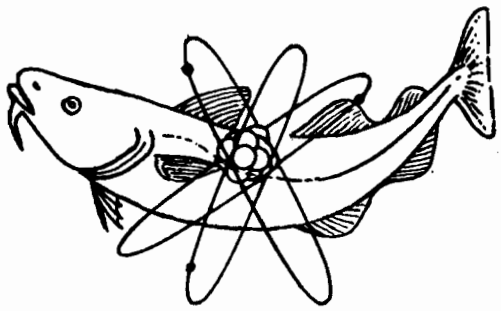
MINISTRY OF AGRICULTURE, FISHERIES AND FOOD

FISHERIES RADIOBIOLOGICAL LABORATORY



RADIOACTIVITY IN SURFACE AND COASTAL WATERS OF THE BRITISH ISLES 1969

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This report, the fourth in an annual series begun in 1967, describes the work done by the Fisheries Radiobiological Laboratory to ensure the safe disposal of radioactive waste to surface waters and the sea. The data for 1969, presented here, result from the now well-established routine monitoring at all the major UK nuclear sites, and also include for the first time work done on behalf of the Irish Republic. These results show that, with the cooperation of the site operators, public interests continue to be the overriding consideration, and that there has been no departure from the high degree of safety achieved in previous years.

H. A. Cole
Director of Fishery Research

CONTENTS

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

Site	Critical material	Critical exposure category	Exposed group
a United Kingdom Atomic Energy Authority			
Windscale	Porphyra (laverbread)	Beta dose to G.I. tract*	General public (south Wales)
Winfrith	Lobster and crab flesh	Beta dose to G.I. tract	Local fishermen and families
Springfields	Silt	Gamma dose to whole body	Dredgermen
Aldermaston	Drinking water	Beta-gamma dose to gonads (genetic hazard)	General public (Greater London)
Harwell	Drinking water	Beta-gamma dose to gonads (genetic hazard)	General public (Greater London)
Amersham	Drinking water	Beta-gamma dose to gonads (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 Seashore	Beta-gamma dose to whole body Gamma dose to whole body	Local fishermen and families Salmon fishermen
b 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	Gamma dose to whole body	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
Trawsfynydd	Trout flesh	Beta-gamma dose to whole body	Local fishermen and families
Dungeness	Fish flesh Silt	Beta dose to G.I. tract 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
Wylfa	Silt Fish and shellfish flesh	Gamma dose to whole body Beta dose to G.I. tract	Local fishermen Local fishermen and families
Hunterston	Fish flesh Seashore	Beta-gamma dose to whole body Gamma dose to whole body	Local fishermen and families Winkle collectors
c 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

*G. I. tract, gastro-intestinal tract.

RADIOACTIVITY IN SURFACE AND COASTAL WATERS OF THE BRITISH ISLES, 1969

1 INTRODUCTION

This is the fourth in an annual series of reports presenting the work of monitoring the aquatic environment by the Fisheries Radiobiological Laboratory and describes surveys made during 1969. Most of the laboratory's effort in this field is directed to fulfilling the Ministry's own 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 now, beginning in 1969, 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 undertaken by each of the operators. Monitoring of the environment provides information to confirm that adequate control of radioactive waste disposal has been achieved, and data in this report show that as in previous years this satisfactory state of affairs has been maintained.

The year 1969 saw no major changes in monitoring operations in that no new sites became operational and none of those under construction reached a stage where monitoring was needed in a pre-operational phase. A number of potential power station sites are however under consideration which, if adopted, will become firm commitments on the laboratory's monitoring programme in due course, and assessments to determine their suitability in respect of low-level radioactive waste disposal have been undertaken. Plans have also been announced to install nuclear facilities at Devonport Dockyard and a radiological assessment has been started of the capacity of the Hamoaze to accept radioactive waste. The complexity of problems associated with the safe disposal of radioactive waste continues to grow as the nuclear power programme expands, and thus demands on the laboratory continue to increase over a wide front of radiological evaluation and assessment. In consequence minor changes have been necessary in many of the monitoring programmes, to keep them up to date and adequate to meet current needs. Habits surveys have been up-dated in respect of discharges from Sizewell nuclear power station and the UKAEA establishment at Chapelcross, and further studies have been made of laverbread consumption, which constitutes the critical pathway for Windscale sea discharges.

Although major changes in exposure pathways, such as the appearance of an entirely new route, occur only rarely, certain factors in existing pathways are liable to change more frequently, underlining the need to repeat habits surveys at regular intervals. Many of the changes in these factors are brought about by changes in effluent composition, and analysis is needed, in conjunction with parallel work on environmental materials, to identify them. A summary of exposure factors involved in the disposal of aqueous radioactive waste from the major sites with which the laboratory is concerned was published in the first of these reports. As this information is now partially out-of-date, and also incomplete because of new sites brought into operation, a revised statement has been included (Table 1).

The extent of wastes varies widely from site to site, as does the magnitude of authorizations granted for their disposal. Authorizations are always set so that they are no higher than the capacity of the particular environment to disperse safely; they are frequently much lower, since a further important condition is that an operator is only permitted to dispose of that amount of radioactivity as waste for which there is a demonstrable need. The magnitude of discharges in 1969 for the major disposals referred to in Table 1 is summarized in Table 2.

Table 2 Major discharges of liquid radioactive wastes to surface and coastal waters during 1969

Site	Radioactivity	Authorized discharge, curies/year	Percentage utilized
Windscale	Total beta	300 000	33
	Ruthenium-106	60 000	38
	Strontium-90	30 000	8
	Total alpha	1 800	74
Winfrith	Total activity	30 000	7
	Ruthenium-106	9 000	< 1
	Strontium-90	1 200	< 1
	Total alpha	1 200	< 1
Springfields	Total alpha	360	4
	Total beta	12 000	8
Aldermaston	Total activity	156*	40
Harwell	Total activity	240*	39
Amersham	Total activity†	72*	35
	Tritium	400	81
Chapelcross	Total activity†	700	3
	Tritium	150	10
Dounreay	Total alpha	240	10
	Total beta	24 000	91
	Strontium-90	2 400	43

Table 2 continued

Site	Radioactivity	Authorized discharge, curies/year	Percentage utilized
Berkeley	Total activity†	200	28
	Tritium	1 500	4
Bradwell	Total activity†	200	57
	Zinc-65	5	2
	Tritium	1 500	12
Dungeness	Total activity†	200	90
	Tritium	2 000	4
Hinkley Point	Total activity†	200	97
	Tritium	2 000	2
Oldbury	Total activity†	100	2
	Tritium	2 000	< 1
Sizewell	Total activity†	200	5
	Tritium	3 000	< 1
Trawsfynydd	Total activity†	40	27
	Tritium	2 000	12
Wylfa	Total activity†	65	Nil
	Tritium	4 000	Nil
Hunterston	Total activity†	200	48
	Tritium	1 200	20
Chatham	Total activity†	20	< 1
	Cobalt-60	10	< 1
	Tritium	20	6
Faslane	Total activity†	1	Nil
Rosyth	Total activity†	30	1

*'Equivalent curie' - see text; † Excluding tritium.

It should be noted that 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 in Table 2.

In addition to the basic task of radiological monitoring, which is to determine the extent of public radiation exposure, research continues to be an important part of the work of the laboratory and data are included in this report from some of the environmental programmes. The Irish Sea is one of the most fruitful areas in this respect, producing valuable data which are also applicable to radiological evaluation of other sites, especially at pre-operational stages. Other environments where contamination is measurable are being investigated on a research basis, including those of a number of power stations. Although the level of contamination is much lower than that from Windscale discharges the results can still be put to good use, particularly since these effluents involve some radionuclides not encountered at Windscale.

2 SITES OPERATED BY THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY

2.1 Windscale and Calder, Cumberland

The critical pathway for discharges from this site is the well-known sequence of contamination of Porphyra seaweed manufactured into the foodstuff laverbread, and the most important part of the monitoring programme consists of sampling the seaweed. This is collected from a network of sampling points along the Cumberland coast where the seaweed is harvested. In addition the laverbread itself is sampled from the production of the three main manufacturers: this gives a more accurate estimate of the actual radiation dose to members of the critical group than can be achieved from information on rates of harvesting, because most of the seaweed supplies come from outside the contaminated area. However, because the situation is subject to change, control of radioactive waste is based on the possibility that laverbread made solely from Cumberland weed could be put on the market. Data for 1969, combined with information on consumption rates and the manufacturing process, confirm that, even on this no-dilution basis, control was adequate - that the critical group would have been subject to considerably less exposure than the ICRP-recommended dose limit and that their exposure would not have exceeded this dose limit even if discharges had been made up to the permitted maximum. In practice the actual dose was even lower (by a factor of about 5) because considerable dilution did occur in the manufacturing process.

Concentrations of the principal contaminants of the seaweed are summarized in Table 3. The fission-product radionuclides ruthenium-106, cerium-144 and zirconium-95/niobium-95 are the most important and their radiological significance decreases in that order. Specific analysis has also been undertaken on bulked samples for the alpha radionuclides plutonium-239/240 and americium-141, replacing the previous system of assessing alpha contamination by a 'total alpha' analytical method. This change has been brought about to permit a close watch on the effect of the slowly increasing discharges of these radionuclides. These discharges have slightly increased the level of alpha contamination over the last few years, although the radiological significance is still very small and a large margin of safety exists. A request was made by the Authority to have the authorized limit increased, and this received considerable publicity. However, it must be emphasized that, even though discharges were close to the then-authorized limit, contamination in 1969 was very low indeed, less than 2 per cent of the derived working limit.

Table 3 Radioactivity in Porphyra in the immediate vicinity of Windscale, 1969

Sampling site	Distance from pipeline (km)	Concentration of radioactivity, pCi/g (wet); mean and range					
		Total beta	^{106}Ru	$^{95}Zr/^{95}Nb$	^{144}Ce	^{239}Pu*	^{241}Am
Maryport	41.0	2.5 (2.0-3.0)	3.5 (2.7-4.3)	1.4 (1.1-1.7)	0.2 (0.2-0.2)	-	-
St. Bees	10.0	81 (47-153)	67 (43-113)	41 (6.1-134)	4.8 (1.5-12)	0.8	0.6
Nethertown	5.6	239 (169-364)	191 (140-279)	198 (40-465)	20 (5.9-48)	2.9	0.8
Braystones North	3.7	223 (76-319)	206 (115-328)	144 (32-394)	17 (3.6-47)	2.1	1.1
Braystones South	1.9	256 (105-536)	223 (91-388)	140 (18-223)	19 (0-81)	2.0	0.8
Sellafield Pipeline	0	185 (104-256)	173 (79-246)	92 (27-240)	8.1 (0-23)	1.0	1.0
Sellafield Bailey Bridge	1.4	216 (114-347)	186 (61-324)	107 (15-257)	11 (0-28)	3.4	0.7
Seascale	3.1	163 (90-253)	153 (81-228)	91 (15-241)	7.4 (0.3-21)	1.3	0.7
Drigg Barnscar	5.6	140 (75-268)	132 (72-222)	78 (15-257)	5.7 (0.6-17)	0.9	0.4
Drigg Rabbit Warren	8.0	112 (109-114)	101 (91-111)	23 (22-23)	4.0 (2.1-5.6)	0.8	1.1
Eskmeals North	10.9	69 (38-121)	50 (35-63)	47 (7.0-148)	1.8 (0.3-3.9)	0.3	0.2
Eskmeals South	14.3	79 (33-117)	70 (28-110)	45 (7.4-154)	3.3 (0-7.2)	0.5	0.3
Gutterby	20.1	73 (27-127)	60 (28-96)	59 (11-148)	4.6 (0-15)	2.9	0.7
Walney Island	38.6	30 (20-41)	29 (22-41)	16 (3.2-56)	1.2 (0.7-3.2)	0.2	0.2

NOTE: The mean concentration of natural radioactivity, ^{40}K, is 5.6 pCi/g (wet).

*Includes ^{240}Pu.

Discharges are not merely authorized at rates which are within the capacity of the environment to accept safely but, within that limit, are set at the lowest rates which the operator can demonstrate are necessary on both economic and operational grounds. The limit in force in 1969 was a case in point; it had remained effectively unaltered for more than 12 years although the amount of alpha activity in irradiated fuel being reprocessed at Windscale has increased many times during this period, principally due to the expansion of the UK nuclear power programme. In addition to consideration of factors of this kind the proposal has been subject to the usual careful scrutiny by the laboratory in terms of radiological exposure. For this purpose a research programme was mounted in 1968 to establish the relationship between discharge rate and degree of contamination. By considering the latter in terms of the public exposure to which it was equivalent, a permissible maximum discharge for this category of radionuclides was

established - permissible, that is, on the basis of the ICRP-recommended dose limit. In fact the new discharge rate requested by the UKAEA is only a small fraction of the permissible limit and the higher authorized limit which came into force in 1970 still leaves a large factor of safety.

Concentrations of ruthenium-106 in the laverbread as sold are summarized in Table 4. A direct comparison, by the reader, of these data with those in Table 3 is not possible without a detailed knowledge of the industry, but it will be seen that the concentrations are substantially lower in laverbread than in Cumberland seaweed; the mean dilution factor for the year taken as a whole was about 5.

Table 4 Ruthenium-106 in laverbread manufactured in South Wales, 1969

Manufacturer	Concentration of ^{106}Ru, pCi/g (wet); mean and range
A	13 (0-68)
B	9.1 (0-31)
C	21 (0-85)

A sub-critical pathway involving external exposure of the public - principally fishermen in the Ravenglass Estuary - has been monitored by regular surveys of the gamma dose-rate in the area concerned. Similar measurements have also been made at Walney Island and in Whitehaven Harbour, these being the only areas outside the Ravenglass area where silt, which adsorbs fission products more readily than other sediments such as sand, is regularly found. Samples have also been taken at each of the dose-rate survey points for laboratory analysis, and the results are included with the dose-rate results in Table 5.

Table 5 Radioactivity in silt, and gamma dose-rates over silt banks in the vicinity of Windscale, 1969

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	^{144}Ce	
Ravenglass Estuary	2770 (1040-7920)	1290 (750-2080)	608 (305-920)	300 (150-500)
Walney Island	-	-	-	68 (25-100)
Whitehaven Harbour	712 (166-1760)	483 (219-1350)	234 (122-760)	94 (70-125)

Dose-rates were higher in 1969 than in the previous year, an effect which was largely due to some higher discharges of zirconium-95/niobium-95 for a short period early in the year, and which was also reflected in nuclides in the silt samples. Despite this, however, exposure of the public was safely within the ICRP-recommended dose limit by a substantial factor.

Traces of radioactivity originating from Windscale discharge can be detected at distances greater than the positions already mentioned and although contamination in these areas is of no radiological significance - especially when compared with the critical exposure pathway - certain measurements have been continued. Most of these positions are in south-west Scotland, where the measurements have been made at the request of Departments of the Scottish Office. Some further results from sampling on the Irish Sea shoreline - from the coasts of both England and Northern Ireland - have been grouped in this section; other monitoring of the coastline of the Irish Republic will be found in Section 7. The materials sampled fall into two groups - seaweeds, and foreshore sand and silt; results for all of these will be found in Table 6.

Other monitoring in the vicinity of Windscale, summarized in Tables 7 and 8, is done largely for research purposes. Contamination of fish is barely measurable (Table 7) and as an exposure pathway is of very little significance; the results set out here are drawn largely from research work utilizing this caesium-labelled environment to study the food-chain of the plaice (Pleuronectes platessa). Seaweeds other than Porphyra are found on the local coasts but are neither eaten nor used in any other way in which they could play a part in public exposure. Some, however, are useful indicators, notably the Fucus family of brown seaweeds, of which Fucus vesiculosus is sampled at four points between St. Bees Head and Walney Island (Table 8). This seaweed shows higher concentration factors for zirconium-95/niobium-95 and caesium-137 than Porphyra but a lower concentration factor for ruthenium-106. The analyses reveal that traces of caesium-134 are also present but their precise estimation is prevented by the presence of large quantities of zirconium-95/niobium-95. Other research work on seaweed ecology has included a relative study of a number of seaweeds growing together at St. Bees. In conjunction with this work, and with the plaice food-chain study, sea water has been sampled (Table 9). Sampling of sea water has no direct radiological significance but also serves to indicate certain changes which might not be noticed in critical materials, such as the rising proportion of caesium radionuclides in the effluent being discharged.

Further sampling of sea water and also of sediment was carried out during an extensive cruise in the Irish Sea, using one of the Ministry's research vessels. In addition sea water has been sampled routinely during regular Irish Sea crossings by packet boats. This will enable a radionuclide inventory of the whole Irish Sea to be made, particularly for the more conservative radionuclides, results of which will be published elsewhere.

Table 6 Radioactivity in seaweed and foreshore materials around the Irish Sea and western Scotland, 1969

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	5.5 (3.9-6.5)	0.6 (0.4-1.0)	1.2 (0.6-1.9)	-	-
Port William	7.6 (4.3-11)	1.4 (0.3-3.8)	2.3 (1.2-5.0)	-	-
Garlieston	6.5 (3.6-10)	1.2 (0.4-2.3)	2.6 (0.8-5.7)	-	-
Fucus vesiculosus					
Port William	9.0 (6.7-12)	1.6 (0.5-2.6)	0.4 (0.2-0.8)	0.3 (0.2-0.3)	0.3 (0.2-0.4)
Garlieston	11 (7.4-15)	4.3 (1.5-9.6)	1.1 (0.4-2.1)	0.6 (0.4-0.9)	0.4 (0.3-0.7)
Rascarrel Bay	10 (7.5-14)	4.0 (1.7-7.9)	0.9 (0.7-1.2)	0.6 (0.3-1.1)	0.6 (0.3-0.9)
Heysham	14 (12-17)	6.4 (2.0-12)	1.7 (1.2-2.5)	1.4 (1.2-1.4)	0.7 (0.5-1.0)
F. serratus					
Millisle	6.7 (5.8-8.5)	0.9 (0.4-2.8)	-	-	-
Silt					
Garlieston	62	17	15	3.2	6.6
Sand					
Heysham	43	-	-	-	-
Fleetwood	13 (9.6-15)	-	-	-	-

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

Table 7 Radioactivity in plaice flesh in the vicinity of Windscale, 1969

Age-group	Concentration of radioactivity, pCi/g (wet); mean and range		
	^{134}Cs	^{137}Cs	^{40}K
0 (0-1 year)	0.4	1.7	3.8
I (1-2 years)	1.0 (0.6-1.4)	3.3 (2.4-4.1)	3.3 (1.6-3.9)
II (2-3 years)	0.8 (0.6-1.0)	3.1 (2.2-3.9)	2.9 (2.4-3.6)

Table 8 Radioactivity in Fucus vesiculosus in the vicinity of Windscale, 1969

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	73 (49-97)	65 (35-100)	19 (18-21)	5.3 (4.9-5.9)	8.1 (5.6-10)
Seascale	128 (116-138)	167 (84-228)	45 (38-51)	9.6 (7.6-12)	18 (13-22)
Gutterby	47 (15-102)	80 (15-177)	11 (2.0-22)	3.6 (1.2-7.0)	5.7 (0.8-13)
Walney	39 (22-85)	55 (10-134)	8.0 (4.5-15)	2.7 (2.0-4.4)	3.4 (2.3-5.0)

Table 9 Radioactivity in coastal sea water in the vicinity of Windscale, 1969

Sampling site	Concentration of radioactivity, pCi/litre; mean and range		
	^{106}Ru	^{137}Cs	^{40}K
St. Bees	91 (8.3-326)	105 (24-393)	282 (264-298)
Seascale	156 (64-225)	129 (84-216)	273 (235-289)

NOTE: ^{134}Cs and $^{95}Zr/^{95}Nb$ were also detected but measurements are imprecise due to mutual interference.

2.2 Springfields, Lancashire

The monitoring programme for disposals from this site to the Ribble Estuary has proceeded unchanged. It is limited to surveys of gamma dose-rate on the banks of the estuary near the outfall, the critical group being workmen maintaining the river banks and servicing navigational aids; their exposure is very low. Samples have also been analysed by gamma spectrometry, contributing to a programme of research in the Irish Sea on the Windscale discharges, whose effect can be detected in the Ribble in terms of the presence of the fission products zirconium-95/niobium-95 and ruthenium-106. Results are summarized in Table 10.

Table 10 Radioactivity in silt and gamma dose-rate over silt banks in the Ribble Estuary, 1969

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	602 (448-887)	37 (3.2-122)	29 (14-68)	882 (307-1820)	14 (10-30)
Upstream*					
90 metres	954 (566-1390)	19 (2.1-43)	25 (8.8-44)	915 (411-1880)	15 (10-30)
460 metres	716 (448-1050)	57 (1.9-147)	45 (8.0-80)	1920 (245-4010)	13 (10-30)
Downstream*					
90 metres	409 (136-579)	47 (2.0-171)	31 (8.1-84)	622 (265-1390)	12 (10-20)

*From pipeline outlet.

2.3 Winfrith, Dorset

It was just possible to detect traces of radioactivity in this environment from disposals from this site in 1969, although both the pattern and composition of discharges were different from those of 1968. The quantities discharged were still only a very small fraction of the authorized limit and public radiation exposure was negligible. Monitoring was thus a combination of research and radiological control, and only occasional random checks on lobsters, crabs, oysters and other edible marine materials were necessary in the latter context. As such, the values in Table 11 are not true averages for the year but are quoted to demonstrate how insignificant the contamination was in radiological terms.

Table 11 Radioactivity in marine materials in the vicinity of Winfrith, 1969

Material	Sampling site	Concentration of radioactivity, pCi/g (wet)		
		^{65}Zn	^{60}Co	^{110m}Ag
Lobster flesh	Kimmeridge	0.1	-	-
Crab flesh	Kimmeridge	1.2	-	-
Oyster flesh	Poole Harbour	0.8	-	-
Limpet flesh	Chapmans Pool	0.1	-	-
Limpet flesh	Osmington Mills	0.1	-	-
Winkle flesh	Chapmans Pool	0.9	0.2	Trace present
Winkle flesh	Osmington Mills	0.2	Trace present	Trace present

NOTE: Zinc-65 and cobalt-60 were also detected at concentrations of the order of 1 and 0.1 pCi/g (wet) respectively in the digestive glands of crab and lobster.

Iodine-131 was found in sea water and Fucus seaweeds but only for a short period early in the year; otherwise fission products have not been in evidence at all. The notable change has been the appearance of metallic activation products, particularly zinc-65 with traces of cobalt-60 and silver-110m. Certain materials which show particularly high concentration factors for these radionuclides have been sampled - chosen, that is, as indicators - and it is expected that these studies, which have been continued in 1970, will provide useful information on the behaviour of several such radionuclides.

2.4 Chapelcross, Dumfriesshire

Sampling of shrimps and silt, both associated with public-exposure pathways, and of the seaweed Fucus vesiculosus, whose function is as an indicator only, made up the monitoring programme operated in 1969 for this site. Each of these materials is slightly contaminated (Table 12) but concentrations are very low and there was no significant exposure of the public from either internal or external sources. Further to this, only a small proportion of this contamination is due to Chapelcross discharges, in which the principal constituents are caesium-134 and -137, the remainder being derived from Windscale.

Table 12 Radioactivity in estuarine materials in the vicinity of Annan, 1969

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	9.8 (5.3-12)	1.7 (0.7-3.8)	1.1 (0.5-2.0)	0.8 (0.4-1.1)	0.7 (0.3-0.9)
Seafield	10 (5.0-12)	1.4 (0.6-2.8)	1.0 (0.7-1.4)	1.0 (0.5-1.5)	0.6 (0.4-0.9)
Silt					
Seafield	84 (34-161)	20 (4.2-51)	35 (7.4-86)	6.8 (2.6-14)	16 (3.9-38)
Shrimp flesh					
Estuary	2.5 (2.2-2.8)	-	-	0.6 (0.4-0.7)	-

*Except silt, pCi/g (dry).
Traces of ^{134}Cs were also present but below the limit of accurate measurement.

An extensive review of exposure pathways from Chapelcross discharges, in the form of a habits survey, was completed towards the end of 1969. Although the study was referred to Chapelcross because this is the source of the only direct discharge to the Solway, these exposure pathways really related primarily to Windscale discharges since, in present conditions, these are responsible for most of the contamination of the materials involved. Internal exposure by consumption of shrimps and fish, including salmon, is probably not as important as was previously thought, and external exposure from salmon fishing operations appears to be the critical route. Although this is a seasonal occupation, long periods are worked on the shore, most of the fishing being by means of fixed nets hanging from stakes driven into the sand between high- and low-water marks. This exposure pathway had previously been monitored by analysis of the radioactive content of silt, which proved that exposure in any foreshore position is very low. Attempts to measure the external dose-rate in working positions failed to show any really significant difference from normal background levels, these areas being essentially clean sand with little or no silt. This is typical of the Solway in which silt accumulates only in isolated places away from most of the salmon fishing areas.

2.5 Dounreay, Caithness

Routine monitoring in 1969 consisted of regular sampling of the indicator materials Fucus vesiculosus and limpet flesh. All samples were analysed for total beta radioactivity; a selection subjected to gamma spectrometry showed the expected fission-products, principally cerium-144, zirconium-95/niobium-95 and ruthenium-106. Results are given in Table 13.

Table 13 Total beta radioactivity in the vicinity of Dounreay, 1969

Material	Sampling site	Concentration of total beta radioactivity, pCi/g (wet); mean and range
F. vesiculosus	Sandside Bay	119 (27-229)
Limpet flesh	Sandside Bay	225 (56-750)

3 NUCLEAR POWER STATIONS OPERATED BY THE CENTRAL ELECTRICITY GENERATING BOARD

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

Environmental monitoring for discharges from these power stations is combined within a single programme because the discharges are made to what is effectively the same reach of the estuary. Oldbury is still at a relatively early stage in its operating life compared with Berkeley and in consequence discharges are much smaller, to such an extent that such little contamination as is measurable is attributable only to Berkeley discharges.

The basic monitoring programme covers external exposure by measurements of gamma dose-rate on silt banks (fishermen and river authority officials constituting the critical group), and internal exposure by sampling and analysis of estuarine foodstuffs (fishermen and their families forming the critical group in this respect). In addition, Fucus vesiculosus is sampled and traces of caesium-137 from Berkeley discharge have been found; the concentrations, however, are very low indeed and internal exposure is negligible - below 0.1 per cent of the ICRP-recommended dose limit. Caesium-137 has also been detected in fish (salmon, elver and flounder have been sampled) and also in shrimps, but as all the species of fish are less sedentary than shrimps it is not surprising that concentrations in them are consistent with fallout only. The effect of power station discharges on the gamma dose-rate over silt banks can hardly be distinguished from natural background, and analysis of samples taken from gamma spectrometric analysis confirms that exposure from external radiation is at a low level similar to that from internal exposure from consumption of shrimps. Results of these surveys are summarized in Table 14.

Table 14 Radioactivity in estuarine materials and gamma dose-rate over silt in the vicinity of Berkeley and Oldbury, 1969

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	2.7	0.10	-
Salmon flesh	-	0.01	-
Shrimp (whole)	2.0 (1.4-2.9)	0.05 (0.04-0.06)	-
Elver	1.5	0.01	-
F. vesiculosus	7.7	1.2	-
Silt	-	-	6.9 (5.3-8.1)

*Except silt, pCi/g (dry).

Natural radioactivity was measured in silt:
^{40}K, 12.4 pCi/g; ^{238}U, 2.4 pCi/g; ^{232}Th, 0.8 pCi/g.

3.2 Bradwell, Essex

The monitoring programme consists largely of sampling of oysters, especially the native species (Ostrea edulis), farmed in the Blackwater Estuary to which discharges are made. One significant change made during 1969 was the deletion of the special 'layings' at the Barrier Wall structure which is used to divert the warmed cooling-water discharge away from the cold-water intake area. Cages of native and of Portuguese oysters (Crassostrea angulata) had been suspended from the Barrier Wall; these layings had been maintained over more than 7 years since the power station began to operate, providing evidence of the maximum conceivable concentration which radioactivity could reach in oysters at any position in the estuary. However, our research in recent years has proved quite conclusively that the highest concentration in marketed oysters is always to be found in those from the commercially worked area nearest to the power station, about $\frac{1}{2}$ km downstream. As there was also increasing difficulty in maintaining these special layings in a most unfavourable habitat at the Barrier Wall, it was decided to discontinue this part of the programme because it was no longer necessary. Samples have been taken from various parts of the estuary, most of them for research purposes, and analyses will be found in Table 15. In addition to zinc-65, the critical nuclide, traces of silver-110m have been detected in oysters from all parts, with similarly low levels of the caesium radionuclides -134 and -137.

Table 15 Radioactivity in oysters in the Blackwater Estuary, 1969

Sampling area	Concentration of radioactivity, pCi/g (wet); mean and range				
	Total beta	^{32}P	^{65}Zn	^{110m}Ag	^{137}Cs
Native species					
Barrier Wall	3.2	-	1.6	0.3	1.1
0.5 km downstream*	3.3 (2.4-4.9)	0.02	1.5 (1.0-2.0)	0.4 (0.3-0.5)	0.1 (0-0.1)
1.6 km upstream*	-	0.01	0.7 (0.4-0.9)	0.3 (0.2-0.3)	0.07 (0.04-0.10)
3.2 km upstream*	-	0.01	0.6 (0.4-0.8)	0.3 (0.2-0.4)	0.07 (0.03-0.10)
Mayland Creek	-	-	0.2 (0.2-0.3)	0.07 (0.06-0.09)	0.06 (0.04-0.07)
Nass End	-	0.01	0.4	0.3	0.02
Goldhanger Creek	2.8	-	0.2	0.04	0.06
Portuguese species					
Barrier Wall	2.8	-	2.7	0.3	1.2
Southey Creek	-	-	0.2	0.4	0.04

*Distance from Barrier Wall.

Evidence of phosphorus-32 has also been found, but the concentrations quoted in Table 15 are not to be regarded as a true mean for the year, since they are merely the result of occasional irregular sampling in the research programme in an attempt to correlate contamination with discharges of this radionuclide. Concentrations of phosphorus-32 in oysters vary in no predictable manner except that they appear to be linked to season and possibly to phytoplankton production. Concentrations of all radionuclides are very low indeed compared with permissible maxima and the total effect in terms of radiation exposure of the critical group (oyster fishermen) does not amount to as much as 0.1 per cent of the ICRP-recommended dose limit. At the mean concentrations found in 1969 some anomalies appear to exist, and mention may be made of the similarity now found between concentrations of zinc-65 at the Barrier Wall and at 0.5 km downstream, whereas in previous years these differed by a factor of 5 to 10. The explanation for this is complex and probably lies in the frequency with which the temporary layings at the Barrier Wall had to be replaced compared with the very long biological half-life in a regime where discharges of zinc-65 have been decreasing. In

contrast to the Barrier Wall layings, the oysters sampled at the commercially worked beds remain there long enough to reach equilibrium with zinc-65. Whilst zinc-65 has been on 'down-run' conditions, concentrations of silver-110m, a radionuclide with a similarly long biological half-life in oysters, have been steadily increasing and have probably now reached equilibrium in the commercial layings. The biological half-life of caesium is however much shorter and the concentration in the oyster reacts to changes in the discharge rate more quickly.

In addition to oyster sampling, two non-critical materials have been retained in the monitoring programme, and the results are shown in Table 16. These are silt, which is sampled at two positions where the gamma dose-rate is also measured, and the seaweed Fucus vesiculosus. The only artificial radionuclides detected are the caesium radionuclides -134 and -137 and cobalt-60. None of these contributes significantly to the gamma dose-rate; the higher value close to the station is due to direct radiation from the reactors and not to contamination of the foreshore by discharges.

Table 16 Radioactivity in non-critical materials and gamma dose-rates over silt in the Blackwater Estuary, 1969

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	^{134}Cs	^{137}Cs	
F. vesiculosus					
1.6 (upstream)	6.8 (5.6-9.1)	0.1 (0.1-0.2)	Present	0.6 (0.3-0.8)	-
Silt					
0	21 (18-26)	0.2	0.2 (0.1-0.3)	0.7 (0.3-1.0)	18 (3-30)
1.6 (upstream)	25 (24-28)	-	1.4 (0.9-2.1)	3.7 (2.4-5.4)	7.4 (7.0-7.8)

*Except silt, pCi/g (dry).

3.3 Dungeness, Kent

The sampling programme for this station has continued largely unchanged except that shrimps are now being fished close to the station and samples have therefore been analysed from time to time. Otherwise internal exposure has been kept under surveillance by monitoring plaice flesh, and external exposure by measuring the gamma dose-rate over the foreshore from which samples of sand have also been taken for analysis.

In general, no contamination from the power station has been found, the traces of caesium measured (see Table 17) being due to fallout. It was in shrimps (recently added to the programme) that the first and only evidence to date of any contamination of the environment from discharges from the power station occurred. Very low concentrations of silver-110m appeared, though only transiently, which were probably associated with discharges of this radionuclide from the power station. Discharges were quite small but shrimps concentrate this radionuclide to such a very high degree that, as samples were obtained close to the cooling water outfall, these factors were sufficient to produce just-measurable concentrations for a short period.

Table 17 Radioactivity in marine materials and gamma dose-rates over beaches in the vicinity of Dungeness, 1969

Material	Concentration of radioactivity, pCi/g (wet)*; mean and range		Gamma dose-rate, μR/hour; mean and range
	Total beta	^{137}Cs	
Plaice flesh	3.0	0.008	-
Shrimps	2.6	0.01	-
Sand	14	0.1 (0.08-0.1)	-
Sand and shingle	-	-	4.3 (3.6-5.0)

*Except sand, pCi/g (dry).

3.4 Hinkley Point, Somerset

Until 1969 no contamination had been found in any critical material at this site, although evidence of power station operation has been noted in the presence of traces of activation products in seaweed on the edge of the cooling-water outflow channel, a position which, by virtue of its proximity to the water into which radioactive waste is discharged, is extremely sensitive to even small concentrations of certain constituents. However, 1969 saw a substantial change, with larger discharges being made, principally of caesium-134 and -137, although all were quite satisfactorily within authorized limits.

The sampling programme previously operated proved adequate to meet the requirements of this new situation, supplies of shrimps and whiting from the local Stolford Flats fishery being analysed so as to monitor internal exposure, and measurements being made of gamma dose-rate on the foreshore to check external

exposure. Silt and Fucus vesiculosus were also sampled, the latter from a number of positions as part of a research programme aimed at establishing the relationship between concentration and distance from the disposal point relative to discharge rate. Results of these surveys are shown in Table 18 with the data from routine monitoring. Caesium was found in all materials but no other radionuclide has been detected so consistently. As in previous years, traces of zinc have been measured in Fucus vesiculosus and samples of this seaweed near the outfall also contained some zirconium-95/niobium-95, ruthenium-106 and cerium-144 for a short period in the middle of the year. None of these radionuclides has been found in critical materials and radiation exposure of the public remains very low, at only a fraction of one per cent of ICRP-recommended dose limits and thus little changed by the increased discharges.

Table 18 Radioactivity in marine materials and gamma dose-rates over silt in the vicinity of Hinkley Point, 1969

Material and distance from pipeline outlet (km)	Concentration of radioactivity, pCi/g (wet)*; mean and range				Gamma dose-rate, μR/hour; mean and range
	Total beta	^{60}Co	^{65}Zn	^{137}Cs	
Shrimp flesh					
Bridgwater Bay	2.6 (1.6-3.2)	-	-	0.2 (0.04-0.3)	-
Whiting flesh					
Bridgwater Bay	-	-	-	0.2	-
Silt					
0	30 (16-43)	-	-	4.3 (0.4-6.4)	9.9 (8.3-11)
F. vesiculosus					
1.6 (east)	8.9 (8.1-9.8)	-	0.1 (0.003-0.1)	0.7 (0.08-1.1)	-
0.8 (east)	8.5 (7.0-11)	-	0.1 (0.04-0.1)	0.4 (0.08-0.8)	-
0	30 (8.0-68)	Trace	0.7 (0.2-1.4)	2.0 (0.2-3.8)	-
0.8 (west)	9.0 (8.4-9.7)	-	0.09 (0.02-0.1)	0.6 (0.08-0.9)	-

*Except silt, pCi/g (dry).

The discharges of caesium-137 have been used to examine dispersion from the Hinkley Point area. Sea water was sampled over a wide area of the Bristol Channel and the Severn Estuary at a time when caesium had been discharged from Hinkley Point for a period of several months and near-steady-state conditions could be presumed to have been reached. The survey was also made at a time when relatively little was being discharged from Berkeley and Oldbury so that, apart from fallout, which masks the effect at low concentration (in the region of 1 pCi/litre), the sampling was following the discharges from Hinkley Point. Full results will be published elsewhere but one of the principal conclusions may be quoted - that water from the Hinkley side of the Bristol Channel does not move across to the northern side. Dilution is considerable within a short distance of the outfall but thereafter, in an east-west direction, concentration falls only slowly with distance.

3.5 Sizewell, Suffolk

Discharges from this site have been very small and no evidence of the power station's activities has been found during the course of environmental monitoring; this also reflects the good dispersion characteristics of the area to which discharges are made. Only a small programme is necessary - sampling of locally-caught fish in respect of internal exposure, and gamma dose-rate measurements on the foreshore in respect of external exposure. It follows that, in the absence of any measurable contamination of these materials by power station operation, public exposure is negligible; traces of caesium-137 are to be found in fish but these are merely due to fallout. The results of analyses and gamma dose measurements are shown in Table 19.

Table 19 Radioactivity in fish and shellfish and gamma dose-rates over sand in the vicinity of Sizewell, 1969

Material	Concentration of radioactivity, pCi/g (wet); mean and range		Gamma dose-rate, μR/hour; mean and range
	Total beta	^{137}Cs	
Cod flesh	3.5	0.07	-
Plaice flesh	3.7	0.03	-
Sole flesh	4.7	0.04	-
Skate flesh	3.8 (3.0-4.5)	0.05 (0.05-0.06)	-
Sand	-	-	4.0 (2.9-5.4)

Table 20 Radioactivity in materials in Lake Trawsfynydd and local streams, and in the Glaslyn Estuary at Portmadoc, 1969

Material	Sampling site	Concentration of radioactivity, pCi/g (wet)*; mean and range						
		Total beta	^{54}Mn	^{60}Co	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce
Water	Cold lagoon	-	-	-	-	0.5 (0.3-0.8)	2.9 (1.7-4.2)	-
	Hot lagoon	-	-	-	-	0.5 (0.2-1.0)	3.3 (1.7-4.8)	-
Trout flesh	Lake	13 (7.5-18)	-	-	-	1.0 (0.5-1.7)	11 (6.0-16)	-
Perch flesh	Lake	24 (15-35)	-	-	-	2.4 (1.2-3.4)	25 (13-34)	-
Inorganic mud	Lake	25	-	-	-	0.6	7.5	-
Organic mud	Lake	33 (28-37)	-	-	-	0.2	9.7 (8.0-12)	-
Peat	Lake	28 (22-34)	-	-	-	0.9 (0.3-1.4)	11 (7.6-13)	-
Fontinalis	Afon Prysor	12 (7.4-17)	0.5 (0.4-0.6)	0.1	3.5 (1.7-5.4)	-	0.4 (0.2-0.7)	3.1 (1.8-3.9)
	Gwylan Stream	15 (13-18)	1.8 (0.9-2.8)	1.7 (0.9-2.5)	4.7 (2.7-6.4)	-	1.4 (0.7-2.0)	2.3 (0-3.8)
Mussel flesh	Portmadoc	1.3 (1.1-1.6)	-	-	-	-	-	-

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

3.6 Trawsfynydd, Merioneth

Routine monitoring for radiological control of the discharges from this power station consists only of sampling fish from the lake - trout and perch. In addition to this, however, other materials are sampled for research purposes designed to elucidate the behaviour of radioactivity discharged to an environment which is unique in the United Kingdom, and to yield information necessary to plan the conduct of future radioactive waste control to the lake. The caesium radionuclides -134 and -137 continue to be the most important components of the discharge and, though other constituents of the effluent are found in the indicator moss Fontinalis, none of these has been detected in perch or trout.

Discharges have been tightly controlled by the CEGB so that despite the sensitivity of this environment to caesium - both species of fish from the lake reconcentrate caesium to high degree - concentrations in these materials have remained low. In fact, the concentrations found in fish in 1969 closely resemble those measured in 1968 and exposure of the critical group is thus still well within the ICRP-recommended dose limits, no member of the group being subject to more than 4 per cent of the dose limit to any organ. Results of monitoring are shown in Table 20.

3.7 Wylfa, Anglesey

This power station was still under construction during 1969, and therefore no routine discharges of radioactive waste were made. Monitoring surveys have continued on the pattern established in 1968 and constitute the completion of the pre-operational phase. Fish and crustacean shellfish are expected to be the critical materials for internal exposure, whilst measurement of gamma dose-rate is necessary to take account of external sources. Seaweeds and molluscan shellfish are also sampled for their value as indicators. All these materials have been analysed by gamma spectrometry in addition to gross beta estimation; the indicators and silt contain some artificial radioactivity due to a combination of discharges from Windscale and, in the case of caesium, a similarly small contribution from fallout. Results are shown in Table 21.

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

4.1 Hunterston, Ayrshire

This is the only nuclear power station operated by the SSEB, although a second unit is under construction on an adjoining site and electricity is generated by nuclear power in the Board's area by the UKAEA site at Chapelcross. Monitoring by the laboratory is undertaken on behalf of Departments of the Scottish Office.

Table 21 Radioactivity in marine materials and gamma dose-rates over silt in the vicinity of Wylfa, 1969

Location	Material	Concentration of radioactivity, pCi/g (wet)*; mean and range					Gamma dose-rate, μR/hour; mean and range
		Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{137}Cs	^{144}Ce	
Cemlyn Bay	Porphyra	6.1	0.4	-	-	-	-
	F. vesiculosus	8.9	-	-	0.1	-	-
	Lobster flesh	2.0	-	-	0.06	-	-
	Crab flesh	2.6	-	-	0.06	-	-
	Pollack flesh	3.3	-	-	0.3	-	-
	Silt	26 (24-29)	2.2 (0.8-4.4)	5.2 (2.9-8.6)	1.9 (1.1-2.8)	4.3 (3.0-6.2)	11 (8-15)
Cemaes Bay	Porphyra	5.6	0.4	-	-	-	-
	F. vesiculosus	7.7	0.5	0.3	0.1	-	-
	Winkle flesh	2.8 (2.3-3.3)	-	-	0.08 (0.04-0.1)	-	-

*Except silt, pCi/g (dry).

Discharges rose during 1969 due to increases in caesium-137 and -134, which have emerged as the critical nuclides. A significant fraction of the artificial radioactivity found in the critical materials fish and sand is attributable to the power station, although in absolute terms the concentrations involved are of negligible importance, exposure of the public being very small indeed.

The routine monitoring programme consists of sampling of soles in respect of internal exposure, and sand in respect of external exposure (the gamma dose-rate is also measured at the sampling point), in addition to which the seaweed Fucus spiralis is collected as an indicator. The fish have been obtained from the White Fish Authority's fish-farming project on a site adjoining the power station and, in conjunction with this, seawater samples have also been collected and analysed for caesium-137.

In addition to caesium, traces of zinc-65 are being detected in Fucus spiralis which occasionally also shows the presence of minute quantities of Windscale-derived fission products. Concentrations are very low and are of no radiological significance, the seaweed merely serving as indicator material. The results of these surveys are shown in Table 22.

Table 22 Radioactivity in materials in the vicinity of Hunterston, 1969

Material	Concentration of radioactivity, pCi/g (wet)*; mean and range			
	Total beta	^{65}Zn	^{106}Ru	^{137}Cs
Sea water	-	-	-	3.8 (2.4-6.6)
F. spiralis	7.8 (4.4-10)	0.1 (0.08-0.2)	0.3 (0-1.1)	1.4 (0.4-3.1)
Sole flesh	1.1	-	-	0.05
Sand	14 (9.3-19)	-	-	0.7 (0.1-2.4)

*Except sand, pCi/g (dry), and sea water, pCi/litre.

Traces of ^{134}Cs were also present but below the limit of accurate measurement.

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

5.1 HM Dockyard, Chatham, Kent

A negligible amount of radioactivity was discharged during 1969 and monitoring is thus effectively still in a pre-operational phase. External exposure is expected to be the most important pathway and the small programme of monitoring has therefore concentrated on gamma dose-rate measurements on silt banks in the estuary, from which samples have also been taken for analysis. The results summarized in Table 23 represent natural background with a small contribution of caesium-137 from fallout.

5.2 HMS NEPTUNE, Faslane, Dunbartonshire

As with other naval discharges external exposure is the critical pathway, and monitoring has continued on the pattern established in 1968, i.e. sampling the bed of the Gareloch for subsequent analysis by gamma spectrometry and supporting these analyses by gamma dose-rate measurements at appropriate points on the shoreline. The latter constitutes the essential part of the programme, the purpose of the loch-bed sampling being largely to predict future trends. Most of the cobalt-60 measurements are not significantly different from those in the Clyde area generally, but one measurement does indicate that discharges from Faslane are now producing an effect which can be measured. This has not been reflected in shoreline gamma dose-rates, which are still indistinguishable from natural background; public radiation exposure in 1969 was thus negligible. The results of these surveys are shown in Table 23.

5.3 HM Dockyard, Rosyth, Fife

Monitoring for discharges from this dockyard follows a pattern similar to that for Faslane. Samples of the seabed of the Firth of Forth are taken for analysis, the emphasis being on the dockyard approaches where the critical group of men working dredgers operates. Public access to the shoreline in the vicinity of the dockyard is limited, but clearly in this situation, too, external exposure is the more important pathway and a small survey of gamma dose-rate measurement has been mounted.

Small discharges were being made during 1969 and cobalt-60 was present in silt around the dockyard entrance and in the approaches. The results quoted in Table 23 (which also include data on shoreline gamma dose-rate) are for the early part of the year but are probably reasonably typical of levels for the year as a whole. They are certainly of very low radiological significance and shoreline gamma dose-rates are not distinguishable from natural background. Later in the year accurate measurement of cobalt-60, the only contaminant attributable to dockyard operations, was hampered by the effects of an experiment to follow silt movements by labelling dredging spoil with scandium-46, and few accurate measurements are available. These confirm the radiological status of contamination found earlier in the year - that exposure of the critical group was a very small fraction of ICRP-recommended dose limits.

Table 23 Radioactivity in materials and gamma dose-rates 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
	^{137}Cs	^{60}Co	
Chatham			
Silt	0.9 (0.4-1.3)	-	5.4 (4.0-6.7)
Faslane			
Seabed	2.1 (0.5-2.8)	2.4 (0.2-16)	-
Foreshore silt	-	-	10 (5-18)
Rosyth			
Dockyard approaches silt	-	3.2 (0.3-9.9)	-
Shoreline	-	-	11 (10-12)

6 THE CHANNEL ISLANDS

The laboratory has a continuing commitment to advise the Channel Islands States. A monitoring programme was conducted in 1969 similar to that of previous years, with the same purpose - to detect any contamination of the shores of these islands from discharges from the French fuel-reprocessing plant at La Hague. The programme consists largely of sampling Porphyra - in this situation an indicator and the most sensitive means of detecting any effect - with a small amount of other materials which could be involved in public exposure if they became contaminated. Only one of these materials, ormer flesh, shows any measurable concentration of artificial radioactivity, a trace of caesium-137. However, the level measured is consistent with fallout and there is no evidence of any contamination attributable to French discharges. Results are summarized in Table 24.

Table 24 Radioactivity in materials on the coasts of the Channel Islands, 1969

Material	Sampling area		Concentration of radioactivity, pCi/g (wet)*; mean and range	
			Total beta	^{137}Cs
Porphyra	Guernsey	Fort Doyle	5.3 (2.8-9.0)	-
		Fermain Bay	4.6 (3.5-5.4)	-
	Alderney	Corblets Bay	8.1 (3.8-11)	-
		Hannaine Bay	5.1 (3.5-6.7)	-
	Jersey	Greve de Lecq	5.4 (4.0-7.3)	-
		La Rozel	4.9 (3.2-6.2)	-
Sand	Guernsey	Bordeaux Harbour	14	-
Silt	Jersey	St. Helier	16	-
Ormer flesh	Jersey		-	0.08

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

7 THE IRISH REPUBLIC

1969 saw the start of a collaborative effort between the laboratory and the Department of Health of the Republic of Ireland. Some monitoring of the eastern and south-eastern coasts of Ireland has been undertaken and sampling was mainly of seaweeds. It was just possible to detect ruthenium-106 and zirconium-95/niobium-95 in some of the species sampled, and although this trace contamination may be due to Windscale discharges it is of negligible radiological significance. Indeed, the concentrations measured - less than 1 pCi/g - were similar to those still occasionally found due to fallout (see Section 8). Results are summarized in Table 25.

Table 25 Radioactivity in seaweeds and sand on the Irish Republic coastline, 1969

Material	Sampling point	Concentration of total beta radioactivity, pCi/g (wet)*
Porphyra	Skerries	9.1
	Colliemore	9.4
	St. Helens	4.3
F. serratus	Skerries	6.9
	Dunsmore East	4.9
F. vesiculosus	Colliemore	6.1
	St. Helens	4.8
Laminaria digitata	Skerries	4.3
	Colliemore	12.9
	Dunsmore East	5.0
L. saccharina	St. Helens	4.8
Sand	St. Helens	10.0

NOTE: Traces of ^{106}Ru and $^{95}Zr/^{95}Nb$ were also found at up to 0.4 and 1.0 pCi/g (wet) respectively.

*Except sand, pCi/g (dry).

8 SURVEYS OF BACKGROUND AND FALLOUT RADIOACTIVITY

A small but nevertheless important part of the laboratory's monitoring programme consists of sampling of certain materials for reference, background, purposes. The numerical value of natural background may often be ascertained by taking samples of materials at increasing distances from a particular discharge; it may also be obtained from pre-operational surveys, but it is still worthwhile collecting material from areas unconnected with the discharges. Several materials which feature in control monitoring programmes can be found in the vicinity of Lowestoft and can conveniently be used for further background measurement. These are seaweed - both Porphyra and a member of the Fucus family, Fucus spiralis - and shrimps. Sand is also sampled. Also included in the data collected together in Table 26 are measurements on Porphyra collected at Dunbar on the eastern Scottish coast, which has been found previously to provide a useful indication of the extent of contamination due to fallout.

Traces of the fission-products ruthenium-106 and zirconium-95/niobium-95 were occasionally found there in 1969, measurements which are helpful for instance when attempting to assess the origin of low-level effects in an area where trace contamination may alternatively be due either to fallout or, for example, to Windscale.

Table 26 Radioactivity in background reference materials, 1969

Material	Sampling area	Concentration of radioactivity, pCi/g (wet)*; mean and range		
		Total beta	^{106}Ru	$^{95}Zr/^{95}Nb$
Porphyra	Lowestoft	4.1	-	0.2
	Dunbar	6.0 (5.2-6.8)	0.1 (0-0.4)	0.2 (0-0.6)
F. spiralis	Lowestoft	4.9	0.2	0.2
Shrimp	Lowestoft	1.9	-	-
Sand	Lowestoft	4.3	-	-

*Except sand, pCi/g (dry).

The laboratory's monitoring of certain commercial fish landings was discussed in the last issue of this series of monitoring reports. Both cod and plaice were sampled in 1969 and, as in previous years, analysis was made for caesium-137, data on which are summarized in Table 27. Traces of this radionuclide can still be detected but concentrations are very small in absolute terms and negligible in their radiological importance. A perspective on the latter can be gained by comparing these concentrations with that of natural potassium-40 - some two orders of magnitude larger.

Table 27 Caesium-137 in commercial fish landings in UK ports, 1969

Species	Fishing area	Concentration of ^{137}Cs, pCi/g (wet)
Cod flesh	Southern North Sea (IVC)	0.06
	Iceland (VA)	0.04
Plaice flesh	Southern North Sea (IVC)	0.03
	Iceland (VA)	0.03

9 CONCLUSIONS

In a climate of opinion where disposal of waste of any type is coming under the closest scrutiny, the control measures adopted for radioactive materials are being subjected to a very close examination. The nuclear industry in the United Kingdom has from the outset met the highest standards in all matters involving safety - and not least where waste disposal is concerned - so much so that it is often mentioned as a model for other industries to follow. Data presented in this report show that this high standard continues to be maintained, and that the exacting requirements of the recommendations of the International Commission on Radiological Protection are not only met, but that in all disposals radiation exposure of the public is well within the prescribed dose limits and in many instances very much less.

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