MINISTRY OF AGRICULTURE, FISHERIES AND FOOD

FISHERIES RADIOBIOLOGICAL LABORATORY

RADIOACTIVITY IN SURFACE AND COASTAL WATERS OF THE BRITISH ISLES 1972 - 73

N. T. MITCHELL

TECHNICAL REPORT FRL 10

HAMILTON DOCK
LOWESTOFT, SUFFOLK

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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
BRITISH NUCLEAR FUELS LIMITED			
Windscale	*Porphyra*/laverbread Estuarine sediment Fish flesh	Beta dose to GI tract* Gamma dose to whole body Beta-gamma dose to whole body	General public (South Wales) Salmon fishermen Fishermen
Springfields	Estuarine sediment	Gamma dose to whole body	Dredgermen
Chapelcross	Shrimp flesh Estuarine sediment	Beta-gamma dose to whole body Gamma dose to whole body	Local fishermen and families Salmon fishermen
UNITED KINGDOM ATOMIC ENERGY AUTHORITY			
Winfrith	Fish and shellfish	Beta dose to GI tract*	Local fishermen and families
Harwell	Drinking water	Beta-gamma dose to whole body (somatic and genetic hazard)	General public (Greater London)
Dounreay	Detritus associated with fishing gear Beach sludge	Beta dose to hands Gamma dose to whole body	Local fishermen Local fishermen and others
THE RADIOCHEMICAL CENTRE LIMITED			
Amersham	Drinking water	Beta-gamma dose to whole body (somatic and genetic hazard)	General public (Greater London)
CENTRAL ELECTRICITY GENERATING BOARD AND SOUTH OF SCOTLAND ELECTRICITY BOARD			
Berkeley	Estuarine sediment Shrimp and salmon flesh	Gamma dose to whole body Beta-gamma dose to whole body	Salmon fishermen/river authority workers Local fishermen and families
Bradwell	Oyster flesh	Gamma dose to whole body	Oyster fishermen and families
Dungeness	Fish flesh Beach sediment	Beta-gamma dose to whole body Gamma dose to whole body	Local fishermen and families Bait diggers
Hinkley Point	Fish and shrimp flesh Beach sediment	Beta-gamma dose to whole body Gamma dose to whole body	Local fishermen and families Local fishermen
Oldbury	Estuarine sediment Shrimp and salmon flesh	Gamma dose to whole body Beta-gamma dose to whole body	Salmon fishermen/river authority workers Local fishermen and families
Sizewell	Fish and shellfish flesh Beach sediment	Beta-gamma dose to whole body Gamma dose to whole body	Local fishermen and families Local fishermen
Trawsfynydd	Trout flesh	Beta-gamma dose to whole body	Local fishermen and families
Wylfa	Fish and shellfish flesh Beach sediment	Beta-gamma dose to whole body Gamma dose to whole body	Local fishermen and families Local fishermen
Hunterston	Fish flesh Beach sediment	Beta-gamma dose to whole body Gamma dose to whole body	Local fishermen and families Shellfish collectors
MINISTRY OF DEFENCE (NAVY DEPARTMENT)			
Chatham	Estuarine sediment	Gamma dose to whole body	General public (houseboat dwellers)
Devonport	Estuarine sediment	Gamma dose to whole body	General public
Faslane	Beach sediment	Gamma dose to whole body	Boatyard workers
Rosyth	Estuarine sediment	Gamma dose to whole body	Dredgermen
MINISTRY OF DEFENCE (PROCUREMENT EXECUTIVE)			
Aldermaston	Drinking water	Beta-gamma dose to whole body (somatic and genetic hazard)	General public (Greater London)

*Gastro-intestinal tract.

RADIOACTIVITY IN SURFACE AND COASTAL WATERS OF THE BRITISH ISLES, 1972-73

1 INTRODUCTION

This is the seventh in a series of reports by the Fisheries Radiobiological Laboratory (FRL) concerned with monitoring the aquatic environment. It describes surveys made during 1972 and 1973. 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 surveys are also done on behalf of Departments of the Scottish Office, the Channel Islands States, and Ireland, and accounts are included. The majority 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 - and are made independently of environmental monitoring by the operators who published their data in annual summary reports.

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 environmental 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.

Much of the data quoted in this report is 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. Although this research is not in itself required to verify the safety of a contaminated regime because our present knowledge provides an adequate basis for setting control measures, it does improve our predictive capability and, in the long term, may contribute to even higher standards of control. 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 the years 1972 and 1973.

Data quoted in the tables in this report have been combined to give an average for the two years 1972 and 1973 and the range is also quoted where significant numbers of measurements have been obtained. A dash is used to indicate that the presence of the radionuclide(s) concerned could not be detected at a reasonable confidence level by the method employed. In cases where activity has been detected but with relatively poor precision, the result is quoted on a 'less than' basis rounding the measured value up to the next highest order of magnitude. The letters 'ND' mean that no determination was attempted. This should not be construed as necessarily indicating that there was none of the radionuclide present; for example, it may refer to the gross beta content of sediments which would not be a useful or relevant measurement to attempt where the significance was confined to external exposure pathways due to gamma radiation.

Table 2 Major discharges of liquid radioactive waste to surface and coastal waters during 1972/73

Site	Radioactivity	Authorized discharge, curies/year	Percentage utilized
Windscale	Total beta	300 000	45
	Ruthenium-106	60 000	57
	Strontium-90	30 000	38
	Total alpha	6 000	73
Springfields	Total alpha	360	6
	Total beta	12 000	12
Chapelcross	Total activity*	700	1
	Tritium	150	7
Winfrith	Total activity	30 000	4
	Ruthenium-106	9 000	< 1
	Strontium-90	1 200	< 1
	Total alpha	1 200	< 1
Harwell	Total activity*	240†	32
	Tritium	240	28
Dounreay	Total alpha	240	11
	Total activity	24 000	73
	Strontium-90	2 400	50
Amersham	Total activity*	72†	40
	Tritium	400	52
Berkeley	Total activity*	200	11
	Tritium	1 500	9
Bradwell	Total activity*	200	43
	Zinc-65	5	< 1
	Tritium	1 500	15
Dungeness	Total activity	200	13
	Tritium	2 000	2

Table 2 (continued)

Site	Radioactivity	Authorized discharge, curies/year	Percentage utilized
Hinkley Point	Total activity*	200	65
	Tritium	2 000	2
Oldbury	Total activity*	100	5
	Tritium	2 000	< 1
Sizewell	Total activity*	200	7
	Tritium	3 000	4
Trawsfynydd	Total activity*	40	60
	Tritium	2 000	4
	Caesium-137	7‡	29‡
Wylfa	Total activity*	65	< 1
	Tritium	4 000	4
Hunterston	Total activity*	200	14
	Tritium	1 200	5
Chatham	Total activity*	20	< 1
	Cobalt-60	10	3
	Tritium	20	< 1
Devonport	Total activity*	4	< 1
	Cobalt-60	1	< 1
	Tritium	10	< 1
Faslane	Total activity*	1	< 1
Rosyth	Total activity*	30	< 1
Aldermaston	Total activity	156†	10

*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.
‡Refers only to part of this period, this clause in the authorization being introduced in November 1972.

2 BRITISH NUCLEAR FUELS LIMITED

2.1 Windscale and Calder, Cumbria

The fuel reprocessing plant at Windscale continues to be the most important single source of liquid radioactive waste in the UK, though only a minute fraction of the total amount of waste which accrues at this site from the processing of irradiated fuel is disposed of to sea. Discharges during 1972/73 have not differed very greatly from those made previously, though for other reasons there have been some important changes in the relative importance of the critical pathways.

For many years past the internal exposure pathway resulting from consumption of the foodstuff laverbread, which is manufactured from the seaweed *Porphyra*, has constituted the most important pathway; indeed, for more than a decade from the time when discharges began it was not only the critical pathway but also the only route to public radiation exposure of any significance. This was because *Porphyra* concentrates fission products, notably ruthenium-106 and cerium-144, leading primarily to exposure of the gastro-intestinal (GI) tract; furthermore, ruthenium-106 was a major component of the waste being released during this period. *Porphyra* also reconcentrates other radionuclides, though mostly to a lower degree than ruthenium-106, and it has provided the most important pathway for return to man for strontium-90 and the transuranics plutonium and americium. Bone is the critical organ for these last-mentioned radionuclides, though exposure has always been considerably lower than that via irradiation of the GI tract from ruthenium and cerium. With discharges at a similar level to 1971 and the seaweed growing in the same profuse and vigorous way as before, levels of radioactivity in the seaweed (Table 3) have remained similar to those in previous years. However, the harvesting pattern changed abruptly in the spring of 1972 when collections from the coastline near to Windscale were discontinued. Since then only a very small amount of Cumbrian seaweed has been dispatched to South Wales and this only from more distant points in the vicinity of Walney Island where radionuclide concentrations are relatively low. The laverbread manufacturers are thus now depending virtually entirely on supplies from areas of the British Isles other than Cumbria; these had always been their mainstay, with Cumbrian seaweed making up no more than 20 per cent of receipts on average over the previous decade. As discussed in previous reports in this series, analysis of radioactivity in the seaweed alone had already ceased to be a reliable index of actual exposure of the laverbread-eating public, serving only to indicate the maximum conceivable concentrations in the foodstuff in the unlikely situation of laverbread being made from wholly Cumbrian *Porphyra*, undiluted with supplies of seaweed from elsewhere. For accurate estimates of the true level of public radiation exposure, sampling of the laverbread itself from each of the main retail outlets has been continued and data on its ruthenium-106 content are summarized in Table 4.

The basis for estimation of public radiation exposure by continuing to collect these analytical data together with information on rates of consumption of the foodstuff, as assessed by interview-type market survey, has recently been reviewed using the results of a new survey in early 1972. Although the precise value of the consumption rate of laverbread which is used for this purpose is no longer crucial in so far as public radiation exposure is well within the dose limits recommended by the International Commission on Radiological Protection

(ICRP), this is still the best pathway on which to evaluate alternative critical group selection procedures. A number of methods have been devised (Preston et al. 1974) but, bearing in mind the dual requirement that the value chosen must both protect the more highly exposed in the population and be such as to ensure that the range of exposure of individuals within the critical group is reasonably small, a value of 130 g/day has been selected for use in control procedures. Based on this figure, mean exposure in 1972/73 of individuals in the critical group for this pathway was less than 2 per cent of the ICRP-recommended dose limit.

With the decline in importance of the laverbread pathway the highest degree of individual public radiation exposure now occurs through external means and is due to uptake of radioactivity by sediments, the sorptive capacity of which varies widely along the Windscale-area coastline. It is highest in areas where mud and silt of fine particle size collects and lowest in those which are essentially sandy. In fact, so low is the level of contamination on sand that dose rates are little higher than background anywhere on the open, essentially sandy, coastline of this region. It is difficult to characterize in its entirety the population exposed via this pathway, although the majority are people who use the beaches and estuaries infrequently, who go there for recreational purposes and whose occupancy is thus low. The components of waste disposals whose major impact is through this pathway has thus been controlled in relation to the habits of those who make most use of the more highly contaminated areas. As identification of a critical group consistent with the ICRP definition of this term does not seem possible, because the more highly exposed are few in number and have highly individual characteristics, it has been customary to assess exposure for the most highly exposed known individuals, namely salmon fishermen working the Ravenglass Estuary. The work pattern of the particular person has been studied for the purpose of assessment of his exposure to radiation from occupation of the estuary. Averaged over the period 1972/73 it was equivalent to about 7 per cent of the ICRP-recommended dose limit for whole body as the critical organ; the measurements on which this is based are quoted in Table 5. The validity of the 1972 estimate was checked over an extended period - most of the salmon fishing season - by means of a thermo-luminescent dosimeter and very good agreement was obtained.

A third pathway which has been increasing in importance, especially in respect of the collective population dose, is due to consumption of fish (and shellfish) caught in the Irish Sea. The critical nuclides are caesium-134 and caesium-137 and, except for minor sources of these foodstuffs from the coastal region close to the pipeline which contain other nuclides such as ruthenium-106, it is only these caesium radionuclides which make any significant contribution to exposure. Data are summarized in Table 6. During 1972 and 1973 shellfish were relatively unimportant as a source of radiation exposure, mainly due to the much larger quantities of fish in the diet of those who make up the critical group. Consumption rates for assessment of individual exposure have been deduced from habits surveys among the coastal communities of the Cumbrian and North Lancashire coasts, whilst estimates of total population dose have been made after recourse to statistics of landings at local ports, especially Whitehaven. Sufficient data were available on individual consumption rates to use the ICRP critical group concept although the method of choice was by no means clear cut (Preston et al. 1974). The survey was conducted deliberately amongst the fishing communities where the largest consumption rates were to be expected, for the aim is, as always, to protect the most highly exposed. The value used for the mean value of the critical group was 300 g/day, more than an order of magnitude higher than the average consumption for the UK fish-eating public at large (20 g/day). Exposure of the critical group during 1972/73 was estimated to be about 3 per cent of the ICRP dose limit whilst the collective dose for the UK population at large who eat fish containing caesium of Windscale origin was about 1.5×10^3 man-rem/year. Due to the largely conservative nature of caesium in the marine environment, part of this estimate is due to caesium in fish stocks outside the Irish Sea, particularly around the coasts of Scotland but also including parts of the northern North Sea. Although the dose to separate individuals is negligibly small, the collective dose is no longer so small as to be without significance. Individual exposure of the non-UK consumers of fish from these waters and from the Irish Sea is also negligibly small and the collective dose to these fish consumers has been judged to be similar to the collective dose to the UK population concerned, the actual value being 1.9×10^3 man-rem/year over the period 1972/73. A number of conservative assumptions have been made in deducing values for collective dose so that the values quoted are consequently upper values, each probably an overestimate. For instance, maximum utilization of the edible fraction and no wastage of landed fish have been assumed. As far as possible doses have been calculated from direct sampling and analysis of fish stocks, but this has had to be supplemented with predictions from seawater sampling, together with concentration factor data. A further factor of conservatism stems from the concentration factors used. These were derived from fallout data but there is an increasing body of evidence to suggest that a smaller value, perhaps only half the value used, is more realistic for caesium derived from such controlled releases as those from Windscale.

In addition to basic monitoring of these pathways, work in the Irish Sea and adjacent water masses where radioactivity of Windscale origin can be detected features extensively in the research programme of the laboratory. This enables minor pathways to be kept under review, leads to a better understanding of the major pathways and makes a contribution to our knowledge of environmental processes in general. The detailed analyses of radioactivity in sediments quoted in Table 5 come from one such programme of research which is aimed at elucidating the way in which radioactivity from Windscale interacts with marine and estuarine sediments. Another example is the analysis of sea water; for some years this has been part of a programme to establish a budget of radioactivity in the Irish Sea and environs. One of the most important nuclides in the water compartment is caesium-137, concentrations of which, together with its companion caesium-134, have been used to deduce concentrations in fish at distances from Windscale and hence the extent of human radiation exposure as discussed above. Data from selected points which have been sampled regularly and are shown on the map in Figure 1 are quoted in Table 7, whilst Figure 2, from Jefferies _et al_. (1973), illustrates the distribution around the northern coastline of Great Britain. This research has also found application in deducing the movement and transit times of coastal water masses.

The most effective and economic way of monitoring the distribution of radioactivity in the coastal zone is by use of indicators, and for this purpose extensive use is made of the _Fucus_ seaweeds along both the English and the

Scottish shores of the Irish Sea (Tables 8 and 9). Some data on sediment and Porphyra are also included in Table 9. Surveys in Scotland are undertaken on behalf of Departments of the Scottish Office and include sampling of the edible seaweed Porphyra. However, concentrations of artificial radioactivity are very low and do not represent a significant source of exposure to individuals who might eat products such as laverbread made from seaweed from this area.

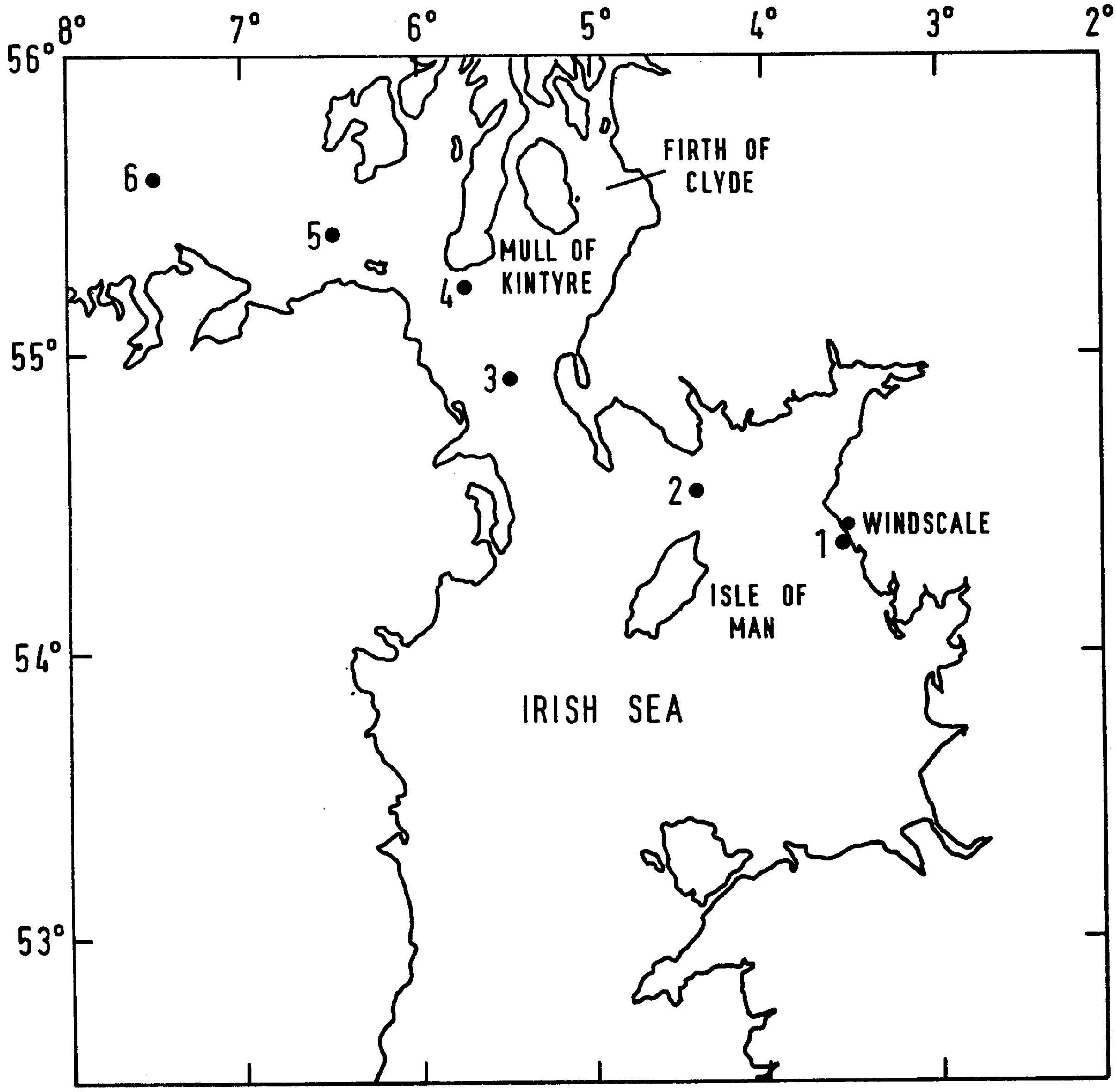

Figure 1 Positions at which sea water was sampled for caesium content (see Table 7).

Table 3 Radioactivity in Porphyra in the immediate vicinity of Windscale, 1972/73

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	^{90}Sr	$^{239/240}Pu$	^{241}Am†
Maryport	41.0	12 (9.0-18)	1.2 (0-1.8)	10 (7.3-15)	0.4 (0.3-0.6)	0.2 (0-0.4)	ND	ND	ND
St Bees	10.0	180 (65-140)	41 (4.8-150)	140 (62-370)	0.9 (0-3.2)	14 (0-46)	0.4* (0.2-0.7)	1.2 (0.4-1.9)	0.2
Nethertown	5.6	310 (83-1000)	80 (8.2-170)	250 (75-450)	1.7 (0-4.2)	22 (0-88)	ND	ND	0.3
Braystones North	3.7	330 (150-600)	77 (13-350)	290 (130-510)	1.8 (0-5.6)	19 (0-56)	0.4* (0.2-0.7)	2.7 (1.1-6.4)	ND
Braystones South	1.9	400 (120-850)	76 (9.7-370)	380 (110-720)	1.1 (0-6.1)	22 (0-58)	0.4* (0.2-0.7)	2.7 (1.1-6.4)	0.4
Pipeline Zero	0	410 (130-1200)	55 (5.1-320)	380 (120-850)	2.2 (0-10)	18 (0-130)	ND	ND	ND
Sellafield Bailey Bridge	1.4	390 (96-750)	62 (6.1-270)	360 (100-730)	2.1 (0-14)	23 (0-100)	ND	ND	ND
Seascale	3.1	370 (120-720)	56 (7.0-250)	340 (100-570)	1.4 (0-6.4)	18 (0-68)	0.4* (0.2-0.7)	2.2 (1.2-3.5)	3.3
Drigg Barn Scar	5.6	280 (58-550)	25 (2.8-77)	260 (45-470)	1.6 (0-7.7)	5.8 (0-30)	ND	ND	ND
Eskmeals North	10.9	140 (52-210)	10 (4.7-16)	120 (59-170)	1.2 (0-3.5)	2.6 (0-12)	ND	ND	ND
Eskmeals South	14.3	190 (53-360)	24 (3.8-130)	180 (61-360)	1.6 (0-11)	5.6 (0-24)	0.4* (0.2-0.7)	1.2 (0.4-1.9)	0.4
Gutterby	20.1	120 (36-270)	12 (2.3-63)	98 (28-220)	1.2 (0-7.5)	4.4 (0-28)	0.2 (0.1-0.4)	0.7 (0.3-1.6)	0.4
Walney Island	38.6	44 (19-87)	5.0 (1.2-20)	38 (20-77)	1.1 (0-3.2)	1.4 (0-7.2)	0.2 (0.1-0.4)	0.4 (0.2-0.6)	ND

* ^{90}Sr samples bulked between these five sites.
† Analyses for ^{241}Am refer to 1972 only.
ND = not determined.

Table 4 Ruthenium-106 in laverbread manufactured in South Wales, 1972/73

Manufacturer	Concentration of ^{106}Ru, pCi/g (wet); mean and range
A	0.4 (0-2.1)
B	0.6 (0-3.9)
C	1.9 (0-23)
D	0.2 (0-1.1)
E	3.2 (0-37)

Table 5 Radioactivity in silt and gamma dose-rates over silt banks in the vicinity of Windscale, 1972/73

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	
Maryport Harbour	640 (54-2600)	790 (230-2300)	68 (30-120)	430 (110-1200)	62 (20-300)
Workington Harbour	470 (16-1800)	660 (25-1400)	76 (11-120)	360 (16-750)	64 (20-180)
Whitehaven Harbour	720 (33-2900)	860 (270-2300)	110 (65-230)	460 (140-1100)	110 (30-500)
Eskmeals	960 (54-2600)	940 (230-2600)	98 (30-190)	560 (110-1600)	130 (20-300)
Walney Island	42	170	25	140	50 (15-120)

Table 6 Radioactivity in fish and shellfish in the Irish Sea, 1972/73

Species	Sampling area	Concentration of radioactivity, pCi/g (wet); mean and range				
		^{106}Ru	^{134}Cs	^{137}Cs	^{90}Sr	$^{239/240}$Pu
Plaice flesh	North Irish Sea*	0.1	0.3 (0.1-0.9)	2.4 (1.2-4.5)	0.04	< 0.01
	Windscale discharge area	1.0	1.4 (0.3-2.6)	8.0 (1.6-16)	0.10	0.03
Dab flesh	Windscale discharge area	2.4	1.6	10	0.16	0.05
Skate edible parts	Windscale discharge area	2.9	1.7	11	ND	ND
Herring edible parts	North Irish Sea*	-	0.2	1.1	ND	ND
Nephrops edible parts	North Irish Sea*	0.2 (0-0.4)	0.2 (0.1-0.4)	1.3 (1.0-1.8)	ND	ND
Mussel flesh	Windscale discharge area	180 (64-260)	0.4	4.9 (3.2-7.4)	ND	ND
Crab	Windscale discharge area	9.7	-	1.6	ND	ND
Queen flesh	North Irish Sea*	11	-	0.5	ND	ND

*Commercial landings at Whitehaven, samples are taken as typical of fish eaten from the North Irish Sea.

Table 7 Caesium-134 and caesium-137 in sea water from the Irish Sea and its north-western approaches, 1972/73

Position number*	Location	Concentration of radioactivity, pCi/litre; mean and range	
		^{134}Cs	^{137}Cs
1	Seascale	75 (13-210)	400 (68-1300)
2	North Irish Sea	2.6 (1.5-5.8)	20 (8.9-43)
3	Mid-North Channel	2.4 (0.7-4.4)	18 (7.3-32)
4	Mull of Kintyre	1.8 (0.3-3.3)	13 (4.4-23)
5	Islay	1.2 (0.2-3.0)	9.2 (2.5-22)
6	Inistrahull ground	0.2 (0-0.7)	1.8 (0.2-7.9)

*See Figure 1.

Table 8 Radioactivity in _Fucus vesiculosus_ in the vicinity of Windscale, 1972/73

Sampling site	Concentration of radioactivity, pCi/g (wet); mean and range					
	Total beta	$^{95}Zr/^{95}Nb$	^{110m}Ag	^{106}Ru	^{137}Cs	^{144}Ce
St Bees	220 (120-480)	42 (11-76)	1.0 (0.6-1.5)	23 (13-34)	7.6 (3.8-14)	10 (4.0-18)
Seascale	440 (210-750)	72 (18-190)	2.3 (1.6-3.2)	51 (28-70)	20 (15-35)	20 (7.8-60)
Gutterby	210 (110-270)	24 (9.5-56)	3.8 (0.5-14)	18 (6.0-26)	7.0 (2.9-13)	6.8 (1.9-14)
Walney Island	91 (52-140)	7.6 (4.5-22)	0.2 (0-0.4)	5.0 (2.1-8.0)	5.4 (2.9-10)	2.0 (0.9-3.9)

Table 9 Radioactivity in seaweed and foreshore materials around the Irish Sea and western Scotland, 1972/73

Material and sampling site	Concentration of radioactivity, pCi/g (wet)*; mean and range					
	Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce
<u>Porphyra</u>						
Labrax Bay	7.1 (5.2-11)	0.1 (0-0.2)	0.7 (0.3-1.5)	-	0.1 (0-0.1)	-
Port William	9.5 (5.8-14)	0.4 (0-1.1)	3.4 (1.3-5.9)	-	0.1 (0-0.3)	-
Garlieston	9.2 (6.3-15)	0.9 (0-2.7)	3.8 (0.9-10)	-	0.3 (0.1-0.6)	< 0.1
Kirkcudbright	8.2 (7.0-10)	-	1.6 (0.6-3.3)	-	0.2 (0.1-0.4)	-
<u>Fucus vesiculosus</u>						
Port William	32 (23-38)	0.8 (0-1.5)	0.4 (0.2-0.7)	0.1 (0-0.2)	0.9 (0.6-1.2)	0.1 (0-0.2)
Garlieston	38 (18-85)	2.3 (0.6-5.9)	1.5 (0.5-2.5)	0.3 (0.1-0.4)	1.6 (0.8-2.3)	0.2 (0-0.8)
Rascarrel Bay	48 (12-140)	3.0 (0.4-5.9)	2.2 (0.8-5.8)	0.3 (0.1-0.5)	1.8 (0.7-3.2)	0.7 (0-2.0)
Heysham	56 (42-92)	1.6 (0.7-3.8)	1.8 (0.7-2.7)	0.6 (0.3-0.9)	3.3 (1.8-5.1)	0.3 (0-0.9)
<u>Fucus serratus</u>						
Millisle	13 (12-15)	0.5 (0.1-0.8)	0.2 (0-0.4)	-	0.5 (0.4-0.6)	-
Silt						
Garlieston	140 (42-400)	6.4 (0.8-14)	25 (7.0-45)	1.1 (0.4-1.7)	6.9 (3.9-9.9)	12 (3.7-22)
Sand						
Heysham	120 (28-390)	1.8 (0-6.0)	8.2 (2.0-28)	1.1 (0.5-1.6)	9.4 (3.6-23)	6.4 (2.3-13)
Fleetwood	23 (13-69)	-	0.3 (0-0.4)	0.3 (0.2-0.4)	1.6 (1.1-1.8)	0.5 (0.2-0.6)

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

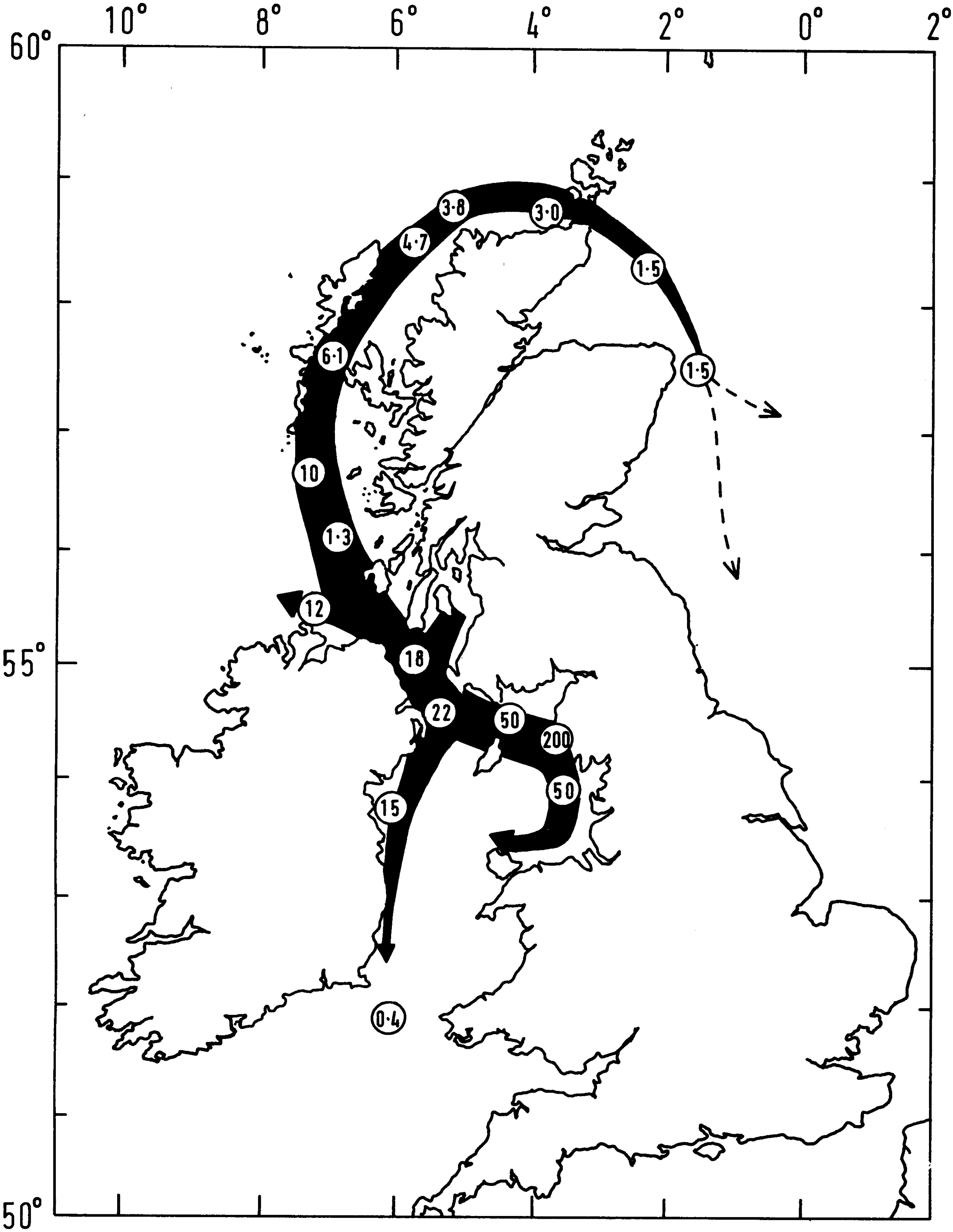

Figure 2 Concentration of caesium-137 in British Isles coastal sea water (pCi/litre), May/June 1972 (from Jefferies, Preston and Steele 1973).

2.2 Springfields, Lancashire

This establishment fabricates fuel elements and in consequence has little in the way of liquid radioactive waste to dispose of, only the natural heavy radioelements, mainly residues from the ore concentrates used in the manufacturing process. The waste is disposed of into the tidal River Ribble but has little environmental impact, its effect being seen through only one pathway; this involves the exposure of those who frequent the banks of the river in the vicinity of the outfall.

Only a limited programme of environmental monitoring is pursued, gamma dose-rate being measured on a quarterly basis at four points along the banks of the estuary. These data are shown in Table 10 together with analyses of the mud by gamma spectrometry done for research purposes. Though these measurements show fission-product activity as well as protactinium-234m, only the latter is attributable to Springfields discharges. Public radiation exposure is very low, at most being a fraction of 1 per cent of the ICRP-recommended dose limit for the few individuals making most use of this environment.

Table 10 Radioactivity in silt and gamma dose-rates over silt banks in the Ribble Estuary, 1972/73

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 (230-1600)	9.9 (4.0-25)	57 (13-100)	23 (18-27)	380 (0-1100)	16 (7.5-40)
Upstream						
90 metres*	640 (190-1200)	10 (6.1-22)	60 (25-92)	27 (21-31)	560 (230-1300)	16 (10-40)
460 metres*	660 (380-1100)	11 (2.8-26)	60 (21-110)	26 (9.2-34)	680 (130-1400)	17 (10-40)
Downstream						
90 metres*	620 (300-1100)	8.2 (4.4-14)	53 (18-100)	26 (9.6-36)	540 (100-1100)	16 (10-25)

*From pipeline outlet.

2.3 Chapelcross, Dumfriesshire

In so far as waste is concerned, Chapelcross may be regarded as another Magnox nuclear power station similar to those operated commercially by the Electricity Generating Boards. As it is in Scotland, the monitoring programme is undertaken on behalf of Departments of the Scottish Office. Low-level liquid radioactivity wastes are disposed of through an overland pipeline into the tidal reach of the River Solway.

Two potentially critical exposure pathways have been identified for liquid waste disposal from Chapelcross, one being internal due to consumption of locally-caught marine foodstuffs, notably shrimps, the other external due to use of the foreshore.

The monitoring programme is thus focussed on these activities, the main elements being regular analyses of shrimps together with gamma dose-rate measurements at selected points on the northern shore of the Solway, especially where salmon fishing takes place. In addition, the seaweed Fucus vesiculosus is sampled as an indicator and samples of silt are also analysed. In general the foreshore is sandy rather than muddy, and this is reflected in the general level of gamma dose-rate which in the areas most frequented is not distinguishable from natural background. Interpretation of the analytical data quoted in Table 11 is complicated by the existence of Windscale which masks any small effect which might be attributed to Chapelcross. Nevertheless, internal exposure from whichever source is considered responsible is low, much less than 1 per cent of the ICRP-recommended dose limit for the most avid consumer of fish and shellfish found by way of habits surveys in the Solway area. Although the contribution from Chapelcross discharges cannot be identified precisely, the levels of contamination in the Solway are entirely consistent with the known effect of Windscale discharges at this distance, and public radiation exposure from liquid waste disposed of from Chapelcross by both pathways can be regarded as negligible.

Table 11 Radioactivity in estuarine materials in the vicinity of Annan, 1972/73

Material and sampling site	Concentration of radioactivity, pCi/g (wet)*; mean and range					
	Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce
F. vesiculosus						
Waterfoot	38 (17-60)	1.0 (0.3-2.0)	1.2 (0.5-2.2)	0.3 (0.1-0.5)	1.8 (1.0-3.9)	0.4 (0-1.1)
Seafield	38 (18-73)	1.4 (0.2-3.0)	2.1 (0.7-5.9)	0.3 (0.1-0.7)	2.0 (1.0-3.9)	1.1 (0-3.1)
Shrimps						
Seafield	8.1 (6.5-10)	0.2 (0.1-0.4)	1.9 (1.0-3.2)	0.2 (0.1-0.2)	1.3 (0.8-1.5)	1.9 (1.3-2.8)
Silt						
Seafield	210 (130-270)	36 (6.0-97)	69 (28-130)	1.9 (1.0-3.4)	14 (6.8-20)	33 (10-71)

*Except silt, pCi/g (dry).

3 UNITED KINGDOM ATOMIC ENERGY AUTHORITY

Following the transfer of the Production Group of the United Kingdom Atomic Energy Authority (UKAEA) to British Nuclear Fuels Limited (BNFL) in 1971, FRL is now monitoring the aquatic environment of only two UKAEA sites. By coincidence these are both involved in research and development on new reactor systems, Winfrith and Dounreay. Monitoring of the latter is done on behalf of departments of the Scottish Office. No monitoring is undertaken in relation to any of the establishments in the River Thames catchment area, such as the Atomic Energy Research Establishment, Harwell, because the consequences of liquid waste discharges with respect to the responsibilities of the Ministry of Agriculture, Fisheries and Food are negligible, the critical pathway being drinking water.

3.1 Winfrith, Dorset

Liquid radioactive waste is discharged at some distance out into Weymouth Bay and, since the quantity is small and most of it is tritium, the environmental impact is very low. The only pathway of potential significance is internal, due to consumption of local seafoods, the area being particularly noted for lobsters and crabs.

Table 12 Radioactivity in marine materials in the vicinity of Winfrith, 1972/73

Material	Sampling site	Concentration of radioactivity, pCi/g (wet); mean and range		
		Total beta	^{60}Co	^{65}Zn
Winkle flesh	Chapman's Pool	5.3	1.2	3.8
	Osmington Mills	4.8	0.8	2.8
Limpet flesh	Chapman's Pool	2.7 (1.7-4.4)	0.5 (0.4-0.8)	0.7 (0.1-1.5)
	Osmington Mills	2.4 (2.0-4.1)	0.3 (0.2-0.5)	0.5 (0-1.2)
Oyster flesh	Poole Harbour	2.5	-	4.3
Fucus serratus	Chapman's Pool	9.1 (6.3-12)	5.4 (1.7-12)	0.4
	Osmington Mills	7.9 (6.1-9.9)	3.4 (0.6-7.1)	0.3
	Weymouth	8.1 (5.8-11)	2.6 (0.6-6.8)	0.2
	Swanage	8.1 (6.2-9.7)	2.5 (1.3-4.3)	0.4
	Portland	8.6 (5.7-13)	1.8 (0.3-5.0)	-

Most of the monitoring, however, is based on the use of indicator materials - Fucus seaweed and molluscan shellfish - from which concentrations in other marine materials can be deduced. Activation products are currently the most radiologically-important nuclides in the effluent, even though the quantities discharged are very low. For instance, low levels of zinc-65 are found in oysters harvested in the Poole Harbour area and traces of this nuclide, together with cobalt-60, are regularly detected in indicator materials on the Dorset coastline close at hand. Nevertheless, public radiation exposure is extremely low, at most no more than a small fraction of 1 per cent of the ICRP-recommended dose limit. A summary of data will be found in Table 12.

3.2 Dounreay, Caithness

The laboratory has continued to concentrate its efforts at this site on the more important of the two critical pathways, namely that associated with fishing operations, especially for salmon. The pathway is unique within our experience and results in mainly beta exposure in the course of handling fishing gear, hand and forearm being the critical 'organ'. The other pathway is foreshore contamination and here surveillance has almost entirely been the province of the UKAEA with only occasional collaborative effort involving FRL; data are not therefore presented here but may be found in the Authority's own monitoring reports (see, for instance, Hill 1974).

Exposure via the fishing gear pathway has been assessed, and a more extensive research programme has been undertaken aimed at correlating it with the discharges of the critical radionuclides, cerium-144 and ruthenium-106. Zirconium-95/niobium-95 also contributes to the dose received but only to a very small degree. Attention has been focussed on fishing at Sandside Bay where the most highly exposed fishermen are to be found. Their exposure (there were only two of them involved at this level in 1972/73) was estimated at about 4 per cent of the ICRP-recommended dose limit and is almost entirely due to salmon fishing by bagnet. There is also fishing for lobsters but doses from the gear used are much lower, even for those fishermen who operate close to the outfall.

Instead of sampling materials from other minor pathways such as fish and shellfish, an indicator monitoring programme has been carried out, which at the same time has enabled us to evaluate the spatial distribution of activity along the coastline. The indicator chosen is the seaweed Fucus serratus and additionally Fucus vesiculosus, winkles and limpets are sampled at one point only (Sandside Bay). Representative data are summarized in Table 13. This work enables us to assess exposure through the non-critical pathways: in no case does it reach 1 per cent of the ICRP dose limit.

Table 13 Radioactivity in the vicinity of Dounreay, 1972/73

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
Limpet flesh					
Sandside Bay	110 (30-440)	26 (3.7-110)	11 (0-38)	0.2 (0-2.2)	34 (11-130)
Winkle flesh					
Sandside Bay	ND	13 (4.7-27)	7.4 (3.9-15)	0.1	42 (24-61)
F. vesiculosus					
Sandside Bay	84 (27-250)	71 (11-280)	2.8 (0-9.1)	0.4 (0-3.6)	31 (8.8-83)
F. serratus					
Pipeline outlet	400 (180-470)	200 (42-420)	16 (0-24)	0.6 (0-2.5)	180 (92-210)
Oigin's Goe (1.6 km east*)	390 (130-730)	240 (49-420)	20 (6-54)	1.1 (0-3.1)	160 (65-240)
Sandside Bay East (1.6 km west*)	120 (55-190)	77 (10-230)	4.0 (0-5.4)	0.3 (0-1.2)	53 (24-73)
Borrowston (3.2 km east*)	370 (100-460)	160 (84-210)	16 (2.2-22)	0.7 (0-3.0)	150 (36-200)
Holborn Head (12.1 km east*)	26 (14-31)	12 (1.4-23)	0.5 (0-1.6)	< 0.1 (0-0.3)	7.6 (2.8-6.8)

*Measured from the beach opposite to the pipeline outlet.

4 NUCLEAR POWER STATIONS OPERATED BY THE CENTRAL ELECTRICITY GENERATING BOARD

4.1 Berkeley, Gloucestershire, and Oldbury, Avon

There is a single environmental monitoring programme of the Severn Estuary with respect to the discharges from these two power stations, since they are so close together that the receiving water masses are effectively the same. Other factors such as effluent composition are also broadly similar so that the critical pathways too are identical for each station. One is internal due to the consumption of locally-caught fish and shrimps, the other external due to contamination of the mud-banks which line this part of the estuary.

A small monitoring programme is adequate since public radiation exposure is very low. Flounders and shrimps are sampled for the internal exposure pathway; also, but less frequently, migrant fish stocks, namely salmon, elvers and eels. The external exposure pathway is covered by measuring the gamma radiation dose-rate at selected sites, samples of sediment for analysis being collected at two of them chosen so as to be close to the power stations. In addition, the seaweed Fucus vesiculosus is collected for indicator purposes.

Data are presented in Table 14 and show that public radiation exposure through each pathway is of the order of 0.1 per cent or less of the ICRP-recommended dose limit. In fact, none of the gamma dose-rates is significantly different from natural background and the extremely low levels of artificial radioactivity in estuarine material is not distinguishable from fallout from weapons testing.

Table 14 Radioactivity in estuarine materials and gamma dose-rates over silt in the vicinity of Berkeley and Oldbury, 1972/73

Material	Mean concentration of radioactivity, pCi/g (wet)*; mean and range		Gamma dose-rate, μR/hour; mean and range
	Total beta	^{137}Cs	
Flounder flesh	2.1 (1.8-2.3)	< 0.1	
Salmon flesh	ND	< 0.1	
Shrimps (whole)	2.2 (2.0-2.8)	< 0.1	
Elvers	2.8	< 0.1	
Eels	2.9	1.0	
F. vesiculosus	7.4	< 0.1	
Silt	21 (16-24)	0.7 (0-1.3)	12 (6.0-72)

*Except silt, pCi/g (dry).

Natural radioactivity in silt: ^{40}K, 11 pCi/g; ^{238}U, 2.1 pCi/g; ^{232}Th, 0.7 pCi/g.

4.2 Bradwell, Essex

The critical exposure pathway for discharges of liquid radioactive waste from this power station into the Blackwater Estuary is well known and involves consumption of oysters. Sampling of oysters is now confined to one oyster bed, some 0.5 km from the station, where experience has shown that the highest concentrations in the estuary are to be found; this is supplemented by sampling of Fucus vesiculosus at one point and silt at three locations close to the discharge area. The gamma dose-rate is measured at each of these three locations, all of them on the south bank of the estuary; values are quoted in Table 15 along with other data. However, it should be noted that the higher-than-background

Table 15 Radioactivity in oysters and non-critical materials, and gamma dose-rates over silt in the Blackwater Estuary, 1972/73

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	
Native oyster							
0.5 (downstream)	2.8 (2.1-4.6)	-	0.3 (0.2-0.4)	1.4 (1.1-2.1)	-	< 0.1	
F. vesiculosus							
1.6 (upstream)	8.7	0.1	-	0.1	0.1	0.3	
Silt							
0.5 (downstream)	24	-	-	0.2	-	0.2	6.8
0	22	-	-	0.1	0.1	0.4	14
1.6 (upstream)	30	0.1	-	0.4	0.8	4.4	6.8

*Except silt, pCi/g (dry).

value on the shore opposite the barrier wall alongside the site perimeter fence is not due to contamination of the sediment, the small excess being attributable to direct radiation from the power station.

Each of the materials sampled is analysed by gamma spectrometry in addition to total beta counting. Silver-110m is still the critical radionuclide in oysters although, like those of zinc-65 which it has eclipsed, concentrations are declining as a result of measures taken by the CEGB to minimize discharges, especially of these two constituents and caesium-134 and -137. Based on pessimistic assumptions that the highest observed consumption rate (75 g/day) could be met from oysters from the chosen sampling point, public radiation exposure would still not have exceeded 0.2 per cent of the ICRP-recommended dose limit for any organ of the body.

Table 16 Radioactivity in marine materials and gamma dose-rates over beaches in the vicinity of Dungeness, 1972/73

Material	Concentration of radioactivity, pCi/g (wet)*; mean and range		Gamma dose-rate, μR/hour; mean and range
	Total beta	^{137}Cs	
Plaice flesh	2.8 (2.5-3.5)	< 0.05	
Whelk flesh	2.1	< 0.1	
Sand	8.2	-	ND
Sand and shingle	ND	ND	4.3 (3.2-5.2)

Except sand, pCi/g (dry).

4.3 <u>Dungeness, Kent</u>

Only a very small monitoring programme is required for this power station, a reflection of the small discharges coupled with the especially good dispersion characteristics in that part of the English Channel which receives the waste. Two potentially-critical exposure pathways are recognized, one internal due to consumption of locally-caught fish, principally plaice, the other external due to use of the foreshore. However, although these may be termed critical in that all other pathways are minor, public radiation exposure via either of them is negligible, certainly less than 0.1 per cent of the ICRP-recommended dose limit; contamination of marine materials attributable to the power station is below the limit of detection.

Monitoring consists of sampling and analysis of locally-caught fish and shellfish, usually only plaice but occasionally also whelks, together with measurement of the gamma radiation dose-rate on foreshore areas where there is sand rather than the pebble of which most of the local beaches are composed. Data are summarized in Table 16. Although no dose-rate significantly higher than background has been detected over either type of beach, there would be a higher chance of finding such an effect over sand.

4.4 Hinkley Point, Somerset

At the point where discharges from this power station are made the Bristol Channel is a relatively broad expanse of water, in many respects like the open sea. In other ways, however, it is characteristic of an estuary with a good deal of fine silt and mud, especially upstream of the point where disposals are made. One of the two critical pathways results in external exposure from use of this muddy area of the foreshore, the Stolford Flats. By coincidence, those who make most use of the Stolford Flats, local fishermen, are also the most highly exposed individuals via the other critical pathway, internal exposure from consumption of locally-caught fish and shrimps.

Table 17 Radioactivity in marine materials and gamma dose-rates over the beach in the vicinity of Hinkley Point, 1972/73

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	^{106}Ru	^{137}Cs	
Shrimp flesh	3 (east)	2.8 (1.9-3.3)	< 0.1	-	
Fish flesh	3 (east)	2.7 (1.1-4.6)	0.1	-	
F. vesiculosus	1.6 (east)	8.0 (5.0-9.9)	0.2 (0-0.3)	< 0.1	
	0.8 (east)	8.2 (6.5-10)	0.2 (0.1-0.3)	< 0.1	
	0	11 (5.8-18)	1.2 (0.1-2.5)	0.4	
	0.8 (west)	8.1 (4.5-11)	0.3 (0.1-0.6)	< 0.1	
Silt/sand	1.6 (east)	47	3.8	6.1	ND
	0.8 (east)	29	1.9	1.9	ND
	0	34 (24-29)	2.4 (1.3-3.8)	3.4 (0-14)	8.5 (7.3-11)

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

The FRL monitoring programme centres on these pathways, taking samples of fish and shrimps and the fine silt/sand of the foreshore. These are analysed for total beta activity and by gamma spectrometry; the gamma dose-rate is also measured on the shoreline close to the pipeline outlet where the highest observable values are normally to be found. The indicator seaweed Fucus vesiculosus is also collected. Most of these materials contain traces of caesium-137 and, apart from fish and shrimps, low levels of ruthenium-106 as well. Concentrations of artificial radioactivity in both fish and shrimps are now so low that they are not significantly different from the levels expected from fallout from weapons testing, and radiation exposure of even the most avid consumer of these foodstuffs is negligible - not that exposure from the external exposure pathway is large, being no more than about 0.2 per cent of the ICRP dose limit for the fishermen working the area.

Data from these surveys are summarized in Table 17.

4.5 Sizewell, Suffolk

In the same way as Dungeness, a combination of small discharges and good dispersion conditions, in this case in the North Sea, serve to make this one of the least important of nuclear power stations in terms of impact on the aquatic environment. The two critical exposure pathways are internal through consumption of locally-caught fish and shellfish, and external through exposure from time spent on the foreshore.

Table 18 Radioactivity in fish and shellfish and gamma dose-rates over the beach in the vicinity of Sizewell, 1972/73

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	3.2 (2.5-3.8)	0.1	
Plaice and sole flesh	3.0 (2.7-3.3)	< 0.1	
Skate flesh	3.6 (2.3-4.5)	< 0.1	
Flounder flesh	3.2	-	
Crab flesh	5.4	-	
Lobster	1.6 (0.9-2.3)	-	
Sand	-	-	4.2 (3.0-6.1)

*Except sand, pCi/g (dry).

The monitoring programme consists of analysis of selected species from within the wide variety of fish and shellfish brought ashore in the locality and of measurement of the shoreline gamma dose-rate, the chosen sites being patches of sand overlaying what is essentially a shingle beach. However, in none of these materials is there evidence of artificial radioactivity attributable to the power station from whose operation public radiation exposure is negligible.

Data are summarized in Table 18.

4.6 Trawsfynydd, Gwynedd

Lake Trawsfynydd continues to be the power station environment most demanding of FRL attention. In addition to radiological monitoring, a considerable radioecological research programme is undertaken there. The critical exposure pathway, indeed the only pathway of any significance, is that due to consumption of lake fish, mainly trout though some perch is also eaten. Permissible discharges to the lake have recently been reviewed, verifying the importance of this pathway and confirming the validity of the value of 100 g/day previously used as a basis for evaluation and assessment of public radiation exposure. In this instance attempts were made to identify a critical group as opposed to taking the highest observed consumption rate, and the above value is believed to be appropriate to such a group. Identification of a meaningful group was made difficult by the relatively small size of the exposed population, some 225 observations of regular consumers of trout and/or perch being obtained.

The data from the environmental programme are quoted in Table 19 and must be viewed in two parts: (1) those on trout and perch needed for assessment of the extent of human radiation exposure, and (2) those which are used for research in conjunction with the fish data. Research is aimed at understanding the environmental behaviour of radioactive waste discharged from the power station into the lake and goes beyond the critical nuclides caesium-137 and caesium-134 found in fish. Whilst antimony-125 has been a major component of the effluent and is now being found in the lake, it is of negligible radiological importance. It is easily detected in the mud and peat of the lake bed and also in Fontinalis in the outlet stream but concentrations in fish are below limits of detection. Other fission products detected in sessile materials in this ecosystem include ruthenium-106, caesium-134 and -137 and, in Fontinalis only cerium-144. Traces of the activation product cobalt-60 are also found.

Table 19 Radioactivity in materials in Lake Trawsfynydd and local streams, 1972/73

Material	Sampling site	Concentration of radioactivity, pCi/g (wet)*; mean and range							
		Total beta	^{60}Co	^{90}Sr	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce
Water	Cold lagoon	ND	-	ND	-	-	3.4 (0.8-7.8)	18 (4.7-41)	-
	Hot lagoon	ND	-	12 (10-17)	-	-	4.5 (1.4-16)	23 (8.8-62)	-
Trout flesh	Lake	22 (5.4-42)	-	0.16	-	-	3.8 (1.8-8.6)	21 (9.7-41)	-
Perch flesh	Lake	52 (33-71)	-	0.26	-	-	9.1 (4.2-14)	53 (32-83)	-
Mud	Lake	53 (41-66)	0.2 (0-0.4)	ND	0.4 (0-3.1)	10 (0-37)	1.5 (0.3-4.3)	22 (10-39)	-
Peat	Lake	84 (27-170)	0.1 (0-0.3)	ND	3.0 (0-12)	46 (12-110)	2.8 (0.3-7.6)	18 (4.4-36)	-
Fontinalis	Afon Prysor	11 (6.2-21)	< 0.1	ND	1.2 (0.4-2.8)	< 0.1	-	0.3 (0-1.9)	1.0 (0-2.8)
	Gwylan Stream	95 (41-140)	0.5 (0-2.5)	ND	12 (5.0-22)	50 (16-80)	2.8 (1.6-4.0)	14 (8.6-25)	0.3

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

Table 20 Radioactivity in marine materials and gamma dose-rates over the beach in the vicinity of Wylfa, 1972/73

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	^{110m}Ag	^{134}Cs	^{137}Cs	^{144}Ce	
Cemlyn Bay	Porphyra	8.0 (5.9-9.7)	-	-	-	-	0.2	-	
	F. vesiculosus	20 (15-25)	0.1 (0-0.2)	0.1 (0-0.3)	0.1 (0.1-0.2)	< 0.1	0.6 (0.3-0.9)	-	
	Lobster flesh	3.5	< 0.1	-	0.2 (0-0.4)	-	0.4 (0.2-0.6)	-	
	Crab flesh	5.2 (2.5-6.3)	-	0.2 (0-0.5)	0.3 (0-0.7)	-	0.1 (0.1-0.2)	0.1 (0-0.3)	
	Pollack flesh	4.6 (3.6-4.8)	0.2	-	0.1	< 0.1	1.1	-	
	Silt	37 (34-42)	1.7 (0-3.3)	3.6 (2.1-6.6)	0.2 (0-0.6)	0.1 (0-1.7)	9.8 (6.1-13)	2.0 (0-5.1)	10 (5-12)
Cemaes Bay	Porphyra	6.2 (4.2-8.4)	-	0.2	-	-	0.1	-	
	F. vesiculosus	19 (13-26)	0.2 (0-0.5)	0.2 (0-0.3)	-	0.1 (0-0.2)	0.7 (0.4-0.9)	-	
	Winkle flesh	4.8 (3.2-6.1)	0.1	0.5 (0-1.7)	0.3 (0-0.7)	< 0.1	0.2 (0.1-0.5)	-	

*Except silt, pCi/g (dry).

4.7 Wylfa, Gwynedd

One of the potentially critical pathways for liquid radioactive waste discharges from Wylfa is internal, through consumption of locally-caught fish and shellfish; the other is external as a result of use of the local foreshore. Both these pathways are monitored, the former by sampling pollack, crabs, lobsters and winkles, the latter by measurement of the gamma dose-rate on the foreshore at Cemlyn Bay, the nearest point to the power station to which the public have ready access. Silt from Cemlyn Bay is also analysed as are samples of seaweed, both Fucus vesiculosus and Porphyra, for indicator purposes.

A summary of the data is shown in Table 20. Reflecting the minimal discharges of radioactivity from Wylfa, none of the measurements show activity attributable to power station operation and public radiation exposure from liquid wastes due to its operation was thus negligible. For the most part the traces of artificial radioactivity which were present in this region of the Irish Sea are a combination of Windscale activity and that from fallout from weapons testing, though the silver-110m was the result of a tracer experiment carried out in Liverpool Bay to determine the movement of sewage sludge dumped there.

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

This section includes only one such power station, that at Hunterston, and as it is in Scotland the monitoring is undertaken on behalf of Departments of the Scottish Office.

5.1 Hunterston, Ayrshire

The main feature of monitoring for the discharges made from this site into the Firth of Clyde reflect the existence of both internal and external critical pathways, consumption of fish and shellfish and use of the foreshore respectively. Several species of shellfish are sampled, cockles, winkles and lobsters, each from local commercial fishing operations, whilst samples of oysters and plaice are made available by the White Fish Authority from their fish farming project on a site adjoining the power station. Sand is sampled and, for indicator purposes, so is the seaweed Fucus spiralis. The sea water sampled also comes from the fish farming project and is analysed for research purposes.

Like the analyses of contaminants of marine materials, gamma dose-rates measured on the foreshore show no detectable contribution above background which can be attributed to the discharges from Hunterston. Other data are quoted in Table 21.

Table 21 Radioactivity in the vicinity of Hunterston, 1972/73

Material	Concentration of radioactivity, pCi/g (wet)*; mean and range					
	Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce
Cockle flesh	2.8 (1.8-3.6)	-	0.2 (0.1-0.3)	-	0.1 (0.1-0.2)	< 0.1
Winkle flesh	4.2	-	0.2	-	0.1	-
Oyster flesh	2.0	-	-	-	0.1	-
Crab flesh	4.2	-	-	-	0.2	-
Plaice flesh	2.8	-	-	< 0.1	0.3	-
Sand	14 (9.9-33)	-	0.1 (0-0.2)	< 0.1	0.3 (0.2-0.5)	-
F. spiralis	14 (6.5-35)	0.2 (0-0.8)	0.4 (0-0.8)	0.1 (0.1-0.2)	0.6 (0.3-0.9)	0.1 (0-0.2)
Sea water†	-	-	-	4.6 (2.3-10)	23 (14-37)	-

*Except sand, pCi/g (dry).
†Sea water, pCi/litre.

6 MINISTRY OF DEFENCE (NAVY DEPARTMENT)

Monitoring has continued much as before in respect of the small discharges made from the naval bases at Chatham, Faslane and Rosyth, and surveillance has now been added at a fourth, Devonport, though disposals to date have been very small indeed. Monitoring of the environments of Faslane and Rosyth is done on behalf of Departments of the Scottish Office.

6.1 HM Dockyard, Chatham, Kent

In common with each of the other MOD(N) sites there is only one critical pathway leading to external exposure, namely that from use of the foreshore. Samples of river silt are analysed to reinforce measurement of gamma dose-rate at selected points on the river banks. Though traces of cobalt-60 attributable to discharges from the dockyard are found in these samples, resulting public radiation exposure is negligible, even to those who are judged to be the most highly exposed, the river house-boat dwellers. Data are presented in Table 22.

Table 22 Radioactivity in materials and gamma dose-rates along the shoreline in the vicinity of establishments operated by the Ministry of Defence (Navy Department), 1972/73

Site and material	Concentration of radioactivity, pCi/g (wet)*; mean and range			Gamma dose-rate, μR/hour; mean and range
	Total beta	^{60}Co	^{137}Cs	
Chatham				
Silt	23 (20-37)	0.4 (0.1-1.0)	0.9 (0.1-1.5)	6.4 (4.7-12)
Devonport				
F. vesiculosus	6.8 (3.3-8.0)	< 0.1	-	
Winkle flesh	3.7	-	-	
Silt	26 (20-37)	< 0.1	0.2 (0-0.5)	8.6 (7.0-11)
Faslane				
Sea bed	34 (31-37)	0.8 (0.3-3.1)	7.2 (4.4-10)	
Foreshore silt	38 (24-99)	0.8 (0-1.9)	2.4 (0.6-4.9)	10 (5-20)
Rosyth				
F. vesiculosus	6.9	-	0.1	
Dockyard approaches silt	ND	0.3 (0.1-0.7)	1.2 (0.1-5.4)	
Shoreline	26	0.1	0.2	8.1 (6.1-9.9)

*Except silt, pCi/g (dry).

6.2 HM Naval Base, Devonport

The monitoring programme in 1972/73 was still effectively in a pre-operational phase and measurements quoted in Table 22 are of natural background only.

A habits survey confirmed that use is made of the foreshore and in consequence external exposure may be expected to be the critical pathway; emphasis in monitoring has thus been placed on measurement of the gamma dose-rate over silt banks and has been supplemented by analysis of silt samples. However, winkles have also been sampled as well as *Fucus vesiculosus*, both for indicator purposes but only on a very small scale.

6.3 HMS NEPTUNE, Faslane, Dunbartonshire

Part of the environmental survey programme for discharges to the Gareloch from this site are for research purposes, namely the grid of seabed sampling stations from which sediment is analysed. The gamma dose-rate is measured at selected points on the foreshore and samples of silt for analysis are taken at a few of them where significant deposits can be found. Elsewhere the nature of the shore ranges from coarse sand to gravel. Though traces of artificial radioactivity are found in these sediments the evidence is that they emanate from sources outside the loch. However, this is of no great importance for, as indicated by the gamma dose-rate which is not distinguishable from natural background, public radiation exposure is negligible. Data are presented in Table 22.

6.4 HM Dockyard, Rosyth, Fife

The principal feature of the monitoring programme here is silt sampled from the dockyard approaches, because the sector of the public most exposed to radioactivity disposed of into the Firth of Forth are the dredgermen who keep the approach channels clear. In addition to this material and the indicator seaweed *Fucus vesiculosus*, the shoreline is sampled at the nearest points to the dockyard to which the public has access and the gamma dose-rate there is measured. Although traces of cobalt-60 attributable to dockyard operations are detected, public radiation exposure is negligible. A summary of the measurements is included in Table 22.

7 THE CHANNEL ISLANDS

In surveillance of possible effects of discharges from the fuel reprocessing plant at Cap de la Hague on the mainland of France to the east of the Channel Islands, the laboratory has continued its programme of analysis on environmental samples made available by the Channel Islands Governments. The range of materials for which measurements are quoted in Table 23 includes fish, shellfish and sand chosen for their possible significance vis-à-vis public radiation exposure but also *Porphyra* seaweed to fulfil an indicator role. Traces of caesium-137 are found in some of these materials but at levels consistent with fallout from weapons testing. There is also evidence of ruthenium-106, especially in Porphyra, though again levels are low and of very little radiological significance. In this case, however, and though a majority of the analyses are consistent with weapons testing fallout, measurements on the shores of Alderney suggest a small contribution from another source, presumably the discharges from the plant at Cap de la Hague.

Table 23 Radioactivity in materials on the coasts of the Channel Islands, 1972/73

Material	Sampling area		Concentration of radioactivity; pCi/g (wet)*; mean and range		
			Total beta	^{106}Ru	^{137}Cs
Porphyra	Guernsey	Fort Doyle	7.0 (3.7-9.1)	0.2 (0-0.3)	-
		Fermain Bay	5.5 (4.0-6.7)	0.2 (0-0.4)	-
	Alderney	Corblets Bay	7.8 (5.8-12)	1.3 (0-2.8)	-
		Telegraph Bay	6.4 (3.7-14)	0.6 (0.3-1.1)	-
		Des Runes	4.1	0.6	-
	Jersey	Greve de Lecq	6.8 (4.3-8.9)	0.2 (0-0.9)	-
		La Rozel	7.4 (4.1-11)	-	-
Ormer flesh	Guernsey		2.6	0.2	0.1
Ray wings	Guernsey		5.2	-	0.1
Sand	Guernsey	Bordeaux Harbour	22	0.3	0.2

*Except sand, pCi/g (dry).

Table 24 Radioactivity in seaweeds on the coastline of Ireland, 1972/73

Material	Sampling point	Concentration of radioactivity, pCi/g (wet); mean and range			
		Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{137}Cs
Porphyra	Skerries	5.0 (4.4-6.6)	-	0.1	-
	Colliemore	6.1 (4.2-7.4)	-	0.1	0.1
	St Helens	5.4 (4.0-6.4)	-	-	-
	Carlingford Lough	5.2 (4.8-5.7)	-	0.1	0.1
	Dunmore East	4.6 (4.1-6.1)	-	-	-
F. serratus	Skerries	12 (11-14)	< 0.1	0.2	0.4
	Colliemore	16	-	0.2	0.2
	St Helens	8.0 (5.9-10)	< 0.1	< 0.1	-
	Dunmore East	6.8 (5.7-8.4)	-	-	-
F. vesiculosus	Skerries	18	-	-	0.2
	Colliemore	16	< 0.1	0.1	0.3
	Carlingford Lough	12	0.2	0.1	0.5
Laminaria digitata	Skerries	14 (11-16)	< 0.1	0.1	0.4 (0.1-0.5)
	Colliemore	14	-	-	0.3
	St Helens	8.1 (5.4-14)	-	-	< 0.1
	Carlingford Lough	15	-	-	0.2
	Dunmore East	9.2	-	-	-
Laminaria saccharina	Skerries	19	0.2	-	0.3
	Carlingford Lough	11	0.2	0.1	0.3

8 IRELAND

Monitoring has again been concentrated on seaweed indicators which have also been used for purposes of comparison between FRL and the Irish National Radiological Monitoring Service.

A variety of seaweeds has been collected, principally from the Irish Sea coastline of the Republic of Ireland, and composed of Porphyra and two species from each of the genus Fucus and Laminaria. Traces of fission products have occasionally been found but at such a low level that they carry no radiological significance. A summary of the data is to be found in Table 24.

9 MISCELLANEOUS SURVEYS

The laboratory does not devote much effort to special surveys for the measurement of weapons testing fallout because, although the traces of fission products such as caesium-137 and ruthenium-106 are commonly present, adequate information considering the low level of radiological significance can often be obtained from surveys mounted in connection with specific controlled releases. Levels at which they are frequently present are small fractions of 1 pCi/g in most materials, except sea water in which only caesium has been detected and generally at a concentration about 3 orders of magnitude lower.

A few measurements of background material are still made (Table 25), and results such as the trace of ruthenium-106 of fallout origin in the St David's sample of Porphyra can help in suggesting the fallout concentration to be expected in other areas which are not remote from the source of controlled releases.

Table 25 Radioactivity in background reference materials, 1972/73

Material	Sampling area	Concentration of radioactivity, pCi/g (wet)*; mean and range	
		Total beta	^{106}Ru
Porphyra	Lowestoft	4.5	-
	Dunbar	5.2 (3.4-7.1)	-
	St Davids	6.4 (4.9-8.8)	0.2
	Cromer	5.9	-
F. spiralis	Lowestoft	5.5 (4.0-7.0)	-
F. vesiculosus	Lowestoft	6.1	-
Sand	Lowestoft	6.9 (6.2-8.1)	-

*Except sand, pCi/g (dry).

These samples are also used as a check on the level of natural activity to be expected, which is mainly potassium-40.

A small programme of monitoring commercial fish landings (Table 26) is directed primarily at analysis for caesium-137. Concentrations found were all close to or below the limit of detection and public radiation exposure from these fish as foodstuffs is very low indeed. As expected, concentrations are lower in fish from Icelandic waters than in fish from the southern North Sea where concentrations of caesium-137 from run-off are higher than in the main ocean water mass.

Table 26 Radioactivity in commercial fish landings in UK ports, 1972/73

Species	Fishing area	Concentration of radioactivity, pCi/g (wet); mean and range	
		Total beta	^{137}Cs
Cod flesh	Southern North Sea (IVC)	4.8	0.1
	Iceland (VA)	3.0 (2.1-3.7)	< 0.1
Plaice flesh	Southern North Sea (IVC)	3.4	< 0.1
	Iceland (VA)	3.3	-
Sole flesh	Iceland (VA)	4.1	-
Herring flesh	Southern North Sea (IVC)	2.8	0.1

10 SUMMARY

The basic aim of the laboratory's environmental monitoring surveys is to provide data from which the extent of public radiation exposure can be assessed, and hence to verify the adequacy of the waste disposal control procedures which have been imposed. As in previous reports, assessment has been made in terms of both dose to the individual and collective dose to the whole population who are involved, in each case via the critical exposure pathways. Some values of individual dose have already been given at appropriate points within this report; these and estimates of collective dose are collated in Table 27. Both are source-related assessments for exposure via the critical pathway(s).

Considerable difficulties are encountered in identifying critical groups which meet the criteria laid down by ICRP, particularly that of homogeneity with respect to those factors that affect the dose received. In consequence it is often only possible to quote estimates for the person identified from habits/consumption surveys who it is believed represents the most highly exposed person in the samples interviewed. Whilst the ICRP recommendation presents a more objective approach, it is usually difficult to apply it because of the small size of many of the exposed populations. Notable exceptions are the well-known Porphyra/laverbread pathway and another Windscale pathway, that from consumption of fish caught in the Irish Sea.

Table 27 Estimates of public radiation exposure from liquid radioactive waste disposals in the United Kingdom, 1972/73

Site	Pathway	Maximum exposure* of an individual (% of ICRP-recommended dose limit)	Approximate total population gonad dose*, man-rem, not exceeding:
BRITISH NUCLEAR FUELS LIMITED			
Windscale	Porphyra/laverbread	2 (to critical group)	10^0
	External dose	7	10^0
	Fish	3 (to critical group)	3×10^3
Springfields	External dose	< 1	10^{-1}
Chapelcross	External dose	$\ll 1$	10^{-2}
	Shellfish	$\ll 1$	10^{-1}
UNITED KINGDOM ATOMIC ENERGY AUTHORITY			
Winfrith	Shellfish	< 1	10^{-1}
Harwell*	Drinking water	< 1	10^2
Dounreay	External dose (foreshore)	< 1	10^0
	Beta dose (fishermen)	4	10^{-2}
	Shellfish	$\ll 1$	10^0
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	$\ll 0.1$	10^{-1}
	Fish	$\ll 0.1$	10^{-1}
Hinkley Point	External dose	0.1	10^{-1}
	Fish/shellfish	0.1	10^0
Sizewell	External dose	$\ll 0.1$	10^{-1}
	Fish/shellfish	$\ll 0.1$	10^{-1}
Trawsfynydd	Lake fish	6	10^0
Wylfa	External dose	$\ll 0.1$	10^{-1}
	Fish/shellfish	$\ll 0.1$	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}
Devonport	External dose	$\ll 0.1$	10^{-1}
Faslane	External dose	< 0.1	10^{-1}
Rosyth	External dose	< 0.1	10^{-1}

*Assessed for discharges from the site named only except Harwell where the entry includes an estimate for other discharges to the River Thames.

Most of the estimates of collective dose given in Table 27 have been rounded off on an order-of-magnitude basis, because in general the quality of the basic data used and the very low radiological significance of the result does not warrant the greater effort needed to achieve a more precise result. In some cases more precise calculation can easily be done; of these, the dose to the population who eat fish which contain radioactivity of Windscale origin is a clear candidate for such treatment. The estimate of collective data in Table 27 includes the dose to populations in other countries through their catches of fish in the British Isles coastal waters. Though exposure from fish consumption is by far the largest value for collective dose from any controlled source of liquid radioactive waste in 1972/73, it was equivalent to much less than 0.1 per cent of the UK limit of 1 rem per person per 30 years.

Most of the data quoted in Table 27 are for discharges in respect of whose control the laboratory plays a leading role because their primary impact on the environment is on fisheries' interests rather than through other aquatic pathways such as drinking water. A particular exception is in the data quoted for the sites which discharge liquid radioactive waste to the River Thames; these are included so that the table can present a comprehensive account of public radiation exposure from all the major discharges of liquid radioactive waste to the aquatic environment. The critical pathway for these discharges to the River Thames is drinking water and, in line with interdepartmental arrangements, the lead is taken by the Department of the Environment (DoE) since it rather than MAFF is more concerned with drinking water quality.

11 CONCLUSIONS

The stringent standards set to limit disposal of radioactive waste in the United Kingdom have been maintained. Data presented in this report show that, as a consequence, radiation exposure of the public is very low and well within the recommendations of the International Commission on Radiological Protection and the dose limits specified in the objectives for UK waste disposal policy. Not only are the exacting requirements of the ICRP recommendations met but, 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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