MINISTRY OF AGRICULTURE, FISHERIES AND FOOD

FISHERIES RADIOBIOLOGICAL LABORATORY

RADIOACTIVITY IN SURFACE AND COASTAL WATERS OF THE BRITISH ISLES 1970

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Readers of the four previous reports by Neil Mitchell in this series will be familiar with their aims and purposes. In presenting the results of the 1970 monitoring programme of the Fisheries Radiobiological Laboratory, he again shows how carefully public health and amenities continue to be safeguarded. The high standards of safety that were set in previous years, and maintained in 1970, could not be achieved without the close cooperation of all who are concerned in the disposal of radioactive wastes to surface water and the sea.

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

Site	Critical material	Critical exposure category	Exposed group
United Kingdom Atomic Energy Authority			
Windscale	*Porphyra* (laverbread) Silt	Beta dose to GI tract* Gamma dose to whole body	General public (South Wales) Fishermen
Winfrith	Lobster and crab flesh	Beta dose to GI tract	Local fishermen and families
Springfields	Silt	Gamma dose to whole body	Dredgermen
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 (somatic and genetic hazard)	General public (Greater London)
Amersham	Drinking water	Beta-gamma dose to whole body (somatic and genetic hazard)	General public (Greater London)
Dounreay	Detritus Beach sludge	Beta dose to hands Gamma dose to whole body	Local fishermen Local fishermen and others
Chapelcross	Shrimp flesh Sand and silt	Beta-gamma dose to whole body Gamma dose to whole body	Local fishermen and families Salmon fishermen
Central Electricity Generating Board and South of Scotland Electricity Board			
Berkeley	Silt 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	Beta dose to GI tract	Oyster fishermen and families
Hinkley Point	Fish and shrimp flesh Silt	Beta-gamma dose to whole body Gamma dose to whole body	Local fishermen and families Local fishermen
Dungeness	Fish flesh Silt	Beta-gamma dose to whole body Gamma dose to whole body	Local fishermen and families Bait diggers
Oldbury	Silt 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 Sand	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 Silt	Beta-gamma dose to whole body Gamma dose to whole body	Local fishermen and families Local fishermen
Hunterston	Fish flesh Sand	Beta-gamma dose to whole body Gamma dose to whole body	Local fishermen and families Shellfish collectors
Ministry of Defence (Navy Department)			
Chatham	River mud/silt	Gamma dose to whole body	General public (houseboat dwellers)
Faslane	Mud/silt	Gamma dose to whole body	Boatyard workers
Rosyth	Silt	Gamma dose to whole body	Dredgermen

*GI tract, gastro-intestinal tract.

RADIOACTIVITY IN SURFACE AND COASTAL WATERS OF THE BRITISH ISLES, 1970

1 INTRODUCTION

This is the fifth in an annual series of reports presenting the work of monitoring the aquatic environment by the Fisheries Radiobiological Laboratory, and it describes surveys made during 1970. Most of the laboratory's effort in this field is directed to fulfilling the Ministry's responsibilities in the control of radioactive waste discharges - that is, in England and Wales - and much of the information in this report refers to these areas. However, 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 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 radiological monitoring by the operators.

Those establishments discharging liquid radioactive waste with which this report is concerned are listed in Table 1, which also includes a summary of the important factors in the critical exposure pathways. The quantities of radioactivity which each of these sites is permitted to dispose of are listed in Table 2, with the percentage utilized alongside. The authorized limit is of course never allowed to exceed the limiting environmental capacity and for many disposals the quantities involved are only a very small proportion of it.

Most of the data included in this report have been produced to demonstrate the radiological safety of environmental contamination. In addition to this basic work, research continues to be a vital part of the laboratory's work and some of the results of these programmes are included - especially where they contribute to a better understanding of the extent and significance of the effects of particular disposals. This comprehensive monitoring of the environment confirms that adequate control of radioactive waste disposal has been maintained throughout 1970.

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*As from 1 April 1971, three of the sites formerly under control of the UKAEA whose disposals are monitored by the laboratory (Windscale and Calder, Springfields and Chapelcross) were transferred to British Nuclear Fuels Limited. As they were UKAEA sites during the period under review they are referred to as such in this report.

Table 2 Major discharges of liquid radioactive wastes to surface and coastal waters during 1970

Site	Radioactivity	Authorized discharge, curies/year	Percentage utilized
Windscale	Total beta	300 000	40
	Ruthenium-106	60 000	46
	Strontium-90	30 000	21
	Total alpha	1 800 (to October 1970)	84
		6 000 (from November 1970)	19
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	5
	Total beta	12 000	8
Aldermaston	Total activity	156†	22
Harwell	Total activity	240†	36
Amersham	Total activity*	72†	35
	Tritium	400	52
Chapelcross	Total activity*	700	2
	Tritium	150	4
Dounreay	Total alpha	240	50
	Total beta	24 000	63
	Strontium-90	2 400	17
Berkeley	Total activity*	200	50
	Tritium	1 500	10
Bradwell	Total activity*	200	64
	Zinc-65	5	2
	Tritium	1 500	6
Dungeness	Total activity*	200	42
	Tritium	2 000	1
Hinkley Point	Total activity*	200	63
	Tritium	2 000	1
Oldbury	Total activity*	100	8
	Tritium	2 000	1

Table 2 continued

Site	Radioactivity	Authorized discharge, curies/year	Percentage utilized
Sizewell	Total activity*	200	12
	Tritium	3 000	< 1
Trawsfynydd	Total activity*	40	35
	Tritium	2 000	3
Wylfa	Total activity*	65	< 1
	Tritium	4 000	9
Hunterston	Total activity*	200	32
	Tritium	1 200	13
Chatham	Total activity*	20	< 1
	Cobalt-60	10	< 1
	Tritium	20	54
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 shown.

2 SITES OPERATED BY THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY

2.1 Windscale and Calder, Cumberland

The two exposure pathways previously of critical importance - internal exposure from consumption of the foodstuff laverbread, manufactured from the seaweed Porphyra, and external exposure from adsorption of radioactivity by sediment, especially in the Ravenglass Estuary - have continued to dominate, though there is now evidence that a third exposure pathway from consumption of fish may become important. This is the result of increasing rates of disposal of caesium-137 and -134, which have so far had no effect on the Porphyra/laverbread pathway, though these radionuclides do appear in sediment and thus contribute to external exposure.

One notable and already well publicized change in 1970 concerns alpha radioactivity and a new authorization came into force late in the year to allow larger rates of disposal. Contrary to the impression from some of the publicity that this change aroused, this is not a particularly important type of radioactivity in a marine context; the only exposure pathways of any possible significance are, of course, internal, and exposure from consumption of fish is of negligible importance compared with that from consumption of Porphyra. The maximum rate of disposal now authorized under the new arrangements is still only a small fraction of the limiting environmental capacity, and although the critical material for exposure from alpha radioactivity is the same as that for fission-products, the radiological effect of these two waste categories is not additive because different body organs are involved. The critical organ for the principal alpha radioactive nuclides in Windscale effluent is bone, to whose exposure ruthenium and cerium contribute negligibly, the converse being true for the gastro-intestinal tract, which is the critical organ for beta radioactivity in relation to Porphyra.

The principal monitoring effort for radiological purposes in 1970 was directed to sampling and analysis of Porphyra, laverbread and sediment. Porphyra was collected from a network of sampling points in the area where it is harvested on the Cumberland and north-west Lancashire coasts (Table 3); the laverbread came from the product of the three main manufacturers in South Wales (Table 4). The original purpose of analysing laverbread was to check the degree of dilution which occurs with supplies of uncontaminated weed from areas remote from Windscale, when such dilution could be estimated from data supplied by British Rail on the movements of the raw material. As the Porphyra-supply network has become more complex, measurement of laverbread has become the only reliable means of estimating the radiation exposure of the laverbread-eating population. On a basis of no dilution, exposure of the critical group would have been 42 per cent of the ICRP recommended dose limit in 1970, whilst from actual measurements on laverbread exposure was found to be no more than 6 per cent of this limit. These data refer to exposure of the GI tract, that of other organs being much less. For instance bone exposure - principally due to discharges of the alpha-emitters and strontium-90 - is estimated at 3 per cent on a no-dilution basis but less than 1 per cent on the basis of laverbread measurements.

The most important area for external exposure is the Ravenglass Estuary where the gamma dose-rate was measured and samples of silt taken for analysis. Similar monitoring was conducted in Whitehaven Harbour and the gamma dose-rate was measured on mud on the eastern shore of Walney Island. These are the only areas where mud is always present; isolated patches, small in extent, occasionally appear on the open beaches, where their overall radiological significance is small. Results are quoted in Table 5 from which it has been deduced that the maximum degree of external exposure in 1970 (in the Ravenglass Estuary) was 12 per cent of the ICRP recommended dose limit.

Increasing attention is being paid to consumption of fish as an exposure pathway because of increases in the rate of disposal of caesium-137 and -134; Table 6 contains a summary of the more important measurements made in 1970, mainly sampling plaice (Pleuronectes platessa), the principal species fished commercially in the Irish Sea. Concentrations in fish caught close to the pipeline are of course higher than those in supplies from commercial landings, which are caught from a wide area of the Irish Sea. It is doubtful whether fish from either area have yet reached equilibrium with caesium radionuclides in sea water (see for instance the concentrations being found in sea water and quoted in Table 7), so that public radiation exposure from fish consumption may be expected to increase over the 1970 value of about 1 per cent of the ICRP recommended dose limit to those who eat the largest quantities of fish.

Sea water has been sampled in several areas and plays an important part in keeping the fish consumption pathway under surveillance, since measurements indicate what concentrations may be reached in fish at a considerably later stage. (Attainment of biological equilibrium is a slow process taking several months.) In addition, because caesium largely remains in sea water, this sampling programme is yielding useful information on water movements over the whole of the Irish Sea and out through the North Channel. Results of measurements of caesium-137 and -134 from a selection of the sampling points used in 1970 are quoted in Table 7, and should be read in conjunction with Figure 1. Other radionuclides are also present but concentrations are not quoted, being of significance only in the north-east Irish Sea and particularly close to the pipeline.

Results of other monitoring not associated with exposure pathways of potential importance are set out in Tables 8 and 9. The former lists analyses on *Fucus* seaweed in the vicinity of Windscale, whilst the latter summarizes surveys at greater distances and includes both *Porphyra* and *Fucus* seaweeds and also sediment. Most of the distant positions quoted in Table 9 are in south-west Scotland, where the measurements have been made at the request of the Departments of the Scottish Office; others from the Irish Sea coastline of England and Northern Ireland are included but not monitoring of the shores of the Irish Republic, which is listed separately in Section 7.

Table 3 Radioactivity in Porphyra in the immediate vicinity of Windscale, 1970

Sampling site	Distance from pipeline (km)	Concentration of radioactivity, pCi/g (wet); mean and range					
		Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{144}Ce	$^{239/240}Pu$	^{241}Am
Dubmill Point	51.5	10	1.0	10	0.8	-	-
Maryport	41.0	8.3	0.6	9.4	0.4	-	-
St. Bees	10.0	81 (24-166)	7.0 (2.6-20)	81 (15-163)	3.7 (0.9-7.0)	0.4	0.6
Nethertown	5.6	160 (95-304)	26 (2.8-66)	152 (98-232)	14 (3.0-41)	-	-
Braystones North	3.7	215 (105-296)	29 (5.6-69)	207 (108-342)	15 (3.0-35)	0.7 (Braystones North and South)	0.6 (Braystones North and South)
Braystones South	1.9	194 (98-342)	31 (6.3-77)	191 (115-337)	13 (2.8-45)		
Sellafield Pipeline	0	194 (79-359)	28 (3.3-82)	181 (69-378)	12 (0.4-32)	-	-
Sellafield Bailey Bridge	1.4	249 (90-423)	35 (6.2-103)	233 (93-375)	16 (1.4-56)	-	-
Seascale	3.1	146 (60-261)	25 (4.2-81)	138 (70-249)	10 (2.1-19)	1.1	0.8
Drigg Barnscar	5.6	146 (53-281)	28 (5.9-51)	138 (72-274)	11 (0.8-25)	-	-
Drigg Rabbit Warren	8.0	105 (36-167)	19 (6.8-38)	90 (49-128)	9.2 (1.9-17)	-	-
Eskmeals North	10.9	100 (79-122)	13 (6.2-25)	96 (78-115)	6.6 (1.2-11)	-	-
Eskmeals South	14.3	84 (40-167)	10 (2.7-27)	83 (50-166)	2.9 (0.3-9.4)	0.4	0.6
Gutterby	20.1	71 (41-105)	8.0 (1.8-18)	70 (40-105)	2.7 (1.2-6.4)	0.9	1.0
Walney Island	38.6	37 (19-70)	3.6 (1.4-9.6)	38 (22-74)	1.3 (0.6-2.6)	0.4	1.2

Table 4 Ruthenium-106 in laverbread manufactured in South Wales, 1970

Manufacturer	Concentration of ^{106}Ru, pCi/g (wet); mean and range
A	14 (0-58)
B	2.4 (0-11)
C	5.2 (0-42)

Table 5 Radioactivity in silt and gamma dose-rates over silt banks in the vicinity of Windscale, 1970

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	
Eskmeals	849 (281-2230)	1220 (961-1620)	60 (25-133)	803 (624-1010)	171 (100-300)
Walney Island	-	-	-	-	67 (50-80)
Whitehaven Harbour	326 (129-563)	512 (413-676)	52 (23-85)	308 (220-387)	81 (70-100)

Table 6 Radioactivity in plaice and lobster flesh in the Irish Sea, 1970

Species	Sampling area	Concentration of radioactivity, pCi/g (wet); mean and range			
		^{40}K	^{106}Ru	^{134}Cs	^{137}Cs
Plaice	Northern Irish Sea*	3.1 (2.2-3.5)	-	0.2 (0.1-0.3)	1.0 (0.5-1.5)
	Windscale discharge area	3.4 (3.1-3.6)	< 0.1	1.0 (0.5-1.6)	5.4 (2.6-8.0)
Lobster	Windscale discharge area	1.7	6.4	2.1	5.2

*Commercial landings at Whitehaven: samples are taken as typical of fish in the northern Irish Sea.

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

Area	Position number	Concentration of radio-activity, pCi/litre; mean and range	
		^{134}Cs	^{137}Cs
Seascale	1	81 (53-185)	376 (217-890)
North Irish Sea	2	6.0 (1.2-19)	28.5 (6.1-90)
Mid-North Channel	3	2.6 (1.1-4.5)	9.9 (3.9-21)
Firth of Clyde	4	1.4* (1.0-2.6)	4.8* (4.1-6.3)
Mull of Kintyre	5	1.4* (0.7-2.1)	3.8* (2.0-8.1)

*First half of 1970 only.

Table 8 Radioactivity in *Fucus vesiculosus* in the vicinity of Windscale, 1970

Sampling site	Concentration of radioactivity, pCi/g (wet); mean and range				
	Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{137}Cs	^{144}Ce
St. Bees	43 (28-52)	15 (6.8-19)	19 (7.1-33)	7.1 (1.9-11)	5.6 (2.8-8.1)
Seascale	88 (71-112)	37 (22-52)	31 (24-39)	10 (5.3-15)	14 (12-17)
Gutterby	57 (49-64)	18 (11-29)	17 (14-23)	6.3 (3.5-8.5)	6.1 (3.6-10)
Walney	30 (21-39)	13 (5.7-20)	8.2 (5.7-12)	4.2 (2.1-6.3)	3.8 (1.7-6.6)

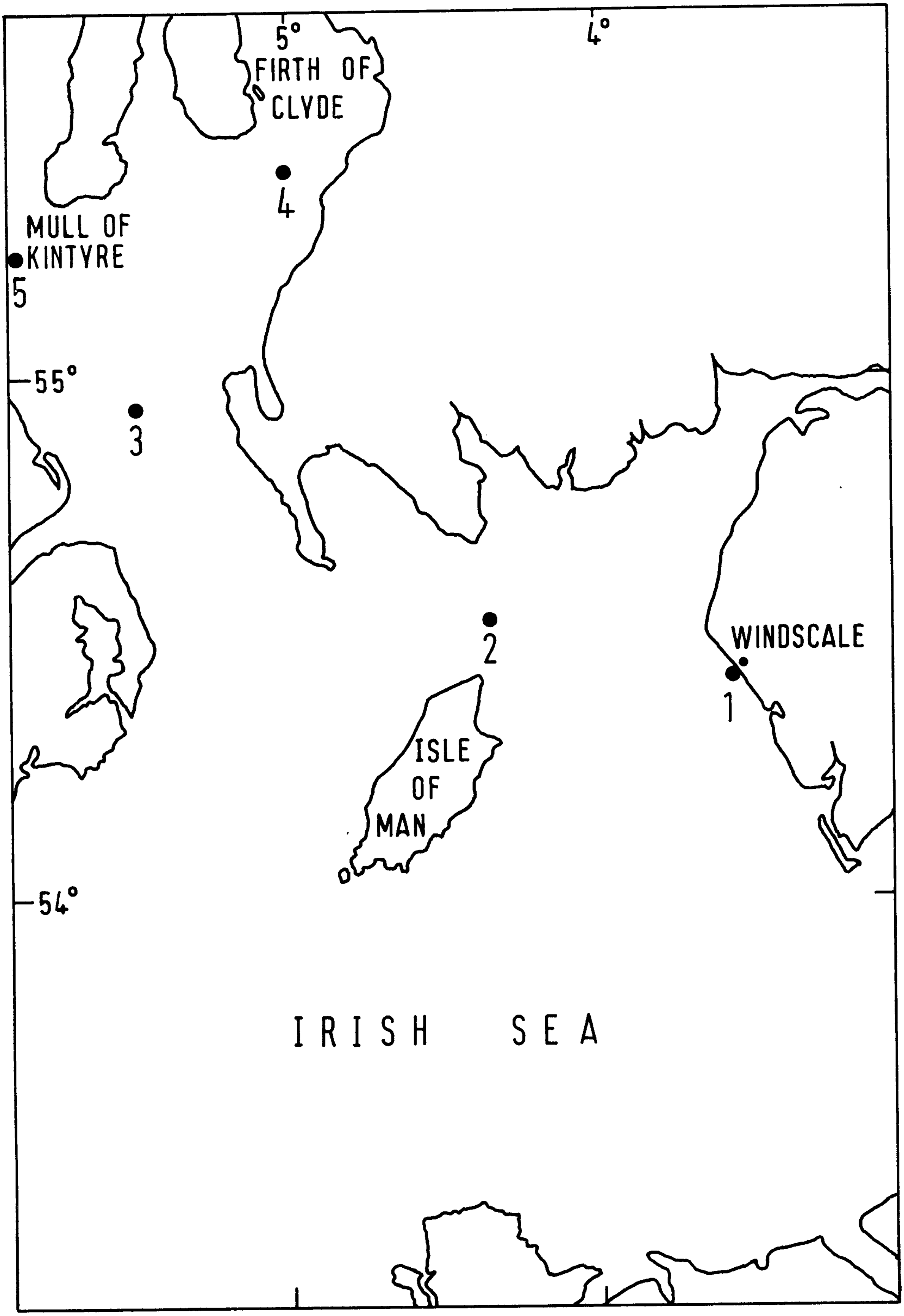

Figure 1 Positions at which sea water was sampled for caesium content (see Table 7).

Table 9 Radioactivity in seaweed and foreshore materials around the Irish Sea and western Scotland, 1970

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
Porphyra					
Labrax Bay	7.0 (6.2-8.5)	0.3 (0.1-0.5)	1.4 (0.9-2.1)	-	-
Port William	7.2 (5.1-8.9)	0.6 (0.2-1.2)	2.8 (1.9-4.5)	-	-
Garlieston	8.9 (6.6-12)	0.7 (0.3-1.0)	3.3 (0.8-6.2)	-	-
Fucus vesiculosus					
Port William	8.6 (5.6-12)	0.7 (0.4-0.9)	0.9 (0.6-1.3)	0.8 (0.2-1.3)	0.3 (0.3-0.4)
Garlieston	14 (8.7-16)	1.9 (1.1-3.2)	2.1 (1.0-3.2)	1.5 (0.5-3.0)	0.9 (0.6-1.2)
Rascarrel Bay	15 (11-25)	1.3 (0.9-1.7)	1.9 (1.6-2.5)	1.8 (0.4-3.4)	0.9 (0.4-1.3)
Heysham	23 (12-35)	3.4 (3.2-3.6)	3.8 (2.3-4.5)	3.1 (1.5-4.3)	1.4 (0.8-2.0)
Fucus serratus					
Millisle	7.3 (5.1-9.1)	0.4 (0.2-0.7)	-	0.3 (0.1-0.4)	-
Silt					
Garlieston	67 (40-125)	10 (3.7-25)	25 (7.6-63)	4.4 (2.6-5.1)	14 (4.5-33)
Sand					
Heysham	46 (32-66)	11 (1.6-18)	8.0 (3.8-14)	3.9 (2.9-5.4)	6.2 (2.5-9.0)
Fleetwood	12	-	-	1.1	-

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

2.2 Springfields, Lancashire

Disposals of liquid radioactive waste from the Springfields factory, where fuel is fabricated into elements for nuclear power stations, are made to the tidal Ribble Estuary. No significant internal exposure pathways exist and the critical pathway involves external exposure of men who work in the estuary, maintaining the river banks and servicing navigational aids. Monitoring thus consists of measurements of the gamma dose-rate on the mud banks in the vicinity of the pipeline outlet, at points where samples are taken for analysis. The results in Table 10 show that public exposure is very low, equivalent to much less than 1 per cent of the ICRP recommended dose limit. Of those contaminants of this mud which can be detected by gamma spectrometry only protactinium-234m is attributable to discharge from Springfields, the concentrations of the fission-products zirconium-95/niobium-95 and ruthenium-106 being due to Windscale.

Table 10 Radioactivity in silt and gamma dose-rate over silt banks in the Ribble Estuary, 1970

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	^{234m}Pa	
Pipeline outlet	1340 (248-2670)	16 (4.4-35)	44 (28-57)	1340 (368-3010)	16 (15-18)
Upstream*					
90 metres	545 (352-774)	18 (2.9-34)	47 (16-71)	602 (528-677)	18 (12-25)
460 metres	445 (210-721)	33 (3.0-71)	75 (18-118)	674 (379-1180)	18 (12-25)
Downstream*					
90 metres	654 (186-1060)	11 (2.2-26)	28 (16-45)	432 (212-566)	17 (12-20)

*From pipeline outlet.

2.3 Winfrith, Dorset

Discharges from Winfrith, which is principally engaged on the development of new reactor systems, including the UK steam-generating heavy water reactor and the OECD high temperature gas-cooled reactor (code name DRAGON), are involved only in internal exposure pathways due to consumption of shellfish, principally crabs and lobsters. Disposals are made in very good dispersion conditions in deep water through a pipeline which terminates 3.2 km offshore; moreover, discharges are only a small fraction of the limiting environmental capacity, so that public exposure has remained negligible.

Monitoring has reverted to a largely research basis relying on indicators - winkles and *Fucus* seaweed - which are in constant supply, rather than the critical materials which are only seasonably available. In addition, oysters are sampled from Poole Harbour.

Traces of the metallic activation products zinc-65 and cobalt-60 have been found, but no fission-products at concentrations significantly above fallout levels. Of considerable research interest is the fact that zinc-65 can be detected in oysters cultivated in Poole Harbour, 40 km from the disposal area. This suggests that this nuclide can behave conservatively in sea water where the suspended load is very low - in contrast to its behaviour in the opposite conditions as found in estuaries elsewhere such as the Blackwater. A summary of these south-coast measurements will be found in Table 11.

Table 11 Radioactivity in marine materials in the vicinity of Winfrith, 1970

Material	Sampling site	Concentration of radioactivity, pCi/g (wet); mean and range	
		^{60}Co	^{65}Zn
Winkle flesh	Chapman's Pool	0.5 (0.4-0.7)	2.0 (1.6-2.2)
Winkle flesh	Osmington Mills	0.2 (0.1-0.4)	0.7 (0.6-1.1)
Oyster flesh	Poole Harbour	-	1.8
Fucus serratus	Chapman's Pool	0.9 (0.5-1.6)	1.3 (0.8-2.2)
Fucus serratus	Osmington Mills	0.3 (0.2-0.5)	0.6 (0.2-1.1)

2.4 Chapelcross, Dumfriesshire

This site contains four Calder Hall-type magnox reactors and is effectively equivalent to a commercial nuclear power station. Low-level liquid radioactive waste is disposed of by pipeline to the Solway Estuary, where the critical pathways are external exposure from contamination of the foreshore and internal exposure from consumption of seafoods, particularly shrimps.

The monitoring programme, undertaken on behalf of Departments of the Scottish Office, consists primarily of measurement of the gamma dose-rate at selected points - salmon fishing areas and areas where silt collects - with analyses of shrimps and salmon. Silt is also examined, as are samples of *Fucus* weed, a useful indicator.

Results are shown in Table 12. It is impossible to detect a contribution from Chapelcross to contamination of the local environment, any such effect being masked by discharges from Windscale; some fission-product activity will also be present from fallout. However, whatever the source of these artificial radionuclides, one fact is not in doubt - that exposure of the public in the Solway area is very low - and no-one is exposed to more than a small fraction of 1 per cent of the ICRP recommended dose limit.

Table 12 Radioactivity in estuarine materials in the vicinity of Annan, 1970

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
F. vesiculosus					
Waterfoot	10 (7.9-15)	0.7 (0.5-1.0)	1.4 (0.8-1.9)	1.3 (0.5-2.6)	0.6 (0.5-0.8)
Seafield	12 (10-16)	0.6 (0.5-0.8)	1.1 (0.8-1.3)	1.4 (0.7-2.1)	0.8 (0.7-0.9)
Silt					
Seafield	95 (53-139)	13 (5.0-28)	47 (16-69)	9.3 (6.6-15)	21 (9.3-31)

*Except silt, pCi/g (dry).

2.5 Dounreay, Caithness

Discharges of liquid radioactive waste from Dounreay come from fuel reprocessing of oxide and metal fuel, mainly from experimental and test reactor systems. There are two important exposure pathways, both of which are external; internal exposure from consumption of fish and shellfish is of little consequence. Contamination of the foreshore occurs when activity is trapped in rocky clefts, carried ashore by suspended matter. This creates a gamma radiation dose field, whilst the other external exposure pathway is concerned with beta radiation - from handling of fishing gear used by salmon fishermen.

The laboratory's monitoring, which is done on behalf of Departments of the Scottish Office, is in close collaboration with the Authority who, for instance, conduct local surveys of gamma dose-rate on the foreshore; in addition, samples of dried spume are occasionally measured. Measurements of dose from nets, an exposure pathway which is effective only over a short season, show that, as in the case of foreshore exposure, only a very small fraction of the ICRP recommended dose limit is realized. Both these pathways are difficult to quantify precisely because of the wide fluctuations which occur in the environmental conditions that control them, and research is under way evaluating seaweed indicators as a means of monitoring the area more easily yet effectively. Selected results of analysis of seaweeds are to be found in Table 13, which also includes data on limpet and winkle flesh.

Table 13 Radioactivity in the vicinity of Dounreay, 1970

Material and sampling point	Concentration of radioactivity, pCi/g (wet); mean and range			
	Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{144}Ce
Limpet flesh				
Sandside Bay	155 (38-618)	55 (9-281)	17 (0-60)	56 (36-218)
Winkle flesh				
Sandside Bay	ND	27	4	27
Fucus vesiculosus				
Sandside Bay	85 (21-225)	85 (12-718)	7 (0-60)	36 (4-187)
Fucus serratus				
Pipeline outlet	ND	150	6	108
Oigin's Goe	ND	96	7	60
Sandside Bay East	ND	120	4	52
Borrowston	ND	43	3	11
Holborn Head	ND	6	1	6

ND = not determined.

3 NUCLEAR POWER STATIONS OPERATED BY THE CENTRAL ELECTRICITY GENERATING BOARD

3.1 The Upper Severn Estuary: Berkeley and Oldbury-upon-Severn, Gloucestershire

These power stations are situated only a few kilometres apart on the east bank of the Severn Estuary, and discharges are considered together for environmental purposes because they affect the same reach of the river. For this reason the same two exposure pathways are considered to be of critical importance, though in absolute terms exposure by either route is very small. One exposure pathway is internal, the result of consumption of local fish and shrimps, and the other external as a result of contamination of mud banks. Caesium-137 and -134 are the critical radionuclides, though to date no discharges resulting in detectable environmental contamination have been made from Oldbury and discharges from Berkeley are declining so that they now contribute little to contamination compared with fallout from testing of nuclear weapons.

Monitoring consists principally of regular surveys of the gamma dose-rate on estuarine silt banks, coupled with sampling of shrimps and fish. Seaweed is examined (for its value as an indicator) close to the point where Berkeley effluent is discharged, and the results are summarized in Table 14 along with measurements on critical materials. These data show how very low public exposure is - at most only a small fraction of 1 per cent of the ICRP recommended dose limit.

Table 14 Radioactivity in estuarine materials and gamma dose-rate over silt in the vicinity of Berkeley and Oldbury, 1970

Material	Mean concentration of radioactivity, pCi/g (wet)*		Gamma dose-rate, μR/hour; mean and range
	Total beta	^{137}Cs	
Flounder flesh	2.6	0.1	-
Salmon flesh	-	0.02	-
Shrimp (whole)	1.7	0.05	-
F. vesiculosus	5.9	0.09	-
Silt	20	1.2	6.9 (5.2-7.9)

*Except silt, pCi/g (dry).

Natural radioactivity was measured in silt: ^{40}K, 12 pCi/g; ^{238}U, 2.7 pCi/g; ^{232}Th, 0.7 pCi/g.

3.2 Bradwell, Essex

This is another power station situated on an estuary, and the environmental significance of its discharges is governed by the local oyster industry and two minor radioactive constituents of the effluent, zinc-65 and silver-110m. Consumption of oysters and the resulting internal exposure forms the critical exposure pathway and indeed the only pathway of any real consequence. This situation has been further confirmed by a repeat habits survey (the previous one was in 1965), which has also shown very little change in the maximum consumption rate for oysters.

The basic monitoring programme to confirm the radiological safety of discharges consists of analyses on samples of oyster flesh from the commercially-worked oyster bed nearest to the station. In addition, there is a small amount of monitoring of seaweed and silt, and the ambient gamma dose-rate is measured at two points where silt is sampled. It should be noted that though the gamma dose-rate measured close to the station is considerably above background this is due to direct radiation and not to contamination of silt which, as shown by gamma-spectrometric analysis, makes no significant contribution to public exposure.

Table 15 Radioactivity in oysters and non-critical materials, and gamma dose-rates over silt in the Blackwater Estuary, 1970

Material and distance from Barrier Wall (km)	Concentration of radioactivity, pCi/g (wet)*; mean and range						Gamma dose-rate, μR/hour; mean and range
	Total beta	^{60}Co	^{65}Zn	^{110m}Ag	^{134}Cs	^{137}Cs	
<u>F.</u> <u>vesiculosus</u>							
1.6 (upstream)	6.9	0.1	-	-	Present	0.6	-
Silt							
0	23	-	-	-	0.4	1.5	26
1.6 (upstream)	36	0.3	-	-	1.2	9.0	7.7
Native oysters							
0.5 (downstream)	2.5 (2.1-3.2)	-	1.0 (0.5-1.5)	1.2 (0.2-2.3)	-	0.2 (0.1-0.3)	-

*Except silt, pCi/g (dry).

Results of monitoring are shown in Table 15. Public radiation exposure via the oyster-consumption critical pathway was very low in 1970 and no-one was subjected to more than 0.16 per cent of the ICRP recommended dose limit to any organ of the body. Although this is similar to the situation prevailing in earlier years, one interesting change did occur in 1970. Whilst concentrations of zinc-65 have fallen as a result of a decline in discharges of this radionuclide, discharges of silver-110m have increased and with them concentrations of this nuclide in oysters. Zinc-65 was of higher radiological significance than silver-110m at the beginning of 1970, but this order had been reversed by the middle of the year and silver-110m was the more important for the year taken as a whole. Following this change the identity of the critical organ has also changed, for silver-110m is more radiotoxic to the GI tract than total body, whereas the reverse is true for zinc-65.

This situation is illustrated in Table 16 which lists contributions to radiation exposure of these organs from the various known contaminants. It should be noted that not all these radionuclides were measured in 1970; concentrations of some minor radionuclides such as iron-55 and cobalt-60 were predicted from data on the composition of the effluent and correlations established by research in previous years.

Table 16 Radiation exposure of individual members of the general public eating oysters from the nearest commercial bed to Bradwell power station at a rate of 75 g/day, 1970

Nuclide	Percentage of the ICRP recommended dose limit	
	Gastro-intestinal tract	Total body
^{55}Fe	< 0.001	< 0.001
^{60}Co	0.002	0.001
^{65}Zn	0.018	0.036
^{110m}Ag	0.136	< 0.001
^{134}Cs	< 0.001	0.022
^{137}Cs	< 0.001	0.034
Total	0.159	0.095

3.3 Dungeness, Kent

Two exposure pathways for discharges from Dungeness power station are taken to be important, though in neither case has contamination reached detectable levels; hence their radiological significance remains negligible. The two pathways involve consumption of locally-caught fish and shellfish, as a source of internal exposure, and occupation of the foreshore, as a source of external exposure. The scale of the monitoring programme is small and reflects the very low radiological significance of discharges. Samples of plaice, shrimps and sand are analysed and the gamma dose-rate is measured in the area from which sand is sampled. Results will be found in Table 17.

Table 17 Radioactivity in marine materials and gamma dose-rate over beaches in the vicinity of Dungeness, 1970

Material	Concentration of radioactivity, pCi/g (wet)*; mean and range		Gamma dose-rate, μR/hour; mean and range
	Total beta	^{137}Cs	
Plaice flesh	3.4 (3.0-4.0)	0.03 (0.02-0.05)	-
Shrimps	1.7	0.05	-
Sand	24	-	-
Sand and shingle	-	-	4.6 (4.1-5.6)

*Except sand, pCi/g (dry).

3.4 Hinkley Point, Somerset

Discharges from Hinkley Point power station affect two important exposure pathways, as verified by the appearance of contamination in 1969. This situation has continued into 1970 though the radiological significance has remained low. The pathways are of near-equal importance and result in internal exposure from consumption of local shrimps and fish and external exposure from gamma-emitting radionuclides adsorbed by silt on the foreshore. These and other possible exposure pathways were re-examined during the year by means of a habits survey which confirmed the identity of the two critical pathways. It also revealed that Porphyra seaweed from beaches near the power station is consumed after manufacture into a product similar to the Welsh laverbread. The radiological importance however was found to be negligible, partly because consumption rate is low but also because contamination was hardly measurable. Operation of nuclear power stations produces only very small quantities of ruthenium-106 requiring local disposal.

The basic monitoring programme consists of regular sampling of shrimps and fish, and the gamma dose-rate is measured in selected areas of the foreshore where silt samples were also taken for analysis. Both caesium-137 and -134 were detected in all these materials in 1970 though only at low level, and none of the exposed population group, the most important of whom are local fishermen, have been subject to more than a fraction of 1 per cent of the ICRP recommended dose limit. Though contamination was measurable in critical materials, Fucus seaweed has been retained in the sampling programme for its value as an indicator; results will be found, together with those on critical materials, in Table 18, which also includes one analysis on Porphyra seaweed made to evaluate the radiological significance of its local use.

Table 18 Radioactivity in marine materials and gamma dose-rate over silt in the vicinity of Hinkley Point, 1970

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	
Shrimp flesh	3 (east)†	2.4 (2.3-2.6)	0.2 (0.1-0.3)	-
Whiting flesh	3 (east)†	2.3	0.09	-
Cod flesh	3 (east)†	3.9	0.4	-
Silt	0	38 (20-54)	7.0 (2.8-11)	8.8 (7.3-12)
F. vesiculosus	1.6 (east)	8.1 (5.6-9.5)	0.8 (0.3-1.5)	-
	0.8 (east)	8.4 (6.7-10)	0.7 (0.3-13)	-
	0	12 (8.7-14)	2.7 (1.9-3.5)	-
	0.8 (west)	8.5 (6.0-10)	1.1 (0.3-2.5)	-
Porphyra	3 (east)‡	3.4	-	-

*Except silt, pCi/g (dry); † Bridgwater Bay; ‡ Stolford.

3.5 Sizewell, Suffolk

Two exposure pathways are considered to be important for discharges from this site, but, because the dispersion capacity of the environment is large, contamination has not reached detectable levels. One pathway, involving internal exposure, is the result of consumption of fish and shellfish and the other, concerned with external exposure, depends on use of the foreshore.

Only a small environmental monitoring programme is needed; in 1970, surveillance of internal exposure was maintained by analysis of fish and shellfish, whilst the gamma dose-rate on the beach was measured to check on external exposure. No indicator material was measured because of the lack of a suitable species on what is a rather barren shingle beach. Results of measurements will be found in Table 19.

Table 19 Radioactivity in fish and shellfish and gamma dose-rate over sand in the vicinity of Sizewell, 1970

Material	Mean concentration of radioactivity, pCi/g (wet)		Gamma dose-rate, μR/hour; mean and range
	Total beta	^{137}Cs	
Cod and whiting flesh	3.7	0.07	-
Plaice and sole flesh	3.1	0.04	-
Crab flesh	2.1	-	-
Lobster flesh	1.0	0.01	-
Sand	-	-	3.3 (3.0-3.8)

3.6 Trawsfynydd, Merioneth

Discharges from this power station have a significant effect only through one pathway, involving internal exposure from consumption of fish from the lake, to which discharges are made via the station cooling water stream. The basic monitoring programme is thus quite simple and requires only sampling of the species of fish concerned, trout and perch. Three radionuclides (caesium-134, -137 and strontium-90) have been found in these fish, though it should be noted that some of the caesium-137 and a substantial fraction of the strontium is due to fallout. The results shown in Table 20, with data on research and indicator materials, have been used to re-evaluate the radiological significance of the three radionuclides. An interesting situation was revealed, with exposure of bone and total body becoming of near-equal importance due to discharges of strontium-90; this is the critical nuclide in relation to bone exposure, but most of the exposure of total body (slightly higher than that of bone) is due to caesium-137 and -134. However, the all-important fact to those concerned with control is that in absolute terms the radiological significance has been kept down to a very low and thus readily acceptable level, none of the exposed population being subjected to more than 3 per cent of the ICRP recommended dose limit for any organ of the body (Table 21).

Table 20 Radioactivity in materials in Lake Trawsfynydd and local streams and in the Glaslyn Estuary, 1970

Material	Sampling site	Concentration of radioactivity, pCi/g (wet)*; mean and range							
		Total beta	^{54}Mn	^{60}Co	^{90}Sr	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce
Water	Cold lagoon	-	-	-	-	-	0.9 (0.4-1.2)	3.5 (1.6-6.1)	-
	Hot lagoon	-	-	-	5.4 (2.4-7.5)	-	1.0 (0.4-1.6)	4.0 (1.9-6.4)	-
Trout flesh	Lake	11 (6.5-20)	-	-	0.12 (0.10-0.13)	-	0.7 (0.1-1.8)	8.3 (3.5-16)	-
Perch flesh	Lake	13 (11-14)	-	-	-	-	1.3 (1.0-1.5)	11 (8.8-12)	-
Mud	Lake	38 (27-59)	-	-	-	-	0.4 (0.1-1.0)	15 (8.9-28)	-
Peat	Lake	24 (16-30)	-	-	-	-	0.5 (0.2-0.8)	8.4 (2.7-12)	-
<u>Fontinalis</u>	Afon Prysor	14 (9.5-23)	-	-	-	4.0 (3.4-5.5)	-	0.5 (0.2-1.1)	4.2 (2.9-5.1)
	Gwylan Stream	23 (20-25)	1.0 (0.8-1.3)	1.0 (0.6-1.3)	-	†	-	1.5 (1.0-2.0)	4.9 (3.8-6.8)
Mussel flesh	Portmadoc	1.2	-	-	-	-	-	-	-

*Except mud and peat, pCi/g (dry), and water, pCi/litre.
†^{106}Ru and ^{125}Sb also present but not separable by current analysis.

Table 21 Radiation exposure of individual members of the general public eating trout flesh from Trawsfynydd Lake at a rate of 100 g/day, 1970

Nuclide	Percentage of the ICRP recommended dose limit		
	Bone	GI tract*	Total body
^{90}Sr	1.37	0.01	0.78
^{134}Cs	0.03	0.01	0.30
^{137}Cs	0.76	0.05	1.88
Total	2.16	0.07	2.96

*Gastro-intestinal tract.

In a sensitive environment, where relatively small discharges of some radionuclides can have a significant effect, considerable effort is needed on research so that predictions can be made of impending changes in the radiological situation which might call for modifications to waste control arrangements. With the co-operation of the Board, lake water, mud and peat from the lake bed and a moss, Fontinalis, are regularly sampled. Water is in a sense an indicator sensitive enough to allow predictions of subsequent changes in concentrations of the critical nuclides in fish. Fontinalis is a much more sensitive indicator and shows a greater number of contaminants some of which, ruthenium-106 and cerium-144, together with part of the caesium-137, are due not to power station discharges but to fallout. Some further radionuclides have been detected which are not yet radiologically significant, including antimony-124 and -125 and cobalt-60.

The only important consequences of discharges from Trawsfynydd power station are to be found in the lake. This is shown by the lack of contamination in mussel samples at Portmadoc, in the estuary to which the lake water ultimately flows. These data, combined with those for the critical and other materials from the lake, have been collected together in Table 20.

3.7 Wylfa, Anglesey

Some very small discharges of radioactivity were made in 1970 but for most of the year the power station was in a pre-operational stage. Two exposure pathways are considered: internal exposure from consumption of fish and shellfish, and external exposure from occupation of the local foreshore. The basic environmental monitoring programme consists of sampling of silt and locally-caught fish and shellfish, and measurements of the gamma dose-rate on the foreshore. This will be sufficient to verify the radiological status of contamination and to establish that controls set on discharges are adequate, though in addition a small amount of indicator monitoring is done on Porphyra and Fucus seaweed. The results

Table 22 Radioactivity in marine materials and gamma dose-rate over silt in the vicinity of Wylfa, 1970

Location	Material	Concentration of radioactivity, pCi/g (wet)*; mean and range					Mean gamma dose-rate, µR/hour
		Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{137}Cs	^{144}Ce	
Cemlyn Bay	Porphyra	4.8	-	-	-	-	-
	F. vesiculosus	9.0 (7.1-10)	0.3 (0.2-0.6)	-	0.3 (0.2-0.3)	-	-
	Lobster flesh	2.3	-	-	0.1	-	-
	Crab flesh	3.2	-	1.6	0.2	-	-
	Pollack flesh	3.4	-	-	0.3	-	-
	Silt	25	2.2	5.0	2.5	4.7	10
Cemaes Bay	Porphyra	4.8	-	-	-	-	-
	F. vesiculosus	8.6 (6.8-11)	0.3 (0.2-0.5)	0.5 (0.1-0.7)	0.3 (0.2-0.3)	0.3 (0.2-0.3)	-
	Lobster flesh	3.6	-	-	0.2	-	-
	Pollack flesh	4.1	-	-	0.4	-	-
	Winkles	3.1 (2.7-3.9)	-	0.3	0.1	0.2	-

*Except silt, pCi/g (dry).

(summarized in Table 22) show that small amounts of artificial radioactivity can be detected, principally from fallout, though some part of the caesium-137, for instance, can be attributed to Windscale discharges.

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

4.1 Hunterston, Ayrshire

Monitoring by the laboratory is undertaken on behalf of Departments of the Scottish Office. The critical exposure pathways concern internal exposure from consumption of local fish and external exposure by contamination of the shore, though for neither of them is public exposure of any real significance, being at most only a small fraction of 1 per cent of the ICRP recommended dose limit.

The sampling programme is a combination of critical and indicator materials - fish and sand covering the former, seaweeds the latter. The gamma dose-rate is also measured in the areas where sand samples are collected. Fish has been sampled from the White Fish Authority's fish-farming project on a site adjoining the power station, and samples of sea water, the results of analyses of which are quoted in Table 23 with those of other monitoring efforts, have been collected for research purposes in conjunction with it.

Table 23 Radioactivity in materials in the vicinity of Hunterston, 1970

Material	Concentration of radioactivity, pCi/g (wet)*; mean and range				
	Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{137}Cs	^{144}Ce
Sea water	-	-	-	12 (5.6-22)	-
F. spiralis	7.3 (6.7-8.1)	0.6 (0.5-0.8)	0.9 (0.7-1.1)	0.8 (0.6-1.0)	0.8 (0.4-1.8)
F. vesiculosus	9.5	1.1	1.3	1.3	1.2
Porphyra	6.3	0.7	1.8	0.3	0.3
Plaice flesh	3.8	-	-	0.5	-
Sand	11 (11-13)	-	-	0.4 (0.2-0.7)	-

*Except sand, pCi/g (dry).

Of the several fission-products which have been detected in the Hunterston environment, only caesium-137 and -134 are connected with Hunterston and only a fraction of these radionuclides is attributable to discharges from the power station. Contamination of seaweeds by traces of fission-products, such as zirconium-95/niobium-95, ruthenium-106 and cerium-144, is largely due to fallout though some may be due to Windscale discharges.

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

Discharges from each of the three sites whose effect on the environment is monitored by the laboratory have one factor in common, i.e. that only external exposure is important, though the nature of the pathways is different for each site.

5.1 HM Dockyard, Chatham, Kent

Various members of the public could be subject to external exposure from disposals from this site, but the most important are considered to be houseboat dwellers living on the water's edge. Consequently the monitoring programme consisted of surveys of the river bank to measure gamma dose-rate over the mud, samples of which were taken for analysis. The gamma dose-rate remained indistinguishable from background, demonstrating that public radiation exposure was negligible, but low-level contamination of the mud by cobalt-60 due to discharges from the Dockyard was measured in mud for the first time since discharges began. A summary of results is shown in Table 24.

Table 24 Radioactivity in materials and gamma dose-rate at sites operated by the Ministry of Defence (Navy Department)

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	0.4 (0.2-0.7)	1.2 (0.8-1.4)	5.9 (4.4-6.7)
Faslane			
Sea bed	1.0 (0.3-2.0)	2.0 (0.7-3.1)	-
Foreshore silt	-	-	10 (10-11)
Rosyth			
Dockyard approaches silt	1.5 (0.1-11)	0.6 (0.2-0.9)	-
Shoreline	-	-	9 (8-10)

5.2 HMS NEPTUNE, Faslane, Dunbartonshire

The critical pathway involves the general public and their use of the foreshore; hence monitoring consists of gamma surveys of the dose-rate around the shore of the Gareloch to which disposals are made, in conjunction with sampling and analysis of silt. Only samples from the shoreline have any direct significance, but surveys of the loch bed have also been conducted so as to keep in touch with possible trends in an area which being small and land-locked has only a low capacity for receiving waste. Some artificial contamination - principally cobalt-60 - has been found and values are quoted in Table 24, but relatively little is of local origin; the total significance is very small, and gamma dose-rates which are not distinguishable from natural background show that public exposure is negligible.

5.3 HM Dockyard, Rosyth, Fife

The critical group for discharges from this site is unusual, being composed of dredgermen who keep the dockyard approaches clear of silt and open to navigation. The monitoring programme consists of sampling of this material by grab from the bed of the Firth of Forth at selected points in the vicinity of the Dockyard. Traces of cobalt-60 were found (Table 24) but their radiological significance was very low. Checks were made on the gamma dose-rate on the shoreline at the nearest point to the Dockyard where the public has access, but results are not distinguishable from natural background.

6 THE CHANNEL ISLANDS

The laboratory's monitoring of the shores of the Channel Islands is done on behalf of the Channel Islands Governments with the express purpose of checking their radiological safety in relation to the effect of discharges from the fuel reprocessing plant at La Hague on the mainland of France. Seaweeds, which are normally the most sensitive means of detection of any fission-product activity, are sampled as indicators, and in addition small quantities of fish and shellfish are examined, since these are the materials which would be involved in exposure pathways if any significant contamination of these shores were to appear. None of the samples taken in 1970 showed any detectable activity attributable to La Hague discharges - results are shown in Table 25 - but a single sample of sea water taken off Alderney in the middle of the year contained more activity than normally present from fallout, which suggests the presence of French discharges. However, this was so small that, considering also the absence of contamination in biological material, its radiological significance is negligible.

Table 25 Radioactivity in materials on the coasts of the Channel Islands, 1970

Material	Sampling area		Concentration of radioactivity, pCi/g (wet); mean and range	
			Total beta	^{137}Cs
Porphyra	Guernsey	Fort Doyle	5.6 (3.8-9.2)	-
		Fermain Bay	4.5 (3.8-5.4)	-
	Alderney	Corblets Bay	8.1	-
	Jersey	Greve de Lecq	5.3 (2.6-8.0)	-
		La Rozel	4.9 (3.4-8.3)	-
Ormer flesh	Guernsey		2.2	-
Skate flesh	Guernsey		2.1	0.07

7 THE IRISH REPUBLIC

The laboratory has continued its co-operation with the Department of Health of the Irish Republic, analysing samples provided by them from their shores. The sampling programme in 1970 consisted almost entirely of seaweeds which, though of no direct significance, are a more sensitive means of indicating possible levels of contamination than are marine foodstuffs. In fact, though traces of fission-products were found in some of the samples, concentrations were so low as to be indistinguishable from fallout and concentrations of total beta radioactivity were within the range for naturally-occurring radionuclides. Results are shown in Table 26.

8 SURVEYS OF BACKGROUND AND FALLOUT RADIOACTIVITY

A few materials, mainly of local (Lowestoft) origin, are kept in the sampling programme for purposes of establishing background reference levels in areas remote from nuclear establishments; they are thus free from artificial radioactivity other than fallout. Two species of seaweed (*Porphyra* and *Fucus vesiculosus*) and sand were sampled from Lowestoft; results are quoted in Table 27, which also includes data for *Porphyra* from Dunbar. This latter source has often shown evidence of fallout in the past, and ruthenium-106 was again detected in 1970.

Table 26 Radioactivity in seaweeds and sand on the Irish Republic coastline, 1970

Material	Sampling point	Concentration of radioactivity, pCi/g (wet)*; mean and range		
		Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru
Porphyra	Skerries	5.4 (3.8-8.4)	0.2 (0.1-0.2)	0.5 (0.2-0.7)
	Colliemore	7.4	-	-
	St. Helens	5.7 (4.2-7.2)	0.3 (0.2-0.4)	-
	Dunsmore East	5.2 (3.3-7.4)	-	-
F. serratus	Dunsmore East	6.1	-	-
	Colliemore	7.8 (7.0-8.5)	0.3 (0.2-0.5)	-
F. vesiculosus	Carlingford Lough	8.8 (7.9-9.8)	0.6 (0.5-0.8)	-
	St. Helens	6.4 (5.7-7.0)	0.2 (0.1-0.3)	0.4 (0.3-0.5)
Laminaria digitata	Skerries	9.2 (6.8-12)	-	-
	Colliemore	11	-	-
	St. Helens	6.6 (4.0-9.7)	-	-
	Dunsmore East	7.8 (4.9-11)	-	-
Sand	St. Helens	8.1	-	-

*Except sand, pCi/g (dry).

Table 27 Radioactivity in background reference materials, 1970

Material	Sampling area	Concentration of radioactivity, pCi/g (wet)*; mean and range	
		Total beta	^{106}Ru
Porphyra	Lowestoft	2.6	-
	Dunbar	5.5 (3.6-7.9)	0.4 (0.3-0.6)
F. vesiculosus	Lowestoft	4.7	-
Sand	Lowestoft	5.1	-

*Except sand, pCi/g (dry).

A limited sampling programme of commercial fish landings has continued, taking several species from North Sea and Icelandic fishing grounds. Caesium-137 was detected in most of the samples but at a very low level similar to that found in previous years. Contamination was thus of negligible radiological significance (Table 28), even for the highest conceivable rates of consumption such as are found among trawl fishermen.

Table 28 Radioactivity in commercial fish landings in UK ports, 1970

Species	Fishing area	Concentration of radioactivity, pCi/g (wet); mean and range	
		Total beta	^{137}Cs
Cod flesh	Southern North Sea (IV C)	3.0 (2.8-3.2)	0.08 (0.06-0.1)
	Iceland (V A)	3.0 (2.9-3.1)	0.03
Plaice flesh	Southern North Sea (IV C)	2.7 (2.3-3.1)	0.04 (0.03-0.06)
	Iceland (V A)	2.4 (1.7-3.0)	0.03
Lemon sole flesh	Iceland (V A)	2.5	-
Herring flesh	Southern North Sea (IV C)	-	0.05

9 DISCUSSION

The crucial test of a waste disposal policy is the extent to which the public is exposed to radiation, the risk to environmental resources such as fish populations having proved, for all UK disposals, to be of minor importance compared with the public health considerations if the latter are limited in terms of ICRP recommendations. Throughout this report comments have been made as to the radiological significance of disposals in terms of exposure of individual members of the public, and values have been quoted in appropriate sections of the text for Windscale and some of the more radiologically significant disposals elsewhere. A summary of these data will be found in Table 29, to which have been added estimates of population gonad dose as an index of genetically significant exposure.

In almost every case somatic exposure (i.e. to individuals) is much more important, judged as a fraction of ICRP-recommended dose limits, than genetic exposure (i.e. to populations), the notable exception being the effect of discharges from UKAEA establishments to the Thames, for which the scale of exposure in these two categories is more nearly similar. It is much more difficult to estimate total genetic exposure from controlled disposals than the somatic exposure of individuals, and the values quoted for the former are certainly considerable overestimates. In the case of internal exposure the estimates have been made on the basis of measured contamination of foodstuffs such as fish, shellfish or seaweed, or by applying detectable limits where no contamination could be found, together with estimates of the total quantity of foodstuff consumed; for external exposure a different technique has been adopted, an estimate being necessary of the number of people involved and the extent of, for example, their occupancy of a contaminated beach. It should be noted that each of the estimates of genetically significant exposure refers to the whole of that population which could be subject to an effect of the disposal concerned, and not merely to the critically exposed population group on whom habits surveys are centred. Special mention must be made of the estimate made for discharges from UKAEA establishments to the Thames, because two factors contribute to imprecision in the value quoted. The presence of fallout radioactivity in the water supply means that direct measurements cannot be used, although these serve to indicate the total gonad dose from all sources, and recourse has been made to an assumption of the fraction of the activity discharged which is drunk. The dose from tritium can, apart from this reservation, be calculated with reasonable accuracy and amounted to not more than 100 man-rem in 1970. Strontium-90 is the only other radionuclide making any comparable contribution, but the extent is difficult to estimate at all accurately. However, it is clear that the total gonad dose commitment could not exceed about 10 times the contribution due to tritium, so that it is of very little radiological significance - this figure being equal to 0.06 per cent of the limit set as an objective of UK policy for the population of the country as a whole.

Contributions to population gonad dose from most other discharges are even smaller and often less than 1 man-rem per disposal. Both of the critical pathways to individual exposure on which Windscale sea discharges are limited are in this category, and the largest contribution to genetic exposure as a result of these discharges is due to the caesium/fish consumption pathway, which, at about 150 man-rem in 1970, was second only to that involving London drinking water. Dounreay, though the source of the second largest disposal of liquid radioactive waste in the UK, contributes very little to population gonad dose, and again both of the critical pathways which produce the highest individual exposure are less important genetically than fish consumption, though it should be emphasized that none was of any real importance in absolute terms.

Contributions to population gonad dose from power stations are invariably very small, reflecting the smaller numbers of people involved and the very low, often unmeasurable, degrees of contamination. The largest contribution comes from Trawsfynydd discharges, yet this is no more than 0.5 man-rem. Where estimates are necessary these are deliberately made from a pessimistic standpoint and in many instances values can only be expressed on a "less than" basis, especially when contamination is below detectable limits. In some cases, for instance Bradwell, a relatively high precision can be reported, in this case of the order of milli man-rems because only small amounts of a foodstuff (oysters) are involved.

10 CONCLUSIONS

Stringent standards are set to limit disposals of radioactive waste in the United Kingdom, 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 the objectives of UK waste disposal policy. Data presented in this report show that this high standard continues to be maintained 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.

Table 29 Estimates of public radiation exposure from liquid radioactive waste disposals in the United Kingdom, 1970

Site	Pathway	Maximum exposure* of an individual (% of ICRP recommended dose limit)	Approximate total population gonad dose*, man-rem
<u>United Kingdom Atomic Energy Authority</u>			
Harwell, Aldermaston, Amersham	Drinking water	$<$ 1	$\ngtr$ 1 000
Windscale	*Porphyra*/laverbread	5 (to critical group)	0.3
	External dose	12	0.5
	Fish	1 (to critical group)	150
Springfields	External dose	$<$ 1	$<$ 0.1
Winfrith	Shellfish	$<$ 1	$<$ 0.1
Chapelcross	External dose	$\ll$ 1	$<$ 0.01
	Shellfish	$\ll$ 1	$<$ 0.1
Dounreay	External dose (foreshore)	$<$ 1	$<$ 0.5
	Beta dose (fishermen)	0.4	$<$ 0.01
	Shellfish	$\ll$ 1	$<$ 1
<u>Central Electricity Generating Board</u>			
Berkeley/Oldbury	External dose	$<$ 0.3	$<$ 0.1
	Fish/shellfish	$<$ 0.1	$<$ 0.1
Bradwell	Oyster	0.1	0.002
Dungeness	External dose	$\ll$ 0.1	$<$ 0.1
	Fish	$\ll$ 0.1	$<$ 0.1
Hinkley Point	External dose	0.1	$<$ 0.1
	Fish/shellfish	0.2	$<$ 1
Sizewell	External dose	$\ll$ 0.1	$<$ 0.1
	Fish/shellfish	$\ll$ 0.1	$<$ 0.1
Trawsfynydd	Lake fish	3	$<$ 0.5
<u>South of Scotland Electricity Board</u>			
Hunterston	External dose	$<$ 0.1	$<$ 0.1
	Fish/shellfish	$<$ 0.1	$<$ 0.1
<u>Ministry of Defence (Navy Department</u>			
Chatham	External dose	$<$ 0.1	$<$ 0.1
Faslane	External dose	$<$ 0.1	$<$ 0.1
Rosyth	External dose	$<$ 0.1	$<$ 0.1

*Assessed as from discharges from the site named only.

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