MINISTRY OF AGRICULTURE, FISHERIES AND FOOD

FISHERIES RADIOBIOLOGICAL LABORATORY

RADIOACTIVITY IN SURFACE AND COASTAL WATERS OF THE BRITISH ISLES 1971

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TECHNICAL REPORT FRL 9

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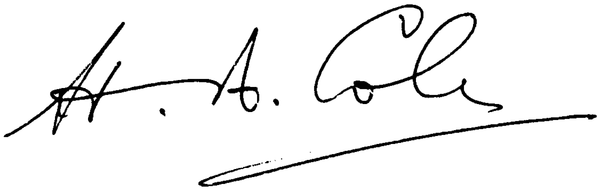
This report reviews the work done in 1971 by the Fisheries Radiobiological Laboratory, Lowestoft, to ensure the safe disposal of liquid radioactive waste to surface waters and the sea. In it Neil Mitchell records the situation as it existed at all the major sites from which waste is discharged, showing the care with which the interests of the public are protected and how the high standard of safety achieved in previous years was fully maintained in 1971.



H. A. Cole
Director of Fishery Research

ERRATA SLIP FOR TECHNICAL REPORT FRL 8

Some of the data quoted in Table 2 are incorrect and the values quoted for Berkeley and Wylfa in the column headed 'Percentage utilized' should read as follows:

Berkeley	Total activity*	12
	Tritium	4
Wylfa	Total activity*	10
	Tritium	< 1

Would readers also note that the positions of stations 4 and 5 in Figure 1 (referring to Table 7) were incorrect. For the correct positions please see Figure 1 in Report FRL 9.

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Table 1 Exposure factors involved in the discharge of aqueous radioactive wastes

Site	Critical material	Critical exposure category	Principal exposed group
A BRITISH NUCLEAR FUELS LTD.			
Windscale	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
B UNITED KINGDOM ATOMIC ENERGY AUTHORITY			
Winfrith	Lobster and crab flesh	Beta dose to GI tract	Local fishermen and families
Aldermaston	Drinking water	Beta-gamma dose to whole body (somatic and genetic hazard)	General public (Greater London)
Harwell	Drinking water	Beta-gamma dose to whole body	General public (Greater London)
Dounreay	Detritus associated with fishing gear	Beta dose to hands	Local fishermen
	Beach sludge	Gamma dose to whole body	Local fishermen and others
C THE RADIOCHEMICAL CENTRE LTD.			
Amersham	Drinking water	Beta-gamma dose to whole body (somatic and genetic hazard)	General public (Greater London)
D CENTRAL ELECTRICITY GENERATING BOARD AND SOUTH OF SCOTLAND ELECTRICITY BOARD			
Berkeley	Estuarine sediment	Gamma dose to whole body	Salmon fishermen/river authority workers
	Shrimp and salmon flesh	Beta-gamma dose to whole body	Local fishermen and families
Bradwell	Oyster flesh	Gamma dose to whole body	Oyster fishermen and families
Hinkley Point	Fish and shrimp flesh	Beta-gamma dose to whole body	Local fishermen and families
	Beach sediment	Gamma dose to whole body	Local fishermen
Dungeness	Fish flesh	Beta-gamma dose to whole body	Local fishermen and families
	Beach sediment	Gamma dose to whole body	Bait diggers
Oldbury	Estuarine sediment	Gamma dose to whole body	Salmon fishermen/river authority workers
	Shrimp and salmon flesh	Beta-gamma dose to whole body	Local fishermen and families
Sizewell	Fish and shellfish flesh	Beta-gamma dose to whole body	Local fishermen and families
	Beach sediment	Gamma dose to whole body	Local fishermen
Trawsfynydd	Trout flesh	Beta-gamma dose to whole body	Local fishermen and families
Wylfa	Fish and shellfish flesh	Beta-gamma dose to whole body	Local fishermen and families
	Beach sediment	Gamma dose to whole body	Local fishermen
Hunterston	Fish flesh	Beta-gamma dose to whole body	Local fishermen and families
	Beach sediment	Gamma dose to whole body	Shellfish collectors
E MINISTRY OF DEFENCE (NAVY DEPARTMENT)			
Chatham	Estuarine sediment	Gamma dose to whole body	General public (houseboat dwellers)
Faslane	Beach sediment	Gamma dose to whole body	Boatyard workers
Rosyth	Estuarine sediment	Gamma dose to whole body	Dredgermen

*GI tract, gastro-intestinal tract.

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1 INTRODUCTION

This is the sixth in an annual series of reports by the Fisheries Radiobiological Laboratory (FRL) concerned with monitoring the aquatic environment. It describes surveys made during 1971. Most of the laboratory's effort in this field is directed to fulfilling the Ministry's responsibilities for the control of radioactive waste discharges in England and Wales, but monitoring is also done on behalf of Departments of the Scottish Office, the Channel Islands States, and the Irish Republic, and accounts of these surveys are included. Most of the surveys are specifically linked to planned discharges within the United Kingdom - from sites of British Nuclear Fuels Limited and the United Kingdom Atomic Energy Authority, from nuclear power stations operated by the Central Electricity Generating Board and the South of Scotland Electricity Board, and from establishments of the Ministry of Defence (Navy Department) - and are made independently of environmental monitoring by the operators.

Those establishments discharging liquid radioactive waste with which this report is concerned are listed in Tables 1 and 2; the first summarizes the important factors for each of the critical exposure pathways concerned, whilst the second presents a statement on discharge rates expressed as a percentage of individual authorized limits. Having regard to the fact that the authorized limit is often only a very small proportion of the permissible limit - that is to say, the limiting capacity of the water mass to which the waste is discharged - and is never allowed to exceed it, many of the discharges quoted in Table 2 carry negligible radiological significance, as will become clearer from the text of this report.

Most of the data quoted in this report are the direct result of the laboratory's routine monitoring programmes; they demonstrate the safety of levels of environmental contamination and related radiation exposure of the public resulting from the planned disposal of radioactive waste. In addition to these basic surveys, which provide the final check on the adequacy of the control measures adopted, a substantial amount of environmental research is done from FRL. The main aim of this work is to enlarge our understanding of the behaviour of radioactivity in the environment and although it is not in itself required to verify the safety of a contaminated regime it improves predictive capability. The results of many of these research programmes are of further value in that they reinforce the conclusions of basic monitoring exercises; where this is so, they are included in this report. This comprehensive monitoring of the aquatic environment has confirmed that, as in previous years, adequate control of radioactive waste disposal has been maintained throughout 1971.

Table 2 Major discharges of liquid radioactive wastes to surface and coastal waters during 1971

Site	Radioactivity	Authorized discharge, curies/year	Percentage utilized
Windscale	Total beta	300 000	53
	Ruthenium-106	60 000	61
	Strontium-90	30 000	41
	Total alpha	6 000	45
Winfrith	Total activity	30 000	4
	Ruthenium-106	9 000	< 1
	Strontium-90	1 200	< 1
	Total alpha	1 200	< 1
Springfields	Total alpha	360	4
	Total beta	12 000	7
Aldermaston	Total activity	156†	12
Harwell	Total activity*	240†	51
	Tritium	240	34
Amersham	Total activity*	72†	38
	Tritium	400	81
Chapelcross	Total activity*	700	3
	Tritium	150	9
Dounreay	Total alpha	240	26
	Total activity	24 000	67
	Strontium-90	2 400	33
Berkeley	Total activity*	200	8
	Tritium	1 500	3
Bradwell	Total activity*	200	41
	Zinc-65	5	1
	Tritium	1 500	5
Dungeness	Total activity*	200	15
	Tritium	2 000	2
Hinkley Point	Total activity*	200	80
	Tritium	2 000	1
Oldbury	Total activity*	100	3
	Tritium	2 000	3
Sizewell	Total activity*	200	6
	Tritium	3 000	3
Trawsfynydd	Total activity*	40	65
	Tritium	2 000	2
Wylfa	Total activity*	65	< 1
	Tritium	4 000	< 1

Table 2 (continued)

Site	Radioactivity	Authorized discharge, curies/year	Percentage utilized
Hunterston	Total activity*	200	11
	Tritium	1 200	13
Chatham	Total activity*	20	< 1
	Cobalt-60	10	< 1
	Tritium	20	8
Faslane	Total activity*	1	< 1
Rosyth	Total activity*	30	< 1

*Excluding tritium.

†The unit used for Aldermaston, Harwell and Amersham is not the curie but a derived unit computed from several components of the effluent and intended to compensate for differences in radiotoxicity. The unit is referred to as the 'equivalent curie'; the actual discharges in curies were somewhat lower than the figures indicated.

2 SITES OPERATED BY BRITISH NUCLEAR FUELS LIMITED

2.1 Windscale and Calder, Cumberland

1971 was a notable year for this establishment, since from 1 April, together with other sites formerly within the Production Group of the United Kingdom Atomic Energy Authority, ownership passed from the UKAEA to British Nuclear Fuels Limited.

In addition, 1971 proved to be an interesting year from an environmental point of view, dispersion in the discharge area being poorer than in many previous years, so leading to higher levels of contamination of seaweed per unit of activity discharged, though still within safe limits. Perhaps the most interesting facet of all, however, has been the discovery of technetium-99, the more so because it appears to be the first time that this nuclide has been found anywhere in the marine environment.

There continue to be three important radiation exposure pathways resulting from Windscale discharges, two leading to internal exposure (the consumption of laverbread manufactured from the seaweed Porphyra and the consumption of fish and shellfish) and one to external exposure, due to the removal of radioactivity on to sediment creating a gamma radiation field on parts of the foreshore. Monitoring of these critical routes accounts for most of the monitoring effort expended in the north-east Irish Sea due to Windscale discharges, though the labelled environment produced there has provided further opportunities for research, as mentioned later in this section.

The *Porphyra* seaweed/laverbread pathway is monitored in two ways, by analysing both *Porphyra* (Table 3) and laverbread (Table 4), each method having its own particular merit. The seaweed surveys facilitate earlier detection of important changes in the levels of contamination than would be possible by relying on laverbread sampling alone, but for true assessment of the radiological significance of this pathway it is now necessary to sample the product. This is because Cumberland sources of weed are diluted with uncontaminated *Porphyra* from other areas to an extent which cannot any longer be readily assessed by other means such as monitoring the rate of raw material supply. Control has always been based on the fail-safe premise that laverbread is made from undiluted Cumberland weed, and although this does occur from time to time such periods are short and data in 1971 show that on average considerable dilution occurred. This varied between manufacturers to such an extent that public radiation exposure, estimated on the basis of a median consumption rate for the critical group of 160 g/day, ranged between 1 and 33 per cent of the ICRP-recommended dose limit, the weighted mean being 8 per cent. In comparison, exposure would have been 84 per cent of this dose limit had dilution not occurred.

These data are for exposure of the GI tract, which is the critical organ in the laverbread pathway. Exposure of other body organs is less, though the dose to the bone is of some interest because a different group of radionuclides, contributing negligibly to GI tract exposure, are involved. Most important in this group are strontium-90 and the alpha-emitting radionuclides of plutonium and americium. The estimated level of exposure in 1971 varied between the several sources of manufacture but would not have exceeded 2 per cent of the ICRP-recommended dose limit for any of them, these being estimates taking dilution into account. Without dilution, exposure would still have been low and could not have exceeded 6 per cent of this dose limit.

The critical external exposure pathway carries a similar level of significance to that of *Porphyra*/laverbread in terms of the maximum degree of individual exposure, though only a few people are involved. Over an extensive stretch of the local coastline contamination is low and is only much in evidence where fine sediment accumulates. The highest dose rates are therefore found in estuaries and harbours, contamination of the open beaches being relatively slight, since these are basically sandy with only isolated patches of overlying silt which are small in size, few in number and rarely stay for long before being scoured away by tidal action.

Monitoring has been concentrated on the Ravenglass Estuary, where the highest dose-rates are to be found (Table 5) and where the most highly-exposed known individual works, a salmon fisherman who was estimated to have received 11 per cent of the ICRP-recommended dose limit in 1971. Other areas are monitored, notably Whitehaven Harbour and the eastern shore of Walney Island, but both ambient dose-rates and the maximum degree of exposure which occurs through occupancy of these areas are much less. Also quoted in Table 5 are some measurements of radionuclide concentrations in surface samples of sediment cores. These data do not form part of the basic monitoring surveys but are part of a supporting research programme designed to elucidate the behaviour of radionuclides in these sediments and so to promote a better understanding of the processes involved.

The third-ranking exposure pathway concerns fish in which the principal radionuclides are caesium-134 and -137, though close in to the discharge area others are found, particularly ruthenium-106. Sampling of fish has become more complex in recent years as caesium has spread through much of the northern Irish Sea due to larger discharges from Windscale. This has meant that sampling is necessary over a wider area than hitherto, with more emphasis on general commercial sources than the relatively small fishing grounds in the near-vicinity of the discharge point. As the areas fished vary according to season and such factors as weather conditions, it will be appreciated that representative sampling has become quite difficult and estimates of public radiation exposure are inevitably less exact for this pathway than for either of the two major pathways. The results quoted in Table 6 confirm that the radiological significance of fish consumption as a public radiation exposure pathway has increased further, though it is still small at an estimated 2 to 3 per cent of the ICRP-recommended dose limit. This of course refers to the exposure of individuals, but the principal interest of this pathway is in a genetic context (see Section 10), in which respect it differs from the Porphyra/laverbread and external exposure pathways.

A varied programme of environmental research is undertaken in the Irish Sea and its environs, the basic aim being to promote a better understanding of the behaviour of the main constituents of the discharge. One example has already been discussed in the context of the external exposure pathway. Much of the laboratory's research into concentration factors is complete and most of the sea-water sampling is devoted to budget studies. Considerable effort, however, is being applied to measurement of radiocaesium, whose transport is of particular interest. Because of its conservative behaviour and the extreme sensitivity of techniques of measurement it can be detected at considerable distances from Windscale, far beyond the limit of any radiological significance. A selection of these data is quoted in Table 7, which should be read in conjunction with Figure 1 on page 9.

Other research involves sampling of Fucus seaweeds in the near-vicinity of Windscale (Table 8) and of these and various other materials of the foreshore at greater distances where contamination of even biota such as Porphyra has no radiological importance. These data (Table 9) include measurements from the south-western coastline of Scotland, where monitoring is undertaken on behalf of the Scottish Office.

The principal value of sampling Fucus seaweed is that it shows the presence of certain radionuclides which would not be detected so easily in other materials. This property has recently been heavily underlined by the discovery of technetium-99 in Fucus seaweeds, especially the vesiculosus variety, though it also concentrates to high degree in Fucus serratus and Fucus spiralis. Its behaviour poses interesting questions, the most paradoxical being that it is conservative in sea water yet concentrates readily in Fucus seaweeds. None has been found in Porphyra, and though small amounts have been detected in certain shellfish close to Windscale it has not appeared in fish, so that overall it has been of trivial radiological significance. A more detailed account of this work is being prepared for publication elsewhere.

Table 3 Radioactivity in *Porphyra* in the immediate vicinity of Windscale, 1971

Sampling site	Distance from pipeline (km)	Concentration of radioactivity, pCi/g (wet); mean and range							
		Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{137}Cs	^{144}Ce	$^{239/240}Pu$	^{241}Am	^{90}Sr
Maryport	41.0	14	1.0	10	1.1	1.1	-	-	-
St. Bees	10.0	150 (49-380)	24 (7.0-96)	140 (53-450)	0.9 (0-2.1)	15 (0-38)	2.0	0.3	0.16
Nethertown	5.6	330 (170-600)	59 (22-145)	290 (130-530)	2.6 (0-7.1)	43 (12-78)	-	-	-
Braystones North	3.7	360 (210-670)	55 (10-110)	330 (160-580)	3.5 (0-8.1)	37 (17-64)	1.3	0.8	0.65
Braystones South	1.9	460 (260-690)	70 (14-130)	410 (190-770)	4.2 (0-9.5)	50 (0-100)	1.5	0.9	1.01
Sellafield Pipeline	0	460 (120-800)	79 (12-280)	420 (98-800)	4.6 (0-14)	52 (0-130)	-	-	-
Sellafield Bailey Bridge	1.4	400 (170-650)	60 (20-180)	390 (130-670)	4.0 (0-11)	38 (0-100)	-	-	-
Seascale	3.1	332 (100-540)	46 (9.0-89)	310 (100-540)	3.6 (0-11)	28 (0-84)	1.8	1.1	0.48
Drigg Barnscar	5.6	178 (120-250)	27 (7.0-47)	160 (45-270)	2.7 (0-8.0)	20 (0-67)	-	-	-
Eskmeals North	10.9	140 (75-190)	16 (6.1-33)	140 (85-185)	1.2	6.1 (4.0-15)	-	-	-
Eskmeals South	14.3	163 (60-260)	17 (4.0-45)	160 (61-230)	1.7 (0-3.0)	11 (4.2-27)	0.8	0.3	0.15
Gutterby	20.1	138 (19-330)	24 (1.1-110)	110 (25-180)	1.7 (0-6.1)	13 (0-65)	1.4	0.5	-
Walney Island	38.6	35 (20-67)	3.1 (0.5-9.8)	36 (11-79)	1.0 (0.6-1.7)	1.3 (0-5.3)	0.9	0.5	0.05

Table 4 Ruthenium-106 in laverbread manufactured in South Wales, 1971

Manufacturer	Concentration of ^{106}Ru, pCi/g (wet); mean and range
A	3.6 (0.4-12)
B	2.3 (0.1-7.0)
C	42 (0-120)
D	1.6 (0-6.4)

Table 5 Radioactivity in silt and gamma dose-rates over silt banks in the vicinity of Windscale, 1971

Sampling site	Concentration of radioactivity, pCi/g (dry); mean and range					Gamma dose-rate, μR/hour; mean and range
	$^{95}Zr/^{95}Nb$	^{106}Ru	^{137}Cs	^{144}Ce	^{241}Am	
Eskmeals	940 (270-2000)	1500 (940-2100)	110 (60-170)	1100 (640-1600)	74 (40-100)	190 (100-300)
Walney Island	-	-	-	-	-	42 (20-60)
Whitehaven Harbour	750 (94-3300)	810 (400-1900)	100 (76-200)	740 (260-2000)	-	86 (75-100)

Table 6 Radioactivity in plaice, skate and shellfish flesh in the Irish Sea, 1971

Species	Sampling area	Concentration of radioactivity, pCi/g (wet); mean and range					
		^{40}K	^{106}Ru	^{137}Cs	^{134}Cs	^{90}Sr	^{239}Pu
Plaice	North Irish Sea	1.6 (1.4-2.0)	0.5	2.7 (1.1-4.7)	0.5 (0.2-0.9)	0.01	-
	South Irish Sea	2.3 (1.2-2.9)	-	1.7 (0.5-3.2)	0.3 (0.04-0.7)	-	-
	Windscale discharge area	2.4 (2.0-2.9)	5.8 (0-12)	8.1 (5.2-16)	1.3 (0.7-2.6)	0.7 (0.2-2.0)	0.03
Skate	Windscale discharge area	2.5 (2.0-3.1)	-	7.9 (4.5-11)	1.3 (0.7-1.7)	-	-
Nephrops	Irish Sea	2.4 (2.1-2.7)	1.2 (0.4-2.4)	3.2 (1.2-4.2)	0.5 (0.2-0.7)	-	-
Crab	Windscale discharge area	-	120	11	0.3	-	-
Lobster	Windscale discharge area	5.0	25	23	3.4	-	-

Table 7 Caesium-134 and caesium-137 in sea water from the Irish Sea and its north-western approaches, 1971

Area	Position number	Concentration of radioactivity, pCi/litre; mean and range	
		^{137}Cs	^{134}Cs
Seascale	1	660 (140-1700)	110 (30-230)
North Irish Sea	2	51 (13-110)	8.8 (1.7-21)
Mid-North Channel	3	19 (12-25)	3.0 (1.3-3.9)
Mull of Kintyre	4	15 (9.5-19)	1.8 (0-3.1)
Islay	5	10 (5.9-16)	1.0 (0-2.0)

Table 8 Radioactivity in Fucus vesiculosus in the vicinity of Windscale, 1971

Sampling site	Concentration of radioactivity, pCi/g (wet); mean and range						
	Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{137}Cs	^{144}Ce	^{110m}Ag	^{90}Sr
St. Bees	320 (170-470)	34 (28-43)	29 (26-36)	9.8 (7.8-12)	12 (9.6-15)	1.2 (0.9-1.5)	2.4 (1.1-3.4)
Seascale	880 (330-1300)	82 (39-120)	68 (35-100)	25 (13-36)	29 (10-44)	2.3 (1.6-3.0)	2.5 (0.7-4.7)
Gutterby	210 (88-330)	20 (10-27)	13 (10-17)	6.7 (5.8-8.0)	5.4 (3.0-6.3)	0.9 (0.5-1.1)	2.3 (1.3-4.1)
Walney	88 (44-130)	6.3 (3.1-11)	3.8 (2.4-4.9)	4.1 (2.9-5.4)	1.6 (0.9-2.6)	0.2 (0.1-0.2)	1.6 (0.7-3.4)

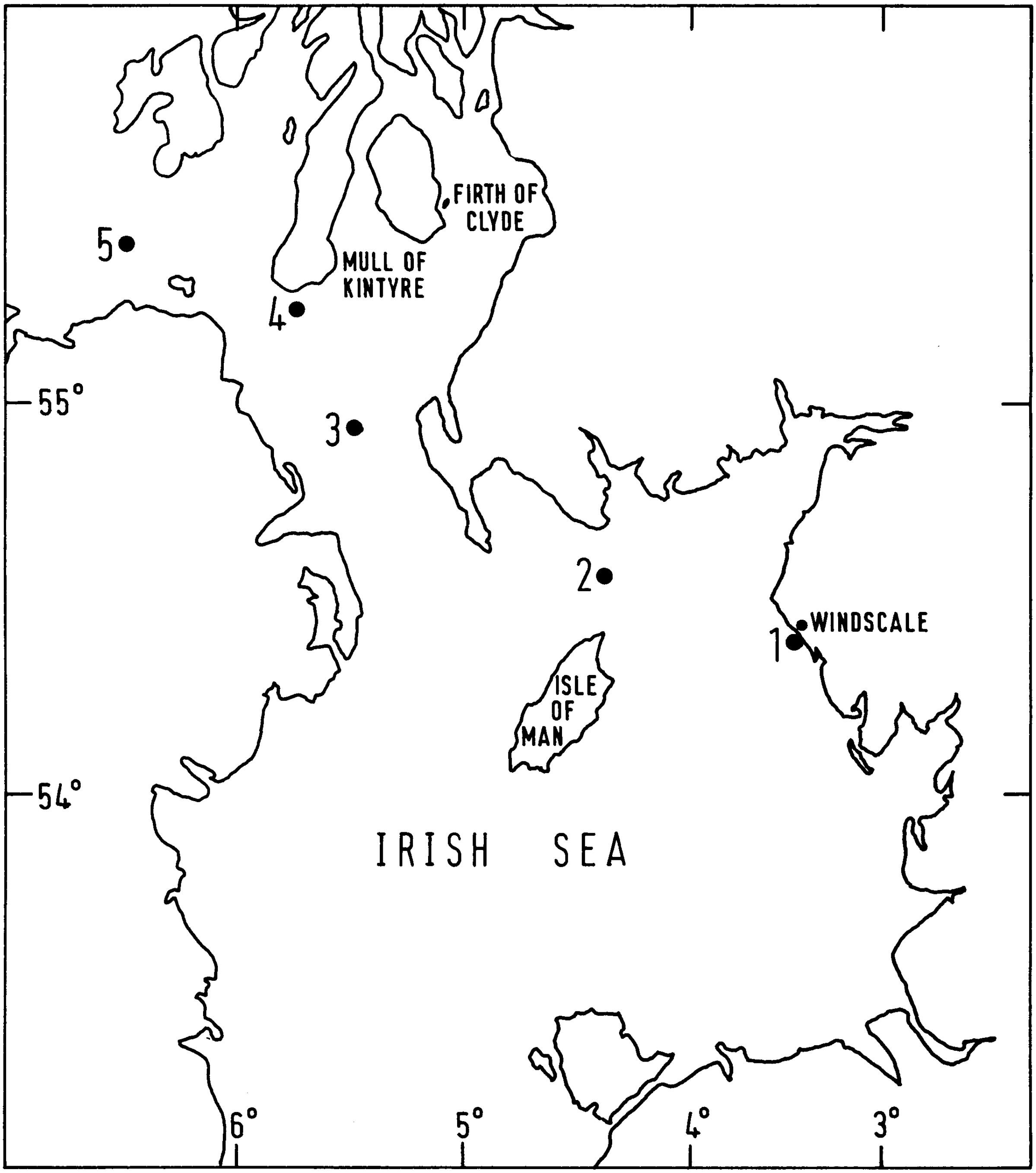

Figure 1 Positions at which sea water was sampled for caesium content (see Table 7).

Table 9 Radioactivity in seaweed and foreshore materials around the Irish Sea and western Scotland, 1971

Material and sampling site	Concentration of radioactivity, pCi/g (wet)*; mean and range				
	Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{137}Cs	^{144}Ce
<u>Porphyra</u>					
Labrax Bay	6.8 (6.0-7.2)	0.5 (0.1-1.1)	1.7 (0.9-2.2)	0.15	-
Port William	8.5 (7.7-9.9)	0.5 (0.2-1.0)	3.4 (1.6-5.5)	0.2 (0.1-0.3)	-
Garlieston	10 (8.8-11)	1.1 (0.2-2.4)	4.6 (2.5-6.6)	0.4 (0.3-0.6)	-
<u>Fucus vesiculosus</u>					
Port William	20 (11-38)	0.7 (0.4-0.9)	0.5 (0.4-0.7)	1.1 (0.8-1.3)	0.2
Garlieston	45 (25-73)	3.4 (1.6-4.8)	1.9 (1.2-2.5)	2.4 (2.1-2.8)	0.9 (0.6-1.2)
Rascarrel Bay	53 (29-84)	3.1 (1.3-6.0)	1.2 (0.9-1.7)	2.6 (2.1-3.2)	1.0 (0.6-1.4)
Heysham	64 (34-90)	0.8 (0.4-1.2)	0.8 (0-1.2)	3.3 (2.9-3.7)	0.2 (0-0.4)
Silt					
Garlieston	75 (63-86)	5.8 (1.2-17)	18 (4.1-32)	7.0 (1.8-12)	11 (3.2-23)
Sand					
Heysham	56 (30-96)	2.9 (0.4-7.3)	10 (3.8-21)	5.3 (4.6-6.5)	5.4 (3.0-9.8)
Fleetwood	22 (16-34)	0.2	0.6 (0.3-1.2)	1.4 (1.1-1.6)	0.5 (0.2-0.7)

*Except silt and sand, pCi/g (dry).

2.2 Springfields, Lancashire

Disposals of liquid radioactive waste from this site, which undertakes fuel fabrication for the nuclear power industry, are made by pipeline into the tidal region of the River Ribble. There is no internal exposure of any consequence, and the impact of discharges is confined to a single external exposure pathway which is the result of removal of radioactivity by mud, particularly protactinium-234m. This generates a field of gamma radiation exposing those few people who frequent the river banks in the near-vicinity of the pipeline outlet, but as dose-rates are low the importance of this pathway is very small - less than 1 per cent of the ICRP-recommended dose limit for the general public. In consequence only a small monitoring programme is maintained, the essential content of which is measurement of the gamma dose-rate on mud banks in the near-vicinity of the pipeline outlet. Results are summarized in Table 10, in which data on analyses of mud by gamma spectrometry are also quoted; these are undertaken for research purposes as part of a programme to follow the distant effects of Windscale discharges, and it is to this source that the presence of fission products is attributed.

Table 10 Radioactivity in silt and gamma dose-rate over silt banks in the Ribble Estuary, 1971

Sampling site	Concentration of radioactivity, pCi/g (dry); mean and range					Gamma dose-rate, μR/hour; mean and range
	Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{137}Cs	^{234m}Pa	
Pipeline outlet	630 (150-1500)	3.5 (0.9-7.2)	29 (12-39)	12 (5-17)	250 (99-390)	14 (10-25)
Upstream						
90 metres	810 (120-2700)	4.2 (2.0-7.4)	35 (13-59)	15 (6-27)	330 (110-540)	14 (10-25)
460 metres	810 (86-2600)	5.0 (1.4-11)	33 (15-56)	12 (6-15)	430 (87-890)	15 (10-40)
Downstream						
90 metres	1500 (100-3600)	3.4 (0.8-6.5)	21 (13-33)	9.3 (4.4-16)	500 (57-1300)	14 (10-30)

2.3 Chapelcross, Dumfriesshire

Discharges from this site to the Solway Estuary are only very small - so much so that they are completely masked by those from Windscale. Whilst several public exposure pathways can be recognized, the impact of Chapelcross disposals in these pathways is negligible; indeed, the total extent of contamination from all sources is hardly significant, none being equivalent to more than a fraction of 1 per cent of the ICRP-recommended dose limit.

Monitoring is undertaken on behalf of the Scottish Office; the programme covers internal exposure by sampling of salmon and shrimps and external exposure by measurement of the ambient gamma radiation dose-rate at selected points in the Solway Estuary. The latter is supported by radiometric analyses of silt, results of which are quoted in Table 11 along with those for seaweed (as an indicator), salmon and shrimps. No gamma radiation dose-rates are quoted, because none of the measurements in 1971 were significantly different from the normal background, emphasizing how insignificant contamination is in this particular area.

Table 11 Radioactivity in estuarine materials in the vicinity of Annan, 1971

Material and sampling site	Concentration of radioactivity, pCi/g (wet)*; mean and range					
	Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{137}Cs	^{134}Cs	^{144}Ce
F. vesiculosus						
Waterfoot	31 (11-48)	1.2 (0.3-3.6)	1.1 (0.5-2.5)	1.9 (1.3-2.2)	0.3 (0.2-0.4)	0.8 (0.2-2.5)
Seafield	28 (16-36)	1.1 (0.5-2.4)	1.0 (0.6-1.6)	2.1 (1.4-2.6)	0.4 (0.2-0.5)	0.8 (0.3-1.2)
Silt						
Seafield	180 (130-200)	25 (2.0-89)	63 (25-120)	18 (10-26)	2.9 (1.8-4.0)	35 (14-81)

*Except silt, pCi/g (dry).

3 SITES OF THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY

With responsibility for several sites formerly under UKAEA control passing to British Nuclear Fuels Limited during 1971, this section now covers the activities of only two sites, Winfrith and Dounreay. These are the only UKAEA establishments which need to dispose of liquid radioactive wastes to areas of concern to fisheries interests, the impact of others such as Harwell and Aldermaston and also the Radiochemical Centre, Amersham, now a separate commercial enterprise, being via the drinking water exposure pathway, with negligible consequences through fish consumption.

3.1 Winfrith, Dorset

Most of the liquid radioactive waste discharged from this site is tritium but in quantities too small to have any environmental importance. Some of the remainder, especially certain neutron activation products, do find their way into marine biota, so that the critical pathways are all internal due to consumption of shellfish, primarily crabs and lobsters. Contamination of these products is so low that public radiation exposure is still negligible; monitoring has remained on a research basis consisting primarily of sampling molluscan shellfish and seaweed, both in the role of indicators. The highest levels of contamination are found in oysters but the amount they contain is of no radiological concern.

A summary of these data is given in Table 12.

Table 12 Radioactivity in marine materials in the vicinity of Winfrith, 1971

Material	Sampling site	Concentration of radioactivity, pCi/g (wet); mean and range		
		Total beta	^{60}Co	^{65}Zn
Winkles	Chapman's Pool	4.3	0.8	1.8
	Osmington Mills	5.5	0.3 (0.2-0.5)	1.4 (0.2-3.2)
Oyster flesh	Poole Harbour	2.7	-	3.5
Fucus serratus	Chapman's Pool	8.6 (8.4-9.1)	3.4 (0.4-5.3)	2.8 (0.3-4.3)
	Portland	8.6 (7.5-10)	1.5 (0.1-2.7)	-
	Weymouth	9.1 (8.6-9.4)	3.3 (0.3-5.2)	0.1
	Osmington Mills	8.4 (6.7-10)	4.2 (0.4-9.0)	2.5 (0.4-5.7)
	Swanage	8.3 (7.2-9.0)	1.3 (0.6-1.7)	0.5

3.2 Dounreay, Caithness

The quantity of waste disposed of from this site, mainly fission product wastes, is second only to Windscale; however, due primarily to the high degree of dispersion available in the waters of the Pentland Firth into which pipeline disposals are made, public radiation exposure is minimal. The principal exposure pathways are both external, contamination of fish and shellfish being so low that no internal exposure pathway is of any consequence. Of the two external exposure pathways the one which is usually judged as the more important affects fishermen who work near to Dounreay. The pathway occurs as a result of contamination of fishing gear, generating a mainly beta radiation dose to their hands. Its significance is liable to fluctuate considerably from year to year, being very dependent on the level of success achieved by a very small group of fishermen, effectively only those who fish from Sandside Bay, which is only about 2½ km from Dounreay. The other pathway may more fairly be described as potential, for one has to envisage occupancy for a significant period of time of clefts in the local rocky coastline which are relatively inaccessible. Wind-generated spume is carried into these places and left behind as a sludge by the receding tide, creating a field of gamma radiation and causing exposure to anyone using these regions. It has never proved possible to establish occupancy rates for these areas with any real confidence although, because access is feasible, the possibility that the public frequents them cannot be ruled out. Radioactive waste control related to this contamination has to be made on rather arbitrary assessments of possible rather than probable occupancy rates, taking a pessimistic view so that any error is on the side of safety. Even on such a cautious basis, exposure by this pathway in 1971 is unlikely to have been as much as 1 per cent of the ICRP-recommended dose limit, whilst the comparable figure for the other pathway, which can be estimated so much more precisely, is judged to have been about 9 per cent.

Monitoring done by the laboratory continues to be in close cooperation with the Authority, and it is a finely judged mixture of routine and research. Results (Table 13) illustrate some of the measurements, particularly those on indicator species of shellfish and seaweed.

Table 13 Radioactivity in the vicinity of Dounreay, 1971

Material and sampling point	Concentration of radioactivity, pCi/g (wet); mean and range				
	Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{137}Cs	^{144}Ce
Limpet flesh					
Sandside Bay	92 (27-180)	31 (8.0-100)	9.0 (0-28)	0.6 (0-3.4)	35 (13-85)
Winkle flesh					
Sandside Bay	ND	7.0 (2.0-13)	7.1 (3.5-9.5)	-	24 (15-32)
F. vesiculosus					
Sandside Bay	61 (28-136)	60 (13-360)	3.5 (0-47)	0.4 (0-1.5)	29 (8.0-98)

ND = not determined.

4 NUCLEAR POWER STATIONS OPERATED BY THE CENTRAL ELECTRICITY GENERATING BOARD

4.1 Berkeley and Oldbury-upon-Severn, Gloucestershire

These two stations are separated by only a few kilometres and, being on the same bank of the tidal Severn Estuary and discharging low-level radioactive wastes to effectively the same reach of the river, it is appropriate as well as convenient to consider them together. The critical exposure pathways were reviewed in a new habits/consumption survey in 1971. This confirmed the identity of the two critical pathways on which control had been exercised previously, one being internal due to consumption of fish and shrimps, the other external and the result of adsorption of radioactivity by mud. In each case the critical nuclides are caesium-134 and -137, affecting an entirely local population composed essentially of the fishing community, though neither pathway generates much radiation exposure, the general level of contamination being equivalent to no more than a small fraction of 1 per cent of the ICRP-recommended dose limit for any known individual.

The 1971 monitoring programme followed a similar pattern to that in previous years and included sampling of estuarine fish and shrimps to cover internal exposure, with gamma dose-rate measurements on the mud banks (supported by some analysis of the sediment) in surveillance of external exposure. A summary of data is given in Table 14 together with analyses of seaweed, whose only role is that of an indicator.

Table 14 Radioactivity in estuarine materials and gamma dose-rates over silt in the vicinity of Berkeley and Oldbury, 1971

Material	Mean concentration of radioactivity, pCi/g (wet)*			Gamma dose-rate, μR/hour; mean and range
	Total beta	^{137}Cs	^{134}Cs	
Salmon flesh	ND	<0.1	-	-
Shrimp flesh	2.1	0.03	0.01	-
Commerical sources of fish	2.0	<0.1	-	-
F. vesiculosus	9.7	0.08	0.05	-
Silt	30	1.5	0.3	7.4 (5.5-8.2)

Natural radioactivity in silt: ^{40}K, 11 pCi/g; ^{238}U, 2.2 pCi/g; ^{232}Th, 0.8 pCi/g.

*Except silt, pCi/g (dry).
ND = not determined.

Table 15 Radioactivity in oysters and non-critical materials, and gamma dose-rates over silt in the Blackwater Estuary, 1971

Material and distance from Barrier Wall (km)	Concentration of radioactivity, pCi/g (wet)*; mean and range						Mean gamma dose-rate, μR/hour
	Total beta	^{60}Co	^{65}Zn	^{110m}Ag	^{134}Cs	^{137}Cs	
F. vesiculosus							
1.6 (upstream)	7.4	0.04	< 0.1	0.1	0.1	0.4	-
Silt							
0	24	-	-	0.2	0.4	1.9	23
1.6 (upstream)	29	0.3	-	0.2	1.1	5.4	7.5
Native oyster	2.8 (2.0-3.1)	-	0.5 (0.4-0.8)	1.5 (1.2-1.8)	-	0.1	-

*Except silt, pCi/g (dry).

4.2 Bradwell, Essex

This is one of the earliest of the Magnox stations and like Berkeley and Oldbury is situated on a tidal estuary, though in this case much nearer to the open sea. The control of discharges is dictated by the well-known internal exposure pathway involving consumption of oysters, for external exposure is of no consequence at all. With a further decline in discharges of zinc-65, once the undisputed critical nuclide, silver-110m is responsible for most of such radiation exposure as does occur, though it must be stressed that in absolute terms this is very low, for it is estimated that no one is exposed to more than 0.2 per cent of the ICRP dose limit.

The small monitoring programme is based on analysis of oysters from the nearest area of the estuary to the power station discharge point where oysters can be farmed commercially. This is supported by analyses on seaweed and silt, with measurements of the gamma dose-rate. It should be noted that, though the gamma dose-rate close to the station is often higher than natural background, this is not due to contamination of sediment, direct radiation from the station being responsible. Results of these measurements and the analyses of estuarine materials are summarized in Table 15.

4.3 Dungeness, Kent

Dispersion conditions in the coastal watermass into which discharges from this station are made are amongst the best anywhere in the British Isles. It is not surprising therefore that, with only small amounts of liquid radioactive waste requiring disposal, contamination of this environment has remained below limits of detection, public radiation exposure in consequence being negligible. Despite this, it is not difficult to identify what would be the important exposure pathways and two have been characterized, one being internal through consumption of fish and shellfish, the other external due to occupation of the foreshore. These form the basis of the small monitoring programme which the laboratory maintains, results of which are summarized in Table 16.

Table 16 Radioactivity in marine materials and gamma dose-rate over beaches in the vicinity of Dungeness, 1971

Material	Mean concentration of radioactivity, pCi/g (wet)		Gamma dose-rate, μR/hour; mean and range
	Total beta	^{137}Cs	
Plaice flesh	5.8	0.02	-
Sand	33	0.08	-
Sand/shingle	-	-	4.4 (3.9-4.9)

4.4 Hinkley Point, Somerset

Discharges from this power station are made to the relatively open waters of the Bristol Channel, though their dispersion is somewhat influenced by the nearby estuary of the River Parrett.

The two critical pathways follow a familiar pattern, with internal exposure from consumption of local fish and shrimps and external exposure from use of the foreshore. Radioactivity attributable to power station operation is detectable in each of the critical materials, but concentrations are low and public radiation exposure via either pathway is only of the order of 0.1 per cent of the ICRP-recommended dose limit. The most highly exposed individuals - local fishermen - are subject to the effects of both pathways but in no case receive more than a fraction of 1 per cent of the ICRP-recommended dose limit.

Monitoring programmes are based primarily on the critical materials, fish and shrimps being sampled regularly for analysis in surveillance of internal exposure, whilst the external pathway is covered by surveys of the local foreshore measuring the ambient gamma dose-rate at selected sites where samples are also taken for analysis. All these materials show the presence of caesium-134 and -137, and occasionally traces of other fission products too. Fucus seaweed has been retained in the programme because of its value as an indicator, though of late it has not shown the presence of any unusual nuclides. Results are summarized in Table 17.

Table 17 Radioactivity in marine materials and gamma dose-rate over silt in the vicinity of Hinkley Point, 1971

Material	Distance from pipeline outlet (km)	Concentration of radioactivity, pCi/g (wet)*; mean and range			Gamma dose-rate, μR/hour; mean and range
		Total beta	^{137}Cs	^{106}Ru	
Shrimp flesh	3 (east)	2.9	0.1	0.2	-
Commercial sources of fish	3 (east)	3.5	0.1	-	-
Silt	0	79 (56-105)	5.9 (3.0-11)	8.5 (1.0-18)	8.8 (7.8-8.9)
F. vesiculosus	1.6 (east)	10 (8.0-12)	0.6 (0.5-0.7)	0.2	-
	0.8 (east)	10 (9.0-12)	0.5 (0.3-0.7)	-	
	0	27 (9.0-70)	8.2 (0.3-25)	2.3	-
	0.8 (west)	9.3 (8.0-10)	0.7 (0.2-1.1)	0.1	-

*Except silt, pCi/g (dry).

4.5 Sizewell, Suffolk

This is another site where the water mass into which waste discharges are made has especially good dispersion characteristics, so that with discharges remaining very low their impact in terms of public radiation exposure has been negligible, with no detectable contamination of any of the potentially critical materials. These are recognized as being local fish and shellfish - which would be the source of internal exposure - and foreshore sediment (coarse sand and shingle) in respect of external exposure. These are the materials which make up the environmental monitoring programme, data from which are given in Table 18.

Table 18 Radioactivity in fish and shellfish and gamma dose-rate over sand in the vicinity of Sizewell, 1971

Material	Concentration of radioactivity, pCi/g (wet)*; mean and range		Gamma dose-rate, μR/hour; mean and range
	Total beta	^{137}Cs	
Cod and whiting flesh	3.5 (3.1-4.1)	< 0.1	-
Flatfish flesh	3.7 (3.1-4.2)	0.03 (0.01-0.05)	-
Crab flesh	ND	< 0.1	-
Lobster flesh	ND	< 0.1	-
Sand	-	-	3.7 (3.3-4.6)

*Except sand, pCi/g (dry).
ND = not determined.

4.6 Trawsfynydd, Merioneth

This is the sole nuclear power station in the UK discharging low-level liquid radioactive waste to fresh water, a mountain lake which by virtue of its restricted size poses special problems of control.

A single critical pathway exists, of quite overwhelming importance by comparison with any other possible route, and involves internal exposure from consumption of lake fish, primarily trout, though some of the local anglers also eat perch. Caesium-134 and -137 are the critical nuclides and concentrate in these fish to a considerable degree, a phenomenon which is related to the softness of the water and particularly its lack of potassium. In addition, there is a little strontium-90 in these fish, much of it derived from fallout, which is also the source of a small part of the caesium-137.

Table 19 Radioactivity in materials in Lake Trawsfynydd and local streams, 1971

Material	Sampling site	Concentration of radioactivity, pCi/g (wet)*; mean and range									
		Total beta	^{54}Mn	^{60}Co	^{90}Sr	^{106}Ru	$^{95}Zr/^{95}Nb$	^{137}Cs	^{134}Cs	^{144}Ce	^{125}Sb
Water	Cold lagoon	-	-	-	-	-	-	18 (3.0-35)	3.9 (0.9-7.2)	-	-
	Hot lagoon	-	-	-	6.3 (3.8-8.3)	-	-	22 (3.0-42)	4.7 (1.0-8.1)	-	-
Trout flesh	Lake	15 (9.0-24)	-	-	0.13 (0.12-0.15)	-	-	12 (7.7-20)	2.0 (1.2-4.0)	-	-
Perch flesh	Lake	28 (17-46)	-	-	0.27 (0.22-0.34)	-	-	26 (14-45)	4.3 (1.5-8.9)	-	-
Mud	Lake	36 (23-57)	-	0.1	-	-	-	12 (7.0-26)	0.6 (0.2-1.5)	-	1.6 (0-4.9)
Peat	Lake	23 (5.0-42)	-	0.05	-	-	-	5.9 (1.3-12)	0.9 (0.2-1.4)	0.5	2.7 (0.9-5.6)
Fontinalis	Afon Prysor	16 (12-22)	0.1 (0-0.4)	0.02	-	2.7 (0.9-4.1)	1.9 (0.8-3.3)	0.1	0.02	3.3 (2.5-4.2)	-
	Gwylan Stream	32 (9.0-77)	0.3 (0.1-0.5)	0.4 (0-0.8)	-	6.4 (3.0-9.5)	3.8 (1.7-5.5)	4.9 (1.2-8.0)	1.1 (0.4-1.5)	4.4 (2.6-7.9)	11 (1.8-26)

*Except peat and mud, pCi/g (dry).

Because of these restrictive factors, discharges of liquid radioactive waste are subject to extremely careful control with particular attention to radiocaesium, a very large proportion of which is retained on site as solid waste and not disposed of to the lake at all. In consequence the level of public radiation exposure from fish consumption has been kept to only a few per cent of the ICRP-recommended dose limit. At most, the value is considered to be about 5 per cent, though in a year when trout were hard to find during the summer months it is probable that the true maximum consumption rate was lower than the value of 100 g/day which has been adopted as the basis of hazard assessment and the true level of public exposure proportionately less.

The basic monitoring programme to prove the radiological safety of discharges consists of regular sampling of trout and perch. However, in a situation as restrictive as this a considerable amount of supporting radio-ecological research has been necessary to gain a better understanding of the basic processes involved within the critical pathway, for which purpose samples of lake water and lake bed have been collected. In addition, the indicator moss Fontinalis is sampled at two points - the inlet stream (Afon Prysor) and one of the lake outlets (Gwylan Stream). It will be noted that antimony-125 appeared again in lake water and for the first time reached detectable concentrations in sediment from certain areas of the lake bed. However, none has yet been found in fish, showing that, though this nuclide has been responsible for a substantial fraction of discharges, it carries no radiological significance for the public.

Results of these surveys are summarized in Table 19.

4.7 Wylfa, Anglesey

Although this station was generating power during 1971, discharges were for all practical purposes zero and public radiation exposure from its operation was negligible. Monitoring has continued on the guidelines already established, greater importance being attached to sampling of fish and shellfish from two local bays, representative of internal exposure pathways, than to silt and measurement of the associated gamma dose-rates whose significance would be related to external exposure. Samples of seaweed were collected as indicators and, in common with some of the fish and shellfish, contain traces of fission products. Most of these activities are due to Windscale, though some may be fallout-derived. However, in absolute terms, public radiation exposure from this contamination is of little significance, as may be judged from the results quoted in Table 20.

Table 20 Radioactivity in marine materials and gamma dose-rate over silt in the vicinity of Wylfa, 1971

Location	Material	Concentration of radioactivity, pCi/g (wet)*; mean and range						Gamma dose-rate, μR/hour; mean and range
		Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{137}Cs	^{144}Ce	^{110m}Ag	
Cemlyn Bay	Porphyra	5.6	0.3	0.3	0.2	-	0.06	-
	F. vesiculosus	11 (9.0-14)	0.3 (0.2-0.5)	0.2	0.5 (0.3-0.7)	-	0.4 (0.2-0.5)	-
	Lobster flesh	3.2	-	-	0.3	-	0.2	-
	Whole crab	5.7	0.08	0.3	0.1	0.2	0.7	-
	Pollack flesh	5.8	-	-	1.4	-	0.07	-
	Mud	31 (29-33)	1.3 (0.9-1.6)	4.1 (2.5-5.6)	5.6 (4.5-6.3)	3.1 (2.4-3.4)	0.4	10 (7.5-12.5)
Cemaes Bay	Porphyra	6.2	0.3	0.6	0.07	-	0.09	-
	F. vesiculosus	11 (9.0-12)	0.3 (0.1-0.7)	0.2 (0.2-0.3)	0.4 (0.3-0.5)	0.1	0.4 (0.2-0.7)	-
	Lobster flesh	3.3	0.05	-	0.2	-	0.5	-
	Winkles	3.9 (3.4-4.5)	0.1	0.5	0.1	-	1.0 (0.3-1.4)	-

*Except mud, pCi/g (dry).

5 NUCLEAR POWER STATION OPERATED BY THE SOUTH OF SCOTLAND ELECTRICITY BOARD

5.1 Hunterston, Ayrshire

Discharges of low-level radioactive waste from this station are made into the Firth of Clyde and can be linked to two exposure pathways. One is internal, due to fish and shellfish consumption, the other external and the result of use of the foreshore, though in neither case is public exposure significant, and none of the low levels of contamination found can be attributed to the station.

The monitoring programme is undertaken on behalf of the Scottish Office, and consists primarily of sampling fish, shellfish and sand, supported by indicator seaweeds. Sea water is provided by the White Fish Authority from their fish-farming project on a site which adjoins the power station; they have also provided samples of plaice in relation to which the sea water is analysed on a research basis.

Results are summarized in Table 21.

Table 21 Radioactivity in materials in the vicinity of Hunterston, 1971

Material	Concentration of radioactivity, pCi/g (wet)*; mean and range					
	Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{137}Cs	^{134}Cs	^{144}Ce
Sea water	-	-	-	13 (12-15)	2.4 (1.4-3.2)	-
F. spiralis	9.2 (8.0-11)	0.7 (0.2-1.2)	0.5 (0.4-0.7)	0.6 (0.5-0.7)	0.1 (0.1-0.2)	0.4 (0.2-0.7)
Cockles	2.6 (1.8-3.4)	0.07 (0.04-0.1)	0.4 (0.3-0.4)	0.1 (0.08-0.2)	-	0.2 (0.1-0.3)
Sand	14 (11-16)	0.2 (0-0.4)	0.2 (0-0.4)	0.3 (0.2-0.3)	0.06 (0.04-0.07)	0.5 (0.2-0.9)

*Except sand, pCi/g (dry).

6 SITES OPERATED BY THE MINISTRY OF DEFENCE (NAVY DEPARTMENT)

6.1 HM Dockyard, Chatham, Kent

Low-level liquid radioactive waste is disposed of into the tidal stretch of the River Medway where there is no important fishery, so that irrespective of the nature of the waste only external exposure needs to be considered. The most important group of the public are houseboat dwellers living on the water's edge near to mud banks, in which traces of radioactivity attributable to Dockyard operations are sometimes found. Monitoring consists mainly of gamma dose-rate surveys supplemented by sampling of mud. Levels of contamination are, however, very low and their significance in terms of public radiation exposure quite negligible, as can be seen from the summary of data in Table 22.

Table 22 Radioactivity in materials and gamma dose-rate at sites operated by the Ministry of Defence (Navy Department), 1971

Site and material	Concentration of radioactivity, pCi/g; mean and range		Gamma dose-rate, μR/hour; mean and range
	^{60}Co	^{137}Cs	
Chatham			
Silt	0.2 (0.1-0.5)	1.0 (0.4-1.5)	5.8 (4.6-6.7)
Faslane			
Sea bed	0.7 (0.2-1.3)	3.9 (1.3-5.3)	-
Foreshore silt	-	-	10 (5.0-17.5)
Rosyth			
Dockyard approaches silt	0.8 (0.1-2.3)	0.5 (0.2-0.7)	-
Shoreline	-	-	8.2 (5.3-11.3)

6.2 HMS NEPTUNE, Faslane, Dunbartonshire

Waste disposal is made into Gareloch, a land-locked basin, and as with that from Chatham only external exposure is even potentially important. This concerns the public who use the shore of the loch, the most important of whom are probably boatyard workers, though in practical terms exposure is quite insignificant as gamma dose-rate surveys have shown. These form the basis of the monitoring programme - undertaken on behalf of the Scottish Office - which so far has failed to detect any difference from natural background levels. Data are quoted in Table 22, along with analyses of silt samples collected from the sea bed and a few isolated areas of the shoreline.

6.3 HM Dockyard, Rosyth, Fife

Discharges are made to the tidal Firth of Forth, and the critical exposure pathway - which is the only one of any possible significance - is once again external. Here the potentially-exposed group of the public are the dredgermen who keep the dockyard approaches open to navigation by clearing them of silt, the highest concentrations of radioactivity being found in the silt in the near-vicinity to the Dockyard entrance. In practice, concentrations have been low, particularly so in 1971, and exposure of none of these workers has reached any notable level.

The monitoring programme, undertaken on behalf of the Scottish Office, consists of sampling surface silt from the sea bed, with particular emphasis on those areas close to the Dockyard from which spoil is dredged. The gamma dose-rate is measured at selected points on the shore near to the Dockyard, though no values were found which are significantly higher than natural background. A summary of data is included in Table 22.

7 THE CHANNEL ISLANDS

The laboratory has continued to undertake a small monitoring programme of the shores of the three largest islands in the group on behalf of the Channel Islands Governments. The fundamental purpose of this effort is to verify the radiological safety of shoreline and marine materials, particularly in view of the proximity of discharges from the fuel-reprocessing plant at La Hague on the mainland of France. The monitoring programme is a balance of edible marine foodstuffs and indicator seaweeds, the results of which are quoted in Table 23, and show that whilst a very low level of contamination can now be found it is of no radiological consequence.

Table 23 Radioactivity in materials on the coasts of the Channel Islands, 1971

Material	Sampling area		Concentration of radioactivity, pCi/g (wet); mean and range		
			Total beta	^{137}Cs	^{106}Ru
<u>Porphyra</u>	Guernsey	Fermain Bay	6.4 (3.8-9.2)	-	0.4 (0.1-0.6)
		Fort Doyle	4.2	-	0.4
	Alderney	Telegraph Bay	6.0 (5.3-7.2)	-	0.5 (0.3-0.6)
		Corblets Bay	5.8 (3.8-8.3)	-	1.3 (0.6-2.0)
	Jersey	Greve de Lecq	6.2 (5.4-7.3)	-	0.3 (0.1-0.6)
		La Rozel - La Coupe	5.3 (4.7-6.5)	-	0.6
Ormer flesh	Guernsey		2.9	0.05	-
Skate flesh	Guernsey		2.9	0.2	-
Sand	Guernsey	Bordeaux	16.3	0.1	-

1971 saw continued collaboration with the Department of Health of the Irish Republic, and the laboratory has analysed further samples of a range of marine materials. The mainstay of the sampling programme has been species of seaweed, because they provide a more sensitive means of detection of the presence of artificial radioactivity than edible marine foodstuffs, such as fish and shellfish. As will be seen from the summary of data quoted in Table 24, traces of fission products have been found, some of which are indistinguishable from fallout, but all at such a low level that in no case is contamination significant in terms of public radiation exposure.

Table 24 Radioactivity in seaweeds and sand on the Irish Republic coastline, 1971

Material	Sampling point	Concentration of radioactivity, pCi/g (wet); mean and range			
		Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{137}Cs
Porphyra	Skerries	4.7 (3.9-6.2)	0.5	0.7	-
	Carlingford Lough	7.7	0.1	0.3	-
	St. Helens	5.3 (4.7-6.1)	0.4 (0.1-0.7)	0.3	-
	Dunsmore East	5.0 (4.2-6.1)	0.1	0.2	-
F. serratus	Skerries	9.9	0.5	0.2	0.4
	Dunsmore East	6.2	0.2	0.1	-
	St. Helens	7.7	0.4	0.1	0.1
	Colliemore	7.7	0.2	0.1	0.3
F. vesiculosus	Skerries	7.0	0.2	-	0.3
	St. Helens	6.6	0.1	-	0.1
	Carlingford Lough	11.6	0.1	-	0.4
Laminaria digitata	Skerries	13.0 (9.6-16.9)	0.2	0.2	0.4
	Carlingford Lough	14.1	0.05	-	0.3
	St. Helens	9.8 (6.9-15.6)	0.2	-	0.1
	Dunsmore East	8.5 (4.6-15.2)	0.1	-	-
	Colliemore	15.9	-	-	0.3

9 GENERAL SURVEYS OF THE UK, INCLUDING BACKGROUND AND FALLOUT RADIOACTIVITY

Most of the monitoring surveys conducted in the UK cover geographically small areas close to the points where discharges are made, though occasionally (because, for instance, of the conservative behaviour of a particular nuclide such as caesium) surveys may extend over a considerable distance, as has been illustrated in Table 7. It is not the policy of the laboratory to undertake blanket surveys without a specific purpose, and the only general surveys undertaken are either in confirmation of natural background levels or for surveillance of fallout, particularly in years gone by when it presented a more serious threat than the trivial concentrations found at the present. Some nationwide surveys were mounted in 1971 but the only programme related to fallout as a source of radioactivity was the sampling of commercial fish landings.

Background surveys continue to have some value, particularly as a reference for use in evaluating measurements made in relation to discharges which have either no effect or one which is barely detectable. Material is occasionally collected by the laboratory for use as a diluent for other materials, before which its content of natural activities must be verified and a summary of these data is included for interest in Table 25.

Table 25 Radioactivity in background reference materials, 1971

Material	Sampling area	Concentration of radioactivity, pCi/g (wet)*; mean and range	
		Total beta	^{106}Ru
Porphyra	Lowestoft	5.2	0.2
	Dunbar	5.7 (4.3-9.0)	0.5
	St. Davids	11.6 (8.5-17.6)	0.2
F. vesiculosus	Lowestoft	6.7 (5.2-8.9)	0.2
Sand	Lowestoft	7.9	-

*Except sand, pCi/g (dry).

Commercial fish landings contain traces of fallout-derived activity, the most important component of which is caesium-137. Table 26 contains measurements of radioactivity in several fish species from the more important fishing grounds used by British trawlers. The radiological significance of this contamination is very low indeed, though measurements continue to have some value, such as in judging the origin of activity in samples collected elsewhere in relation to controlled discharges.

Table 26 Radioactivity in commercial fish landings in UK ports, 1971

Species	Fishing area	Concentration of radioactivity, pCi/g (wet); mean and range	
		Total beta	^{137}Cs
Cod flesh	Southern North Sea (IV C)	3.5	0.05
	Iceland (V A)	2.7	< 0.01
Plaice flesh	Southern North Sea (IV C)	3.2	0.04
	Iceland (V A)	3.1	0.02
Herring flesh	Southern North Sea (IV C)	-	0.04

10 DISCUSSION

First and foremost of the several uses to which we put environmental monitoring data is their application to radiological evaluation, and to be more specific, assessment of radiation exposure of the public. In routine operation the mere comparison of an individual measurement against the derived working limit for the critical material is sufficient to prove the radiological safety of the particular disposal concerned at that time, though individual measurements are not sufficient on their own, regular and systematic surveillance being necessary. It has become common practice at the Fisheries Radiobiological Laboratory to assess the consequences of contamination and the extent of public radiation exposure on no shorter period of time than one year, this period being chosen as the minimum which is consistent with ICRP-recommendations on dose limits. Whilst the importance of establishing the actual level of exposure may be considered to lessen as discharges decrease to a point where they are limited more by justifiable need than compliance with the ICRP-recommended dose limits, the assessment of exposure is still a key factor in much of our work, in making decisions regarding discharge limits and in reviewing the consequences of implementing them.

Frequent reference has been made throughout the text of this report to the somatic consequences of individual disposals in terms of exposure of members of the public. These conclusions are summarized in Table 27, in which the innovation of the 1970 report is repeated including estimates of total population gonad exposure as an index of genetically-significant exposure. In almost every situation this category of exposure is of minor importance in relation to somatic exposure and, indeed, each is well within the dose limits recommended by the ICRP and those of UK policy*.

*Paragraph 117 in "The Control of Radioactive Wastes"; Cmnd 884. HMSO, London, 1955.

Table 27 Estimates of public radiation exposure from liquid radioactive waste disposals in the United Kingdom, 1971

Site	Pathway	Maximum exposure* of an individual (% of ICRP recommended dose limit)	Approximate total population gonad dose*, man-rem, not exceeding:
BRITISH NUCLEAR FUELS LTD.			
Windscale	Porphyra/laverbread	33 (to critical group)	10^0
	External dose	11	10^0
	Fish	3 (to critical group)	10^2
Springfields	External dose	< 1	10^{-1}
Chapelcross	External dose	≪ 1	10^{-2}
	Shellfish	≪ 1	10^{-1}
UNITED KINGDOM ATOMIC ENERGY AUTHORITY			
Winfrith	Shellfish	< 1	10^{-1}
Aldermaston Harwell	Drinking water	< 1	10^2
Dounreay	External dose (foreshore)	< 1	10^0
	Beta dose (fishermen)	9	10^{-2}
	Shellfish	≪ 1	10^0
THE RADIOCHEMICAL CENTRE LTD.			
Amersham	Drinking water	< 1	+
CENTRAL ELECTRICITY GENERATING BOARD			
Berkeley/Oldbury	External dose	< 0.3	10^{-1}
	Fish/shellfish	< 0.1	10^{-1}
Bradwell	Oyster	0.1	10^{-1}
Dungeness	External dose	≪ 0.1	10^{-1}
	Fish	≪ 0.1	10^{-1}
Hinkley Point	External dose	0.1	10^{-1}
	Fish/shellfish	0.1	10^0
Sizewell	External dose	≪ 0.1	10^{-1}
	Fish/shellfish	≪ 0.1	10^{-1}
Trawsfynydd	Lake fish	5	10^0
Wylfa	External dose	≪ 0.1	10^{-1}
	Fish/shellfish	≪ 0.1	10^{-1}
SOUTH OF SCOTLAND ELECTRICITY BOARD			
Hunterston	External dose	< 0.1	10^{-1}
	Fish/shellfish	< 0.1	10^{-1}
MINISTRY OF DEFENCE (NAVY DEPARTMENT)			
Chatham	External dose	< 0.1	10^{-1}
Faslane	External dose	< 0.1	10^{-1}
Rosyth	External dose	< 0.1	10^{-1}

*Assessed as from discharges from the site named only.
+Included in the value for Harwell and Aldermaston.

The method of calculation of both these categories of exposure is as described in last year's report, though the assessment of genetic exposure has been re-examined and further refined in some cases. By the nature of much of the data used, estimates of genetic exposure tend to be less precise than those of somatic exposure and, in being of such low significance, the values quoted are limited to an order-of-magnitude basis. However, in a situation where these contributions to public exposure are so very small - both in absolute terms and as a proportion of the dose limit specified in UK policy - this lack of precision is unimportant.

The largest sources of genetically-significant exposure from liquid radioactive waste disposal are Windscale and the Thames-area establishments. Estimates for the latter are included for completeness, even though the critical pathway is not fish but drinking water, with control of liquid wastes, therefore, being exercised primarily by the Department of the Environment. There has been considerable uncertainty in the past about the importance of strontium-90, because the data quoted in ICRP Publication 2 were thought to be unreliable, being based on pessimistic approximations. This uncertainty has now been resolved*, confirming in the case of discharges to the Thames that most of the genetically-significant exposure is due to tritium, though this, at an estimated 10^2 man-rem in 1971, is only of minute significance. Genetically-significant exposure from Windscale is of this same order of magnitude, so that even the two sources together are of very little significance - representing only about 0.01 per cent of the dose limit specified in UK policy.

Assessment of the genetic significance of Windscale discharges is interesting, not merely because this is the largest UK source of liquid radioactive waste whose disposal must be controlled, but also because of the contrasts shown. The reader will already be well aware that the laverbread and external exposure pathways rank high above that of fish consumption in terms of their impact on individual members of the public; this situation is reversed when genetically-significant exposure is reviewed. A further contrast is revealed by examination of individual contributions to gonad exposure due to consumption of laverbread, for ruthenium and cerium, the two dominant nuclides in somatic terms, are now joined by a third, caesium-137. However, total population exposure in 1971 was very low, in the region of about 3 man-rem only.

Gonad exposure due to the external exposure pathway is of the same order of magnitude, though, in common with external pathways elsewhere, exact calculation is very difficult because of the problem of predicting the habits of the probably large number of people, each individually exposed to a very minor extent. By comparison, exposure of the smaller number of the public in relation to whose habits control is set can be assessed reasonably accurately and is judged to have amounted to about 0.5 man-rem in 1971; it seems unlikely that adding exposure of the rest of the public will more than double this figure, so that the best estimate of total public exposure is about 1 man-rem and with little doubt can be no more than 10^0 on an order-of-magnitude basis.

*"Alkaline Earth Metabolism in Adult Man". ICRP Publication 20. Pergamon Press, 1973.

The genetic significance of the fish exposure pathway is due entirely to the presence of caesium-137 and -134, and has risen to prominence during recent years as a result of higher discharges of these nuclides, contamination from which needs to be taken into account over a large area of the north-east Irish Sea. Total public radiation exposure is assessed by combining statistics on fish landings with the laboratory's monitoring data. Fish cannot be sampled as representatively as, say, laverbread, so that without a very large increase in the scientific effort put into assessing this exposure pathway - which could not be justified in view of its low absolute significance - only an estimate on an order-of-magnitude basis is offered, the estimate for 1971 being 10^2 man-rem.

The foregoing are the principal sources of genetically-significant exposure from liquid waste disposal in the UK, and though estimates for other sources are quoted in Table 27 their cumulative effect is negligible, with only one instance of the collective dose being as much as 1 man-rem - Trawsfynydd, where the familiar combination of fish and caesium radionuclides is responsible. In total, genetically-significant exposure from all liquid radioactive waste discharges in the UK was only 0.01 per cent of the UK dose limit.

11 CONCLUSIONS

The stringent standards set to limit disposal of radioactive waste in the United Kingdom have been maintained, and as a consequence radiation exposure of the public is very low and well within the recommendations of the International Commission on Radiological Protection and dose limits specified in the objectives of UK waste disposal policy. Data presented in this report show that this high standard of compliance continues, and that the exacting requirements of the ICRP recommendations are not merely met but that, in all disposals, radiation exposure of the public is well within the prescribed dose limits and in many instances is very much less.

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