MINISTRY OF AGRICULTURE, FISHERIES AND FOOD

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RADIOACTIVITY IN SURFACE AND COASTAL WATERS OF THE BRITISH ISLES 1968

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In previous reports in this series, Neil Mitchell has reviewed the work done by the Fisheries Radiobiological Laboratory, Lowestoft, to ensure the safe disposal of radioactive waste to surface waters and the sea. FRL 5, the third report in a now-yearly series, covers the work done in 1968 and records the changes which have occurred at the various sites where waste is discharged. The information supplied shows the care with which the interests of the public are protected and how the high standard of safety achieved in previous years was fully maintained in 1968.

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CONTENTS

Page

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INTRODUCTION

The laboratory's work of radiological control has been described in previous reports in this series[1, 2] which have recorded summaries of monitoring data for the past five years. This issue reports similar work carried out during 1968 and reviews its meaning and implications. Most of the information refers to sites in England and Wales where the Ministry has a direct responsibility, but results are also included of work done in Scotland and in the Channel Isles on behalf of the appropriate government departments. A section is also included on radioactivity measured in general coastal areas in the UK, not necessarily linked to specific discharges. Together, the information in this report may thus be taken to be a general account of the state of radioactive contamination of the marine environment of the British Isles as a whole - from which it can be judged that this contamination has been maintained at a very low level, and that radiation exposure anywhere in this area, as a result of contamination, is well within internationally recommended dose limits.

The pattern of monitoring effort required to establish this picture is never static and minor changes have occurred during the year to meet changing situations. These are the result of factors such as variations in the quantity and isotopic composition of discharges, changes in the behaviour of critical groups as shown by regularly-conducted habits surveys, and new sites which are introduced into survey and sampling programmes in advance of the start of discharges. Monitoring has begun in two new areas at a pre-operational stage - on the coast of Anglesey for the nuclear power station at Wylfa, and in the Medway Estuary for HM Dockyard, Chatham.

Research continues to be an important aspect of the laboratory's work and at times involves a considerable part of the monitoring effort. This concerns only a few environments - those where contamination is readily measurable - and some of the work of value to research simultaneously fulfils requirements of a routine radiological control nature. The research programme has to be flexible because opportunities presented by contaminated environments sometimes occur at short notice. In this way field research monitoring may vary in its content considerably from year to year within the underlying programmes basic to the laboratory's responsibility as the technical arm of the Fisheries Department concerned with radioactivity.

WORKING METHODS

Most of the analytical methods used during the year under review have been employed previously, but some changes have been made, particularly where improved techniques and equipment have become available. The principal change concerns the assessment of gross beta activity, which still plays a useful role in control monitoring both as a preliminary screen and also where only one nuclide is present. Automatic equipment is now being used whose other advantages and working details have been discussed by Dutton[3].

A large part of the laboratory's work depends on gamma spectrometry and it is frequently necessary to resolve complex spectra arising from the presence of several radionuclides. For routine work, the laboratory depends on sodium iodide detectors[4], but applications of germanium detectors are being developed. Lithium-drifted germanium detectors offer considerable advantages - particularly excellent resolution - but the small size of the only detectors which have until recently been available commercially has limited their use to samples containing relatively large amounts of radioactivity. An improvement in the technique used to resolve spectra from sodium iodide crystals is being developed. Hitherto this has been done by an inverted matrix system whose principal disadvantage is that the composition of the mixture must be known, qualitatively, in advance. A new method is being developed which, like the matrix method, depends on computer analysis. This matches the spectral shapes to obtain the best fit by the statistical system of least squares, and is known as the "least squares fit". In this system the computer will select nuclides from its memory without previous instruction, and it is expected that this will be more accurate and reliable than the matrix method. Trials of the computer program are now under way with a view to putting it into routine use during late 1969 or 1970.

UNITED KINGDOM ATOMIC ENERGY AUTHORITY SITES

Windscale and Calder, Cumberland

Sampling of Porphyra seaweed, the raw material for laverbread, continues to be the dominant feature of control monitoring for this discharge, although the importance of external exposure as a result of contamination of local estuarine and foreshore areas must not be overlooked. This north-east area of the Irish Sea has again been extensively used for research purposes, and a survey was made during the year of the whole of the Irish Sea and its approaches.

The year 1968 was far from being typical, in two special ways. The composition of discharges of radioactivity differed considerably from that of previous years; in particular this was reflected in a larger proportion of cerium-144 and higher discharges of alpha-emitting radionuclides. In addition, the discharge rate was somewhat uneven.

These factors resulted in higher than normal concentrations of the controlling radionuclides during the early months of the year, a condition which returned during the summer months when it was primarily due to slower than average dispersion, attributable to an extended period of calm weather. In the latter case the effect was more pronounced in areas local to the discharge point, and concentrations in seaweed decreased rapidly with distance from it. Despite these unusual features, radiation exposure to the critical group was maintained at a satisfactory level. This exposure was just over half of the ICRP recommended dose limit to the average member of the critical group if the effects of dilution of the laverbread with weed from other areas are ignored. In practice, exposure was much lower because considerable dilution does occur, and the average exposure was about one-tenth of this dose limit. Concentrations of the important radionuclides in Porphyra along the local coast where it is harvested are summarized in Table 1. Concentrations of the alpha-emitting radionuclides have been increasing, and though the radiological significance of current levels is low, some work has been started to study radionuclide composition in the weed. Most of this type of radioactivity is due to plutonium-239 and -240 and americium-241, but a little curium-242 is also present. Samples of laverbread have been analysed for the critical radionuclide, ruthenium-106, and measurements are summarized in Table 2.

The most important area of the local environment in so far as external exposure effects are concerned is still the Ravenglass Estuary. This is where the main areas of silt exist, a material which is much more receptive to radioactivity than the clean sand of the exposed shoreline, and it is in this estuary that the greatest use is made of the foreshore. Small patches of silt develop along the beaches of the open coastline but are limited in area and rarely persist for long; their importance is thus low. Silt accumulates in Whitehaven Harbour but dose rates are consistently lower there than in the Ravenglass Estuary, as can be seen from Table 3 which also includes measurements at the other point regularly surveyed on Walney Island. However, this exposure is still well within the ICRP recommended dose limit and reached no more than 15 per cent of this level for the extreme member of this group in 1968.

Fish sampling during 1968 was restricted to plaice (Table 4) which remains a very minor source of exposure. Much of this work is connected with the research effort discussed later. A variety of other materials has been sampled, again as part of the laboratory's research programme, and includes the brown seaweed Fucus vesiculosus, coastal sea water and the sea bed, details of measurements on which can be found in Tables 5, 6 and 7 respectively.

Table 1 Radioactivity in Porphyra in the immediate vicinity of Windscale, 1968

Sampling site	Distance from pipeline (miles)	Concentration of radioactivity, pCi/g (wet); mean and range				
		Total beta	^{106}Ru	$^{95}Zr/^{95}Nb$	^{144}Ce	Total alpha
Dubmill Point	32.0	7.0	8.2	1.2	0.9	-
Maryport	25.5	8.4 (3.3-12)	8.5 (5.0-13)	2.1 (0.4-3.4)	1.3 (0.3-2.2)	-
St. Bees	6.2	97 (55-161)	70 (41-115)	38 (13-137)	10 (4.4-21)	see Eskmeals
Nethertown	3.5	171 (50-285)	128 (49-173)	96 (13-280)	16 (7.0-26)	
Braystones North	2.3	192 (43-394)	147 (47-237)	112 (10-428)	22 (6.2-58)	
Braystones South	1.2	361 (38-2914)	263 (28-1718)	222 (15-1850)	62 (3.7-556)	
Sellafield Pipeline	0	165 (31-466)	154 (34-403)	108 (4.3-717)	17 (1.9-73)	2.3 (1.4-4.1)
Sellafield Bailey Bridge	0.9	212 (60-811)	153 (59-303)	76 (6.7-349)	15 (2.8-49)	
Seascale	1.9	152 (48-308)	130 (51-221)	57 (10-179)	14 (0-51)	
Drigg Barnscar	3.5	103 (26-280)	89 (31-182)	40 (5.7-208)	8.0 (0.2-22)	
Drigg Rabbit Warren	5.0	85 (35-149)	75 (32-111)	27 (4.3-68)	5.7 (1.0-11)	-
Eskmeals North	6.8	96 (39-211)	73 (34-138)	38 (7.9-132)	7.7 (0.9-18)	
Eskmeals South	8.9	75 (15-171)	66 (17-116)	22 (2.8-55)	4.6 (1.0-15)	2.9 (with St. Bees)
Gutterby	12.5	65 (4.0-252)	43 (7.8-88)	28 (1.4-149)	7.9 (0-36)	0.7
Walney Island	24.0	23 (7.0-48)	21 (9.8-36)	6.3 (0.6-21)	3.1 (0-12)	1.6

NOTE: The mean concentration of natural radioactivity, ^{40}K, is 5.1 pCi/g (wet).

Table 2 Ruthenium-106 in laverbread manufactured in South Wales, 1968

Manufacturer	Concentration of ^{106}Ru, pCi/g (wet); mean and range
A	16 (0.2-38)
B	14 (0-55)
C	15 (0-64)

Table 3 Radioactivity in silt, and gamma dose-rates over silt banks in the vicinity of Windscale, 1968

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	1440 (617-3680)	1030 (680-2300)	968 (536-1690)	200 (100-395)
Walney Island	247 (19-1220)	184 (55-527)	219 (55-937)	53 (20-145)
Whitehaven Harbour	389 (140-669)	310 (178-543)	220 (116-370)	85 (70-100)

Table 4 Radioactivity in plaice flesh in the vicinity of Windscale, 1968

Group	Mean concentration of radioactivity, pCi/g (wet)		
	^{134}Cs	^{137}Cs	^{40}K
0 (0-1 year)	0.7	1.6	4.2
I (1-2 years)	0.6	2.0	3.0
II (2-3 years)	0.2	0.7	2.9
III (3-4 years)	0.2	0.9	3.2
IV (4-5 years)	0.2	1.1	2.8
V (5-6 years)	0.3	1.0	3.8

Table 5 Radioactivity in Fucus vesiculosus in the vicinity of Windscale, 1968

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	58 (35-75)	44 (11-83)	13 (5.7-19)	2.4 (1.1-3.7)	6.0 (3.6-8.9)
Seascale	138 (56-278)	140 (23-353)	40 (13-99)	6.9 (2.5-16)	15 (5.2-30)
Gutterby	35 (24-45)	18 (11-24)	9.5 (4.0-17)	1.4 (1.2-1.8)	3.5 (2.2-4.0)
Walney	20 (18-25)	7.0 (4.5-9.8)	2.8 (1.7-4.1)	0.9 (0.6-1.1)	1.8 (1.2-2.8)

Table 6 Radioactivity in coastal sea water in the vicinity of Windscale, 1968

Sampling site	Concentration of radioactivity, pCi/litre; mean and range			
	$^{95}Zr/^{95}Nb$	^{106}Ru	^{137}Cs	^{40}K
Whitehaven	56	22	24	251
St. Bees	44 (5.5-195)	45 (1.1-147)	36 (10-90)	263 (221-287)
Braystones	91 (4.9-288)	108 (10-305)	64 (13-155)	260 (214-293)
Seascale	91 (14-380)	103 (25-514)	62 (21-200)	255 (218-286)
Drigg Barnscar	60 (37-95)	46 (20-77)	35 (17-47)	266 (257-276)
Eskmeals	54 (23-86)	40 (4.1-75)	30 (15-44)	271 (250-291)
Gutterby	20 (12-28)	14 (0.8-31)	16 (11-22)	264 (238-283)
Walney	10 (7.1-15)	18 (11-30)	16 (10-21)	266 (246-286)

Table 7 Radioactivity in seabed samples in the vicinity of Windscale, 1968

Sampling position	Concentration of radioactivity, pCi/g (dry); mean and range		
	$^{95}Zr/^{95}Nb$	^{106}Ru	^{144}Ce
Off St. Bees	96 (43-131)	41 (26-53)	32 (22-45)

Springfields, Lancashire

A resurvey of the habits of the critical group during the year has confirmed that external gamma radiation exposure is the critical factor. Two classes of workmen make up the critical group; one maintains the river banks and the other services navigational aids. Previous estimates of the time spent by these people in exposed situations have been modified slightly but this has hardly affected the degree of radiation exposure, which is still only a very small fraction of the ICRP recommended dose limit.

The monitoring programme is thus limited to occasional measurements of the gamma dose-rate close to the point in the estuary where effluent is discharged, supported by a programme of analysis of the important gamma emitters in the silt. This shows that the only important radionuclide in the silt whose origin can be attributed to Springfields discharges is protactinium-234m, the minor amounts of fission-product activity being typical of silt at this distance from Windscale. Results are summarized in Table 8.

Table 8 Radioactivity in silt and gamma dose-rate over silt banks in the Ribble Estuary, 1968

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	734 (302-1410)	12 (1.2-34)	20 (9.1-39)	880 (300-1520)	20 (10-24)
Upstream*					
100 yards	608 (219-1110)	27 (8.0-48)	43 (36-51)	2290 (534-5210)	30 (24-38)
500 yards	620 (366-1340)	24 (2.8-69)	42 (21-72)	1530 (543-3180)	20 (10-24)
Downstream*					
100 yards	1110 (331-1990)	16 (1.0-46)	23 (7.8-46)	1490 (536-2500)	19 (10-27)

*from pipeline outlet.

Winfrith, Dorset

For the first time in the history of this establishment there has been a significant amount of radioactivity to dispose of, although the quantity actually discharged made up only a small fraction of the authorized limit. It made very little impact on the environment; this was largely due to the nature of the radioactivity discharged, most of which had only a very short half-life.

The critical group for this discharge is the fishing population local to the part of Weymouth Bay to which discharge is made, and only internal exposure from the consumption of shellfish is of any potential importance. Concentrations in critical materials were negligible and most of the monitoring was based on seaweed, used in this context as an indicator. This provided a much more sensitive means of estimating contamination in critical materials than was possible by direct measurement, which yielded results at or below the sensitivity of detection. With concentrations of radioactivity at such very low levels, public exposure was negligible.

A number of varieties of seaweed were sampled from time to time in relation to specific discharges, and for several short periods it was possible to detect some iodine-131. This has been turned to some practical value in the research programme as discussed later, but the measurements have no direct radiological significance because none of the seaweeds in this area is involved in any exposure pathway.

Chapelcross, Dumfriesshire

The important materials monitored in relation to discharges from this site are shrimps, silt and sand, and *Fucus* seaweed, the last named being sampled as an indicator. The results (Table 9) show that radiation exposure is very low, and Chapelcross discharges are responsible for only a small part of this. During 1968, caesium-134 and -137 were the most important radionuclides present in the discharges.

Table 9 Radioactivity in estuarine materials in the vicinity of Annan, 1968

Material	Sampling area	Concentration of radioactivity, pCi/g (wet)*; mean and range				
		Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{137}Cs	^{144}Ce
F. vesiculosus	Waterfoot	12 (8.5-16)	1.4 (0.5-2.4)	1.4 (1.0-2.0)	0.9 (0.3-2.6)	-
	Seafield	13 (11-16)	1.4 (0.5-2.4)	1.4 (1.0-2.0)	1.3 (0.5-2.6)	-
Silt	Seafield	195 (155-270)	90 (10-189)	57 (27-72)	8.5 (3.8-17)	30 (13-41)
Shrimp flesh	Estuary	2.4	-	-	0.4	-

*except silt, pCi/g (dry).

Dounreay, Caithness

The only materials which were sampled regularly in 1968 were the seaweed Fucus vesiculosus and limpets, data on which are shown in Table 10. Samples were analysed by total beta as a routine and occasional samples were subjected to gamma spectrometry. The important contaminants of both materials are cerium-144, zirconium-95, niobium-95 and ruthenium-106; none of the other constituents of the discharges, such as caesium-137 and strontium-90, were detected at anything approaching comparable concentrations.

Table 10 Total beta radioactivity in the vicinity of Dounreay, 1968

Material	Sampling site	Concentration of total beta radioactivity, pCi/g (wet); mean and range
F. vesiculosus	Sandside Bay	176 (47-724)
Limpet flesh	Sandside Bay	210 (59-695)

NUCLEAR POWER STATION SITES

Upper Severn Estuary

Berkeley and Oldbury-on-Severn, Gloucestershire

At present only discharges from Berkeley have any measurable effect on this environment, because Oldbury was only in the early stages of operation during the period under review, and the following remarks therefore apply to the Berkeley station.

It is now clear that caesium-134 and -137 are the critical radionuclides and indeed they are the only radionuclides that have so far been detected in critical materials. A large part of this radioactivity which originates as a liquid waste is now being stored on site after conversion to a solid form, the Board having installed special treatment plant with a view to restricting the amount which needs to be disposed of to the estuary. Public radiation exposure resulting from these discharges is still very low - less than 1 per cent of the ICRP recommended dose limit for any organ or the whole body.

The basis of monitoring has been a survey of gamma dose-rates on silt banks, combined with measurements of the radioactive content of silt samples; results are summarized in Table 11. A variety of fish and shellfish have been sampled (Table 12), the most important species being shrimp. Certain species of fish such as salmon and elver are only present in the estuary during a limited season and not surprisingly show no radioactivity attributable to power station operation, the caesium-137 concentrations being entirely due to fallout. Part of the caesium-137 found in shrimps and silt is also due to fallout, but most of this radioactivity, such as it is, is the result of power station disposals.

One indicator material is included in the monitoring programme - Fucus vesiculosus, sampled near the outfall. Most of the radioactivity is of natural origin, but a trace of caesium-137 is present and most of it is the result of power station discharges (Table 12).

Table 11 Radioactivity in, and gamma dose-rate over, silt banks in the Upper Severn Estuary, 1968

Site	Distance from pipeline outlet (miles)	Concentration of radioactivity, pCi/g (dry); mean and range		Gamma dose-rate, μR/hour; mean and range
		Total beta	^{137}Cs	
East bank	0	19 (17-21)	1.4 (0.8-2.1)	-
	1-3	19 (15-23)	1.3 (0-2.6)	7.6 (6.7-8.8)
	3-6	18 (17-20)	0.8 (0.4-1.8)	7.0 (6.0-8.2)
	6-10	19 (17-23)	0.9 (0.5-1.5)	7.1 (6.4-8.3)
	> 10	-	-	7.0 (6.0-8.0)
West bank	1-3	18 (18-19)	0.6 (0.3-1.1)	7.5 (6.3-9.8)
	3-6	18	0.5	6.9 (6.5-7.4)
	6-10	19 (13-21)	0.5 (0-1.9)	6.5 (5.3-9.0)

NOTE: The mean concentrations of natural radioactivity are: ^{40}K, 12 pCi/g; ^{238}U, 3.0 pCi/g; ^{232}Th, 0.8 pCi/g.

Table 12 Radioactivity in fish, shrimps and seaweed in the Upper Severn Estuary, 1968

Material	Concentration of radioactivity, pCi/g (wet); mean and range	
	Total beta	^{137}Cs
Flounder flesh	2.2	0.10
Salmon flesh	2.9	0.03
Shrimp (whole)	2.5	0.06
Elver	2.8	0.01
F. vesiculosus (pipeline outlet)	5.9* (5.1-7.3)	0.2

*^{55}Fe also present at a concentration of 0.2 pCi/g (wet).

Bradwell, Essex

The pattern of discharges from this power station has now changed considerably, the previous upward trend having been reversed by the installation by the CEGB of additional treatment plant to remove a large fraction of what had become the major constituents, caesium-134 and -137. This treatment plant has also reduced discharges of zinc-65 and, though this remains the critical nuclide, concentrations of it in the critical material - oysters farmed in the Blackwater Estuary - have decreased and public radiation exposure from Bradwell discharges in 1968 was even less than the already very low level at which it had been held previously. Samples of oysters have been taken at a variety of other points in the estuary, but only those at the Barrier Wall, where effluent diluted with cooling water outflow is discharged into the estuary, and at the nearest commercial bed (one-third of a mile downstream of the Barrier Wall) are maintained for the radiological control programme. Various analyses have been performed, particularly zinc-65, but in common with previous years traces of other radionuclides have been detected (Table 13).

Other monitoring for Bradwell has consisted of seaweed and silt, in which there is occasional evidence of minor amounts of radioactivity from the station. The gamma dose-rate has been measured on estuary silt banks close to the station, though the values measured are due to a combination of natural background and direct radiation from the station, the contribution from radioactivity absorbed by the silt being negligible. These results are summarized in Table 14.

Table 13 Radioactivity in oysters in the Blackwater Estuary, 1968

Sampling area	Concentration of radioactivity, pCi/g (wet); mean and range							
	Total beta	^{32}P	^{55}Fe	^{60}Co	^{65}Zn	^{110m}Ag	^{137}Cs	^{134}Cs
<u>Native species</u>								
Barrier Wall	3.5 (2.5-4.3)	0.25 (0.1-0.3)	0.28	0.28	7.6 (5.4-12)	0.38	1.4	0.6
1/3 mile downstream*	-	0.097	0.11	0.043	3.0 (1.0-5.0)	0.28	0.40 (0.32-0.47)	-
1 mile upstream*	-	0.090	0.067	0.015	1.5 (0.9-1.9)	0.22	0.32	-
2 miles upstream*	-	0.070	-	0.014	1.2 (0.8-1.6)	-	-	-
Mayland Creek	-	0.028	-	0.007	0.3 (0.2-0.4)	-	-	-
Nass End	-	-	-	-	0.5 (0.4-0.6)	-	-	-
Goldhanger Creek	-	-	-	-	0.3 (0.2-0.4)	-	-	-
<u>Portuguese species</u>								
Barrier Wall	3.8 (2.3-5.2)	-	-	-	14 (6.8-24)	-	-	-
Southey Creek	-	-	-	-	0.3 (0.3-0.5)	-	-	-

*distance from Barrier Wall.

Table 14 Radioactivity in non-critical materials and gamma dose-rates over silt in the Blackwater Estuary, 1968

Material	Distance from Barrier Wall (miles)	Mean concentration of radioactivity, pCi/g (wet)*					Gamma dose-rate, μR/hour; mean and range
		Total beta	^{55}Fe	^{60}Co	^{134}Cs	^{137}Cs	
F. vesiculosus	1 (upstream)	7.2	0.06	0.2	-	0.6	-
Porphyra	0	6.5	-	-	-	-	-
Silt	0†	25	-	≈0.1	1.5	3.5	13 (5.2-23)
	1 (upstream)†	25	-	0.3	2.6	5.5	-

*except silt, pCi/g (dry)
†also shows traces of ^{60}Co in first half of year, 0.1-0.3 pCi/g (dry).

Dungeness, Kent

Only a very small monitoring programme is maintained for discharges from this site, because at the rates at which discharges have been made it is unlikely that any effect would be detectable.

The critical factors for the public were reviewed in a new habits survey during the year which has confirmed that both internal and external exposure are of potential importance, the former through consumption of fish and shellfish, the latter as a result of time spent on the sandy beaches to the east of the station, by bait diggers in particular. The monitoring programme has consisted only of these critical materials, because no suitable indicator material has been found in this environment. The measurements given in Table 15 show that there is indeed no detectable contamination from the power station discharges and thus that public radiation exposure is negligible. The trace of caesium-137 detected in plaice is consistent with measurements made elsewhere on samples remote from such discharges as those from Dungeness, and the concentration is wholly attributed to fallout.

Table 15 Radioactivity in marine materials and gamma dose-rates over beaches in the vicinity of Dungeness, 1968

Material	Mean concentration of radioactivity, pCi/g (wet)*		Gamma dose-rate, μR/hour; mean and range
	Total beta	^{137}Cs	
Plaice flesh	3.2	0.04	-
Sand	18	-	-
Sand and shingle	-	-	4.5 (3.7-5.5)

*except sand, pCi/g (dry).

Hinkley Point, Somerset

Discharges during 1968 remained low and were little different from those of previous years. Because of this and the good dispersion conditions, no contamination of critical materials was even detectable and public radiation exposure was thus negligible. Traces of cobalt-60, iron-55 and zinc-65 have been found in the seaweed *Fucus vesiculosus* at a position close to the cooling water outfall. This does not, of course, have any direct radiological significance; it is sampled as an indicator material, but its role in this way is now proving to be most valuable. It has made possible an actual estimate of the maximum degree of public radiation exposure, assessed as 0.07 per cent of the ICRP recommended dose limit, and, more important in forward planning, estimates of the actual dilution factors which are effective in the local water mass.

Routine control monitoring of critical materials for this site consists of gamma dose-rate surveys on the foreshore from which samples are also taken for analysis, and sampling of whiting and shrimp flesh. The results of these measurements, and those of the indicator seaweed, are summarized in Table 16.

Table 16 Radioactivity in marine materials and gamma dose-rates over silt in the vicinity of Hinkley Point, 1968

Material	Distance from pipeline outlet (miles)	Mean concentration of radioactivity, pCi/g (wet)*					Gamma dose-rate, μR/hour; mean and range
		Total beta	^{55}Fe	^{60}Co	^{65}Zn	^{137}Cs	
Shrimp flesh	Bridgwater Bay	2.2	-	-	-	0.04	-
Whiting flesh	Bridgwater Bay	3.1	-	-	-	0.06	-
Silt	0	20	-	-	-	0.5	7.5 (6.5-9.0)
F. vesiculosus	1 (east)	7.0	-	-	-	-	-
	0.5 (east)	6.8	-	-	0.2	-	-
	0	7.8	0.8	0.2	1.0	0.3	-
	0.5 (west)	5.7	-	-	-	-	-

*except silt, pCi/g (dry).

Sizewell, Suffolk

This is another site (like Dungeness) where only a very small programme of monitoring is necessary. This is because discharges are still very low and are made to an environment which has good dispersion characteristics. To date, routine discharges from the site have not resulted in any measurable degree of contamination, and public radiation exposure has thus been quite negligible. This is the type of situation where an indicator would normally be included in the monitoring programme and be an important feature. However, the shoreline, which is composed essentially of shingle overlaying patches of sand, does not support growth of any seaweed (which is normally the laboratory's first choice for this purpose), nor has any other suitable indicator been found.

The materials sampled are the potentially critical foodstuffs, local fish and shellfish, and the gamma dose-rate is measured along the shoreline to cover the other potential exposure pathway of external radiation. The results of these measurements are summarized in Table 17. The small concentrations of caesium-137 found in fish are due to fallout and no significant fraction can be attributed to power station discharges.

Table 17 Radioactivity in fish and shellfish and gamma dose-rates over sand in the vicinity of Sizewell, 1968

Material	Mean concentration of radioactivity, pCi/g (wet)		Gamma dose-rate, μR/hour; mean and range
	Total beta	^{137}Cs	
Cod flesh	3.1	0.06	-
Plaice flesh	1.8	0.02	-
Lobster flesh	1.6	0.01	-
Sand	-	-	3.4 (2.8-4.3)

Trawsfynydd, Merioneth

The caesium radionuclides -134 and -137 have now clearly emerged as the critical radionuclides and no other radioactivity from the power station makes any significant contribution to public radiation exposure. Discharges have been minimized by means of treatment plant, and the maximum degree of exposure to any member of the critical group has not exceeded 4 per cent of the ICRP recommended dose limit to the critical organ. Information on the consumption of lake fish, the critical foodstuff, was updated in a new habits survey made in 1968. The overall consumption rate of the heaviest consumers is not substantially different from data obtained previously, but the survey showed that some perch is eaten now in addition to the more popular trout, a factor which had not been quantified before.

The monitoring necessary for basic radiological control purposes consists of sampling trout and perch, whose flesh is analysed for gross beta and gamma radioactivity. Mussels from Portmadoc have again been included for this purpose, although it is now clear that it is the lake fish and not the mussels which constitute the critical material. Radioactivity in the mussels is still at background levels - the only artificial radioactivity being due to fallout - and this material may not be sampled in the future.

A variety of measurements have been made for research purposes and a summary of the data is set out in Table 18, which also includes information of routine monitoring of fish and mussels. The tritium measurements in lake water which feature for the first time in these reports are a typical average for the year, although tritium of power station origin was only present in the lake for a few weeks following a specific disposal. The minimum figure quoted of about 0.5 pCi/ml is due to fallout from weapons testing. The moss *Fontinalis* - used as an indicator - continues to show a wide range of radionuclides, of which some are due to fallout - ruthenium-106, cerium-144, and small parts of the manganese-54 and caesium-137. Cobalt-60, caesium-134 and most of the manganese-54 and caesium-137 are the result of discharges from the power station.

Table 18 Radioactivity in materials in Lake Trawsfynydd and local streams, and in the Glaslyn Estuary, 1968

Material	Sampling site	Concentration of radioactivity, pCi/g (wet)*; mean and range						
		Total beta	^{3}H	^{54}Mn	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce
Water	Lake (cold water intake)	-	0.9 (0.5-5.7)	-	-	-	0.0088 (0.0042-0.032)	-
	Lake (hot water outfall)	-	-	-	-	-	0.0097 (0.0047-0.027)	-
Trout flesh	Lake	12 (6.9-18)	-	-	-	0.9 (0.7-2.4)	9.6 (4.1-18)	-
Perch flesh	Lake	27 (14-40)	-	-	-	2.7 (0.6-5.4)	23 (12-37)	-
Inorganic mud	Lake	36 (28-46)	-	-	-	-	11 (9.4-12)	-
Organic mud	Lake	-	-	-	-	-	12 (6.1-20)	-
Peat	Lake	21 (15-28)	-	-	-	-	8.6 (8.1-9.5)	-
<u>Fontinalis</u>	Afon Prysor (inlet to lake)	11 (8.7-14)	-	1.1 (0.7-1.6)	3.6 (2.5-4.2)	-	0.4 (0.2-0.5)	3.0 (2.7-3.4)
	Gwylan Stream (outlet from lake)	16 (15-17)	-	⨍	4.3 (2.3-6.8)	⨍	4.3 (3.1-4.9)	2.2 (1.6-3.1)
Mussel flesh	Portmadoc	1.5	-	-	-	-	-	-

*except mud and peat, pCi/g (dry); lake water, pCi/ml.
⨍these radionuclides are present but the concentrations cannot be estimated precisely because of mutual interferences: ^{60}Co is also present in <u>Fontinalis</u> collected from the Gwylan Stream.

Wylfa, Anglesey

This will be the largest of the magnox stations; it is now approaching completion and no discharges have been made so far.

Monitoring of this area in 1968 marks the beginning of the pre-operational survey to confirm the important materials and establish reliable sources of samples. In addition it does of course serve to confirm background levels against which to compare future measurements after the power station begins to operate. The critical materials are expected to be local fish, shellfish and silt, the local fishing population being the critical population. Many species of seaweed grow on Anglesey and Porphyra and Fucus vesiculosus are being sampled as indicator species, there being no commercial collection of Porphyra from this area for the laverbread industry.

Results (Table 19) so far show a mixture of natural and fallout radioactivity, with a contribution from Windscale discharges which is a minor fraction in most materials and of no radiological significance in any.

Table 19 Radioactivity in marine materials and gamma dose-rate over silt in the vicinity of Wylfa, 1968; pre-operational data

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	4.8 (4.4-6.1)	-	-	-	-	-
	F. vesiculosus	7.4	-	-	-	-	-
	Lobster flesh	1.7	-	-	0.04	-	-
	Mussel flesh	2.0	-	-	0.02	-	-
	Silt	29	2.7	7.4	2.0	5.2	10 (8-13)
Cemaes Bay	Porphyra	6.7 (5.4-7.6)	-	-	-	-	-
	Winkles	3.2 (2.2-4.0)	-	-	0.05 (0.02-0.07)	-	-

*except silt, pCi/g (dry).

Hunterston, Ayrshire

This station has not discharged much radioactivity so far and, as at Hinkley Point, the only contamination of the environment which has been detected is in an indicator material. Public radiation exposure is thus still at negligible levels. The habits survey for discharges from this site was repeated in 1968: it showed a general decline in the amount of fishing, particularly with regard to the collection of molluscan shellfish, although the maximum values of data used in exposure assessment - consumption rates of marine foodstuffs and time spent on beaches - have not changed substantially.

The principal monitoring in 1968 has consisted of the analysis of sand and the seaweed Fucus spiralis; the latter contains some artificial radioactivity but only the zinc-65 can be definitely correlated with power station operation. Sole flesh has been analysed from the White Fish Authority's Fish Farming Project at Hunterston and the measurements, though made primarily in connection with this development, can be regarded as typical of concentrations in fish from the Firth itself - that is, very low, with as yet no significant contamination from power station discharges. A summary of these measurements is in Table 20.

Table 20 Radioactivity in materials in the vicinity of Hunterston, 1968

Material	Concentration of radioactivity, pCi/g*; mean and range			
	Total beta	^{65}Zn	^{106}Ru	^{137}Cs
F. spiralis	6.8 (6.2-7.4)	0.2 (0.1-0.3)	0.8 (0.6-1.1)	0.3 (0.1-0.5)
Sole flesh	2.4	-	-	0.01
Sand	12 (9.8-15)	-	-	-

*for F. spiralis and sole flesh, pCi/g (wet); for sand, pCi/g (dry).

SITES OPERATED BY THE MINISTRY OF DEFENCE (NAVY DEPARTMENT)

There are now three such sites in the United Kingdom at which the laboratory conducts monitoring surveys to cover the interests of the appropriate Departments, and there is sufficient information from them for it to be worth incorporating a summary in these reports. The dockyards are Crown property, and although discharges are therefore subject to different administrative arrangements from those applying to other sites, the same safety standards are adhered to in waste control with the common aim of ensuring that public exposure does not exceed ICRP recommended dose limits.

HM Dockyard, Chatham, Kent

During 1968 this dockyard was at a pre-operational stage as far as discharges were concerned, and the data quoted in Table 21 are background measurements only.

Table 21 Radioactivity in, and gamma dose-rate over, silt banks in the Medway Estuary, 1968

Station numbers	Material	Concentration of radioactivity, pCi/g (dry); mean and range				Gamma dose-rate, μR/hour; mean and rate
		^{137}Cs	^{238}U	^{40}K	^{232}Th	
101-107, 302, 307	Silt	0.8 (0.4-1.1)	2.8 (1.9-3.4)	14 (8.8-15)	0.9 (0.6-1.1)	5.6 (4.1-7.2)

The critical group is expected to be composed of people who reside in houseboats moored permanently on the shores of the tidal River Medway, to which discharges will be made, and thus the emphasis has been on measuring the gamma dose-rate in these positions. Some shrimp fishing is conducted several miles from the discharge area and is the only fishing activity of any importance in the estuary. This material will also be sampled to check on internal exposure, but assessments taking into account the nature of the effluent predict that this could not be of limiting importance and it is expected that such work will need to make up only a minor part of the monitoring effort.

HM Dockyard, Faslane, Dunbartonshire

The critical pathway for discharges from this base leads to external exposure, the critical group being boatyard workers in working positions on the foreshore. The loch supports no regular commercial fishing, and relative to the occupation of these boatyard workers fish would not be important as a source of exposure even if the loch were to be intensively fished.

Discharges to Gareloch have been very small and the concentrations of cobalt-60 shown in Table 22 are typical of levels in the Clyde generally. The gamma dose-rate measurements are not significantly different from those resulting from natural background, and thus public radiation exposure has been quite negligible.

Table 22 Radioactivity in seabed and gamma dose-rate on the shore of the Gareloch, 1968

Location	Concentration of radio-activity, pCi/g (dry); mean and range		Gamma dose-rate, μR/hour; mean and range
	^{60}Co	^{137}Cs	
Sea bed	0.8 (0.4-1.4)	1.6 (0.6-2.3)	-
Foreshore (silt)	-	-	11 (5-25)

HM Dockyard, Rosyth, Fife

Radiation exposure of the public from discharges from this dockyard is confined to a small group of men working on dredgers which keep the channel and approaches to the dockyard clear of silt. This area of the Firth of Forth does not support fishing and hence no route to internal exposure exists. The critical material is thus the silt, either dredged from the bed of the Firth of Forth or as found on parts of the foreshore to which the public has access.

Measurements made in two phases of 1968 showed a changing pattern as the dockyard began to discharge effluent. The analyses of caesium-137 and natural radionuclides (potassium-40, thorium-232 and uranium-238) quoted in Table 23 make up the normal background level and this was the only radioactivity present in silt for most of the year. The data on cobalt-60 are typical only of a short period late in the year, so that the exposure of the critical group for the whole year was very small - estimated at less than 1 per cent of the ICRP recommended dose limit. Gamma dose-rates at the nearest points to the Dockyard to which the public have access were measured but registered no similar effect of discharges. Measurements were indistinguishable from natural background, and exposure of the remainder of the general public was thus also negligible.

Table 23 Radioactivity in silt in the vicinity of HM Dockyard, Rosyth, 1968

Location	Concentration of radioactivity, pCi/g (dry); mean and range				
	^{60}Co	^{137}Cs	^{40}K	^{232}Th	^{238}U
Dockyard approaches	11 (0.3-51)	0.3 (0.2-0.4)	12 (10-15)	0.8 (0.6-0.9)	3.0 (2.3-3.8)

CHANNEL ISLANDS

A small programme of monitoring has continued for the Channel Islands States to check on possible effects of discharges from the fuel reprocessing plant at La Hague on the mainland of France. The programme has included materials such as fish and silt which, if contaminated, could be involved in direct exposure pathways, but the emphasis has been placed on the seaweed Porphyra, used in this situation entirely as an indicator. The results, summarized in Table 24, show no evidence of the La Hague discharge, and the concentrations of radioactivity quoted are typical of natural levels with a minor contribution from fallout.

Table 24 Radioactivity in materials on the coasts of the Channel Islands, 1968

Material	Sampling area		Concentration of radioactivity, pCi/g (wet)*; mean and range: Total beta	^{137}Cs
Porphyra	Guernsey	Fort Doyle	6.5 (4.4-8.5)	-
		Fermain Bay	7.1 (5.2-9.1)	-
	Alderney	Corbletts Bay	7.3 (5.0-9.9)	-
		Honnaine Bay	6.0 (4.8-8.3)	-
	Jersey	Greve de Lecq	5.8 (4.0-6.9)	-
		La Rozel	5.7 (5.2-6.4)	-
Silt	Guernsey	Bordeaux Harbour	12	-
Skate flesh	Guernsey		-	0.09
Ormer flesh	Guernsey		1.7	-

*except silt, pCi/g (dry)
NOTE: Traces of ^{106}Ru were detected in *Porphyra* samples at different times of the year in the range up to 0.8 pCi/g (wet).

UK SURVEYS

Some monitoring is carried out which has no direct use in exposure assessment of the public, the areas involved embracing much of the coastline of the United Kingdom. The main purpose of these surveys is research; some are associated with specific discharges, though not of course in relation to any critically important exposure pathway, and a few measurements have been made to establish the natural background level of radioactivity in a particular material, choosing a location remote from any discharge point.

DISTANT EFFECTS OF WINDSCALE

Although the only important contamination from Windscale is confined to the coastline within approximately 20 miles of the pipeline, effects of these discharges can be detected for some considerable distance. A variety of indicator materials including those of the foreshore have been sampled, principally around the Irish Sea, but extending northwards further into Scotland. These are summarized in Tables 25 and 26.

Table 25 Radioactivity in seaweed around the Irish Sea and western Scotland, 1968

Seaweed 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	5.9 (4.9-6.8)	0.3 (0.2-0.5)	1.5 (1.1-2.0)	-	-
Port William	8.1 (7.3-8.7)	0.8 (0.4-1.4)	3.7 (2.6-4.5)	-	-
Garlieston	8.8 (5.5-14)	1.1 (0.6-1.6)	3.7 (2.0-6.9)	-	-
St. Helens	5.8 (3.4-7.5)	-	-	-	-
F. vesiculosus					
Port William	9.1 (7.8-10)	1.1 (0.6-1.5)	0.7 (0.4-0.9)	0.2 (0.2-0.2)	-
Garlieston	13 (11-16)	3.1 (1.7-5.8)	1.5 (1.1-1.8)	0.4 (0.2-0.5)	0.6 (0.4-0.7)
Rascarrel Bay	16 (14-20)	4.6 (1.0-9.8)	1.6 (1.4-1.6)	0.5 (0.4-0.7)	1.0 (0.8-1.2)
Heysham	13 (12-15)	-	1.2 (1.0-1.3)	0.5 (0.4-0.6)	0.8 (0.4-1.5)
St. Helens	7.1	-	-	-	-
F. serratus					
Millisle	7.1 (5.5-9.6)	-	-	-	-

Table 26 Radioactivity in foreshore materials around the Irish Sea and western Scotland, 1968

Material and sampling site	Concentration of radioactivity, pCi/g (dry); mean and range				
	Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{144}Ce	^{137}Cs
Silt					
Garlieston	44 (40-50)	10 (2.6-17)	15 (9.0-24)	8.1 (5.0-11)	1.7 (1.5-1.8)
Cutters Pool	62 (40-100)	20 (4.8-43)	32 (16-61)	19 (10-36)	2.3 (1.8-3.1)
Sand					
Heysham	40 (27-63)	-	-	-	-
Fleetwood	9.9 (8.8-11)	-	-	-	-
St. Helens	9.6 (8.0-13)	-	-	-	-

BACKGROUND SURVEYS

There is often need for background reference samples of the biological materials which form part of environmental surveys for specific discharges. In addition to truly natural radioactivity, such as potassium-40 and the heavy radio-elements uranium, thorium and members of their decay series, radioactivity from fallout is still detectable in the aquatic environment generally, and the presence of radionuclides such as caesium-137 can confuse the interpretation of results from, for instance, power station environments to which there are controlled discharges of this same radionuclide.

Most of these background reference samples are taken in the vicinity of the laboratory itself - summarized in Table 27; the only exception included in this table is a sample of Porphyra from Dunbar. This area has been found to be sensitive to fallout, and sampling there has been continued to indicate the proportion of contamination which might be attributed to fallout in areas where there is also a contribution from controlled discharges. During 1968 concentrations of fallout in this seaweed were very small but some ruthenium-106 was noted, probably associated with the testing of nuclear devices by the Chinese Peoples Republic.

Table 27 Radioactivity in background reference materials, 1968

Material	Sampling area	Concentration of radioactivity, pCi/g (wet)*; mean and range		
		Total beta	^{106}Ru	$^{95}Zr/^{95}Nb$
Porphyra	Lowestoft	4.0	-	-
	Dunbar	6.1 (3.5-7.7)	0.3 (0.1-0.6)	0.2 (0.1-0.4)
F. spiralis	Lowestoft	5.4	-	-
Sand	Lowestoft	6.3	-	-

*except for sand, pCi/g (dry).

FALLOUT IN FISH

This is a study which was started some years ago when the rate of deposition of radioactivity from fallout was much higher than now and before it was known whether contamination from this source would become serious. Concentrations in sea water are now declining but, principally because of the long biological hold-up in the food chains to the fish, concentrations in fish have only recently begun to decrease. The fish chosen for this study are commercially important - mainly cod and plaice. They were sampled from the fishing areas IVA and VA of the northern North Sea and Iceland. The Icelandic landings were chosen because this is the largest source of fish for UK consumption. Although landings from the northern North Sea are less important in that sense, they were likely to show higher concentrations of radioactivity because of the effects of surface run-off and a relatively shallow water mass, and the area was therefore included in this study. It was soon found that strontium-90 measurements in the edible parts of the fish were not only small but quite insignificant compared with caesium-137, which is the only fission product of which regular measurements are now made (Table 28).

All these concentrations are very low and have no radiological significance. Public exposure to radiation from eating such fish in 1968 was quite negligible, as it has always been, even when fallout deposition was at its maximum rate.

Mention may also be made here of the analysis of cod from off Cape Farewell, Greenland. This followed public alarm voiced in some quarters following the incident at Thule, Greenland, involving the loss of unexploded H-bombs by a US aircraft. Although an assessment by the laboratory demonstrated conclusively that it was inconceivable that contamination of fish in any of the areas off Greenland fished by British trawlers could reach measurable levels and that no radiological hazard would arise, it was decided to make a measurement of plutonium-239 as a final confirmatory check (Table 28). The result of the analysis was consistent with the effect of fallout and none could be attributed to the Thule incident. Fallout levels of this radionuclide are very small indeed and do not have any significance at all as a source of public radiation exposure.

Table 28 Radioactivity in commercial fish landings in UK ports, 1968

Species	Fishing area	Mean concentration of radioactivity, pCi/kg	
		^{137}Cs	$^{239+240}Pu$
Cod flesh	Northern North Sea (IVA)	0.05	-
	Iceland (VA)	0.03	-
	Cape Farewell (South Greenland)	0.02	$< 1 \times 10^{-4}$
Plaice flesh	Northern North Sea (IVA)	0.05	-
	Iceland (VA)	0.02	-

COASTAL WATER SURVEYS

Probably the most important of the general surveys made by the laboratory involves sea waters of the continental shelf around the British Isles. The principal aim of this work in 1968 has been to study the far-distant effects of major discharges such as Windscale - beyond the areas where such discharges have any significant effect through exposure pathways - to provide scientific data on which to judge allegations of harmful effects from such operations. The results within the Irish Sea show that pronounced variations occur, associated with water movements. The net flow of water is northward and the water which enters at the southern end contains only natural radioactivity and fallout. Concentrations outside the North Channel decrease rapidly with distance and are soon indistinguishable from those of the north-east Atlantic Ocean and the south-western approaches to the British Isles. The enclosed waters of the North Sea show higher values than the open Atlantic, an effect which is due to surface run-off and the shallow nature of these waters, higher values being observed close to the land masses, an effect which is particularly noticeable around the exit from the Baltic Sea.

The results for 1968 are summarized in Table 29 which should be read in conjunction with the map in Figure 1 as a key. These confirm that the radiological consequences both of controlled discharges of radioactivity and of fallout in the seas and ocean around the British Isles are negligible. In addition they show that the controlled discharges make no measurable contribution to concentrations in the open ocean compared with fallout.

Table 29 Concentrations of strontium-90 and caesium-137 in estuarine, coastal and open sea waters, 1968

	Sampling site	Concentration of radioactivity, pCi/litre; mean and range	
		^{90}Sr	^{137}Cs
1	St. George's Channel	0.44	0.42
2	South-west Irish Sea	1.30 (0.89-1.95)	2.1 (1.0-3.4)
3	South-east Irish Sea	3.67 (1.38-7.62)	6.9 (2.1-11)
4	Heysham	2.33 (1.59-4.15)	4.7 (2.3-7.5)
5	North Channel	2.13 (1.68-2.70)	3.7
	North-east Atlantic		
6	Station A	1.84 (1.55-2.63)	3.4 (2.9-4.6)
7	Station B	1.39 (0.80-1.78)	2.6 (1.9-3.4)
8	Station C	0.47 (0.26-1.01)	0.67 (0.34-1.6)
9	Station D	0.26 (0.18-0.39)	0.42 (0.35-0.58)
10	Station E	0.20 (0.14-0.38)	0.38 (0.13-0.46)
11	Dubhartach Ground	1.06	1.4
12	Barra-Ganna Bank	0.35	0.91
13	Solan Bank	0.58	0.83
14	Papa Bank	0.33	0.47
15	Muckle Flugga	0.70	0.67
16	Bressay Ground	0.32	0.40
17	North-west Inflow	0.50	0.96
18	Forth	1.14	0.76
19	Flamborough	0.50	0.69
20	Mid North Sea	0.48	0.71
21	Skagerrak	0.49	0.63
22	Heligoland	0.43	0.80

Table 29 continued

23	Gabbard	0.40	0.77
24	Newhaven-Dieppe	0.43	0.54
25	Channel Islands	0.39	0.60
26	Western English Channel	0.26	0.68

For key to the position numbers see Figure 1.

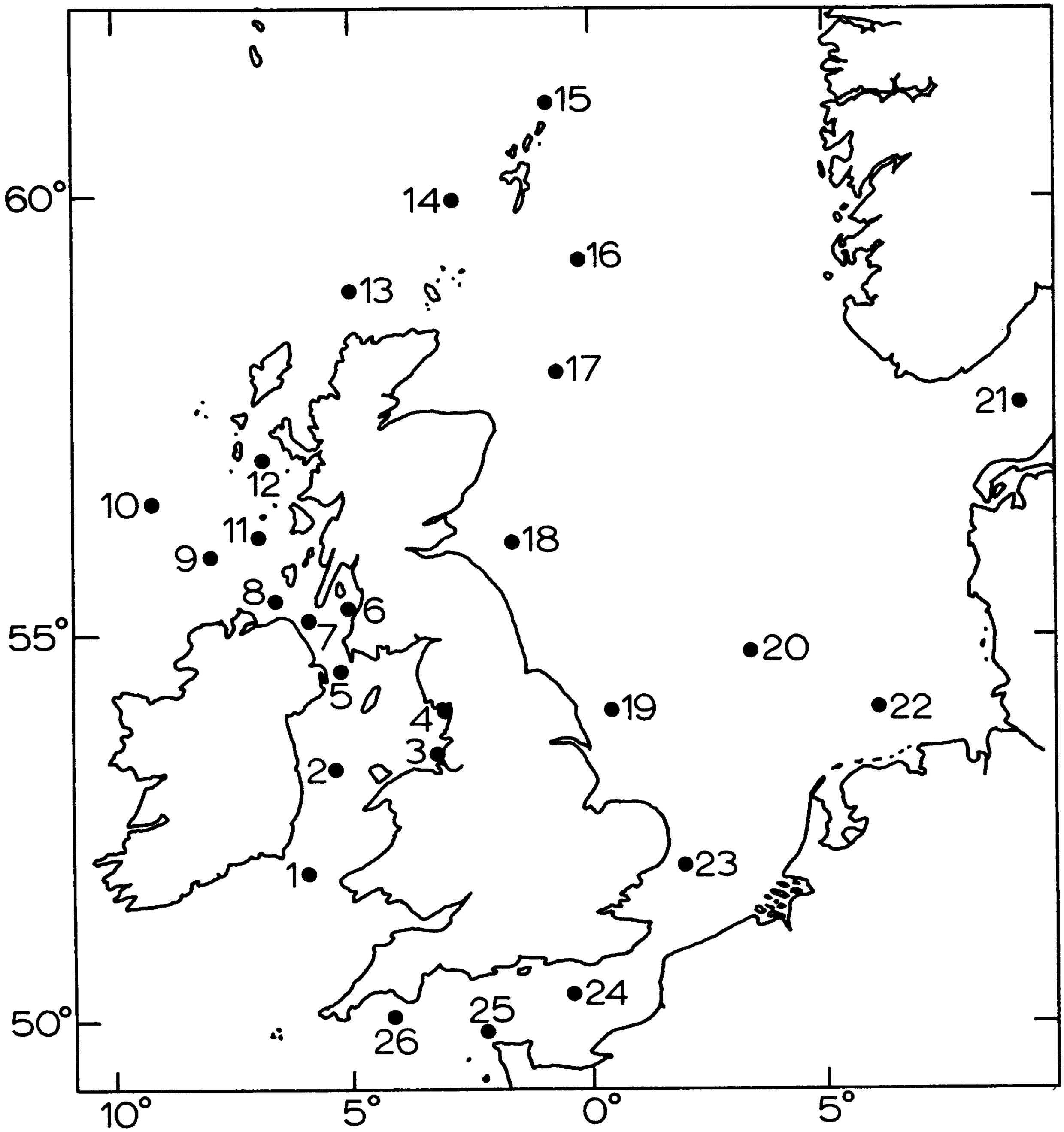

Figure 1 Sampling positions for ^{90}Sr and ^{137}Cs in surface sea water (see Table 29).

DISCUSSION

The use of monitoring data collected by the laboratory has been outlined briefly in previous reports in this series. Their use in the basic work of radiological control, assessing public radiation exposure from planned discharges, is already well known. In some cases where the effect of discharges does not even reach measurable levels, monitoring can achieve no more purpose than proof of the safety of the discharges concerned, but in the few situations where contamination is measurable even routine control monitoring can be put to research use. This is now an important aspect of the environmental work of the laboratory and supplements laboratory-based radiobiological studies, often producing information to be fed back into technical discharge assessments which is not available from any other source. Environments which contain artificial radioactivity offer unique opportunities for ecological research, and some examples of the laboratory's field research programme in 1968 will show how monitoring information has been put to more extensive use than its basic purpose. It will be convenient to discuss these projects in relation to the site whose discharge effects are being utilized in this way.

Windscale

As the largest single discharge in the United Kingdom it is obvious that this will provide considerable opportunities for research, many of which have already been extensively realized. However, the range of radioactive nuclides is small and largely confined at present to fission products, although it is now becoming possible to follow some of the transuranic alpha emitters such as plutonium-239 and -240, americium-241 and curium-242.

The principal research effort in 1968 was to supplement control monitoring with two extensive research vessel cruises in the Irish Sea. From these surveys the budget of artificial radionuclides introduced from Windscale will be made, and estimates of the residence time of radionuclides such as caesium-137 and strontium-90 which behave conservatively will be attempted.

The area of St. Bees Head supports the growth of a number of seaweed species in addition to the edible Porphyra, and a comparative study has been made of the reconcentration of various radionuclides by green, brown and red varieties. Concentration factors appear to decrease in that order, but a further important factor is the extent of tidal immersion.

This area of the Irish Sea has in the past produced a considerable amount of data on concentration factors which has been widely used in site evaluations, and though much of this type of work has now been completed some of it is still in progress. Following the discovery of some native oysters off St. Bees Head during a trawl for plaice, a project has been started to follow the uptake of fission-product radioactivity by oysters, using full-grown animals in cages above the sea bed. This should yield useful data which are not available from work in the Blackwater Estuary, where the radioactivity found is mainly due to neutron activation. In Table 30 are shown typical results which give an idea of the radionuclides that can be found in oysters living in this environment. It is in conjunction with this project and the seaweed experiment that the seawater analyses summarized in Table 6 have been made.

Table 30 Radioactivity in native oysters dredged from the north-east Irish Sea

Radionuclide	Mean concentration pCi/g (wet)
^{55}Fe	0.07
^{65}Zn	1.8
$^{95}Zr/^{95}Nb$	1.2
^{106}Ru	6.5
^{110m}Ag	2.3

Radioactivity from Windscale discharges can easily be measured in sediments in the Ravenglass Estuary, analyses of which have been quoted earlier (Table 3). This has enabled concentration factors to be evaluated for most of the gamma-emitting radionuclides disposed of from Windscale, in a range of sediment types from beach sand to estuarine silt. A study has also been made of the distribution of the different radionuclides with depth.

Other work with plaice has involved direct measurement of the dose received, by marking adult fish with a modified Petersen type identification tag incorporating a lithium fluoride dosimeter, and some laboratory work with plaice eggs to evaluate doses received by the egg, by measuring the distributions of particular radionuclides in controlled experiments. All this work on plaice supports the view that the radiation dose is not such as to be dangerous to the fish at any stage in its development and the measurement of the actual doses received is of particular value. In addition, a study of plaice chromosomes has been set up as a further check on the adequacy of waste control measures.

Winfrith

Discharges of radioactivity from this site have been so low that until 1968 no environmental contamination was even detectable, and in consequence the area offered no opportunities for field research. Most of the 1968 discharges were relatively isolated, and those which contained iodine-131 were used to provide information on dispersion from what was effectively a pulse of radioactivity. The factors necessary to plan the siting of the outfall off Arish Mell were evaluated in 1958 by an experimental programme, Exercise Mermaid(5), using Amino G acid as a "dye" tracer. These iodine-131 discharges in 1968 have provided the first opportunity to check the conclusions of this work. Exercise Mermaid showed that adequate dilution of the effluent could be achieved within Weymouth Bay, and the results indicated that a further very great dilution would occur when the water was mixed within the races off Portland and St. Albans Head.

The dispersion study was constructed around seaweed sampling because this material provided an easy means of estimating much lower concentrations in the sea water, direct measurements on which would have presented considerable analytical difficulties. Most of the brown seaweeds concentrate iodine-131 to useful degrees (up to factors of 10^4) and biological equilibrium is rapidly attained, so that the seaweeds are useful indicators of changes in the water mass and follow these changes faithfully. Figure 2 shows typical results of seaweed surveys following two specific pulsed releases. Other work, on samples collected 29 km from the pipeline, showed that dispersion was essentially "diffusion velocity" controlled, fitting the Joseph and Sendner model(6) with a coefficient of 1 cm sec^{-1}, and thus that in certain, though possibly not all, conditions the St. Albans race has no effect.

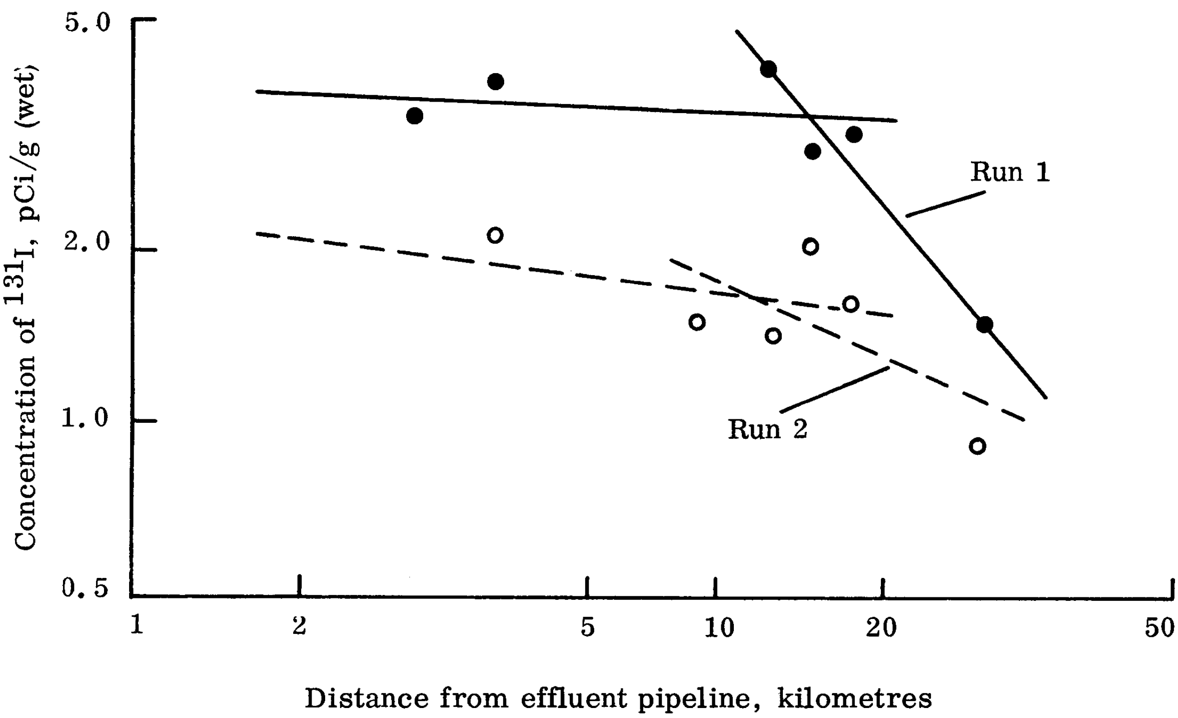

Figure 2 Distributions of ^{131}I in Laminaria digitata in the vicinity of Winfrith.

This work has been of obvious value in the assessment of the Winfrith environment, but it has been even more useful because one of the radionuclides involved in the discharges happened to be iodine-131. This is the radionuclide most likely to be limiting in any nuclear emergency, and these discharges have provided a means of obtaining the information on dispersion from accidental releases to the aquatic environment needed for emergency planning.

Bradwell

Research opportunities offered by discharges from this site have been confined to oysters. Radiological monitoring has shown that considerable variations exist in the concentration of several radionuclides in oysters within the estuary, as will be evident already from the data in Table 13 and from data recorded in previous reports in this series. The variation with distance differs from one radionuclide to another, and, according to such behaviour, radionuclides can be divided into two classes. Caesium-137, silver-110m and phosphorus-32 are relatively evenly dispersed radionuclides which are associated with the aqueous phase and not to any great extent with particulate matter. The behaviour of zinc-65, iron-55 and cobalt-60 is in sharp contrast; for these there is a rapid attenuation of concentration with distance from the discharge point, both along the estuary and (particularly) across it. This points to a strong association of these radionuclides with particulate matter.

The Bradwell discharges have also provided an opportunity for a further study of the rates of uptake and loss of zinc-65, which is being supported by laboratory investigations on tissue distribution.

Trawsfynydd

This power station has posed entirely new problems to the laboratory because it is the first in the UK to discharge effluent to a freshwater environment.

The principal research in Trawsfynydd Lake, apart from monitoring, has been concerned with studies of the uptake of radiocaesium by trout and perch and the mechanism by which radioactivity reaches the fish. This is the main reason for the measurements of caesium-134 and -137 in lake water and bed materials quoted in Table 18. The tritium measurements quoted were also made for research purposes, following a specific isolated discharge which gave an opportunity to evaluate the turnover time of the lake and the rate of recirculation of water through the power station.

CONCLUSIONS

The laboratory has continued to monitor the effects of radioactive waste discharges to the aquatic environment of the United Kingdom. Results of routine monitoring, supported by more extensive information of a research nature, show that in 1968 radiation exposure of the public was within internationally acceptable levels at all sites. In many cases no radiation exposure of the public due to waste disposal could be detected, and the control of waste discharges was achieved with complete safety everywhere.

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