environment. Due to an increased demand for radiopharmaceuticals, the company have built a new laboratory to manufacture these near Cardiff. An authorisation issued by the Welsh Office, to dispose of liquid radioactive wastes from this establishment to a sewer discharging into the Severn Estuary, came into force in October 1979. No discharges were made until December 1979, and were then only very minor. However, in April 1979 FRL began an environmental monitoring programme in order to establish background levels and to confirm reliable sources of samples. The programme 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. It is expected that the environmental consequences of discharges from this establishment will be very small and difficult to detect

Table 29 Radioactivity in environmental materials and gamma dose rates near Wylfa nuclear power station, 1979

Material	No. of observations	Mean radioactivity concentration (wet)*, Bq kg^{-1}							
		Total beta	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am
Flatfish	2	160	ND	1.6	30	ND	NA	NA	NA
Turbot (Fish Farm)	2	120	"	0.91	39	"	"	"	"
Crabs	1	110	"	ND	14	"	"	"	"
Winkles	3	150	"	"	12	"	"	"	"
Mussels	2	140	"	1.6	16	"	0.041	0.19	0.25
Fucus vesiculosus	6	870	"	1.7	34	"	NA	NA	NA
Mud	3	1980	110	60	980	25	9.7	47	52

Mean gamma dose rate in air at 1 m over intertidal mud (11 observations): 0.11 μGy h^{-1}

NA = not analysed.
ND = not detected.
*Except for mud where dry concentrations apply.

Table 30 Radioactivity in environmental materials and gamma dose rates near naval establishments, 1979

Establishment	Material	No. of observations	Mean radioactivity concentration, (wet)*, Bq kg^{-1}				
			Total beta	^{54}Mn	^{60}Co	^{65}Zn	^{95}Zr + ^{95}Nb
Chatham	Sediment	6	840	3.0	11	ND	ND
Devonport	Winkles	2	120	ND	ND	"	"
	Fucus vesiculosus	2	220	"	2.0	"	"
	Sediment	6	990	1.7	3.6	1.7	0.43
Faslane	Sediment	4	720	1.1	5.3	ND	ND
Rosyth	Sediment	2	650	1.6	2.0	"	"
Holy Loch	*Fucus spiralis*	4	300	ND	ND	"	"
	Sediment	2	500	2.2	50	"	"

Establishment	Material	No. of observations	Mean radioactivity concentration (wet)*, Bq kg^{-1}			Mean gamma dose rate in air at 1 m	
			^{134}Cs	^{137}Cs	^{144}Ce	No. of observations	μGy h^{-1}
Chatham	Sediment	6	ND	44	ND	16	0.068
Devonport	Winkles	2	"	0.22	"	NP	NP
	Fucus vesiculosus	2	"	ND	"	"	"
	Sediment	6	"	11	"	12	0.092
Faslane	Sediment	4	9.5	220	"	16	0.10
Rosyth	Sediment	2	ND	59	"	7	0.087
Holy Loch	*Fucus spiralis*	4	1.7	37	"	NP	NP
	Sediment	2	ND	90	13	33	0.10

ND = not detected.
NP = not applicable.
*Except for sediment where dry concentrations apply.

above the background levels due to fallout, adjacent nuclear power stations, and possibly Sellafield. The results of monitoring in 1979 are presented in Table 31. The only artificial radioactivity detected was due to radiocaesium. However, no radiocaesium was discharged by this establishment in 1979; the results were therefore due to the combined background effects noted above. The exposure of the critical group of fish and shellfish consumers due to these effects in 1979 was less than 0.1% of the ICRP-recommended dose limit for members of the public. Gamma dose rates over sediment were indistinguishable from those to be expected from natural background.

Table 31 Radioactivity in environmental materials and gamma dose rates near the outfall of the sewer serving Amersham International Ltd, Cardiff, 1979

Material	No. of observations	Mean radioactivity concentration (wet)*, Bq kg^{-1}		
		Total beta	^{134}Cs	^{137}Cs
Flounder	3	110	0.20	4.9
Winkles	4	130	ND	2.5
Fucus spiralis	4	200	"	0.78
Fucus vesiculosus	4	240	"	0.54
Sediment	8	980	3.7	60

Mean gamma dose rate in air at 1 m over intertidal sediment (8 observations): 0.080 μGy h^{-1}

ND = not detected.
*Except for sediment where dry concentrations apply.

9. Channel Islands monitoring

FRL has 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 1979 are given in Table 32. Concentrations of caesium-137 in fish and shellfish were not significantly in excess of those to be expected from fallout. However, the presence of transuranics in fish and shellfish may be attributed to discharges from the plant at Cap de la Hague. The presence of ruthenium-106 in environmental materials

Table 32 Radioactivity in marine environmental materials from the Channel Islands, 1979

Material	Sampling area	No. of observations	Mean radioactivity concentration (wet)*, Bq kg^{-1}								
			Total beta	^{65}Zn	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am
Skate	Guernsey	1	90	ND	ND	ND	3.1	ND	0.00077	0.0032	0.0025
Spider crabs	Jersey	1	120	"	"	"	1.7	"	0.0018	0.0054	0.0062
	Guernsey	1	90	"	"	"	1.1	"	0.00061	0.0033	0.0024
Mussels	Jersey	1	90	"	31	"	0.9	5.1	0.033	0.10	0.053
Oysters	Jersey	1	85	2.5	5.3	"	1.3	ND	0.0091	0.030	0.0088
Limpets	Jersey	1	74	ND	3.7	"	0.8	"	0.0099	0.029	0.010
	Guernsey	1	72	"	ND	"	0.7	"	0.0054	0.016	0.0056
	Alderney	1	170	"	16	"	1.9	"	NA	NA	NA
Porphyra	Jersey										
	Greve de Lecq	4	310	"	13	"	ND	"	"	"	"
	La Rozel	4	240	"	7.9	"	"	"	"	"	"
	Guernsey										
	Fort Doyle	4	230	"	13	"	"	"	"	"	"
	Fermain Bay	4	230	"	4.9	"	"	"	"	"	"
	Alderney										
	Telegraph Bay	4	230	"	26	"	"	"	"	"	"
	Quenard Point	4	220	"	58	"	"	"	"	"	"
Fucus serratus	Jersey										
	La Rozel	4	340	"	4.7	"	"	"	"	"	"
	Guernsey										
	Fermain Bay	4	310	"	ND	"	"	"	"	"	"
	Alderney										
	Quenard Point	4	370	"	17	"	"	"	0.035	0.11	0.022
Silt	Jersey										
	St Helier Harbour	1	870	"	160	1.7	11	36	1.0	2.8	1.2
	Guernsey										
	Bordeaux Harbour	1	350	"	ND	ND	2.3	ND	0.065	0.32	0.97
	Alderney										
	Crabbe Harbour	1	680	"	45	"	5.8	"	NA	NA	NA

NA = not analysed.
ND = not detected.
*Except for silt where dry concentrations apply.

Table 33 Summarised estimates of public radiation exposure from discharges of liquid radioactive waste in the UK, 1979

Establishment	Radiation exposure pathway	Critical group	Effective dose equivalent (as % of ICRP-recommended dose limit of 5 mSv year^{-1} for members of the public)
BRITISH NUCLEAR FUELS LIMITED			
Sellafield	Fish and shellfish consumption	Local fishing community Commercial fishing community	21 15
	External	Occupiers of intertidal areas	3.2
	Porphyra /laverbread consumption	Consumers in South Wales	<0.1
Springfields	External	Dredgermen	<1[a]
Capenhurst (Meols outfall)	Shellfish consumption	Local fishing community	<2[a]
Chapelcross	External Fish and shellfish consumption	Local fishermen	<2[a]
UNITED KINGDOM ATOMIC ENERGY AUTHORITY			
Winfrith	Fish and shellfish consumption	Local fishing community	1.1
Dounreay	External to hands: fishing gear External Shellfish consumption	Local fishermen Winkle pickers Local fishing community	<0.1[b] <1[b] <0.1[b]
NUCLEAR POWER STATIONS OPERATED BY THE ELECTRICITY BOARDS			
Berkeley and Oldbury	Fish and shellfish consumption External	Local fishing community	<0.1[b]
Bradwell	Fish consumption	Local fishing community	<0.3[b]
Dungeness	Fish consumption External	Local fishing community	<0.2
Hartlepool[c]	Fish and shellfish consumption External	Local fishing community Coal collectors	<0.6[a]
Heysham[c]	Fish and shellfish consumption External	Local fishing community	15[a] <1[a]
Hinkley Point	Fish and shellfish consumption External	Local fishing community	<0.3[b]
Hunterston	Fish and shellfish consumption External	Local fishing community	<3[b]
Sizewell	Fish and shellfish consumption External	Local fishing community	<0.3[b]
Trawsfynydd	Fish consumption	Local fishing community	<2
Wylfa	Fish and shellfish consumption External	Local fishing community	<0.4[a]
NAVAL ESTABLISHMENTS			
Chatham	External	Houseboat dwellers	<0.1
Devonport	External	Bait diggers	<0.1
Faslane	External	Boatyard workers	<0.1[b]
Rosyth	External	Dredgermen	<0.1[b]
Holy Loch	External	General public	<0.1[b]
AMERSHAM INTERNATIONAL LIMITED			
Cardiff	Fish and shellfish consumption External	Local fishing community	<0.1[a]

[a]Mainly due to discharges from Sellafield.
[b]Partly due to discharges from Sellafield.
[c]No radioactive discharges made in 1979. Potential critical pathways given; exposures are due to other sources of artificial radioactivity.

may also be attributed to this plant. However, the concentrations of artificial radionuclides in each of these materials were of negligible radiological significance.

10. Summary and conclusions

A summary of estimated public radiation exposures in 1979 resulting from liquid radioactive waste discharges from nuclear establishments monitored by FRL is presented in Table 33. The exposures are expressed in terms of the effective dose equivalent to members of the critical group or groups as percentages of the ICRP dose equivalent limit for members of the public. All exposures were well within this limit. Discharges from Sellafield have, as in previous years, given rise to the highest exposures. The most important contribution to this exposure was from radiocaesium which originated mainly from the fuel element storage ponds. The reduction in 1979 to 21% of the ICRP-recommended dose limit to the critical group of local fish and shellfish consumers from the 1978 value of 26% (Hunt, 1980) was probably mainly due to decreases in discharges particularly of radiocaesium. Contributions to exposures near many other nuclear establishments were also caused by radioactivity from Sellafield. Since apportionment of exposure to radioactivity of local origin is often difficult, the exposure from all sources (including the small contribution due to fallout) is quoted in Table 33, with an appropriate footnote.

As in previous years, collective doses from UK liquid radioactive discharges have 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 were given in section 4.1.1. The collective effective dose equivalent to the UK population in 1979 was 130 man-Sv, generally similar to that in 1978. For the population of other European countries the collective effective dose equivalent was 170 man-Sv in 1979. This represents an increase over the result for 1978, owing to generally higher radiocaesium concentrations in the North Sea and further afield in 1979 as compared with 1978. These increased concentrations are likely to be the result of the higher rate of radiocaesium discharges from Sellafield since 1974, which have been generally reducing since 1978. These recent reductions in radiocaesium discharges are expected to result in lower collective doses to the populations of the UK and other countries in later years.

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