MINISTRY OF AGRICULTURE, FISHERIES AND FOOD

FISHERIES RADIOBIOLOGICAL LABORATORY

RADIOACTIVITY IN SURFACE AND COASTAL WATERS OF THE BRITISH ISLES

TECHNICAL REPORT FRL 1

LOWESTOFT
SUFFOLK

OCTOBER
1967

In this report, the first of a series dealing with the work of the Fisheries Radiobiological Laboratory, Lowestoft, Neil Mitchell describes the arrangements made by the Ministry of Agriculture, Fisheries and Food to ensure the safe disposal of radioactive waste to surface waters and the sea. He shows clearly that the discharge of radioactive wastes in this manner is completely safe. The greatest care is exercised to ensure that at each and every one of the sites where radioactivity is present in wastes the most stringent precautions are taken to safeguard the public.

It is our policy to publish the results of our surveys, so as to assist in creating an informed climate of public opinion in which the peaceful uses of nuclear energy may be fully exploited.

H. A. Cole
Director of Fishery Research

CONTENTS

Figure 1 Major sources of aqueous radioactive wastes.

INTRODUCTION

The Fisheries Radiobiological Laboratory, Lowestoft provides the technical support and advice for the control, by the Minister of Agriculture, Fisheries and Food, of liquid radioactive waste discharged to surface waters and the sea. A considerable proportion of the Laboratory's effort is devoted to monitoring of the aquatic environment as final proof that the control exercised is adequate. The object of this report is to summarize most of the information arising from this monitoring programme for 1966 and, for comparison, data are also presented for the years 1963-65 where available and appropriate.

The Minister's responsibilities under the Radioactive Substances Act 1960 are limited to major nuclear sites - that is, those which are either operated by the United Kingdom Atomic Energy Authority (U. K. A. E. A.), or are licensed nuclear sites, such as the nuclear power stations of the Central Electricity Generating Board (C. E. G. B.). These commitments relate to England and Wales only; at similar sites in Scotland monitoring is carried out on behalf of the Departments of the Scottish Office who have similar responsibilities under that Act. Further monitoring is done in the Channel Islands for the Channel Island Authorities. Not all major nuclear sites feature in the Laboratory's monitoring programmes; in particular, most of those which are situated inland and discharge to inland waterways do not give rise to any potential aquatic hazards in the sphere of fisheries interests. Inland sites are more commonly considered in relation to the use of water for drinking or for agricultural purposes. A notable exception to this generalization is the C. E. G. B. nuclear power station on the shore of Lake Trawsfynydd, Merioneth.

The range of sites where the Laboratory has commitments can be seen from Figure 1. Monitoring of these environments varies considerably from site to site and in different phases of pre- and post-operation. Monitoring programmes are designed with two main objectives, the first being to establish that members of the public are not at risk, as a result of the operations of these sites, to any greater extent than that regarded as acceptable by the International Commission on Radiobiological Protection (I. C. R. P.) and endorsed by the Medical Research Council. Where environmental contamination is measurable the aim is to quantify the degree of this exposure. The second aim, in which the work of the Laboratory goes beyond the programmes required of the operators by the Ministry, is to provide environmental data for revising site assessments which set out to calculate maximum permissible discharge limits. In this latter context the range of materials monitored is often wider than that necessary to demonstrate public safety, and this work also includes measurements which have no direct connection with exposure of the public. For instance, the radioactivity of non-edible seaweeds and other materials may be a useful indicator of certain radionuclides, and can give valuable advance warning of the presence of such nuclides in the water mass before they are detectable in critical materials.

The extent of discharges varies widely; Figure 2 shows the quantities released in 1966 from United Kingdom establishments, and compares these with the maximum authorized limits. The magnitude of each discharge is not, by itself alone, an indication of the potential degree of exposure in the environment of the site concerned, but must be examined in relation to many factors: among them are the conditions controlling dispersion and dilution, and those which determine the extent to which the more important constituent radionuclides are concentrated by physical and biological materials. The authorized limit does not in any way signify a maximum safe limit. Whilst the former is never greater than the latter, it is also subject to the requirements of the operator, which are frequently represented by a discharge rate that is very much less than the maximum rate at which each environment could safely accept radioactive waste of this nature.

The design of monitoring programmes to demonstrate public safety depends on the concept of a critical group of the population - that fraction which is subject to the greatest degree of exposure as a result of the discharge from a particular site. This, first of all, requires the identification of the most important ("critical") pathways to exposure and the critical materials involved. These concepts and their implications have recently been discussed by Preston(1). No two situations are identical: the variety of materials monitored and the relative emphasis laid upon them illustrate this point. The important factors at the U.K.A.E.A. and nuclear power station sites are summarized in Table 1. The critical population is frequently, though not invariably, found close to the site, a particular exception to this being the laverbread-eating population of South Wales in relation to the Windscale discharge. The two routes to exposure - internal, by consumption of aquatic foodstuffs, or external, by contamination of the terrain - are often important simultaneously to the same critical group. Such a situation is encountered at a number of sites, where the critical group consists of the local fishermen and their families, who eat the greatest amount of locally-caught fish. In addition, the fishermen are subject to external exposure as a result of working on affected beaches, or through the handling of nets contaminated by radioactive silt which results in a beta dose to the hands. In other situations the external hazard may be entirely one of gamma radiation.

The types of analysis necessary vary according to the discharge and the site. A total beta measurement is generally made and is useful as a screening method for early recognition of unusual levels of some forms of radioactivity. The total beta measurements quoted in this report all refer to infinitely-thick samples counted under end-window GM assemblies against potassium chloride as standard. Hence, many isotopes whose energies are lower than that of ^{40}K will be under-estimated by this method and only a few with higher energies, such as ^{106}Ru, will be over-estimated. However, a transition is now taking place to very thin sources counted in a proportional counter, where the energy dependence is much less, and results by this method will, it is expected, feature in future reports.

More specific analyses are made for critical nuclides and others of exceptional interest. Analytical methods will not be discussed here in detail, being based on standard techniques; they will be set out in subsequent reports which will be published in this series. Many requirements can be filled by gamma spectrometry - for example, the estimation of ^{106}Ru, $^{95}Zr/^{95}Nb$, ^{65}Zn and ^{137}Cs. Others, such as ^{90}Sr and ^{144}Ce, are catered for by specific radiochemical analyses.

Many of the measurements, especially in the more slightly contaminated environments, show only natural radioactivity - chiefly ^{40}K and the natural uranium and thorium series. No data are presented on these natural radio-elements, since the Laboratory is only concerned, in respect of its monitoring work, with exposure as a result of wastes discharged. The dose limits proposed by I. C. R. P. are over and above the exposure received from the natural background. However, much information on these radionuclides is obtained from analyses for other nuclides and is often of considerable value. For instance, ^{40}K is useful as a direct measure of the salinity of sea water, and also provides a guide to the condition of many of the materials which are sampled.

Throughout the tables of this report the figures normally quoted are arithmetic means of samples collected throughout the year, the figures quoted in parentheses being the range found. The latter is occasionally omitted, due to too few samples being available to offer a meaningful range. Absence of a figure does not imply that the nuclide or fraction was itself absent but, more often, that no measurement of this particular constituent was made.

Site	Authorization: Radioactivity	Authorization: Curies/year
Windscale	Total Beta	300 000
	Ruthenium-106	60 000
	Strontium-90	30 000
	Total Alpha	1 800
Winfrith	Total Alpha	1 200
	Ruthenium-106	9 000
	Strontium-90	1 200
	Total activity	30 000
Springfields	Total Alpha	360
	Total Beta	12 000
Aldermaston	Total activity	156
Harwell	Total activity	240
Amersham	Total activity	72
	Tritium	400
Berkeley	Total activity	200
	Tritium	1 500
Bradwell	Zinc-65	5
	Total activity	200
	Tritium	1 500
Hinkley Point	Total activity	200
	Tritium	2 000
Trawsfynydd	Total activity	40
	Tritium	2 000
Dungeness	Total activity	200
	Tritium	2 000
Oldbury		
Sizewell	Total activity	200
	Tritium	3 000
Dounreay	Total Alpha	190
	Total Beta	19 000
	Strontium-90	1 900
Chapelcross	Total activity	90
	Strontium-90	0.45
Hunterston	Total activity	200
	Tritium	1 200

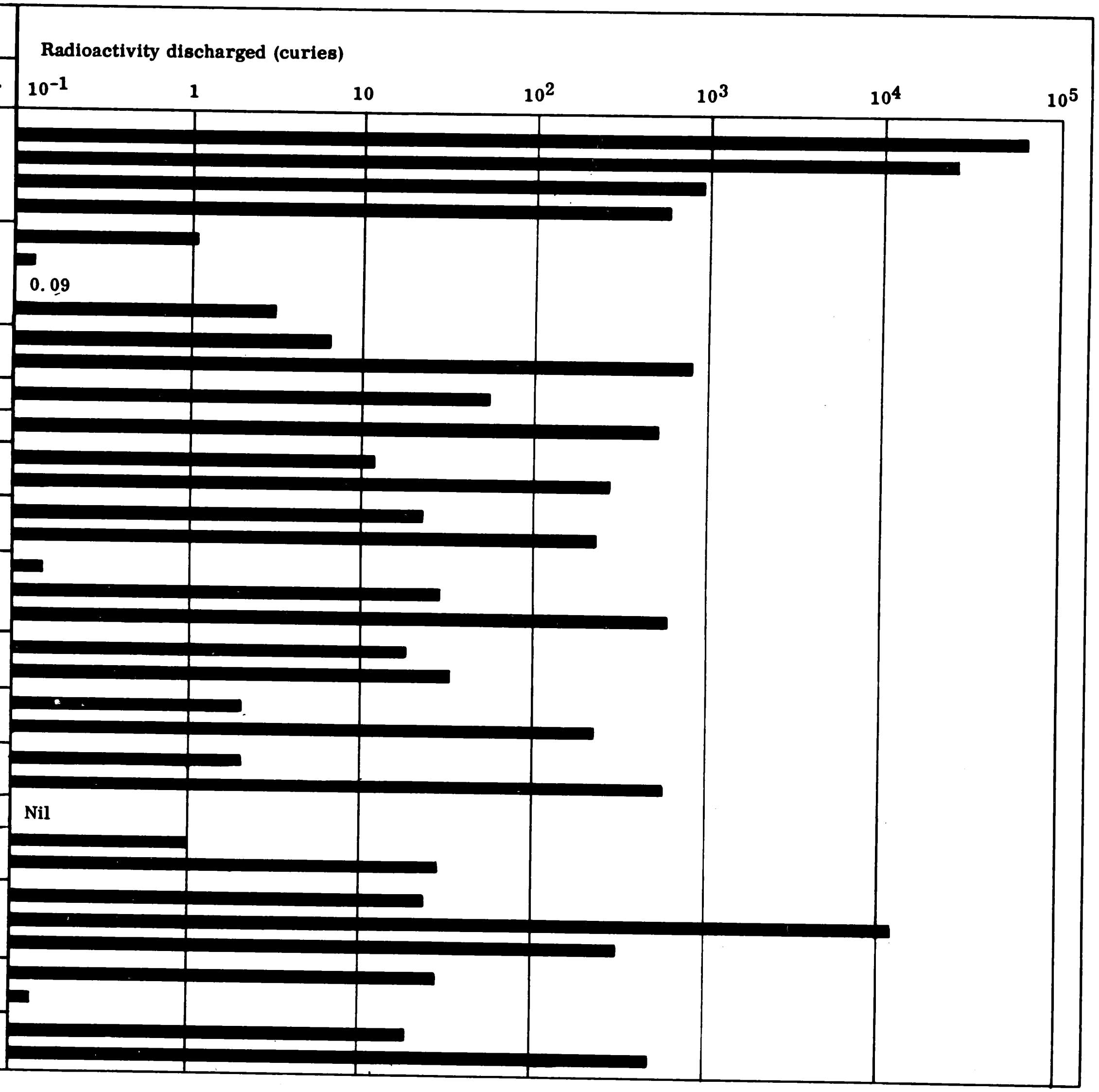

Figure 2 Major discharges of liquid radioactive wastes to surface and coastal waters during 1966.

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

Site	Critical material	Critical exposure category	Exposed group
1. ENGLAND & WALES			
U.K.A.E.A.			
Windscale	Porphyra (laverbread)	Beta dose to G.I. tract	General public (S. Wales)
Winfrith	Lobster and crab flesh	Beta dose to G.I. tract	Local fishermen and families
Springfields	Silt	Gamma dose to whole body	Dredgermen (Preston Docks and Harbour Board)
Aldermaston, Harwell, Amersham	Drinking water	Beta-gamma dose to gonads (genetic hazard)	General public (Greater London)
C.E.G.B.			
Berkeley	Silt	Gamma dose to whole body	Salmon fishermen
	Shrimp and salmon flesh	Beta dose to G.I. tract	Local fishermen and families
Bradwell	Oyster flesh	Gamma dose to whole body	Oyster fishermen and families
Hinkley Point	Flatfish and shrimp flesh	Beta dose to G.I. tract	Local fishermen and families
	Silt	Gamma dose to whole body	Local fishermen
Trawsfynydd	Trout flesh	Beta dose to G.I. tract	Local fishermen and families
Dungeness	Fish flesh	Beta dose to G.I. tract	Local fishermen and families
	Silt	Gamma dose to whole body	Bait diggers
Oldbury	Silt	Gamma dose to whole body	Salmon fishermen
	Shrimp and salmon flesh	Beta dose to G.I. tract	Local fishermen and families
Sizewell	Fish flesh	Beta dose to G.I. tract	Local fishermen and families
2. SCOTLAND			
U.K.A.E.A.			
Dounreay	Detritus (salmon fishing net)	Beta dose to hands	Local fishermen
	Beach sludge	Gamma dose to whole body	Local fishermen and others
Chapelcross	Shrimp flesh	Beta dose to G.I. tract	Local fishermen and families
	Sea shore	Gamma dose to whole body	Winkle collectors
S.S.E.B.			
Hunterston	Fish flesh	Beta dose to G.I. tract	Local fishermen and families
	Sea shore	Gamma dose to whole body	Winkle collectors

G.I. tract - gastro-intestinal tract.

UNITED KINGDOM ATOMIC ENERGY AUTHORITY SITES

Windscale and Calder, Cumberland

With its relatively long history of receiving radioactivity from this site, the Irish Sea off the Cumberland coast is probably the best understood of the environments monitored by the Laboratory. Nevertheless, since this is by far the largest single discharge in the United Kingdom, monitoring and other studies in relation to this site make up a major proportion of the Laboratory's effort.

The discharge is complex and, whilst somewhat variable in composition, isotopes of ruthenium, zirconium and niobium are the dominant constituents. As is well known, the seaweed *Porphyra umbilicalis* is the critical material, through its use for the production of the foodstuff "laverbread", eaten in substantial quantities in South Wales. In this context ^{106}Ru is the critical nuclide, though for certain much smaller groups of the public in the vicinity of the Windscale site external exposure from contamination of silt is the critical pathway, and both ^{106}Ru and $^{95}Zr/^{95}Nb$ are of major importance. Much of this coastline is relatively free from silt, and the most important places where the shoreline is contaminated are estuaries where silt is trapped.

Porphyra is monitored regularly (Tables 2-4), with particular emphasis on the areas where it is harvested, so that the actual dose to the gastro-intestinal tract of eaters of laverbread can be estimated. In addition to ^{106}Ru, other fission products are measured. By extensive monitoring, particularly from 1959 onwards, a relationship of ^{106}Ru concentrations in *Porphyra* with distance from the outfall has been built up. Figure 3 illustrates this and is based on data collected from 1959-66(3). In this figure the influence of climatic conditions is illustrated by plotting the 1959 data separately; this year was notable for very slow dispersion, due to the exceptionally fine calm summer.

More recently, regular monitoring of silt in specific locations has been instituted (Table 5), following the change in the Windscale effluent composition (increasing the proportion of $^{95}Zr/^{95}Nb$) brought about by the commissioning of the new fuel processing plant in 1964. Measurements of ^{106}Ru at these and more distant locations have been used to establish the relationship shown in Figure 4(4), and a similar relationship has been established for $^{95}Zr/^{95}Nb$ in silt at the same sampling points.

The principal marine foodstuff at Windscale, after *Porphyra*, is plaice, which is fished predominantly in the pipeline area. Concentrations in plaice flesh are not large for any nuclide and this exposure pathway is of minor importance, but measurements are made from time to time for this and other species of fish (Table 6), the dominant nuclide being ^{137}Cs. Shellfish are also found locally - limpets, winkles, mussels and shrimps (Table 6).

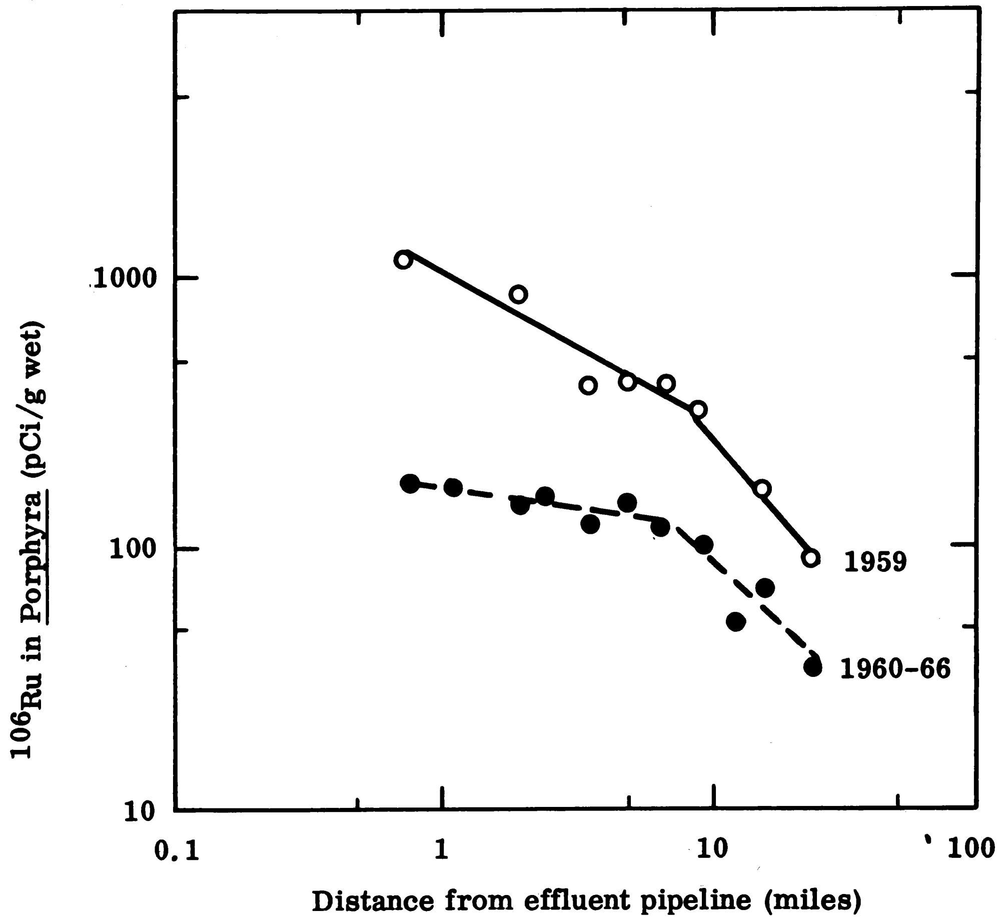

Figure 3 The concentration of Ruthenium-106 in Porphyra as a function of distance from the Windscale effluent pipeline.

Measurements are also made of certain non-critical materials; these include seawater monitoring, which has occasionally been extended to points well out to sea. The notable feature of this (Table 7) is the way in which concentrations decrease with distance offshore to a greater extent than with distance along the coast from the sea pipeline. Various Fucus seaweeds are collected (Tables 3 and 8) and occasional seabed samples are taken (Table 9), the latter in relation to seawater sampling.

As can be seen from Figures 3 and 4 the effect of the discharge can be detected over considerable distances, though it should be emphasized that such measurements are of no radiological significance in terms of public health. In this category fall sand and seaweed measurements along distant coasts of the Irish Sea (Tables 10 and 11); Tables 12 and 13 contain measurements on seaweeds at specific background locations, chosen for their remoteness from Windscale in order to establish the normal concentration of radioactivity which is not due to Windscale discharges. Whilst most of the non-Windscale activity in the distant Irish Sea samples is due to ^{40}K, a fraction of the content of artificially produced radioactivity, quite appreciable in the earlier years covered by this report, is due to fallout from weapons-testing. Recent measurements of fallout nuclides in seaweeds are collected together in Table 13.

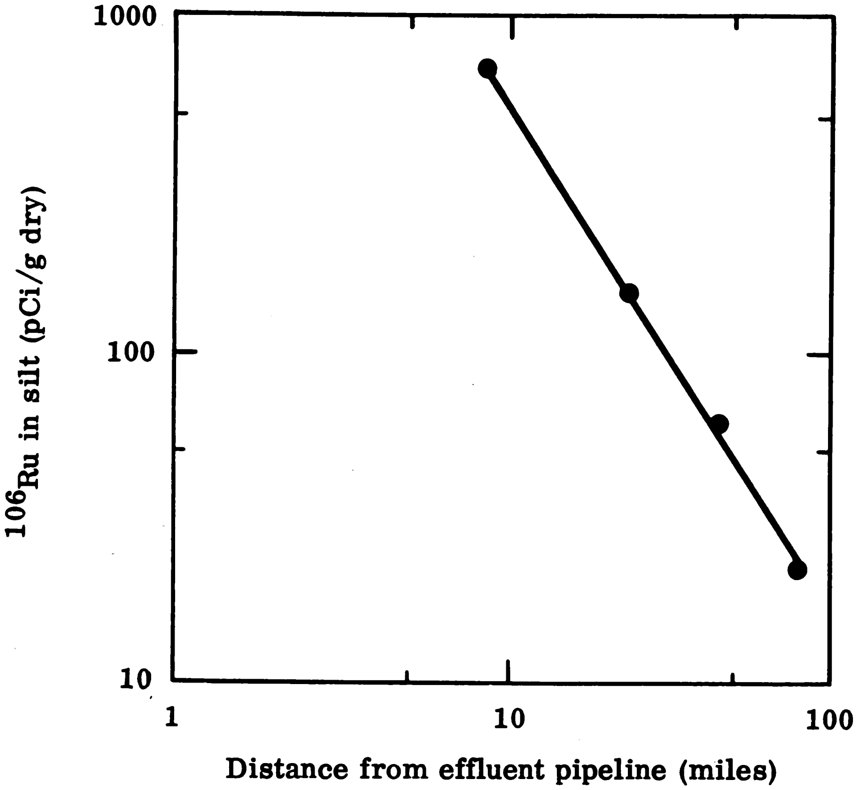

Figure 4 The concentration of Ruthenium-106 in silt as a function of distance from the Windscale effluent pipeline.

Table 2 Total beta, zirconium-95/niobium-95 and ruthenium-106 in Porphyra in the immediate vicinity of Windscale, 1963-66

Sampling site	Distance from pipeline zero (miles)	Concentration of radioactivity, pCi/g (wet); mean and range											
		Total Beta				$^{95}Zr/^{95}Nb$				^{106}Ru			
		1966	1965	1964	1963	1966	1965	1964	1963	1966	1965	1964	1963
Dubmill Point	32.0	25 (7.1-42)	26 (8.0-65)	52 (28-79)	55 (13-110)	2.0 (0.1-8.7)	2.7 (0.3-9.6)	1.2 (0.2-9.3)	1.8 (0.4-5.2)	11 (3.0-19)	13 (4.4-33)	22 (10-32)	24 (6.0-40)
Maryport	25.5	31 (16-45)	20 (6.4-50)	57 (31-122)	69 (23-122)	2.3 (0.4-11)	2.2 (0.5-6.6)	1.7 (0.2-8.5)	1.8 (0.4-2.8)	14 (6.9-21)	10 (4.3-27)	23 (10-48)	29 (15-52)
St. Bees	6.2	213 (95-353)	155 (79-241)	222 (120-317)	304 (85-518)	23 (3.2-78)	27 (5.0-55)	22 (0.2-76)	2.3 (0.8-4.5)	91 (41-143)	76 (40-127)	100 (55-145)	116 (35-205)
Nethertown	3.5	302 (190-503)	264 (166-381)	357 (208-575)	432 (184-810)	33 (3.0-71)	32 (10-76)	25 (0.2-106)	3.2 (0.2-9.2)	131 (90-219)	122 (65-262)	161 (96-216)	180 (66-334)
Braystones North	2.3	310 (162-595)	266 (109-509)	471 (264-822)	487 (123-981)	24 (2.7-71)	30 (4.0-124)	26 (0.2-115)	2.7 (0.2-7.0)	137 (67-288)	131 (45-285)	223 (118-366)	198 (47-368)
Braystones South	1.2	278 (174-402)	358 (202-503)	541 (382-859)	652 (322-960)	19 (2.7-41)	39 (8.8-197)	32 (0.4-118)	4.2 (0.8-12)	123 (64-184)	170 (92-240)	259 (172-378)	249 (111-336)
Sellafield pipeline zero	0	336 (147-579)	340 (149-623)	482 (110-778)	641 (469-875)	34 (2.3-96)	50 (5.7-249)	59 (0.2-343)	2.9 (0.7-10)	148 (74-242)	163 (68-319)	229 (62-398)	248 (180-341)
Sellafield Bailey Bridge	0.9	330 (181-638)	327 (186-579)	354 (96-517)	584 (177-771)	35 (3.4-130)	47 (7.4-240)	33 (0.8-133)	3.8 (0.6-9.2)	146 (74-269)	157 (82-299)	181 (46-322)	222 (77-301)
Seascale	1.9	288 (115-604)	296 (175-637)	342 (162-698)	405 (117-669)	27 (3.0-109)	52 (7.7-292)	72 (0.9-247)	4.2 (0.8-7.4)	126 (39-270)	141 (78-297)	170 (77-306)	178 (71-243)
Drigg Barnscar	3.5	396 (125-673)	294 (141-474)	397 (91-684)	514 (206-791)	27 (2.4-83)	30 (3.5-104)	30 (0.4-76)	2.7 (0.3-6.3)	174 (53-294)	145 (64-249)	190 (44-362)	209 (77-331)
Drigg Rabbit Warren	5.0	333 (52-491)	282 (169-419)	321 (149-478)	436 (192-684)	18 (3.3-28)	24 (7.1-93)	32 (0.2-104)	2.5 (0.9-6.6)	151 (21-220)	135 (79-192)	159 (69-282)	172 (68-266)
Eskmeals North	6.8	261 (129-450)	275 (160-431)	389 (258-695)	395 (199-645)	15 (3.4-34)	21 (5.8-102)	17 (0.9-76)	3.0 (0.2-6.4)	122 (59-213)	131 (82-206)	178 (106-289)	148 (75-267)
Eskmeals South	8.9	235 (93-429)	197 (73-346)	294 (158-397)	379 (184-560)	15 (2.3-77)	17 (3.6-56)	27 (0.7-78)	2.0 (0.2-4.4)	104 (40-200)	96 (32-181)	137 (78-194)	145 (72-208)
Gutterby	12.5	217 (146-287)	163 (83-280)	227 (141-330)	272 (153-386)	11 (3.4-33)	13 (4.5-24)	15 (0.2-51)	2.7 (0.2-6.9)	97 (65-131)	79 (37-146)	103 (18-123)	106 (55-165)
Walney Island	24.0	66 (35-107)	62 (44-123)	100 (48-254)	118 (62-189)	5.0 (1.2-14)	7.0 (2.1-16)	5.2 (0.2-25)	2.0 (0.2-5.6)	31 (18-58)	29 (20-60)	47 (21-100)	46 (24-78)

Table 3 Strontium-90 in seaweeds in the immediate vicinity of Windscale, 1963-66

Seaweed	Sampling site	Concentration of ^{90}Sr, pCi/g (wet)			
		1966	1965	1964	1963
Porphyra	Nethertown	-	0.019	0.024	0.028
	Sellafield Bailey Bridge	-	0.017	0.037	0.045
	Seascale	-	0.014	0.038	0.048
	Drigg Barnscar	-	0.011	0.027	0.039
	Walney Island	-	-	0.038	0.014
F. vesiculosus	St. Bees	0.20	-	-	-
	Nethertown	-	0.10	-	-
	Sellafield Bailey Bridge	-	0.08	-	-
	Seascale	0.30	0.26	-	-
	Drigg Barnscar	-	0.07	-	-
	Gutterby	0.22	-	-	-
	Walney Island	0.25	0.18	-	-

Table 4 Total alpha and cerium-144 in Porphyra in the immediate vicinity of Windscale, 1963-66

Sampling site	Concentration of radioactivity, pCi/g (wet)					
	Total Alpha				^{144}Ce	
	1966	1965	1964	1963	1966	1965
Nethertown		0.7	0.6	0.3		
Braystones North		-	-	-		
Braystones South		-	-	-		
Sellafield pipeline zero	0.9	-	-	-	5.7	1.7
Sellafield Bailey Bridge		0.6	0.4	-		
Seascale		0.6	0.5	0.3		
Drigg Barnscar		0.5	0.3	0.2		
St. Bees		-	-	-		
Eskmeals North	0.8	-	-	-	3.8	1.0
Eskmeals South		-	-	-		
Gutterby	0.5	-	-	-	1.5	0.7
Walney Island	0.2	0.1	0.1	0.1	0.5	0.2

Table 5 Radioactivity in silt and sand, and gamma radiation dose-rates over silt in the vicinity of Windscale, 1963-66

Material	Sampling site	Concentration of radioactivity, pCi/g (dry); mean and range								Gamma dose-rate, μR/hr	
		Total Beta		$^{95}Zr/^{95}Nb$		^{106}Ru		^{144}Ce			
		1964	1963	1966	1965	1966	1965	1966	1965	1966	1965
Silt	Eskmeals	-	-	742 (286-1143)	755 (328-1228)	742 (550-893)	750 (643-891)	377 (260-527)	213 (164-293)	134 (90-180)	172 (70-225)
	Walney Island	-	-	165 (12-534)	265 (41-1036)	146 (47-338)	162 (56-439)	69 (20-160)	63 (18-221)	39 (20-73)	66 (27-125)
Sand	St. Bees	37 (33-41)	-	-	-	-	-	-	-	-	-
	Sellafield pipeline zero	-	74 (58-84)	-	-	-	-	-	-	-	-
	Seascale	54 (36-71)	54 (37-65)	-	-	-	-	-	-	-	-
	Drigg Barnscar	62 (43-81)	-	-	-	-	-	-	-	-	-
	Walney Island	-	26 (19-33)	-	-	-	-	-	-	-	-

Table 6 Radioactivity in fish and shellfish flesh in the vicinity of Windscale, 1963-66

Species	Sampling site	Concentration of radioactivity, pCi/g (wet); mean and range							
		Total Beta				^{137}Cs			
		1966	1965	1964	1963	1966	1965	1964	1963
Plaice flesh 2-3 years	Pipeline outfall	3.7	-	3.7 (3.4-4.0)	4.4 (3.2-5.2)	0.6	-	0.5 (0.4-0.6)	0.5 (0.4-0.6)
Plaice flesh 3-4 years	Pipeline outfall	4.5 (3.8-5.2)	3.6 (3.1-4.2)	4.2	3.7 (3.1-4.2)	0.7	0.8 (0.7-0.8)	0.7 (0.6-0.9)	0.5 (0.4-0.9)
Whiting flesh	Pipeline outfall	2.6	-	-	-	0.9	-	-	-
Cod flesh	Pipeline outfall	3.7	-	-	-	0.5	-	-	-
Skate flesh	Pipeline outfall	-	1.8	-	-	-	0.6 (0.4-0.8)	-	-
Limpet flesh*	St. Bees	168 (63-367)	151 (64-260)	146 (86-296)	141 (55-332)	-	-	-	-
Winkle flesh	St. Bees	296 (118-614)	231 (90-1009)	149 (59-208)	315 (48-614)	-	-	-	-
Mussel flesh	Braystones	391 (138-1076)	305 (111-724)	368 (205-565)	440 (217-807)	-	-	-	-
Whole shrimps**	Braystones	-	95 (46-172)	12 (10-17)	-	-	-	1.3 (0.4-1.6)	-

* Sampled in 1963 at Seascale
**Sampled in 1964 at Seascale.

Table 6 continued

Species	Sampling site	Concentration of radioactivity, pCi/g (wet); mean and range								
		$^{95}Zr/^{95}Nb$				^{106}Ru				^{90}Sr
		1966	1965	1964	1963	1966	1965	1964	1963	1965
Plaice flesh 2-3 years	Pipeline outfall	-	-	-	-	0.7	-	0.2 (0.1-0.4)	0.3 (0.1-0.6)	-
Plaice flesh 3-4 years	Pipeline outfall	-	-	-	-	0.7	0.6	0.3 (0.1-0.6)	0.3 (0.1-0.8)	0.006
Whiting flesh	Pipeline outfall	-	-	-	-	-	-	-	-	-
Cod flesh	Pipeline outfall	-	-	-	-	-	-	-	-	-
Skate flesh	Pipeline outfall	-	-	-	-	-	0.1	-	-	0.006
Limpet flesh*	St. Bees	23 (4.1-49)	30 (11-58)	16 (0.2-84)	4.1 (2.8-9.2)	58 (21-138)	59 (24-108)	53 (29-108)	55 (19-107)	0.3 (0.2-0.5)
Winkle flesh	St. Bees	35 (8.0-84)	34 (8.2-92)	24 (1.0-149)	3.9 (1.8-10)	98 (36-198)	95 (36-424)	55 (24-76)	116 (42-196)	0.4 (0.3-0.6)
Mussel flesh	Braystones	72 (3.3-350)	55 (6.1-303)	34 (1.2-155)	2.7 (0.7-5.6)	149 (66-289)	135 (45-345)	150 (107-186)	172 (77-286)	0.2 (0.1-0.3)
Whole shrimps**	Braystones	-	7.3 (2.3-12)	1.4 (0.1-4.3)	-	-	43 (17-68)	5.5 (3.1-9.9)	-	0.9 (0.7-1.0)

* Sampled in 1963 at Seascale
**Sampled in 1964 at Seascale.

Table 7 Radioactivity in sea water in the Irish Sea, 1963-66

Sampling site	Distance offshore (miles)	Concentration of radioactivity, pCi/l											
		$^{95}Zr/^{95}Nb$				^{106}Ru				^{137}Cs			
		1966	1965	1964	1963	1966	1965	1964	1963	1966	1965	1964	1963
Maryport	0	17	9.3	38	25	21	14	25	43	11	6.2	6.8	5.4
Whitehaven	0	22	20	68	40	28	27	46	89	11	9.4	11	7.4
"	2.5	35	7.4	34	-	41	7.2	32	45	14	8.1	10	5.1
St. Bees	0	65	45	110	75	65	54	91	111	22	20	17	11
"	1.5	29	56	18	-	185	53	56	42	25	18	12	5.3
"	3	30	16	22	-	43	36	62	41	14	14	11	4.1
"	15	8.7	15	27	-	14	33	106	-	6.4	10	13	-
Braystones	0	77	58	174	94	94	82	139	144	27	22	25	12
"	1.5	68	28	85	27	387	100	533	214	49	35	50	13
"	3	39	22	37	-	59	52	137	43	16	20	18	5.5
"	6	17	14	22	-	20	34	43	-	9.0	12	8	-
0.5 mile N of Sellafield pipeline zero	1.5	126	41	543	14	255	137	854	323	48	63	80	15
Sellafield pipeline zero	1	64	67	722	17	243	134	544	305	38	67	58	19
"	2	92	95	825	6.4	229	207	528	157	59	50	55	9.1
"	3	73	-	-	-	175	-	-	-	46	-	-	-

Table 7 continued

Sampling site	Distance offshore (miles)	Concentration of radioactivity, pCi/l											
		$^{95}Zr/^{95}Nb$				^{106}Ru				^{137}Cs			
		1966	1965	1964	1963	1966	1965	1964	1963	1966	1965	1964	1963
0.5 mile S of Sellafield pipeline zero	1.5	43	54	1102	8.8	121	173	642	529	25	49	55	24
Seascale	0	87	82	339	26	106	94	203	162	31	27	31	14
"	1.5	51	49	702	26	164	109	377	831	30	57	35	25
"	3	30	26	75	7.2	69	96	116	1628	18	29	18	14
"	6	12	10	50	-	16	32	48	-	8.5	13	10	-
Ravenglass	1.5	45	30	436	11	64	121	399	187	17	41	45	14
"	3	28	24	226	6.3	30	86	299	180	12	28	36	12
"	15	10	7.1	6.3	-	13	16	25	-	4.9	6.2	4.5	-
Eskmeals	0	44	56	174	111	57	50	130	123	19	17	21	14
Bootle	1.5	27	29	92	7.1	33	103	175	96	12	24	19	10
Haverigg	1.5	-	12	-	-	-	26	-	-	-	8.1	-	-
Walney Island	0	21	28	77	83	30	27	56	58	13	12	12	9.0
"	1.5	-	11	-	-	-	17	-	-	-	8.0	-	-
"	6	-	12	12	-	-	24	31	-	-	10	8	-

Table 8 Radioactivity in Fucus seaweeds in the immediate vicinity of Windscale, 1963-66

Seaweed	Sampling site	Concentration of radioactivity, pCi/g (wet); mean and range							
		Total Beta				$^{95}Zr/^{95}Nb$		^{106}Ru	
		1966	1965	1964	1963	1966	1965	1966	1965
F. vesiculosus	Seascale	116 (62-164)	72 (45-86)	87 (37-115)	71 (41-96)	100 (16-156)	96 (63-116)	40 (26-54)	23 (14-32)
	Walney Island	20 (16-21)	-	-	-	12 (6.4-22)	-	4.9 (1.9-8.2)	-
	St. Bees	-	-	37 (24-44)	40 (25-51)	-	-	-	-
	Sellafield pipeline zero	-	89 (72-101)	120 (55-192)	92 (46-121)	-	159 (81-204)	-	28 (26-30)
	Drigg Barnscar	-	-	122 (52-182)	113 (48-185)	-	-	-	-
F. serratus	St. Bees	-	-	62 (45-73)	67 (54-81)	-	-	-	-
	Sellafield pipeline zero	-	-	165 (104-250)	136 (105-177)	-	-	-	-
	Seascale	-	-	134 (85-182)	117 (77-171)	-	-	-	-
F. spiralis	St. Bees	-	-	-	42 (31-51)	-	-	-	-

Table 9 Radioactivity in seabed samples from the Irish Sea in the vicinity of Windscale, 1965

Sampling site	Distance offshore (miles)	Concentration of radioactivity, pCi/g (dry)		
		$^{95}Zr/^{95}Nb$	^{106}Ru	^{144}Ce
St. Bees	1.5	397	494	150
"	3	133	271	73
Braystones	1.5	1637	1423	379
"	3	153	358	91
"	6	76	187	40
Seascale	1.5	210	307	121
Ravenglass	1.5	43	63	29
"	3	99	152	59
Haverigg	1.5	19	27	12
"	9.5	10	24	7

Table 10 Total beta radioactivity in sand around the United Kingdom and the Irish Republic, 1963-66

Sampling site	Concentration of Total Beta radioactivity, pCi/g (dry); mean and range			
	1966	1965	1964	1963
Heysham	26 (21-31)	20	-	26 (20-30)
Fleetwood	8.2 (4.5-12)	7.4 (5.5-9.3)	-	8.8 (7.7-10)
Lowestoft	4.0 (2.7-4.9)	4.3 (1.7-5.3)	3.9 (1.3-5.8)	-
St. Helens	-	5.5	10 (5.1-19)	-
East Runton	-	-	5.2 (3.7-6.6)	5.8 (3.5-7.7)
Sennen Cove	-	-	19 (15-30)	-
Farchyns	-	-	20 (12-39)	-
Llanaber	-	-	6.4 (5.0-6.8)	-
Bloody Foreland	-	-	13 (12-15)	-

Table 11 Radioactivity in seaweeds on Irish Sea coasts remote from Windscale, 1963-66

Seaweed	Sampling site	Concentration of radioactivity, pCi/g (wet); mean and range									
		Total Beta				$^{95}Zr/^{95}Nb$		^{106}Ru		^{137}Cs	
		1966	1965	1964	1963	1966	1965	1966	1965	1966	1965
<u>Porphyra</u>	Port William	9.9 (6.6-12)	12 (10-17)	21 (11-34)	48 (23-99)	0.5 (0.2-1.0)	-	2.6 (1.1-3.8)	4.2 (2.8-6.5)	-	-
	Labrax Bay	-	11 (8.3-16)	-	-	-	-	-	1.8 (1.2-2.5)	-	-
	Garlieston	-	17 (10-27)	33 (25-48)	35 (26-52)	-	-	-	3.8 (1.8-5.4)	-	-
	Broadsea Bay	-	-	14 (10-18)	-	-	-	-	-	-	-
<u>F. vesiculosus</u>	Port William	7.8 (6.6-8.6)	9.2 (6.9-14)	11 (8.8-14)	13 (12-15)	1.6 (0.6-3.4)	1.3 (0.8-2.1)	0.8 (0.6-1.0)	0.6 (0.5-0.6)	0.1	0.2 (0.1-0.2)
	Rascarrel Bay	16 (13-20)	12 (6.1-21)	-	-	6.0 (2.8-9.2)	3.5 (1.7-4.7)	2.7 (1.5-3.4)	1.1 (0.7-1.6)	0.3 (0.2-0.4)	0.2 (0.2-0.3)
	Heysham	14 (9.0-19)	12 (10-15)	-	18 (12-25)	4.5 (1.7-8.2)	4.6 (2.2-6.8)	2.5 (1.2-4.1)	1.5 (1.3-2.0)	0.4 (0.3-0.5)	0.4
	Barlocco Bay	-	-	16 (9.0-20)	22 (17-26)	-	-	-	-	-	-
	Cutters Pool	-	-	16 (12-18)	26 (18-45)	-	-	-	-	-	-
<u>F. serratus</u>	Heysham	-	-	-	19 (17-21)	-	-	-	-	-	-

Table 12 Total beta radioactivity in seaweeds: United Kingdom and Irish Republic background surveys, 1963-66

Sampling site	Concentration of Total Beta radioactivity, pCi/g (wet); mean and range											
	Porphyra				F. vesiculosus			F. spiralis				F. serratus
	1966	1965	1964	1963	1965	1964	1963	1966	1965	1964	1963	1966
East Runton	-	-	9.4 (5.2-15)	14 (9.0-21)	-	6.9 (5.9-7.7)	8.9 (7.9-9.7)	-	-	6.7 (5.7-8.8)	7.3 (6.2-8.4)	-
Lowestoft	4.4 (4.2-4.5)	4.6 (3.0-5.7)	6.5 (4.8-9.3)	-	-	-	-	7.6 (4.3-13)	4.7 (3.6-6.6)	5.4 (4.6-6.1)	-	-
Sennen Cove	-	-	7.9 (6.2-9.7)	-	-	9.3 (7.0-13)	-	-	-	-	-	-
Llanaber	-	-	9.7 (6.9-14)	-	-	8.4 (5.4-11)	-	-	-	-	-	-
Bloody Foreland	-	-	14 (7.7-19)	-	-	-	-	-	-	-	-	-
Glengad	-	6.8 (4.5-9.8)	13 (10-16)	-	7.1 (6.2-9.2)	17 (8.3-34)	-	-	-	-	-	-
St. Davids Head	5.7 (4.1-6.9)	5.3 (5.1-5.5)	-	-	-	-	-	-	-	-	-	-
Dunbar	6.2 (4.9-7.3)	5.9 (4.9-6.8)	-	-	-	-	-	-	-	-	-	-
Millisle	-	-	-	-	-	-	-	-	-	-	-	8.3 (6.6-10)
St. Helens	-	-	-	-	-	9.2 (6.1-15)	-	-	-	-	-	-
Farchyns	-	-	-	-	-	-	-	-	-	16 (10-21)	-	-

Table 13 Fallout radioactivity in seaweeds around the United Kingdom, 1966

Sampling site	Concentration of radioactivity, pCi/g (wet)					
	$^{95}Zr/^{95}Nb$			^{106}Ru		
	Porphyra	F. vesiculosus	F. spiralis	Porphyra	F. vesiculosus	F. spiralis
Lowestoft	-	-	0.2 (Nov)	0.2 (May)	-	0.5 (Nov)
St. Davids Head	-	-	-	0.6 (Feb) 0.1 (Nov)	0.1 (Feb)	-
Dunbar	0.1 (Nov)	-	-	0.5 (Nov)	-	-
Colwyn Bay	0.2 (Apr)	-	-	0.2 (Apr)	-	-
Red Point	-	-	-	0.6 (May)	-	-
Ardnamurcham	-	0.6 (May)	-	-	0.3 (May)	-
Helmsdale	-	0.4 (Jul)	-	-	0.2 (Jul)	-
Turnberry Bay	-	-	-	-	0.3 (Aug)	-
Skipness	0.1 (Aug)	0.2 (Aug)	-	0.3 (Aug)	0.2 (Aug)	-
Seaham Harbour	-	-	-	0.3 (Jul)	-	-
Bradwell	-	0.6 (Nov)	-	-	-	-
Berkeley	-	0.7 (Nov)	-	-	-	-

NOTE: These are individual spot samples at various times of the year and are not comparable.

Springfields, Lancashire

This plant, the uranium fuel manufacturing plant of the U.K.A.E.A., discharges waste to the Ribble Estuary. No marine foodstuff is involved and the only potential risk to members of the public is via dredging of silt. This is of little radiological significance, as can be seen from measurements of the gamma dose-rate made in 1965-66 (Table 14), the maximum effect of this discharge being less than the natural background radioactivity at comparable sites. Analyses of the silt by gamma spectrometry (Table 14) show low concentrations of fission nuclides from Windscale. Of the gamma-active constituents of Springfields origin, only ^{234m}Pa has been detected at easily measurable concentrations.

Table 14 Gamma radiation dose-rates over, and radioactivity in, silt in the Ribble Estuary, 1965-66

Sampling site	Gamma dose-rate, μR/hr	Concentration of radioactivity, pCi/g (dry); mean and range			
		Total Beta	^{106}Ru	$^{95}Zr/^{95}Nb$	^{234m}Pa
Pipeline outlet	14	278 (161-395)	31 (13-54)	13 (4.2-27)	821 (252-1485)
Upstream (yards)					
100	13	-	-	-	-
500	13	205 (111-330)	52 (30-94)	21 (6.0-47)	674 (240-1194)
1000	9.6	-	-	-	-
3000	8.5	-	-	-	-
Downstream (yards)					
100	11	186 (166-207)	40 (21-65)	17 (8.3-31)	449 (205-669)
1000	12	-	-	-	-
5500	12	-	-	-	-
12000	8.3	-	-	-	-

Chapelcross, Dumfries-shire

The extent of monitoring carried out in connection with Chapelcross is minor. The only important local marine foodstuff - and hence the critical material - is the brown shrimp, which forms a traditional industry of some importance based on Annan. Accordingly, shrimp flesh is monitored, though again by far the greater part of the fission nuclides are attributable to Windscale. These data are presented in Table 15, which also contains reference background data on shrimps collected at Lowestoft. Seaweed, sand and silt are analysed on a regular basis, but the artificial radionuclides present are largely attributable to Windscale (Table 16).

Table 15 Radioactivity in shrimps from Annan and Lowestoft, 1963-66

Material	Site	Concentration of radioactivity, pCi/g*; mean and range					
		Total Beta				^{137}Cs	
		1966	1965	1964	1963	1966	1965
Flesh	Annan	2.7 (2.7-2.8)	2.2 (1.9-2.4)	3.1 (2.7-3.5)	3.1 (3.0-3.2)	0.2	0.2 (0.11-0.21)
Flesh	Lowestoft	2.2 (2.1-2.3)	2.3 (2.0-2.6)	2.5 (2.1-3.6)	2.8 (2.1-5.2)	0.02 (0.01-0.04)	0.04 (0.03-0.04)
Shell	Lowestoft	2.0 (1.7-2.2)	2.6 (1.8-3.0)	3.4 (2.4-5.2)	3.4 (2.5-4.5)	0.02 (0.02-0.03)	0.04 (0.03-0.05)

*As grammes of wet material for flesh, dry for shell.

Table 16 Radioactivity in estuarine materials in the vicinity of Annan, 1963-66

Material	Concentration of radioactivity, pCi/g (wet)*; mean and range											
	Total Beta				$^{95}Zr/^{95}Nb$		^{106}Ru		^{137}Cs		^{144}Ce	
	1966	1965	1964	1963	1966	1965	1966	1965	1966	1965	1966	1965
Silt	105 (50-168)	141 (112-176)	195 (76-448)	140 (54-278)	26 (5.2-62)	18 (7.3-30)	40 (14-67)	42 (5.5-66)	-	-	15 (5.2-21)	11 (2.8-16)
F. vesiculosus (Waterfoot)	8.3 (7.3-9.6)	7.4 (5.3-8.9)	9.3 (7.1-11)	13 (9.4-20)	1.0 (0.5-1.3)	0.8 (0.5-1.2)	1.0 (0.7-1.4)	0.6 (0.3-0.8)	0.3 (0.2-0.4)	0.2 (0.1-0.3)	0.6 (0.4-0.6)	-
F. vesiculosus (Seafield)	8.5 (7.0-10)	8.5 (5.3-11)	11 (9.2-13)	13 (12-14)	1.1 (0.4-2.5)	0.7 (0.6-0.7)	1.1 (0.6-2.2)	0.5 (0.4-0.7)	0.3 (0.2-0.3)	0.2	0.7 (0.4-1.4)	-
F. spiralis	-	-	8.4 (5.4-15)	14 (9.0-25)	-	-	-	-	-	-	-	-
Sand (Waterfoot)	-	-	21 (17-28)	35 (14-62)	-	-	-	-	-	-	-	-
Sand (Seafield)	-	-	24 (18-34)	42 (13-118)	-	-	-	-	-	-	-	-

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

Dounreay, Caithness

Only those results appropriate to routine check-monitoring are quoted (Tables 17 and 18). Sea water is sampled from the shoreline, both opposite the outfall and at Sandside Bay, which is some two miles distant and the nearest part of the coast to the site used by the public. The critical factor is the dose to salmon fishermen handling nets, and it is thus the beta-active component which is of greater importance, since direct contact with the contaminated nets is involved. Direct measurements of beta dose-rates have been made on a standard pack of net measuring approximately 12 x 8 x 2 inches, and analyses have been made on samples of net for ^{144}Ce, ^{106}Ru and $^{95}Zr/^{95}Nb$. In addition, limpets and Fucus seaweed are examined as indicators of shoreline contamination.

Table 17 Radioactivity in, and beta dose-rates from, salmon fishing nets at Sandside Bay, 1965-66

	Concentration of radioactivity, pCi/g (wet); mean and range			Beta dose-rate, μ Rad/hr; mean and range
	$^{95}Zr/^{95}Nb$	^{106}Ru	^{144}Ce	
1966	36 (4.1-87)	27 (5.4-56)	56 (15-167)	74 (14-264)
1965	335 (20-1982)	43 (4.9-102)	115 (5.2-452)	142 (7.1-514)

Table 18 Radioactivity in marine materials in the vicinity of Dounreay, 1964-66

Material	Concentration of radioactivity, pCi/g (wet)*; mean and range										
	Total Beta			$^{95}Zr/^{95}Nb$			^{106}Ru			^{137}Cs	^{144}Ce
	1966	1965	1964	1966	1965	1964	1966	1965	1964	1966	1964
Water (shoreline opposite pipeline outlet)	-	-	-	125 (7.1-445)	108 (33-394)	-	28 (4.1-79)	22 (3.8-132)	-	6.9 (1.1-18)	-
Water (Sandside Bay)	-	-	-	66 (8.3-419)	86 (8.0-293)	-	11 (2.5-23)	10 (1.0-41)	-	3.3 (1.4-11)	-
Limpet flesh (Sandside Bay)	104 (40-208)	159 (55-370)	97 (31-143)	-	-	32 (21-55)	-	-	19 (16-24)	-	20 (14-30)
F. vesiculosus (Sandside Bay)	83 (28-439)	108 (22-293)	117 (53-374)	-	-	76 (48-102)	-	-	-	-	26 (18-31)

*Except water - pCi/l.

Winfrith, Dorset

No routine monitoring is conducted at present at this site. Amounts of radioactivity discharged are very small and, being made from a very long pipe-line into deep water, there is no likelihood of any contamination being detected. This has been confirmed by occasional measurements made by the Laboratory and by the more regular measurements made until recently by the Authority.

CENTRAL ELECTRICITY GENERATING BOARD AND SOUTH OF SCOTLAND ELECTRICITY BOARD NUCLEAR POWER STATION SITES

Wastes discharged from all present nuclear power station sites are diluted to a very considerable degree by being fed initially into the spent cooling water. Consequently, sites which are located on the open coast (e.g. Dungeness and Sizewell) or on estuaries (e.g. Berkeley and Hinkley Point), with considerable reserves of water for further dilution, cannot be expected to give rise to extensive measureable contamination, particularly where they have as yet been operating for a relatively short time in respect of the build-up of radioactive waste. However, most of the stations have not reached equilibrium operating conditions in respect of turnover of fuel, so that it may be too early to judge whether the presence of radioactivity in these environments, attributable to normal power station operation, will become detectable.

The notable exceptions to this are currently found at Bradwell, where ^{65}Zn is detectable in oysters, and at Trawsfynydd, where it is expected that, with the combination of trout and a freshwater lake of very low hardness, the presence of certain nuclides will be detected in due course. These environments have been discussed in some detail by Preston(5) and by Preston, Jefferies and Dutton(6).

Nevertheless, the environment of each of these power stations is monitored regularly, though in most cases only background and fallout activities are detected.

Bradwell, Essex

The Blackwater Estuary, at the mouth of which the Bradwell Power Station discharges its waste, is well known for its oyster fishery. Regular temporary layings of oysters of both Native and Portuguese species are made at a site close to the Barrier Wall which serves to keep spent cooling water clear of the cold-water intakes. These oysters are analysed for total beta radioactivity and ^{65}Zn, the critical nuclide, and the measurements give an indication of the maximum conceivable concentration of radioactivity likely to be present in oysters at the commercial beds, the nearest of which is about 500 yards away. Oysters are sampled at several other points in the estuary and the results fully support this (Tables 19 and 20). Sufficient information is now available to plot the concentrations of ^{65}Zn in oysters against distance from the outfall (Figure 5(5)).

Gamma dose-rates have been measured along the shoreline, particularly where silt can be found, though the programme has recently been reduced (Table 21). The only measurements significantly above background are those taken alongside the perimeter fence of the site, where the gamma dose is due to direct radiation from the station and not contamination of silt; this has been verified by direct measurements on silt samples (Table 22). Seaweeds are also found in this estuary and show concentrations of radioactivity which, until very recently, have been no higher than those found in situations remote from nuclear installations.

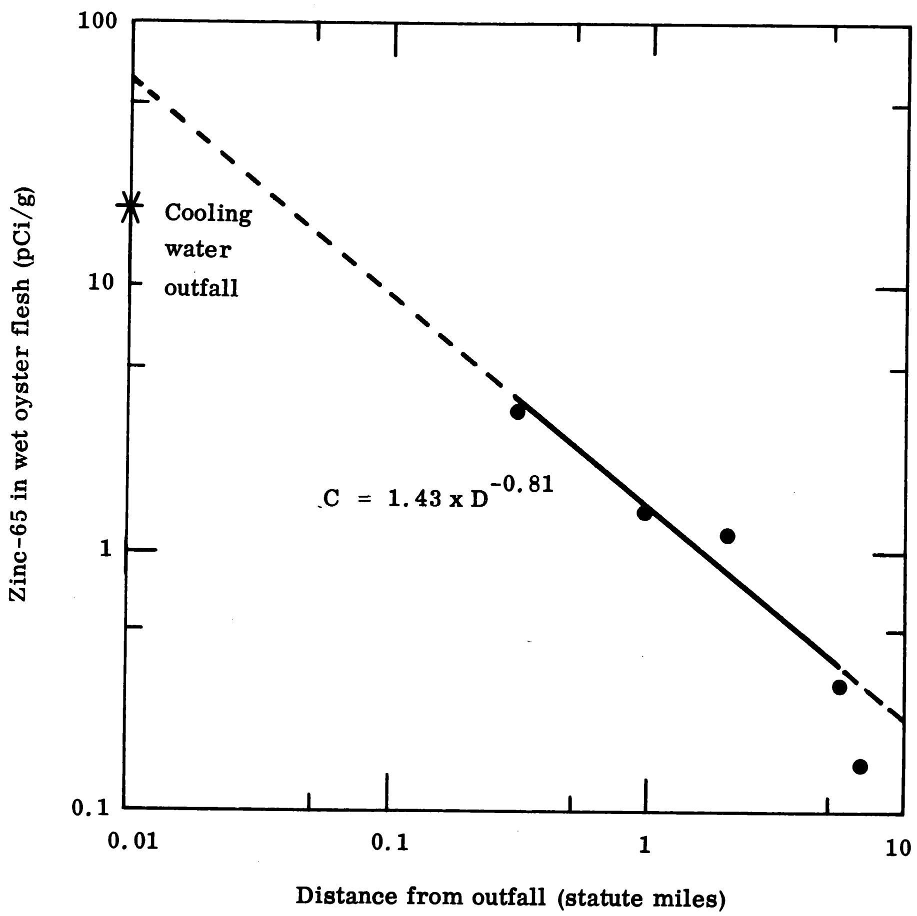

Figure 5 The concentration of Zinc-65 in oyster flesh as a function of distance from the Bradwell cooling water outfall.

Both seaweed and silt show natural activities of uranium and thorium series, so that it is not usually possible to identify fission nuclides and ^{65}Zn with the precision of similar measurements in oysters. Recently, however, during the latter half of 1966, ^{65}Zn, ^{60}Co and ^{55}Fe have been positively identified in a number of estuarine materials (Table 23). Whilst none of these levels carry any real significance in terms of public exposure, they are nevertheless of interest, being the first evidence of such contamination from a power station site.

Table 19 Total beta radioactivity in the flesh of oysters in the Blackwater Estuary, 1963-66

Sampling site	Concentration of radioactivity, pCi/g (wet); mean and range						
	Native species				Portuguese species		
	1966	1965	1964	1963	1966	1965	1964
Barrier Wall	2.7 (1.9-4.1)	2.7 (2.2-3.3)	2.9 (2.2-3.4)	-	2.7 (2.2-4.8)	2.4 (1.8-2.7)	3.0 (2.1-4.2)
Strood Channel	-	-	-	-	1.8 (1.2-2.5)	1.9 (1.2-2.4)	2.1 (1.7-2.8)
Tollesbury Creek	-	-	-	2.7 (2.3-3.2)	-	-	-

Table 20 Zinc-65 in the flesh of oysters in the Blackwater Estuary, 1963-66

Sampling site	Concentration of ^{65}Zn, pCi/g (wet); mean and range						
	Native species				Portuguese species		
	1966	1965	1964	1963	1966	1965	1964
Barrier Wall	21 (10-38)	19 (0.8-29)	6.2 (1.4-20)	-	32 (25-37)	16 (1.4-31)	13 (1.6-40)
0.33 mile seaward*	4.4 (3.0-5.4)	3.7 (2.5-6.2)	1.4 (0.2-4.0)	-	-	-	-
1 mile upstream*	2.7 (1.8-3.8)	1.8 (0.9-2.6)	-	-	-	-	-
2 miles upstream*	2.4 (1.5-5.7)	1.4 (0.7-2.2)	-	-	-	-	-
Mayland Creek	0.5 (0.3-0.6)	0.4 (0.2-0.5)	-	-	-	0.6 (0.6-0.9)	-
Thirslet Creek	0.7 (0.4-0.9)	-	-	-	-	-	-
Nass End	0.7 (0.4-1.0)	-	-	-	-	-	-
Goldhanger Creek	0.4 (0.2-0.4)	-	-	-	-	-	-
Strood Channel	-	-	-	-	0.2 (0.1-0.3)	0.2 (0.1-0.3)	0.1 (0.03-0.2)
Southey Creek	-	-	-	-	0.4 (0.3-0.5)	0.4 (0.2-0.5)	-

*Distance measured from Barrier Wall discharge point.

Table 21 Gamma radiation dose-rates along the shoreline of the Blackwater Estuary, 1963-66

Distance from Barrier Wall (miles)	Gamma dose-rate, μR/hr; mean and range			
	1966	1965	1964	1963
South bank				
0- 1	12 (5.0-27)	15 (7.0-29)	9.4 (6.0-19)	9.4 (6.8-16)
1- 3	-	6.0	6.5 (5.5-7.5)	6.6 (5.2-8.0)
3- 6	-	6.8	6.9 (6.2-7.8)	8.7 (6.8-11)
6-10	-	6.0	5.8 (5.5-6.0)	6.2 (6.0-6.2)
North bank				
1- 3	-	6.6 (5.8-7.2)	6.4 (5.5-7.8)	6.9 (6.0-8.0)
3- 6	-	6.8 (5.0-8.2)	6.9 (5.2-8.8)	7.0 (5.5-8.8)
6-10	-	6.2 (5.8-6.5)	6.2 (5.5-6.8)	7.4 (6.0-9.2)
>10	-	3.8	3.7 (3.2-4.0)	4.0 (3.5-4.5)

Table 22 Total beta radioactivity in silt and seaweed in the Blackwater Estuary, 1963-66

Material	Site	Concentration of Total Beta radioactivity, pCi/g (wet)*			
		1966	1965	1964	1963
Silt	Barrier Wall	18 (15-21)	20 (18-25)	24 (20-30)	22 (21-23)
Porphyra	Barrier Wall	-	3.9 (2.3-5.6)	5.5 (4.8-6.1)	7.3 (4.4-12)
F. vesiculosus	Barrier Wall	-	7.6 (7.3-7.8)	7.9 (6.8-9.0)	-

*Except silt - pCi/g (dry).

Table 23 Radioactivity in seaweed and silt and shellfish flesh in the Blackwater Estuary, 1966

Material	Concentration of radioactivity, pCi/g (wet)*		
	^{60}Co	^{55}Fe	^{65}Zn
F. vesiculosus	0.3	N.D.	0.4
Silt	0.5	N.D.	0.6
Winkle flesh	0.1	N.D.	0.3
Oyster flesh (native)	0.6	0.5	see Table 20

*Except silt - pCi/g (dry)
N.D. - not determined.

Berkeley, Gloucestershire

The main effort of monitoring by the Laboratory is directed to the measurement of gamma dose-rates on silt (Table 24), due to the extensive use made of the river by salmon fishermen. To date no effect of the station has been detected, enhanced levels close to the station being due to direct radiation from the station and not to silt contamination. Silt and *Fucus vesiculosus* taken from the shore adjacent to the outfall confirm this - the former being compared with silt from a control upstream site at Blue Boys Farm which is relatively remote from the power station (Table 25). Various fish, the other critical path to exposure, are sampled as available (Table 25).

Table 24 Gamma radiation dose-rates over silt banks in the vicinity of Berkeley, 1963-66

Distance from pipeline zero (miles)	Gamma dose-rate, μR/hr			
	1966	1965	1964	1963
East bank				
0- 1	53 (32-66)	34 (7.0-71)	16 (8.0-52)	25 (7.0-56)
1- 3	7.4 (6.2-9.8)	7.3 (6.5-9.0)	7.7 (6.5-8.5)	8.9 (7.0-11)
3- 6	7.5 (6.5-9.5)	7.2 (6.2-8.2)	7.2 (6.5-8.0)	8.2 (7.2-10)
6-10	7.0 (5.8-8.8)	7.1 (6.2-7.8)	7.4 (7.0-7.8)	8.5 (7.0-9.8)
>10	6.9 (6.2-7.5)	-	7.6 (7.2-8.2)	8.6 (7.0-9.8)
West bank				
1- 3	6.6 (5.0-7.5)	7.2 (6.5-8.5)	7.4 (6.2-8.5)	8.1 (6.5-11)
3- 6	6.5 (4.8-8.0)	6.9 (6.5-7.5)	6.9 (6.5-7.5)	7.7 (6.8-9.8)
6-10	6.3 (5.2-8.0)	6.5 (5.5-7.5)	6.6 (5.8-7.8)	7.4 (5.5-9.8)
>10	-	7.4 (7.2-7.8)	8.2 (8.0-8.2)	10 (9.0-12)

Table 25 Radioactivity in estuarine materials in the River Severn in the vicinity of Berkeley, 1963-66

Material	Site	Concentration of radioactivity, pCi/g (wet)*; mean and range						
		Total Beta				^{137}Cs		
		1966	1965	1964	1963	1966	1965	1964
F. vesiculosus	Berkeley	6.7 (4.9-7.8)	6.5 (4.9-8.4)	6.8 (4.8-8.1)	6.6 (5.2-8.6)	-	-	-
F. vesiculosus	Clevedon	-	-	8.3 (5.6-12)	8.8 (6.4-12)	-	-	-
Silt	Berkeley	19 (18-21)	26 (23-28)	30 (22-44)	42 (23-81)	-	-	-
Silt	Blue Boys Farm	14 (11-17)	26 (21-34)	22 (17-34)	47 (14-102)	-	-	-
Salmon flesh	Estuary	2.5 (2.0-2.9)	2.9 (2.5-3.4)	2.6 (2.2-3.2)	2.3 (2.2-2.5)	0.04 (0.03-0.04)	0.05 (0.04-0.05)	0.1
Flounder flesh	Estuary	2.5 (2.2-2.8)	2.2 (1.8-2.4)	-	2.5 (2.4-2.6)	0.04 (0.02-0.05)	0.04 (0.03-0.04)	-

*Except silt - pCi/g (dry).

Hinkley Point, Somerset

Estuary sites are monitored for gamma dose-rates (Table 26), and silt and Fucus vesiculosus are collected from chosen sites (Table 27). Fish fillets and shrimps are also monitored (Table 27), the latter being the more important commercially.

Table 26 Gamma radiation dose-rates over silt in the vicinity of Hinkley Point, 1963-66

Distance from pipeline zero (miles)	Gamma dose-rate, μR/hr			
	1966	1965	1964	1963
0	6.5 (4.8-8.8)	7.6 (7.2-7.8)	8.2 (7.8-9.2)	9.2 (8.2-10)
0.5	7.1 (6.2-7.5)	7.4 (6.5-9.0)	7.4 (7.2-7.5)	9.7 (7.8-11)
1	8.1 (7.5-9.2)	7.9 (6.5-9.5)	7.6 (7.2-7.8)	8.1 (7.5-8.8)

Table 27 Radioactivity in materials in the vicinity of Hinkley Point, 1963-66

Material	Distance from pipeline zero (miles)	Concentration of radioactivity, pCi/g (wet)*; mean and range						
		Total Beta				^{137}Cs		
		1966	1965	1964	1963	1966	1965	1964
F. vesiculosus	1 east	8.4 (7.0-9.9)	6.4 (3.7-8.1)	7.6 (5.5-8.8)	7.9 (6.4-8.9)	-	-	-
	0.5 east	8.0 (6.2-9.3)	6.5 (4.6-7.5)	7.6 (5.6-8.9)	8.4 (6.2-10)	-	-	-
	0	7.4 (5.4-9.6)	6.6 (4.8-7.9)	7.4 (6.4-8.9)	7.9 (6.2-9.4)	-	-	-
	0.5 west	7.0 (5.1-8.8)	5.3 (3.6-6.3)	7.0 (6.0-8.2)	6.9 (5.1-9.6)	-	-	-
F. spiralis	2 east	-	-	5.5 (4.6-6.8)	-	-	-	-
	12 west	-	-	5.9 (4.1-7.1)	-	-	-	-
Silt	0	6.8 (5.2-8.5)	16 (10-26)	36 (21-57)	43 (24-68)	-	-	-
Whiting flesh	Bridgwater Bay	2.5 (2.4-2.6)	2.4 (2.2-2.6)	2.5 (2.2-2.9)	-	0.04 (0.03-0.05)	0.05 (0.04-0.06)	0.05 (0.05-0.06)
Shrimp flesh	Bridgwater Bay	2.2 (1.7-2.8)	2.6 (2.3-2.8)	-	2.6 (2.6-2.8)	0.02 (0.02-0.03)	0.03 (0.02-0.03)	-

*Except silt - pCi/g (dry).

Dungeness, Kent

Beach gamma dose-rates are measured along the eastern approaches to Dungeness Point (Table 28), and plaice are monitored for total beta and ^{137}Cs radioactivity (Table 29). The beach in this region varies from shingle, with only small overlaying patches of sand at low-water mark, to pure sand, and at no location is any amount of silt noticeable. Hence dose-rates are very low indeed and are almost entirely cosmic in origin.

Table 28 Gamma radiation dose-rates over the beach in the vicinity of Dungeness, 1964-66

Distance from pipeline zero (miles)	Gamma dose-rate, µR/hr		
	1966	1965	1964
0.5	4.8	3.3 (3.0-3.8)	3.5 (3.0-4.0)
1.5	4.8 (4.5-5.2)	3.8 (3.2-4.5)	5.0 (4.5-5.5)
3	4.5 (4.0-5.0)	4.5 (4.0-5.0)	4.8 (4.0-5.8)
4.5	3.8 (3.5-4.2)	4.4 (4.2-4.8)	4.6 (4.0-5.8)

Table 29 Radioactivity in marine materials in the Dungeness environment, 1964-66

Material	Concentration of radioactivity, pCi/g*; mean and range				
	Total Beta		^{137}Cs		
	1966	1965	1966	1965	1964
Plaice flesh	3.2 (2.3-4.7)	2.8 (2.3-3.2)	0.02 (0.02-0.04)	0.03 (0.03-0.04)	0.02 (0.01-0.03)
Sand	6.8 (4.6-8.6)	4.4 (4.1-4.7)	-	-	-

*As grammes of wet material for plaice flesh, dry for sand.

Sizewell, Suffolk

This site, like Dungeness, has a shingle foreshore and shows the same very low gamma dose-rates (Table 30). In addition, fish are sampled (Table 31).

Table 30 Gamma radiation dose-rates over the beach in the vicinity of Sizewell, 1965-66

Distance from pipeline zero (miles)	Gamma dose-rate, μR/hr	
	1966	1965
0-1	4.0	4.1
1-3	3.4	3.6
3-6	3.6	3.8

Table 31 Radioactivity in fish flesh in the vicinity of Sizewell, 1965-66

Species	Concentration of radioactivity, pCi/g (wet)			
	Total Beta		^{137}Cs	
	1966	1965	1966	1965
Sole flesh	2.4	2.9	0.03 (Sole and Plaice combined)	0.03
Plaice flesh	2.7	2.1		0.03
Whiting flesh	3.1	-	0.04	-

Trawsfynydd, Merioneth

This site is unique in being the only nuclear power station using fresh water for cooling and disposal of its low-level liquid wastes. The critical food-stuff leading to public exposure in the aquatic environment is fish from the lake, particularly trout, for which Lake Trawsfynydd is well known. This fish is particularly important because of its high concentration factor for caesium. Trout and perch and a variety of materials from the lake and streams in the area are sampled (Tables 32 and 33). The station was commissioned in 1965; consequently, discharges are still building up and radioactivity detected in the environment up to the end of 1966 was still at background level, the degree of artificial nuclides detected being wholly attributable to fallout from the testing of nuclear weapons.

Table 32 Radioactivity in fish flesh and lake materials in Lake Trawsfynydd, 1963-66

Material	Concentration of radioactivity, pCi/g (wet)*; mean and range											
	Total Beta				^{137}Cs				^{90}Sr			
	1966	1965	1964	1963	1966	1965	1964	1963	1966	1965	1964	1963
Trout flesh	4.0 (3.9-4.2)	4.0 (3.4-5.1)	3.8 (3.0-4.4)	5.1 (3.4-8.2)	1.9 (1.3-2.3)	3.4 (2.9-3.8)	3.2 (2.6-4.4)	2.8 (1.8-3.4)	0.060 (0.031-0.102)	0.082 (0.053-0.117)	0.069 (0.038-0.108)	0.018 (0.011-0.022)
Perch flesh	3.9 (3.0-4.7)	-	-	-	3.8 (2.5-5.0)	-	-	-	-	-	-	-
Water	-	-	-	-	0.5 (0.5-0.6)	0.8 (0.7-0.9)	-	-	-	-	-	-
Peat	23** (12-31)	58 (47-76)	60 (42-72)	-	-	-	-	-	-	-	-	-
Mud	62** (22-109)	76 (64-109)	65 (47-93)	-	-	-	-	-	-	-	-	-
Sedge	-	95 (63-120)	212 (177-268)	-	-	-	-	-	-	-	-	-

*Except mud - pCi/g (dry); water - pCi/l
**^{125}Sb detected November 1966.

Table 33 Radioactivity in stream and estuarine materials in the vicinity of Lake Trawsfynydd, 1964-66

Material	Concentration of radioactivity, pCi/g (wet); mean and range											
	Total Beta			^{54}Mn		^{106}Ru			^{137}Cs		^{144}Ce	
	1966	1965	1964	1966	1965	1966	1965	1964	1966	1965	1966	1965
<u>Fontinalis</u> (Afon Prysor)	9.3 (6.7-13)	14 (11-16)	-	3.8 (2.0-6.8)	5.6 (2.8-9.0)	2.9 (2.0-4.2)	4.2 (2.3-5.9)	-	0.4 (0.2-0.9)	0.5 (0.4-0.6)	4.1 (3.0-6.1)	5.7 (3.9-7.8)
<u>Fontinalis</u> (Ceunant Llennyrch)	-	68 (44-100)	-	-	22 (8.2-35)	-	16 (7.9-23)	-	-	1.5 (1.4-1.7)	-	28 (12-46)
<u>Fontinalis</u> (Maentwrog)	13* (8.3-19)	-	-	4.6 (2.4-6.7)	-	5.1 (3.1-7.4)	-	-	0.8 (0.5-1.0)	-	5.5 (2.9-8.2)	-
Mussels (Portmadoc)	1.2 (1.1-1.3)	1.9 (1.2-2.3)	3.9 (2.6-6.1)	-	-	-	-	0.9 (0.2-2.0)	-	-	-	-

*^{60}Co also detected late 1966, at 0.2 pCi/g (wet).

Hunterston, Ayrshire

At this site, which is operated by the South of Scotland Electricity Board (S.S.E.B.), a limited degree of monitoring is carried out and covers seaweed, silt and sand. The results are given in Table 34, which may be compared with Table 11 showing the outer environs of Windscale. There is no evidence of radioactivity in this environment from the power station, most of the artificial radioactivity detected being attributable to Windscale.

Table 34 Radioactivity in marine materials in the vicinity of Hunterston, 1963-66

Material	Concentration of radioactivity, pCi/g (wet)*; mean and range						
	Total Beta				$^{95}Zr/^{95}Nb$	^{106}Ru	
	1966	1965	1964	1963	1965	1966	1965
Porphyra	-	9.2 (7.7-11)	-	-	-	-	2.2 (1.3-3.1)
F. vesiculosus	7.0 (5.7-7.9)	8.2 (7.6-9.2)	9.8 (7.6-13)	12 (10-13)	0.2 (0.1-0.4)	0.7 (0.3-0.8)	0.5 (0.4-0.6)
F. spiralis	-	-	-	15 (13-17)	-	-	-
F. serratus	-	-	-	14 (12-17)	-	-	-
Sand	5.7 (4.9-6.3)	6.8 (4.3-9.1)	9.5 (7.5-11)	13 (8.9-17)	-	-	-

*Except sand - pCi/g (dry).

CHANNEL ISLANDS

The Channel Islands, situated as they are relatively close to the French mainland, are not very far from the fuel reprocessing plant at Cap de la Hague, operated by the Commissariat à l'Energie Atomique. The Laboratory is now monitoring Porphyra seaweed (as an indicator of foreshore contamination) on behalf of the Channel Islands States, with whose agreement the results in Table 35 are reproduced. These represent the pre-operational phase of the plant and show only background activity similar to other locations remote from nuclear installations.

Table 35 Total beta radioactivity in Porphyra on Channel Islands coasts, 1965-66

Sampling site	Concentration, pCi/g (wet); mean and range
Corbletts Bay (Alderney)	6.1 (3.7-7.4)
Telegraph Bay (Alderney)	6.0 (2.9-8.1)
Fort Doyle (Guernsey)	6.4 (4.1-7.9)
Fermain Bay (Guernsey)	5.7 (3.7-7.8)
Greve de Lecq (Jersey)	4.2 (3.3-5.6)

DISCUSSION

A lot of attention has been devoted to the assessment of risk from radiation in recent years - so much so that the risk from the discharge of radioactive waste is probably more accurately known than any other kind of industrial risk. In fact few other industries, if any, can claim, because of the known genetic risk, to be conducting their operations in such a way as to be safeguarding future generations. In this situation and with the I. C. R. P. recommendations as internationally-accepted working standards, the Ministry is in a position to control radioactive waste discharges with a high degree of safety.

The Ministry's policy has always been to keep exposure within the dose limits set by I. C. R. P. and, indeed, as far within them as reasonably practicable, putting into practice the aims set out in the White Paper on "The Control of Radioactive Wastes"(7). This Paper, whilst accepting the dose limits set by I. C. R. P. recommendations, expressed as one of its aims "To do what is reasonably practicable, having regard to cost, convenience and the national importance of this subject, to reduce the doses far below these levels". Thus more restrictive conditions are often applied than those considered adequate by I. C. R. P. standards, though without imposing on the operator restrictions which would prove difficult or unduly uneconomic.

Maximum permissible discharge rates are the best possible estimates, on the data available, of the capacities of the environments to accept waste safely. Authorized discharge rates are never allowed to exceed these calculated maxima and are often much less, being also set according to the needs of the operator. In the initial phase of operation of a site, such calculations have to be made without the benefit of data from environmental and effluent monitoring, using only information on dispersion, a theoretical effluent composition, and habits survey data. Because of imprecisions in much of the information, a safety factor of 10 is applied. Thus a discharge is limited to no more than 10 per cent of the calculated maximum, until such time as the results of environmental monitoring are available. The authorization is subsequently revised, as necessary, following a recalculation of maximum permissible rates of discharge, using the environmental data. Actual discharges are usually well within the authorized limit. This reflects, in part, the margin of operating flexibility allowed, but is also due in large part to U.K.A.E.A., C.E.G.B. and S.S.E.B., who make every effort to keep discharges down to a minimum.

Information on the habits of critical groups is of the greatest importance to the setting of maximum permissible discharges and in the assessment of potential hazards. These habits-surveys identify and quantify all pathways leading to public exposure, taking particular care to ensure that the exceptional person, in respect of eating habits or time spent on potentially contaminated beaches, is not overlooked. Whilst I. C. R. P. now suggests using the mean exposure of the critical group(8), and not of the extreme member, the Ministry policy continues to take particular account of that person in the group who, by virtue of his habits, is subject to the greatest degree of exposure, and the maximum permissible discharge rate is set by the habits of this person. In this way, no one is subject to more than the I. C. R. P. -recommended dose limit.

Data from habits-surveys are also used in hazard assessment by first deriving a working limit of radioactivity in the critical materials - again on the basis of the exceptional person in the exposed group. Where one nuclide is of overriding importance, that is, it is the "critical" nuclide, it is relatively easy to evaluate the maximum degree of public exposure by comparing monitoring data and the appropriate derived working limit (DWL). In many environments - those of the power stations in particular - contamination has been so low as to be undetectable so far. Until critical nuclides can be verified by identification in the environment it is not possible to present a complete range of comparable DWLs. Values of DWLs are not being quoted in this report, since on their own they are not sufficient for a complete assessment of hazard. For instance, the estimation of exposure due to consumption of laverbread requires a knowledge of collection, distribution and manufacturing factors, in addition to concentrations of radioactivity in Porphyra and the appropriate DWL. It would clearly be beyond the scope of this report to quote all such information in sufficient detail for the reader to calculate degrees of exposure for himself. Radiation exposure resulting from the laverbread industry has recently been discussed in some detail by Preston and Jefferies(9).

The Laboratory itself does assess maximum degrees of exposure, and by quoting the larger values of these it will be seen that the control of discharges is entirely satisfactory. The highest degree of exposure for any critical group is that for laverbread eaters, and in 1966 this stood at a maximum of 18 per cent of the dose limit considered safe for continuous exposure. This figure is typical of recent years and though higher in 1959, due to exceptional weather conditions, was even then maintained below the recommended dose limit. The largest degree of exposure relating to a power station discharge is that arising from consumption of oysters from the Blackwater Estuary. Here an even more satisfactory situation exists, the maximum degree of exposure for the year 1966 being less than 0.2 per cent of the recommended dose limit. The greatest degree of external exposure found in the British Isles relates to Windscale, but has never exceeded 12 per cent of the recommended dose limit.

For the several environments where there is no detectable contamination, it is obviously not possible to quote the proportions of the permissible dose limit received by members of the critical groups, though the safety of these populations will be readily apparent from the absence of contamination. However, some further, and reassuring, calculations can be made by comparing the sensitivity of detection of various types of radioactivity with habits-survey data.