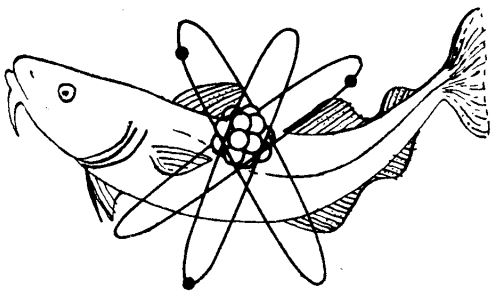
MINISTRY OF AGRICULTURE, FISHERIES AND FOOD
DIRECTORATE OF FISHERIES RESEARCH



RADIOACTIVITY IN SURFACE AND COASTAL WATERS OF THE BRITISH ISLES, 1976. PART 1: THE IRISH SEA AND ITS ENVIRONS

N. T. MITCHELL

FISHERIES RADIOBIOLOGICAL LABORATORY
TECHNICAL REPORT FRL 13
LOWESTOFT 1977

The author:

N. T. Mitchell, C Chem PhD ARIC, is a Senior Principal Scientific Officer of the Directorate of Fisheries Research. He is Officer-in-Charge of the Fisheries Radiobiological Laboratory, Lowestoft.

Tech. Rep. Fish. Radiobiol. Lab., MAFF Direct. Fish. Res., (FRL 13). 15 pp.

TECHNICAL REPORT FRL 13

Radioactivity in surface and coastal waters
of the British Isles, 1976

Part 1: The Irish Sea and its environs

ERRATA

Page 8, Figure 1

Caption should read:

Concentrations of caesium-137 in filtered sea water (pCi/kg) from British Isles coastal and North Sea waters, May/June 1976.

Page 15, line 8

should read

0.22 millirem/person....

CONTENTS

FOREWORD

It has become established practice to publish an annual report covering the whole of the monitoring activities of the Fisheries Radiobiological Laboratory (FRL) of the Ministry of Agriculture, Fisheries and Food and the latest of these covering work done in 1975 has recently been published as Technical Report FRL 12. These activities cover not only the Ministry's responsibilities for ensuring adequate control of radioactive waste discharges in England and Wales but also work done on behalf of departments of the Scottish Office, the Channel Islands States and the Irish Republic.

Whilst it is intended that this series will continue, and the 1976 data for other areas are in process of being assembled for publication, this report dealing with the Irish Sea has been prepared separately in recognition of intense current interest in the environmental effect of discharges of radioactive waste into the Irish Sea and so as to make data available as early as possible. It is confined to monitoring in relation to discharges into the Irish Sea, with special reference to those from the British Nuclear Fuels Limited fuel reprocessing plant at Windscale.

RADIOACTIVITY IN SURFACE AND COASTAL WATERS OF THE BRITISH ISLES, 1976. PART I: THE IRISH SEA AND ITS ENVIRONS

1. INTRODUCTION

In this report a similar format to that of recent reports in this series has been adopted, particularly with regard to the tabular and diagrammatic information, so as to facilitate comparison. However, this has not been possible in all cases, for instance, fish monitoring activities where the surveillance programme has been further expanded to include more species sampled from an increased number of sources. In the interests of rapid publication, certain information included in previous reports has been omitted from this report. This includes the explanations of the objectives and status of the monitoring and research information and of the method of presentation of the results, together with some general information on the nature of the establishments involved. Details of these will be found in the previous report in this series (Ref. 1) which is available on request.

The establishments referred to in this report, that is those from which discharges are made to the Irish Sea, are listed in Table 1. They are three sites operated by British Nuclear Fuels Limited (BNFL) and one nuclear power station of the Central Electricity Generating Board (CEGB). This table sets out the characteristics of the major pathways by which the waste discharged from each site causes irradiation of the general public.

Table 1 Principal exposure pathways for the major discharges of liquid radioactive waste to the Irish Sea

Site	Critical material	Critical exposure category	Principal exposed group
BRITISH NUCLEAR FUELS LIMITED			
Windscale	Fish flesh	Beta/gamma dose to whole body	Fishermen
	Estuarine sediment	External gamma dose to whole body	Fishermen
	Porphyra/laverbread	Beta dose to GI tract*	General public (South Wales)
Springfields	Estuarine sediment	Gamma dose to whole body	Dredgermen
Chapelcross	Shrimp flesh	Beta/gamma dose to whole body	Local fishermen and families
	Estuarine sediment	Gamma dose to whole body	Salmon fishermen
CENTRAL ELECTRICITY GENERATING BOARD AND SOUTH OF SCOTLAND ELECTRICITY BOARD			
Wylfa	Fish and shellfish flesh	Beta/gamma dose to whole body	Local fishermen and families
	Beach sediment	Gamma dose to whole body	Local fishermen

*Gastro-intestinal tract.

2. DISCHARGES OF LIQUID RADIOACTIVE WASTE

Details of discharges from the four establishments listed in this report are set out in Table 2 in order to give scale and perspective to the discussion on environmental data. The amounts of radioactive waste discharged in 1976 are shown (generally rounded off to the nearest curie); the discharges are also expressed in terms of the percentage of the

authorized limits. These limits are generally lower (often very much lower) than the amounts which could be permitted without exceeding the dose limits recommended by the International Commission on Radiological Protection (ICRP) and embodied in national policy.

Table 2 Major discharges of liquid radioactive waste to the Irish Sea, 1976

Site	Radioactivity	Authorized* discharge, curies/year	Amount released	
			Curies	As % of authorized limit
Windscale	Total beta†	300 000	183 482	61
	Ruthenium-106†	60 000	20 698	34
	Strontium-90†	30 000	10 344	35
	Total alpha	6 000	1 613	27
Springfields	Total alpha†	360	53	15
	Total beta†	12 000	2 842	24
Chapelcross	Total activity (other than tritium)	700	32	5
	Tritium	150	9	6
Capenhurst	Total activity† (other than U and decay products)	0.04	0.0084	21
Wylfa	Total activity (other than tritium)	65	6.3	10
	Tritium	4 000	198	5

* The authorized limits set out here are not all precisely as in the authorizations. This is because there are cases in which there is no annual limit but only one which refers to a shorter period of time such as three consecutive months. In these the actual limit has been scaled up appropriately so as to provide a basis for direct comparison of the actual discharges made. The instances where this has been done are marked thus †.

3. ENVIRONMENTAL MEASUREMENTS

3.1. BNFL, Windscale and Calder, Cumbria

Total discharges in 1976 were smaller than in 1975, particularly those of total beta radioactivity which stood at 61% of the authorized limit compared with 82% in 1975, part of

the decrease being due to smaller discharges of caesium-134 and -137. Discharges of ruthenium-106 remained similar to those in 1975 at about one-third of the individual authorized limits, whilst discharges of strontium-90 and of total alpha radioactivity each fell to 35 and 27% respectively of the limits authorized for these categories of radioactivity. In consequence all the authorized limits were met and, since these limits are less than those which are equivalent to the ICRP-recommended dose limits, public radiation exposure stayed well within the latter.

The extent of the FRL environmental survey activities in respect of Windscale discharges can be seen in Tables 3-11 and in the two figures. Currently the most important of the critical pathways is that due to consumption of fish and shellfish; accordingly a great deal of effort goes into its surveillance. Second in importance to it is exposure to external radiation from use of the local foreshore; the once-important pathway from consumption of laverbread made from the seaweed Porphyra remains a potential source of radiation exposure though very little occurred via this route in 1976. In addition to monitoring to assess radiation exposure via these three main pathways, indicator species are monitored and an extensive research programme related to radionuclides discharged from Windscale has been maintained. Some of this work devoted to understanding the long-term behaviour of fission product and transuranic radionuclides has been supported by a research contract with the European Atomic Energy Community (EURATOM).

3.1.1. The fish/shellfish consumption exposure pathway

Reflecting the increasing importance of radiation exposure via this route, there has been further expansion of the sampling programme. The principal radionuclides present are caesium-137 and -134; in fish they account effectively for all the radiation exposure which occurs. Some other fission products can be detected in shellfish, but again caesium-137 and -134 carry the greatest radiological importance. Measurements of beta activity and caesium-134 and -137 in Irish Sea fish are summarized in Table 3 whilst Table 4 contains data on Irish Sea shellfish. Data on fish from outside the Irish Sea which contain detectable amounts of Windscale-derived radiocaesium are in Table 5. It has been shown previously (Ref. 2) that public radiation exposure from the transuranics is very low, so all the samples collected for caesium measurements are not therefore also analysed for the transuranics. However, a selection is analysed and data on them are in Table 6. Most of the samples of fish and shellfish are from normal commercial sources so as to represent the actual intakes by the public as closely as possible, but it has been necessary to undertake special surveys close to Windscale and to take also the samples referred to as landed from the 'Windscale area' in Tables 3, 4 and 6. Within the area extending from St Bees Head to Walney Island there is a steep gradient in the concentration of radioactivity in sea water (see for instance Figure 2) and because also fish populations in this area are migratory, a wide range of concentrations is encountered between individual fish. The aim of collecting fish/shellfish representative of those which are eaten, particularly the intake of those people who are most highly exposed, could probably be met by intensive sampling over the whole of the fishing grounds. However, so as to minimize the risk of underestimating radiation exposure, fish samples are not taken at random from this whole area but instead only from a standard reference area in the zone of highest water concentrations, the samples being caught by special fishing surveys undertaken by, or specially commissioned by, FRL. The sampling area is part of a grid used over many years by FRL for research purposes and is a box running parallel to the shore, 1 nautical mile wide and 2 nautical miles long, with its most northerly point at the end of the pipeline. Samples coming from this area have therefore been caught within 5 km of the pipeline outlet. It

Table 3 Beta/gamma radioactivity in fish from the Irish Sea, 1976

Material	Landing point	Mean concentration of radioactivity, pCi/g (wet)		
		Total beta	^{134}Cs	^{137}Cs
Plaice	Windscale area*	46 ± 16	5.5 ± 2.0	41 ± 14
	Whitehaven	12 ± 4.0	1.4 ± 0.7	11 ± 4.9
	Fleetwood	15 ± 4.6	1.7 ± 0.7	13 ± 4.6
	Isle of Man	5.7 ± 1.5	0.2 ± 0.04	2.2 ± 0.6
Dab	Windscale area*	40 ± 11	4.3 ± 1.6	33 ± 5.7
Cod	Windscale area*	42 ± 3.1	4.9 ± 0.2	35 ± 4.9
	Whitehaven	23 ± 12	2.0 ± 1.0	15 ± 6.6
	Fleetwood	30 ± 17	3.0 ± 1.7	21 ± 11
	Isle of Man	15 ± 13	0.8 ± 0.7	8.4 ± 8.6
	N Ireland	9.0 ± 1.6	0.4 ± 0.2	3.8 ± 1.8
Flounder	Morecambe Bay	17 ± 5.6	2.0 ± 0.5	16 ± 3.5
Herring	Whitehaven	11 ± 2.3	1.4 ± 0.6	9.3 ± 4.2
	Isle of Man	13 ± 2.6	1.3 ± 0.8	8.6 ± 4.0
Salmon	Ravenglass Estuary	11 ± 10	0.8 ± 1.0	8.1 ± 12
Pollack	N Anglesey	10 ± 5.4	0.4 ± 0.2	5.1 ± 0.9

*Reference collection point within 5 km of the end of the Windscale effluent pipeline (see text).

Table 4 Beta/gamma radioactivity in shellfish from the Irish Sea, 1976

Material	Landing point	Mean concentration of radioactivity, pCi/g (wet)					
		Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce
Nephrops	Whitehaven	10 ± 4.4	not detected	not detected	0.7 ± 0.4	6.1 ± 3.4	not detected
	N Ireland	6.3 ± 1.1	"	"	0.2 ± 0.02	1.4 ± 0.1	"
Crab	Windscale area*	62 ± 28	"	26 ± 6.1	3.2 ± 1.5	21 ± 11	"
	N Anglesey	4.0 ± 0.3	"	not detected	0.1 ± 0.04	0.9 ± 0.1	"
Lobster	N Anglesey	2.1	"	"	0.1	0.5	"
Mussels	Windscale area*	361 ± 86	20 ± 12	260 ± 60	4.0 ± 1.6	23 ± 7.3	18 ± 15
Scallop	Isle of Man	5.2 ± 2.0	not detected	not detected	0.1 ± 0.01	0.9 ± 0.1	not detected
Shrimp	Morecambe Bay	16 ± 7.2	"	0.7 ± 0.5	1.1 ± 0.4	8.2 ± 4.2	"
Cockle	Morecambe Bay	12	0.3	2.5	0.5	3.6	"
Winkle	N Anglesey	7.2 ± 1.3	not detected	0.9 ± 0.4	0.2 ± 0.1	1.5 ± 0.5	"

*Reference collection point within 5 km of the end of the Windscale effluent pipeline (see text).

Table 5 Beta/gamma radioactivity in fish from the Minch and the North Sea, 1976

Material	Sampling area	Mean concentration of radioactivity, pCi/g (wet)		
		Total beta	^{134}Cs	^{137}Cs
Plaice	Minch	3.2 ± 0.2	<0.1	0.2 ± 0.1
	Northern North Sea	2.7 ± 0.4	not detected	<0.1
	Southern North Sea	3.3 ± 0.5	"	<0.1
Cod	Minch	3.4 ± 0.5	0.1 ± 0.1	0.6 ± 0.4
	Northern North Sea	3.2 ± 0.3	not detected	<0.1
	Southern North Sea	3.0 ± 0.1	"	<0.1
Herring	Minch	3.4 ± 0.7	<0.1	0.4 ± 0.2
	Southern North Sea	4.1	not detected	0.1

Table 6 Transuranic radioactivity in fish and shellfish from the Irish Sea, 1976

Material	Landing point	Mean concentration of radioactivity, pCi/g (wet)	
		$^{239+240}Pu$	^{241}Am
Plaice	Windscale area*	0.0042	0.0071
	Whitehaven	0.0014	0.0017
Cod	Windscale area*	0.00014	0.00046
Nephrops	Whitehaven	0.0044	0.015
Scallop	Isle of Man	0.014	0.004
Mussels	Windscale area*	3.1	9.2

*Reference collection point within 5 km of the end of the Windscale effluent pipeline (see text).

seems unlikely that any person's all-the-year-round consumption of fish will be from just this small area; however, if exposure is based on samples from it alone, we are hardly likely to have underestimated the maximum level of radiation exposure.

The assessment of actual radiation exposure of members of the public due to consumption of Irish Sea fish and shellfish is complex. There are three main variables - the quantities eaten (up to several hundred grammes per day being not unusual in fishing communities), the relative quantities of individual species eaten and the concentration of radioactivity in those species. Values of concentration of radioactivity are dictated more

by the area from which fish have come, particularly the distance they were from Windscale when they acquired their content of radioactivity, than by any fundamental interspecies differences, because variations in concentration factor for radiocaesium between species are relatively small. There is thus a wide range in rates of radiation exposure of individual members of the public who eat fish from the Irish Sea. The largest degrees of radiation exposure are believed to occur within the Windscale area coastal fishing community, though doses to some of the most avid consumers of fish elsewhere, such as full-time fishermen working out of Whitehaven and Fleetwood, may be similar. However, there are few people in either of these categories and even in these extreme cases doses were well within the ICRP-recommended dose limit. For the vast majority of the public with smaller consumption rates, even for those who derive all their fish from the Windscale area, exposure is very much less.

Table 7 summarizes dose rates computed on different assumptions. Consumption rates of fish and shellfish have been studied in the Windscale coastal area and, with particular emphasis on high-rate consumers, in other areas such as Whitehaven and Morecambe Bay. In so important a situation this is an ongoing commitment. In 1976 it was considered that the highest rate of radiation exposure of an individual deriving his fish from the immediate Windscale area is represented by a consumption rate, averaged throughout the year, of 265 g/day (224 g/day fish and 41 g/day shellfish). It is further assumed that plaice is representative of his intake of fish; it is the most plentiful of species in these inshore fishing grounds and showed the highest concentration of caesium of any species in 1976 (see Table 4). A less reasonable assumption is that fish from the FRL 'Windscale area' sampling position referred to above constitute the whole of the intake of the highest rate local consumers of fish: this is likely to lead to an overestimate of dose. On these assumptions the highest degree of radiation exposure in 1976 was judged to be 44% of the ICRP-recommended dose limit. If exposure at this level was attained it will have been by only a very few people: exposure of the average member of the local critical group of fish eaters was much less. For an average consumption rate of 52 g/day, exposure in 1976 would have been 9% of the ICRP-recommended dose limit if the fish came solely from the immediate vicinity of the pipeline, rather less if part or whole was drawn from a wider area of the coastal fishing grounds. Landings at the commercial fishing ports are an important source of dose and high rates of consumption have been recorded for a few people, again those associated with fishing itself. These people constitute another critical group with an average consumption rate estimated at about 300 g/day; in 1976 their exposure was estimated at about 17% of the ICRP-recommended dose limit on the basis of an equal mix of plaice, cod and herring. For the average consumer of fish exposure was much lower: at a consumption rate of about 40 g/day, which may be considered as representative of the typical fish-eater, the dose would be about 2-4% of the ICRP-recommended dose limit.

As in previous years, collective dose has been calculated. However, for the present, only the dose from UK landings of fish can be estimated, since the statistics of fish landings by other countries are not yet available. The provisional estimate of 12×10^3 man-rem includes the dose from Windscale-derived radiocaesium in fish caught off the coasts of Scotland and in the North Sea as well as in the Irish Sea and compares with a value of 8×10^3 man-rem in 1975. Though the 1976 values for both collective and individual dose are higher than the comparable values for 1975, it is believed that they have now reached a peak or have come to equilibrium with the higher rates of discharge in recent years. With the down-turn in discharge rates which began in 1976, reflecting measures

Table 7 Maximum rates of radiation exposure from Windscale discharges in 1976 due to consumption of fish and shellfish from the Irish Sea

Population group and persons concerned	Assumed consumption rate and source	Radiation exposure (% of ICRP-recommended dose limit)
		Total body
Coastal fishing community: maximum consumer	265 g/day Local supplies	44
Coastal fishing community: average consumer	52 g/day Local supplies	9
Other fish-eaters: critical group average	300 g/day Commercial: Whitehaven/Fleetwood landings	17
Public at large: typical consumer	40 g/day Commercial: Whitehaven/Fleetwood landings	2.4

taken to overcome the problems which have been creating this waste, dose rates should begin to fall. However, just as the increase in dose rates occurred over a period of years and has taken some time to reach equilibrium in concentration and exposure, the fall will also be gradual, the rate being also dependent on how quickly the BNFL measures take their full effect.

Collective dose is estimated from the measurements in fish and shellfish samples quoted in Tables 3, 4, 5 and 6. Data on the distribution of radiocaesium in sea water around the coasts of Great Britain are used in conjunction with concentration factors to supplement direct measurements on fish and examples of these are shown in Figures 1 and 2. They were obtained from research vessel cruises and are quoted from a programme of work whose aims include a continuing assessment of the distribution and behaviour of radiocaesium as well as estimation of the budget of the radionuclides concerned.

3.1.2. External exposure

This is the second most important radiation exposure pathway for liquid radioactive wastes released from Windscale and is due to the uptake of radioactivity by sediment. Of particular importance are the fine-grained sediments, muds and silts predominantly found in river estuaries and harbours; by comparison the coarser-grained sediments of the open, sandy foreshore are very much less receptive. Several radionuclides are readily taken up by sediment but by far the largest degrees of radiation exposure are from a group of gamma-emitting fission products, notably zirconium-95/niobium-95, ruthenium-106 and cerium-144. In recent years caesium-137 and -134 have also made important contributions to the dose received by this means because of higher discharge rates. However,

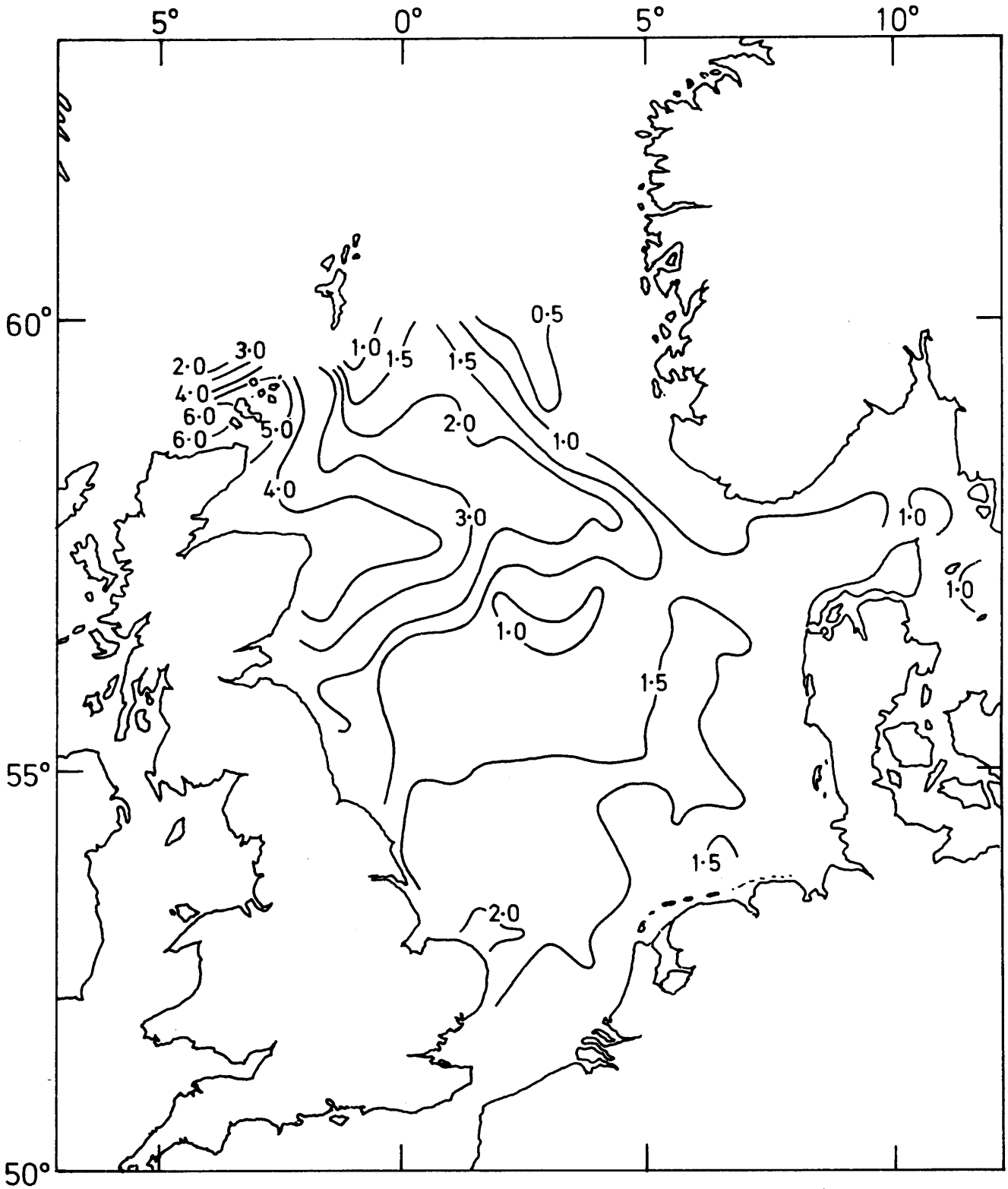


Figure 1 Concentrations of caesium-137 in filtered sea water (pCi/kg) from British Isles coastal and North Sea waters, January 1976.

curie-for-curie they are much less effective than the others cited, most of the radio-caesium activity staying in solution to be carried out of the Irish Sea by the sea-water transport process.

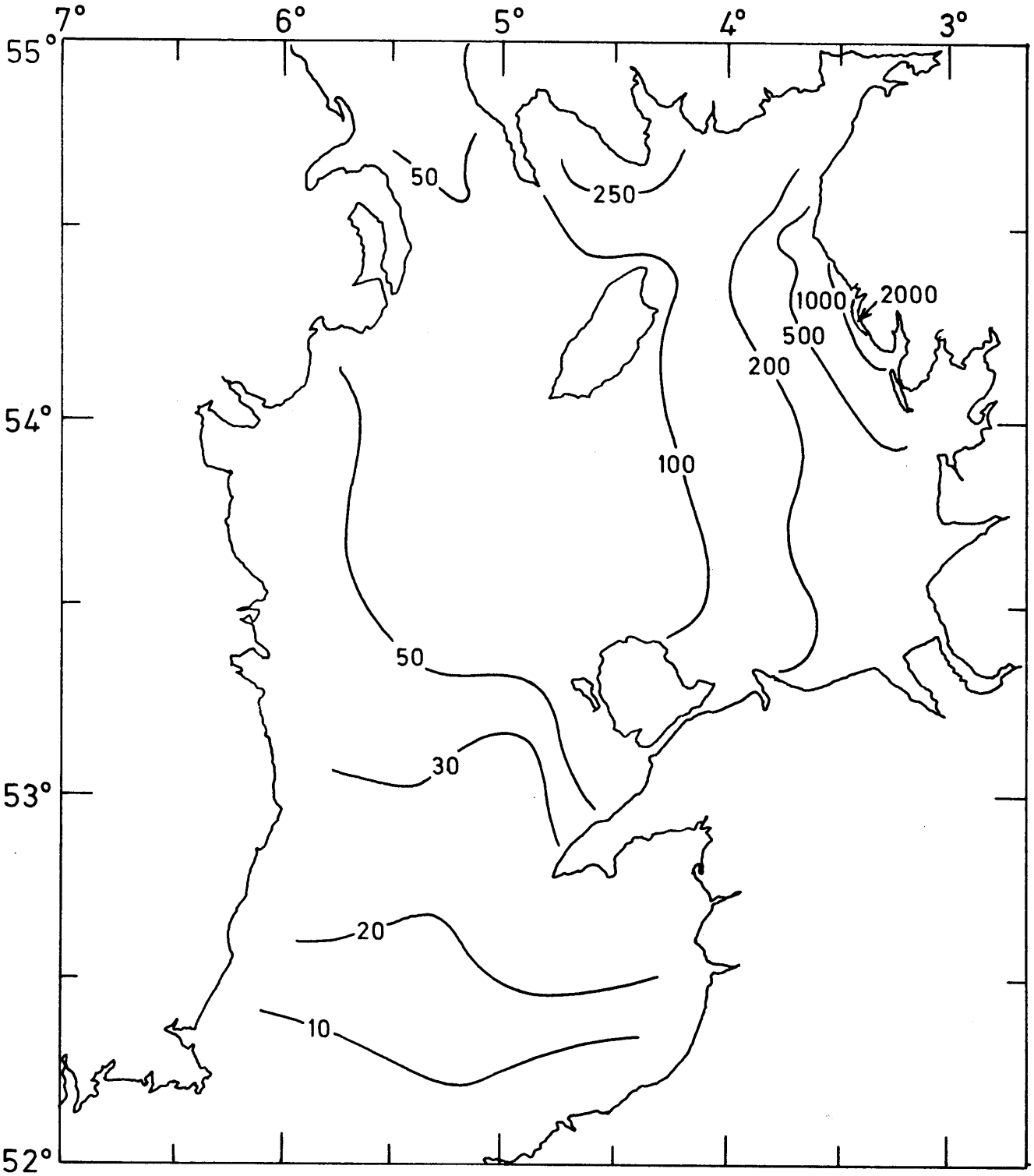


Figure 2 Concentrations of caesium-137 in filtered sea water (pCi/kg) in the Irish Sea, January 1976.

In monitoring for assessment of external exposure, a range of coastal locations is visited and the gamma dose rate measured with portable field instruments. The locations vary in nature from coarse sand to mud but, reflecting the higher dose rates over the latter, it is this type of environment that commands the greatest attention when monitoring, as can be appreciated from the summary data in Table 8 which include a description of the characteristics of each measurement site.

Table 8 Gamma radiation dose rates over intertidal areas of the Cumbrian coast, 1976

Site	Sediment type	Gamma dose rate*, μR/h
Maryport	Mud	70 ± 9
Whitehaven Harbour	Mud	85 ± 7
Braystones	Coarse sand	35 ± 5
Ravenglass Estuary (Eskmeals)	Mud	150 ± 33
Ravenglass Estuary (Salmon Garth)	Mud/ mussel bed	145 ± 27
Walney Island	Mud	60 ± 13
Walney Island	Coarse sand	25 ± 2

*Includes a contribution from background estimated at about 10 μR/h.

From studies of the use of the coastal environment of Windscale and bearing in mind that the highest dose rates along this coast are generally to be found within the Ravenglass Estuary, it has been concluded that those who make use of that estuary constitute the critical group. A few individuals regularly spend substantial amounts of time there, particularly over the mud banks surrounding the salmon garth which is tended. The dose rate over these mud banks is generally as high as anywhere else in the estuary and much higher than over most of it which is essentially sandy. In assessing the significance of these dose rate measurements, the usual approach of the pessimistic worst case is adopted and exposure of the salmon garth fisherman operating the largest amount of time at this work is taken to represent the upper limit to exposure. In 1976 his exposure was equivalent to 8% of the ICRP-recommended dose limit.

3.1.3. Porphyra/laverbread pathway

This once-limiting pathway is still of little more than potential importance in 1976 because there was no resumption of harvesting of local Porphyra, though late in the year a small amount was dispatched from Barrow. However, because this pathway does remain of potential importance, monitoring of the seaweed has been maintained; in addition it is a useful indicator. Samples are collected regularly from three locations along the Cumbrian coast and analysed for total beta radioactivity and for fission product radionuclides, including those which would be responsible for most of the dose if harvesting were to be resumed. These data are summarized in Table 9. Additionally, laverbread itself is analysed from each of the major manufacturers (Table 10) and these data establish the actual degree of radiation exposure which occurred. At a consumption rate of 130 g/day, as identified for the average member of the critical group of high-rate consumers of this foodstuff, exposure over the whole of 1976 was less than 0.2% of the ICRP-recommended dose limit.

Table 9 Radioactivity in Porphyra from the Cumbrian coast, 1976

Sampling point	Concentration of radioactivity, pCi/g (wet)							
	Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce	$^{239/240}Pu$	^{241}Am
Braystones South	290 ± 140	13 ± 10	260 ± 150	2.5 ± 0.9	12 ± 3.2	7.4 ± 8.3	2.9 ± 2.0	2.6 ± 1.4
Seascale	220 ± 180	13 ± 18	160 ± 100	2.0 ± 1.2	13 ± 1.2	8.4 ± 16	-	-
Walney Island	42 ± 14	0.8 ± 0.8	27 ± 18	0.7 ± 0.4	5.1 ± 2.4	0.2 ± 0.2	-	-

Table 10 Radioactivity in laverbread from the markets of South Wales, 1976

Manufacturer	^{106}Ru concentration, pCi/g (wet)	% of DWL
A	0.2 ± 0.3	0.1
B	0.3 ± 1.8	0.2

3.1.4. Other surveys

The importance of research such as measurements of the distribution of certain radionuclides in water and sediment and in indicator seaweeds has already been mentioned. Although it is not the purpose of these reports to present a complete account of these surveys, for papers on research projects are published in the scientific literature, some further data are included where they can be usefully descriptive of the general regime of radioactivity in the Irish Sea. Further Irish Sea data are included in sections 3.2, 3.3 and 3.4 under the headings of Springfields, Chapelcross and Wylfa even though the effects of these discharges are masked by those from Windscale.

A variety of seaweeds is collected from the south-western coasts of Scotland and the results of analyses, together with data on sediments from this region and from parts of the English coastline of the Irish Sea distant from Windscale, are quoted in Table 11. The Scottish area monitoring is done on behalf of departments of the Scottish Office. Some of the Porphyra from this coastline is used for human consumption: concentrations are very low and do not represent a significant source of public radiation exposure.

A range of seaweeds has also been examined in the form of samples collected by authorities in the Republic of Ireland and analysed by FRL on their behalf. The data are presented in Table 12 and here again the concentrations have no radiological significance, the monitoring programme serving an indicator purpose only.

3.2. BNFL Springfields, Lancashire

This establishment fabricates fuel elements for the nuclear industry and only small amounts of naturally-occurring radionuclides accrue for disposal via pipeline into the tidal River Ribble. The waste has little radiological impact, with slightly enhanced radiation dose levels occurring on the muddy banks of the river in the vicinity of the outfall. The FRL environmental monitoring programme here is therefore only small, consisting of

Table 11 Radioactivity in seaweed and sediment around the English and Scottish shorelines of the Irish Sea, 1976

Material and sampling point	Concentration of radioactivity, pCi/g (wet)*					
	Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce
Fucus vesiculosus						
Port William	17 ± 3.0	0.1 ± 0.2	0.1 ± 0.2	0.5 ± 0.2	4.0 ± 0.5	not detected
Garlieston	27 ± 6.6	1.2 ± 1.9	1.1 ± 0.8	1.2 ± 0.5	8.9 ± 2.7	"
Rascarrel Bay	37 ± 5.7	0.5 ± 0.9	1.0 ± 0.9	1.5 ± 0.4	9.3 ± 4.5	"
Heysham	41 ± 14	0.5 ± 0.9	1.9 ± 0.9	2.2 ± 0.5	16 ± 2.8	<0.1
Porphyra						
Larbrax Bay	6.6 ± 1.7	not detected	0.5 ± 0.4	0.1	0.5 ± 0.1	not detected
Port William	7.0 ± 1.0	<0.1	1.3 ± 0.4	0.1 ± 0.1	0.9 ± 0.3	"
Garlieston	11 ± 2.0	0.2 ± 0.3	3.5 ± 3.2	0.3 ± 0.1	2.0 ± 0.8	0.1 ± 0.3
Kirkcudbright	7.1	0.1	1.0	0.3	2.1	not detected
Sediment						
Garlieston (silt)	74 ± 26	not detected	5.5 ± 5.8	2.4 ± 0.8	18 ± 5.5	2.1 ± 2.9
Heysham (sand)	300 ± 130	3.1 ± 2.8	35 ± 36	5.7 ± 3.5	41 ± 21	14 ± 15
Fleetwood (sand)	29 ± 9.2	0.2 ± 0.2	not detected	0.5 ± 0.3	5.6 ± 1.7	0.6 ± 0.7

*Except sand - pCi/g (dry).

Table 12 Radioactivity in seaweeds on the coasts of Ireland, 1976

Material	Concentration of radioactivity, pCi/g (wet)				
	Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{134}Cs	^{137}Cs
Porphyra					
Skerries	4.8 ± 0.3	not detected	0.1	<0.1	0.3 ± 0.1
Colliemore	5.4 ± 1.4	"	not detected	<0.1	0.3 ± 0.1
St Helens	7.0 ± 2.9	"	0.2 ± 0.3	not detected	0.1 ± <0.1
Dunmore	5.5 ± 2.5	"	0.1 ± 0.2	"	<0.1
Carlingford	6.9	"	0.4	"	0.4
Fucus vesiculosus					
Skerries	13 ± 2.2	0.2 ± 0.2	not detected	0.1 ± 0.1	1.3 ± 0.1
Colliemore	15 ± 1.1	0.1 ± 0.1	"	0.2	1.4 ± 0.4
St Helens	10 ± 1.5	not detected	"	<0.1	0.3 ± 0.1
Dunmore	7.4 ± 1.3	"	"	not detected	0.1 ± 0.1
Carlingford	14 ± 1.7	0.3 ± 0.2	"	0.2 ± 0.1	1.6 ± 0.3
Laminaria					
Skerries	12 ± 4.4	not detected	not detected	0.2	1.2 ± 0.1
Colliemore	15 ± 5.5	0.1 ± 0.1	"	0.2	1.5 ± 0.6
St Helens	8.8 ± 4.3	0.1 ± 0.1	"	<0.1	0.3 ± 0.2
Dunmore	9.2 ± 3.2	not detected	"	<0.1	0.1 ± 0.1
Carlingford	17 ± 1.5	"	"	0.1 ± <0.1	0.9 ± 0.2

gamma dose rate measurements at four points in the near-vicinity of the outfall. Samples of mud were also taken and analysed for protactinium-234m, the only radionuclide present attributable to discharges from Springfields,and for fission products which are of Windscale origin. Results are summarized in Table 13. Maximum radiation exposure of the public from these discharges via the critical pathway, namely external exposure of those who frequent the river banks near the outfall, is low. Together with a component attributable to Windscale it is estimated at about 1% of the ICRP-recommended dose limit in 1976.

Table 13 Radioactivity in mud and gamma dose rates over the mud banks in the Ribble Estuary, 1976

Sampling site	Concentration of radioactivity, pCi/g (dry)				Gamma dose rate, μR/h
	^{106}Ru	^{134}Cs	^{137}Cs	^{234m}Pa	
Pipeline outlet	54 ± 24	14 ± 5	87 ± 24	790 ± 660	40 ± 9
Upstream					
90 m	61 ± 33	16 ± 9	104 ± 38	1060 ± 1090	43 ± 10
460 m	68 ± 24	16 ± 9	117 ± 37	1350 ± 1400	43 ± 13
Downstream					
90 m	77 ± 10	14 ± 10	124 ± 25	880 ± 280	40 ± 10

3.3. BNFL Chapelcross, Dumfriesshire

Discharges from this site are made into the Solway Firth under authorization of the Scottish Development Department. Monitoring by FRL (on behalf of departments of the Scottish Office) has concentrated on the two critical pathways, internal exposure due to consumption of local fish and shellfish principally shrimps, and external exposure due to time spent in intertidal areas of the foreshore. In addition, samples of the seaweed Fucus vesiculosus are collected because of their value as an indicator. The results of these surveys are shown in Table 14.

Table 14 Radioactivity in materials from the Solway estuary in the vicinity of Chapelcross, 1976

Material and sampling site	Concentration of radioactivity, pCi/g (wet)*					
	Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce
Shrimps						
Seafield	9.1 ± 2.5	0.1 ± 0.3	<0.1	0.7 ± 0.1	5.4 ± 1.5	not detected
Fucus vesiculosus						
Waterfoot	20 ± 6.1	0.1 ± 0.2	0.6 ± 0.4	1.2 ± 0.4	8.2 ± 3.3	<0.1
Seafield	23 ± 5.7	0.1 ± 0.1	0.7 ± 0.4	1.2 ± 0.4	8.6 ± 3.6	<0.1
Sediment						
Seafield	275 ± 210	2.9 ± 2.3	20.7 ± 8.3	6.6 ± 2.7	52.0 ± 13.5	6.3 ± 3.1

Gamma dose rate over intertidal area at Seafield = 19 ± 3 μR/h

*Except sediment - pCi/g (dry).

The radiological impact of Chapelcross discharges on the Solway estuary cannot be assessed precisely because of the overriding effect of the much larger discharges from Windscale. The levels of radioactivity found in the area are consistent with those to be expected at this distance from Windscale and the contribution from Chapelcross is still judged to be no more than a very small fraction of 1% of the ICRP-recommended dose limit.

3.4. CEGB Wylfa, Gwynedd

This is the only operating nuclear power station of the CEGB sited on the Irish Sea coastline, and discussion of environmental monitoring done by FRL in surveillance of its discharges completes this report on the monitoring of the Irish Sea in 1976. Monitoring covers the two potentially critical pathways, internal exposure due to consumption of local fish and shellfish and external exposure from use of the local foreshore. In addition indicator seaweeds are collected.

The internal exposure pathway is covered by sampling of the predominant species of fish and shellfish (pollack, lobster, crab and winkle) and analysing them for total beta radioactivity and gamma-emitting components. Total radiation exposure from the consumption of these foodstuffs is estimated at a maximum of 4% of the ICRP-recommended dose limit and applies to those at the upper end of the consumption rate range. For those with average intakes of fish, exposure is very much less.

The external exposure pathway is monitored by measuring gamma dose rates, together with sampling of sediment from the same locations. For these purposes muddy areas of the foreshore are used close to the power station, because these are the only areas where dose rates distinguishable from background can be detected. On the probably pessimistic assumption that these areas are used extensively, the exposure would still have been less than 1% of the ICRP-recommended dose limit in 1976; over much of the foreshore exposure would have been negligible. As with internal exposure through fish/shellfish consumption, such external exposure as did occur was wholly due to Windscale discharges with no effect from the small power station discharges being detectable.

Summaries of the data from these monitoring programmes will be found in Table 15.

Table 15 Radioactivity in environmental materials on the north coast of Anglesey near Wylfa nuclear power station, 1976

Material	Concentration of radioactivity, pCi/g (wet)*					
	Total beta	^{137}Cs	^{106}Ru	^{144}Ce	^{134}Cs	$^{95}Zr/^{95}Nb$
Pollack	10.5 ± 5.4	5.1 ± 0.9	not detected	not detected	0.4 ± 0.1	0.5 ± 0.2
Lobster	2.1	0.5	"	"	0.1	not detected
Crab	4.0 ± 0.3	0.9 ± 0.1	"	"	0.1	"
Winkle	7.2 ± 1.3	1.5 ± 0.5	0.9 ± 0.4	"	0.2 ± 0.1	"
Porphyra	6.3 ± 0.6	1.0 ± 0.1	not detected	"	<0.1	"
Fucus vesiculosus	17 ± 1.7	3.6 ± 0.8	<0.1	"	0.5 ± 0.1	<0.1
Mud	84 ± 23	37 ± 19	4.6 ± 2.5	"	3.5 ± 1.8	2.6 ± 2.2

Gamma dose rate over intertidal mud = 14 ± 1 μR/h

*Except mud - pCi/g (dry).

4. SUMMARY AND CONCLUSIONS

Summarizing the findings from FRL environmental monitoring of discharges into the Irish Sea, Table 16 lists the values of individual public radiation exposure given in this report. These relate specifically to the sites named; they show that the only important source is the effluent discharged by BNFL from the Windscale and Calder site. Furthermore, this is the only important source of public radiation exposure in terms of collective dose and is estimated at 12 x 10^3 man-rem to the UK fish-eating population in 1976. This is equivalent to a per caput dose averaged over the population of the whole country of 0.22 rem/person and 0.7% of the national policy limit of 33 millirem per person per year.

Table 16 Summary of estimates of maximum individual public radiation exposure from disposals of liquid radioactive waste to the Irish Sea, 1976

Site	Pathway	Maximum exposure of an individual as % of ICRP-recommended dose limit
BRITISH NUCLEAR FUELS LIMITED		
Windscale	Fish/shellfish	44
	External dose	8
	Porphyra/laverbread	0.2
Springfields	External dose	<1
Chapelcross	External dose	<1
	Shellfish	<1
CENTRAL ELECTRICITY GENERATING BOARD		
Wylfa	Fish/shellfish	<0.1
	External dose	<0.1

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