MINISTRY OF AGRICULTURE FISHERIES AND FOOD
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RADIOACTIVITY IN SURFACE AND COASTAL WATERS OF THE BRITISH ISLES 1974

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FOREWORD

This is the eighth in the series of reports concerned with the monitoring of radioactivity in the aquatic environment by the Fisheries Radiobiological Laboratory (FRL) of the Ministry of Agriculture, Fisheries and Food. It describes the results of monitoring surveys carried out in 1974.

Most of the laboratory's monitoring work is directed to fulfilling the Ministry's responsibilities for the control of radioactive waste discharges in England and Wales. In addition, some work is done on behalf of Departments of the Scottish Office, the Channel Islands States and the Irish Republic, and the results of this are included in this report. The majority of the surveys are specifically linked to planned discharges of radioactive waste from nuclear sites operated by either the British Nuclear Fuels Limited or the United Kingdom Atomic Energy Authority or the Central Electricity Generating Board and the South of Scotland Electricity Board, or the Ministry of Defence. They are made independently of the environmental monitoring which the operators of the sites are required to undertake as conditions of their discharge authorizations.

A substantial amount of environmental as well as other research is also carried on by FRL. The main aim of this is to enlarge the existing knowledge of all aspects of the behaviour of radioactivity in the aquatic environment. Although this work is not essential to the primary objective of ensuring the safety of existing discharges, it does improve the basic framework of knowledge in which decisions about future proposals to discharges are taken.

A. J. Lee
Director of Fisheries Research

Table 1 Principal exposure pathways from the discharge of liquid radioactive wastes

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

*Gastro-intestinal tract.

RADIOACTIVITY IN SURFACE AND COASTAL WATERS OF THE BRITISH ISLES, 1974

by J. A. Hetherington

1. INTRODUCTION

Those establishments discharging liquid radioactive waste with which this report is concerned are listed in Tables 1 and 2. In Table 1 the principal pathways by which the waste discharged from each site causes irradiation of the general public are summarized and the principal exposed groups are identified. In Table 2 the amounts of radioactivity discharged from each site during the year are given as a percentage of the appropriate authorized limit.

Almost all of the data presented in this report are the direct results of the laboratory's monitoring programmes which have been undertaken primarily to ensure the safety of the level of environmental contamination resulting from these planned disposals of radioactive waste. Throughout the report, therefore, the levels of contamination have been interpreted as far as possible in terms of the radiation exposure they cause to the groups of the population principally affected by each discharge - the so-called critical groups. This has been done by expressing the measured contamination in the environmental materials as a fraction of the derived working limit (DWL) in each case. The derived working limit is a secondary standard which relates the commodity which it is required to limit, namely the radiation exposure of the individual members of the public, to that which it is feasible to measure, namely the levels of environmental contamination. In this particular context of the control of radioactive waste released to the environment, the DWL is based on two principal factors - the intake of contaminated material (or the occupancy of contaminated areas) by the members of the critical group and the metabolic data relating rates of intake of radioactivity to radiation exposure dose in human beings. For every discharge situation under the jurisdiction of this Ministry, the task of identifying the critical group (or groups) has been undertaken by FRL and the habits of these groups, insofar as they affect their exposure to radiation from environmental contamination, have been established by direct surveys of the populations concerned. Rates of intake of potentially contaminated materials and the times spent in intertidal areas have been estimated by interviewing representative samples of the population. From this information rates of intake and occupancy which are representative of the critical group as defined by the International Commission on Radiological Protection (ICRP) (Ref. 1) have been established for each exposure pathway, and these have been used to calculate the amount of radioactivity in the various materials (and the dose rates in the areas regularly frequented) which would cause doses just equal to the appropriate ICRP dose limits. Provided these levels are not exceeded it may be concluded that none of the dose limits has been exceeded; the difference between the measured contamination in any material and the DWL gives an indication of the margin between

Table 2 Major discharges of liquid radioactive waste to surface and coastal waters during 1974

Site	Radioactivity	Authorized discharge, curies/year	Percentage utilized
Windscale	Total beta	300 000	69
	Ruthenium-106	60 000	49
	Strontium-90	30 000	35
	Total alpha	6 000	76
Springfields	Total alpha	360	13
	Total beta	12 000	10
Chapelcross	Total activity*	700	< 1
	Tritium	150	< 1
Winfrith	Total activity	30 000	3
	Ruthenium-106	9 000	< 1
	Strontium-90	1 200	< 1
	Total alpha	1 200	< 1
Harwell	Total activity*	240	11
	Tritium	240	30
Dounreay	Total alpha	240	5
	Total activity	24 000	23
	Strontium-90	2 400	49
Amersham	Total activity*	72	35
	Tritium	400	61
Berkeley	Total activity*	200	12
	Tritium	1 500	4
Bradwell	Total activity*	200	45
	Zinc-65	5	1
	Tritium	1 500	8
Dungeness	Total activity*	200	35
	Tritium	2 000	1
Hinkley Point	Total activity*	200	63
	Tritium	2 000	2
Oldbury	Total activity*	100	33
	Tritium	2 000	2
Sizewell	Total activity*	200	8
	Tritium	3 000	8
Trawsfynydd	Total activity*	40	48
	Tritium	2 000	3
	Caesium-137	7	32

Table 2 (continued)

Site	Radioactivity	Authorized discharge, curies/year	Percentage utilized
Wylfa	Total activity*	65	< 1
	Tritium	4 000	3
Hunterston	Total activity*	200	35
	Tritium	1 200	6
Chatham	Total activity*	20	< 1
	Cobalt-60	10	< 1
	Tritium	20	< 1
Devonport	Total activity*	4	< 1
	Cobalt-60	1	< 1
	Tritium	10	6
Faslane	Total activity*	1	< 1
Rosyth	Total activity*	30	< 1
Aldermaston	Total activity	156	8

*Excluding tritium.

the situation as it exists and the maximum acceptable under the recommended standards of the ICRP, which have been endorsed for use in the UK by the Medical Research Council (MRC).

In accordance with the established procedure, a quantity of solid radioactive waste of low specific activity was disposed of into the North Atlantic in 1974. The operation was carried out under the auspices of the Nuclear Energy Agency of OECD and included waste from a number of the European countries. The United Kingdom participation in the exercise was coordinated by AERE Harwell, who acted under an authorization granted by this Ministry. The waste was dumped during the period 20-23 July in the Atlantic in an area defined by the circle of radius 15 nautical miles around the point 46°15'N and 17°25'W. Altogether from the United Kingdom, 2 104 drums of waste containing a total of 399 Ci of alpha active and 94 126 Ci of beta active material (over 90% of which was tritium) were disposed of. The total weight of material was 1 256 tonnes. No environmental monitoring is carried out in connection with this type of disposal; as the quantities of activity involved are very small compared with the environmental capacity monitoring is entirely valueless, and these details of the disposal are included here simply for the sake of completeness.

2. PRESENTATION OF RESULTS

The format of this report has been changed from that of previous years. Some of the information which tends not to alter much from year to year has been omitted, particularly descriptions of the critical pathways and monitoring details of sites where discharges are very small. If readers require this information, they are directed to previous reports in this series, particularly the FRL Technical Report 10 (Ref. 2), which are available on request from this laboratory.

Changes will be found in some of the tables, which have been simplified in an effort to make the interpretation of data easier. The information given is usually the total beta activity (measured using a thin source, referred to a standard source of potassium-40 (^{40}K)) together with the individual gamma activities of those artificial radionuclides present which are of actual or potential radiological significance. The gamma activity has been measured using NaI (Tl) or Ge (Li) spectrometers. The results are reported in units of pCi/g (wet) unless otherwise stated: the usual exceptions are that sediment activities are reported as pCi/g (dry), water activities as pCi/l, and gamma dose rates as μR/h. Each result reported is the mean of all MAFF observations, together with the standard deviation wherever possible. The latter figure replaces the range figures previously reported, but is intended to fulfil the same purpose within a simpler presentation: the range quoted as ± one standard deviation will contain about 70% of the individual observations used to compute the mean.

In order to avoid confusion between possible meanings of the abbreviations ND, NA, NS, etc., the appropriate comment has been included in full. The only exception is that a dash (-) is used to indicate that a figure is not applicable; for example, it is not meaningful to express the concentration of activity in an indicator material as a fraction of a derived working limit since, by definition, indicator materials are not consumed and do not therefore contribute to public radiation exposure.

It should also be noted that the gamma dose rate figures are intended to indicate the radiation exposure arising from contamination of the foreshore (if any), and therefore exclude any results affected by direct radiation from the installations, as may be the case at sites close to power stations when the reactors are on load.

In interpreting the information given, it may be of use to readers to know the natural radioactivity of the materials sampled. Some representative values are set out in Table 3.

Towards the end of 1975 the MRC published a report which included some revised data for the metabolism of a number of radionuclides (Ref. 3). Amongst these was caesium-137 (^{137}Cs) which is a major constituent of the effluent of many of the nuclear power establishments covered by this present report. In assessing the public health significance of the caesium-137 detected in environmental samples, use has been made of the most up-to-date information for this nuclide as published by the MRC. The new data lead to a maximum permissible concentration in drinking water for persons continuously exposed in the course of their work of 1.4×10^{-4} μCi/ml compared with the value of 2×10^{-4} μCi/ml in the original report of Committee II of the ICRP (Ref. 4). For members of the public the continuous daily intake which would lead to exposure at the ICRP dose limit has been taken as 0.03 μCi/day.

Table 3 Natural radioactivity of various materials

Material	Total beta activity	Comments
Fish	1 to 3 pCi/g (wet)	Mostly ^{40}K
Shellfish	1 to 3 pCi/g (wet)	Mostly ^{40}K
Fucus seaweeds _Porphyra_ seaweeds	5 to 15 pCi/g (wet)	Mostly ^{40}K
Sand	5 to 10 pCi/g (dry)	^{40}K plus U, Th and their decay products
Mud	20 to 30 pCi/g (dry)	^{40}K plus U, Th and their decay products
Sea water	300 pCi/l	Mostly ^{40}K

The natural background dose rates over intertidal areas vary, according to the nature of the sediment. Over sand the dose rate is in the range 3 to 5 μR/h, while over mud it is between 5 and 10 μR/h.

3. BRITISH NUCLEAR FUELS LIMITED

British Nuclear Fuels Limited is concerned primarily with the design and production of fuel for the existing and proposed nuclear reactor systems and with the reprocessing of irradiated fuel after it has completed its useful life. The laboratory monitors the environment of three BNFL sites in respect of liquid waste discharges. These are Springfield and Windscale, which are concerned respectively with fuel fabrication and reprocessing, and the magnox power station at Chapelcross.

3.1. Windscale, Cumbria

The fuel element reprocessing plant at Windscale handles all the irradiated fuel from the UK nuclear power programme and is therefore the most important single source of liquid radioactive waste, even though the amount of radioactivity actually discharged is a very small fraction indeed of the total activity handled and stored at the site. Regular discharges of low specific activity aqueous waste were made during the year to the north-east Irish Sea and the quantities released are summarized in Table 2. It is seen that all the discharges were within the limits set in the authorization certificates issued to BNFL by the controlling departments. During 1974 the amount of ruthenium-106 (^{106}Ru) and strontium-90 (^{90}Sr) discharged to sea decreased compared with the previous two years (see Ref. 2), although the total quantity of beta-emitting radioactivity increased from 45 to 69% of the authorized limit. This rise was due entirely to an increase in the abundance of the radiocaesium nuclides caesium-134 and caesium-137 in the effluent during the year. There was an increase of 4% in the discharges of alpha-emitting nuclides compared with 1972-73.

The extent of the environmental monitoring conducted by the laboratory in relation to the Windscale discharges has been similar to that of previous years, although some changes in emphasis have been made to take account of factors such as the changes in isotopic composition mentioned above. As before, the monitoring has been orientated primarily towards the established radiation exposure pathways associated with these discharges and to the control of public radiation exposure. At the same time considerable effort has been deployed on investigating some aspects of the behaviour of other components of the effluent which, although of no current radiological significance, may be of importance for other reasons. Two examples are tritium and plutonium nuclides; neither of these presents any significant problem in terms of public radiation exposure, but both may be expected to be increased in abundance in the waste streams of the fuel reprocessing plants of the future as both the nuclear generation capacity of the country and the fuel burn-up times increase. In accordance with the laboratory's established policy, these radionuclides are included in the environmental research programmes so as to extend the information already available on the ecological processes operating in the area and to ensure a proper basis for continued control.

3.1.1. Porphyra-laverbread pathway

The decline over recent years in the importance of the well known exposure pathway via the uptake of radionuclides by the edible seaweed *Porphyra umbilicalis* was described in the last monitoring report of the laboratory. By 1974 the people who collected the weed had finally retired and as a result no Cumbrian weed reached the South Wales laverbread manufacturers. This was confirmed by the analysis of samples of the laverbread sold in South Wales and Table 4 shows that the concentrations of ruthenium-106 in the material were less than 0.2% of the derived working limit.

Table 4 Radioactivity in laverbread samples from the markets of South Wales during 1974

Manufacturer	^{106}Ru concentration, pCi/g (wet)	% of DWL
A	0.2 ± 0.3	0.1
B	0.1 ± 0.1	< 0.1
C	0.3 ± 0.3	0.2
D	0.2 ± 0.2	0.1
E	0.3 ± 0.2	0.2

Despite the disappearance of the laverbread pathway as a source of public radiation exposure, some monitoring of this species was continued during 1974. Since good quality Porphyra weed continues to grow in great abundance on the Cumbrian coast, a revival of harvesting must be considered to be possible and, in view of its potential radiological significance, some sampling of this material is regarded as a necessary part of the monitoring programme. In addition, the concentrations of the various nuclides in this and other seaweed species provide a valuable indicator of longer-term changes in seawater concentrations which may give evidence of changes in dispersion patterns in the area as well as a check on the amounts of radioactivity being released from Windscale. Regular collections of Porphyra were made from Braystones South, Seascale and Walney and the concentrations of radioactivity detected in these samples are shown in Table 5. In general the concentrations of all the radionuclides decreased slightly compared with the 1972-73 values, the only exception being caesium-137 whose concentration increased roughly in proportion to the changes in the rate of discharge referred to earlier.

Table 5 Radioactivity in Porphyra from Windscale vicinity, 1974

Sampling site	Concentration of radioactivity, pCi/g (wet)							
	Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{137}Cs	^{144}Ce	^{90}Sr	$^{239/240}Pu$	^{241}Am
Braystones South	390 ± 215	27 ± 29	340 ± 168	15 ± 12	34 ± 38	0.6*	4.4 ± 2.8	14 ± 12
Seascale	300 ± 102	18 ± 24	281 ± 98	14 ± 8	15 ± 10		1.8 ± 1.0	5.2 ± 3.1
Walney Island	46 ± 19	1.4 ± 1.5	38 ± 16	3.8 ± 2.5	1.9 ± 0.9	0.2	0.4 ± 0.25	0.8 ± 0.9

*Result for composite sample of weed collected from stations from St Bees to Eskmeals.

It is of interest to relate the radioactivity in the Porphyra weed to the doses which would have been received via the laverbread pathway had harvesting of Cumbrian weed continued according to the same pattern as in earlier years. The method by which this may be done has been described in detail in earlier reports in this series. Surveys of the amount of Porphyra being shipped from west Cumbria up to 1971 have shown that the average fraction of Cumbrian-derived weed present in the laverbread offered for sale in South Wales did not exceed 20%, and during the manufacturing process an equal weight of water is added to the raw weed. Thus, on average, the concentration of the radioactivity in laverbread should not exceed one-tenth of that in the Cumbrian Porphyra. Studies of the consumption habits of the population of laverbread eaters in South Wales have shown that there is a sub-group of people who eat on average 130 g/day of laverbread and this figure was adopted for control purposes in accordance with the recommendations of the ICRP. Since this consumption level would correspond to the intake of approximately 13 g/day of Cumbrian weed, it is possible to estimate the corresponding rate of intake of radioactivity from the data of Table 5. For this purpose it is convenient to group the different radionuclides according to their radiological significance following ingestion. Zirconium-95 (^{95}Zr), ruthenium-106 and cerium 144 (^{144}Ce) are of greatest significance in relation to the irradiation of the gastro-intestinal (GI) tract; strontium-90 and the transuranic nuclides, plutonium (Pu) and americium (Am), are bone-seeking elements; for caesium the organ of reference is the whole body. An assessment of the radiological significance of each group of nuclides which would be present in the daily diet of a person eating 130 g/day of laverbread containing 20% of Braystones Porphyra is provided in Table 6, where the doses to the GI tract, to bone, and to the total body are expressed as percentages of the respective ICRP dose limits.

Table 6 Potential radiological significance of the radioactivity in Porphyra weed during 1974, assuming a laverbread consumption rate of 130 g/day

Exposure	Dose expressed as % of ICRP dose limit
GI tract	22
Bone	3
Total body	< 1

3.1.2. External exposure pathway

Marine sediments reconcentrate many of the radionuclides released from Windscale, particularly some of the important gamma ray emitters such as zirconium-95/niobium-95 ($^{95}Zr/^{95}Nb$), ruthenium-106 and caesium-137, and this provides another route by which these discharges cause irradiation of the general public. The dose rates in the areas where sediments become contaminated are increased and the people who visit these areas in the course of their work or recreation are exposed to whole body irradiation from Windscale-derived radioactivity. Regular measurements of the gamma dose rates have been continued at a number of locations from Walney in the south to Maryport Harbour in the north, and the results are summarized in Table 7. It has been shown that the uptake of radioactivity by these sediments is essentially a surface adsorption process (Ref. 5) and that the dose rates tend to be highest in those areas where mud collects, the uptake by the coarser sands being very much less by comparison. As in previous years, the highest readings have been recorded in the Ravenglass Estuary which is also an area visited frequently by a number of people digging for bait, repairing boats or operating salmon traps in the River Esk. It is these people who constitute the critical group for external irradiation. From occupancy data and the dose rate measurements it has been calculated that the maximum individual exposure during 1974 was equivalent to about 7% of the ICRP recommended dose limit.

It should be noted that the dose rates measured in the estuary are not representative of the average situation along the Cumbrian coast at large. Most of this consists of coarse sand and the dose rates over the beaches are much lower, as is shown by the entries for Seascale and St Bees in Table 7.

Table 7 Gamma radiation dose rates over intertidal areas on the Cumbrian coast during 1974

Site	Gamma dose rate, μR/h
Maryport	46 ± 7
Workington Harbour	61 ± 10
Whitehaven Harbour	70 ± 10
St Bees	16 ± 1
Seascale	22 ± 4
Ravenglass Estuary (Eskmeals)	165 ± 17
Walney	40 ± 6

3.1.3. Fish and shellfish pathway

The other exposure pathway of significance in relation to Windscale is that via the consumption of fish and shellfish. In earlier years when the harvesting of Porphyra was at its height this route of exposure was of relatively minor importance because the reconcentration of the fission products such as ruthenium-106 is very much less by fish than by Porphyra. In addition the reconcentration by Porphyra of ruthenium-106 is greater than of caesium-137 by a factor of about 100 and, for as long as the rates of discharge of these two nuclides were approximately the same, the radiological significance of ruthenium-106 via the Porphyra-laverbread pathway remained many times greater than that of either nuclide via the fish pathway. However, with the decline in the harvesting of Porphyra and the increase in the abundance of caesium in Windscale effluent, the situation has changed so that the contamination of fish and shellfish with caesium-134 and caesium-137 has now become a more important source of internal radiation exposure.

For this reason the fish exposure pathway has been the subject of continued attention during 1974. Measurements have been made on the fish caught during special surveys of the area immediately adjacent to Windscale, as well as on samples of the landings at Whitehaven market from commercial boats which operate throughout the Irish Sea. Shellfish from the same areas have also been monitored and most of the effort has been concentrated on those species which are consumed regularly by members of the public. Although mussels are not eaten regularly they have also been included because they grow in great abundance in the Windscale area and provide a useful indicator material. The results of this work are summarized in Table 8 which includes the concentrations of strontium-90 and the transuranic elements as well as of ruthenium-106 and the nuclides of caesium. The data emphasize the importance of caesium relative to ruthenium-106 in the species examined.

Table 8 Radioactivity in fish and shellfish from the Irish Sea, 1974

Species	Sampling area	Concentration of radioactivity, pCi/g (wet)					
		^{106}Ru	^{134}Cs	^{137}Cs	^{90}Sr	$^{239/240}Pu$*	^{241}Am*
Plaice flesh	Windscale area	0.6 ± 1.1	2.5 ± 1.9	11.2 ± 6.2	0.04	0.0054 ± 0.0005	0.011 ± 0.002
"	North Irish Sea	0.2 ± 0.2	0.7 ± 0.6	3.4 ± 2.0	0.03	0.0007 ± 0.0001	0.0012 ± 0.0002
Dab flesh	Windscale area	1.8 ± 1.0	3.7 ± 2.7	15.6 ± 10.0	not analysed	not analysed	not analysed
Herring edible parts	North Irish Sea	not detected	0.14	1.1	not analysed	0.00019 ± 0.00007	0.00014 ± 0.00008
Nephrops edible parts	North Irish Sea	2.8 ± 2.5	0.6 ± 0.2	3.1 ± 0.2	0.04	not analysed	not analysed
Mussels	Windscale area	183	2.0	7.8	not analysed	1.09 ± 0.08	5.0 ± 0.3

*Errors quoted are those due to counting statistics only.

The public health significance of the radioactivity in fish and shellfish may be evaluated by considering the dose to the limiting group of consumers, which consists of a small number of people from west Cumbrian coastal communities such as Braystones, St Bees and Ravenglass. These people both fish regularly in the Windscale area and also eat a substantial fraction of their own catches of fish and crustaceans. For the purpose of calculating the dose to these consumers it is appropriate for two reasons to consider the combined consumption of fish and crustaceans. First, the maximum consumers of demersal fish tend also to eat crustaceans in substantial amounts and, second, the reconcentration factor for caesium is approximately the same in both species. On this basis, the surveys of these communities have shown that the mean and maximum consumption rates of the critical group are 57 and 265 g/day respectively. When these values are combined with the data for the mean concentrations of radiocaesium detected in the fish and shellfish from the Windscale locality during 1974, it is found that the maximum total body dose to any member of the public was just less than 14% of the ICRP dose limit, while the dose to a person eating at the average rate for this community was equivalent to 3%.

The radiological significance of the other nuclides reported in Table 8 is much less than that of radiocaesium. The dose from ruthenium-106 to the GI tract of the maximum consumer was less than 2% of the ICRP dose limit, while the maximum bone dose to any member of the general public from the very low concentrations of plutonium and americium in the edible parts of the fish and crustaceans was less than 0.5% of the limit. The concentrations of both ruthenium-106 and the transuranic nuclides in molluscan shellfish are greater than in fish and crustaceans, but this is of very little radiological significance because no molluscs are harvested commercially and their consumption even amongst local fishing communities is virtually nil. There have been occasions when local winkles have been collected and eaten and when, for short periods, individual dose rates for a very few people may have reached those from fish and crustaceans. When the exposure from this source is viewed in the normal context recommended by ICRP of assessing doses on a yearly basis, it is seen to be of even lower significance than that from fish.

The radiological impact of caesium nuclides via the fish caught throughout the Irish Sea has been assessed by monitoring the commercial landings at Whitehaven market. It has been found that, on average, the concentration in plaice landed there is approximately three times lower than in that caught in the Windscale vicinity. The mean consumption rate of the critical group of the larger population which eats commercially landed fish has been estimated as 300 g/day, a figure which is not greatly different from the maximum individual consumption rate established for the local fish-eating communities. Thus the mean total body dose within this larger critical group is just a factor of three times lower than that in the coastal community, equivalent therefore to just less than 5% of the ICRP limit during 1974.

In addition to the intake of caesium nuclides by these groups of fish consumers in the immediate vicinity of Windscale there is a wider problem associated with the discharge of radiocaesium. This arises from a combination of two factors, first, the conservative nature of caesium in sea water and, second, the long half life of caesium-137 compared with those of other nuclides such as ruthenium-106 which have been important in the past. Thus caesium-137 due to Windscale is now detectable in the water throughout the Irish Sea itself and also further afield in the north-east Atlantic and the North Sea. The presence of the radioactivity in these waters means that the fish stocks too contain radioactivity of Windscale origin; these stocks provide fish which is eaten by large numbers of people both in the UK and in other West European countries. These concentrations and the consequent exposure of individuals are very small, but because large numbers of people are involved it is necessary for the purpose of radiological control to view the situation on a collective population dose basis as recommended by the International Commission on Radiological Protection (Ref. 6). For this reason a programme of water sampling has been undertaken since 1971 in north-west Scottish waters and in the North Sea in order to study the dispersion of caesium-137 after its release from Windscale. The programme was continued during 1974 and the results obtained are summarized in the two diagrams in Figures 1 and 2 which describe the distributions of radiocaesium in the Irish Sea and in more distant waters. It has been assumed that all the caesium-137 detected in these waters, additional to that attributable to nuclear weapon testing fallout, is due to Windscale. Since the total amount of caesium discharged from all other sources in the United Kingdom during the year was about 1% of that from Windscale, this assumption is reasonable.

The concentrations of caesium-137 in sea water have been combined with the 1974 fish landing statistics in order to compute the collective doses to the populations affected on the basis of the total amounts of the nuclide entering their diets. For the purpose of the calculation two separate population groups have been considered; that of the UK itself and that formed by the other nations of western Europe which consume fish from the areas concerned. For each group the landings of fish from the Irish Sea, north-west Scottish waters, and statistical areas IVA, B and C of the North Sea have been considered and the total amounts of caesium-137 in the edible fraction, additional to that attributable to nuclear weapon testing fallout, has been calculated. It has been assumed that the factor by which caesium is reconcentrated in the flesh of the more important fish species is equal to 30 and that all the edible fish landed is used for human consumption in one form or another. In addition, those parts of the

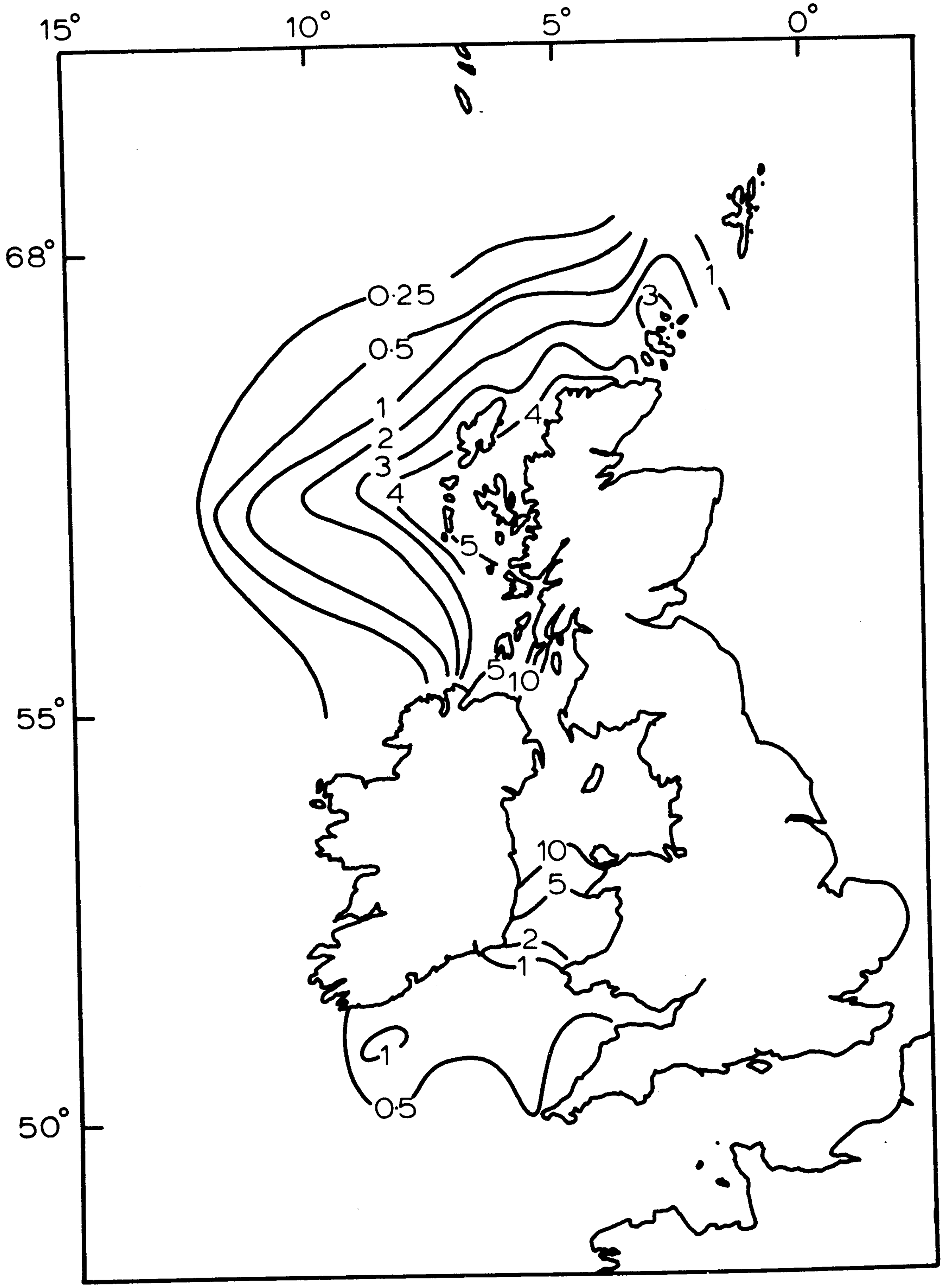

Figure 1 Concentrations of caesium-137 in filtered sea water (pCi/l) from Scottish coastal and Atlantic waters, July 1974.

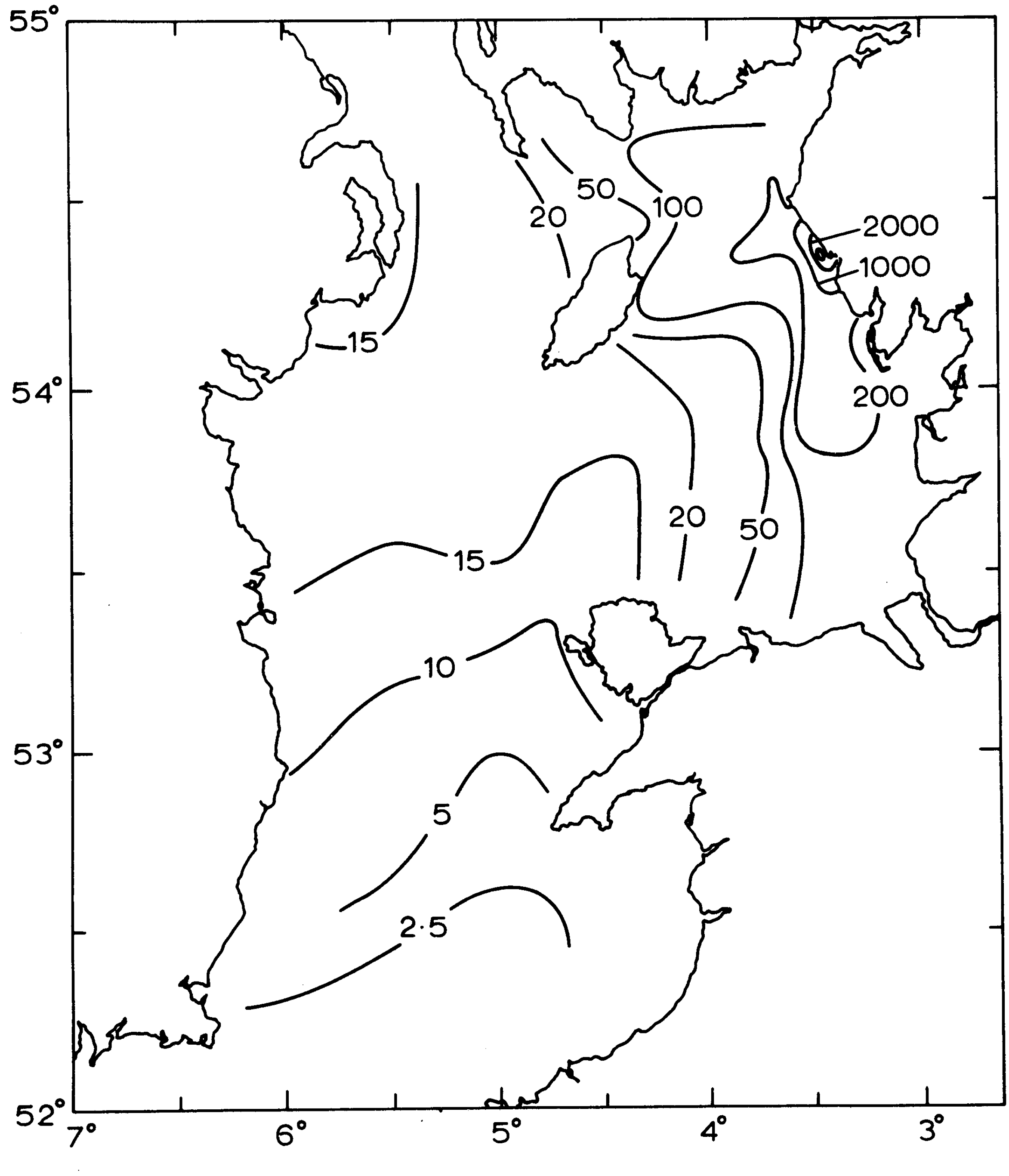

Figure 2 Concentrations of caesium-137 in filtered sea water (pCi/l) in the Irish Sea, July 1974.

calculation concerned with the fish from the Irish Sea and north-west Scottish waters, and to a lesser extent the North Sea fishery, have been substantiated by direct measurements of the caesium-137 contents of samples of fish from these areas, obtained both by the Ministry's own research vessels and from the major commercial markets in the UK. The results of this exercise are summarized in Table 9. It is seen that the total dose during 1974 due to radiocaesium was 4.3×10^3 man-rem to the UK population itself and 3.0×10^3 man-rem to the other nations affected. Since, in the case of caesium nuclides, the whole body dose is the same as the genetically significant dose, it is possible to relate the collective dose to the UK population to the limit adopted by this country for radioactive waste disposal operations. This is set at 1 rem/person/generation, equivalent to a _per capita_ dose of 30 millirem/year. The dose due to Windscale caesium was equivalent therefore to approximately 0.2% of this limit during 1974. The _per capita_ dose to other western European nations was less than 0.06% of the UK limit.

Table 9 Collective dose commitments from the consumption of fish contaminated by radiocaesium nuclides from Windscale, 1974

Population group (and size)	^{137}Cs consumption, µCi/year*	Collective dose, man-rem/year	Average _per capita_ dose, millirem/year	Average _per capita_ dose as % of UK limit
United Kingdom (5.5×10^7)	7.7×10^4	4.3×10^3	0.07	0.20
Other nations of western Europe (1.4×10^8)	5.8×10^4	3.0×10^3	0.02	0.06

*Although consumption is given in terms of ^{137}Cs only, the estimates of dose take into account the contribution of ^{134}Cs.

3.1.4. Indicator materials

The value of a number of environmental materials as sensitive indicators of environmental pollution has been mentioned already, and for this reason monitoring of the _Fucus_ species of seaweed and of sediment has been continued at a number of stations along the English and Scottish shorelines of the Irish Sea. Some of the results of this work are included in Table 10. The surveys around the south of Scotland included some monitoring on behalf of Departments of the Scottish Office and _Porphyra_ weed is sampled from some of the areas where this is used for human consumption. The concentrations of artificial radioactivity are very low and do not represent a significant source of public radiation exposure.

Table 10 Radioactivity in seaweed and sediment around the English and Scottish shoreline of the Irish Sea, 1974

Material and sampling site	Concentration of radioactivity, pCi/g (wet)*					
	Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce
Fucus vesiculosus						
Port William	22 ± 7	0.4 ± 0.3	0.5 ± 0.4	0.2 ± 0.1	1.3 ± 0.5	0.2 ± 0.2
Garlieston	29 ± 4	0.9 ± 0.2	1.6 ± 0.3	0.6 ± 0.5	3.2 ± 2.6	0.6 ± 0.1
Rascarrel Bay	54 ± 2	0.8 ± 0.2	1.8 ± 0.4	0.6 ± 0.6	3.5 ± 2.6	0.8 ± 0.2
St Bees	120 ± 23	5.7 ± 2.6	14 ± 5.0	3.3 ± 2.8	14 ± 11	3.8 ± 1.6
Seascale	248 ± 98	19 ± 8	37 ± 21	10.9 ± 8.0	50 ± 35	10 ± 6
Gutterby	154 ± 19	7.5 ± 2.7	18 ± 6	5.5 ± 4.0	25 ± 17	3.7 ± 2
Walney	71 ± 9	3.5 ± 1.9	4.5 ± 0.9	2.6 ± 2.0	13 ± 10	1.6 ± 1.8
Porphyra						
Labrax Bay	6.5 ± 1.0	0.1 ± 0.1	1.6 ± 0.8	<0.1	0.1 ± 0.1	not detected
Port William	8.5 ± 1.5	0.2 ± 0.1	3.2 ± 0.7	0.1 ± 0.1	0.3 ± 0.1	0.1 ± 0.2
Garlieston	10.3 ± 4	0.2 ± 0.3	3.0 ± 2.4	0.1 ± 0.1	0.6 ± 0.3	not detected
Kirkcudbright	8.2 ± 0.4	not detected	3.5 ± 1.8	<0.1	0.4 ± 0.1	not detected
Sediment						
Garlieston (silt)	144 ± 117	1.2 ± 1.9	14 ± 12	1.9 ± 1.9	8.3 ± 7.3	7.3 ± 6.4
Heysham (sand)	45 ± 12	not detected	4.6 ± 2.8	1.9 ± 1.8	7.1 ± 5.2	1.8 ± 1.8
Fleetwood (sand)	16 ± 2.8	not detected	0.1 ± 0.2	0.4 ± 0.3	2.0 ± 0.8	0.8 ± 0.6

*Except sediment, pCi/g (dry).

3.2. Springfields, Lancashire

This establishment fabricates nuclear fuel elements and only small amounts of naturally-occurring radionuclides appear in the liquid waste which is discharged from this site into the River Ribble. Once discharged, the only radiological impact of this waste is via its reconcentration in the muddy areas which occur on either side of the river and which are visited from time to time by members of the public. Samples of the mud have been collected from the vicinity of the factory outfall and measurements have been made of the environmental dose rates. The only radionuclide in the mud attributable to the Springfields factory was protactinium-234m (^{234m}Pa) and its concentration and the dose rates are summarized in Table 11. The significance of the dose rates in radiological terms is virtually nil, amounting to less than 1% of the derived working limit.

Table 11 Radioactivity in mud and the gamma dose rates over the mud banks in the River Ribble Estuary, 1974

Sampling site	^{234m}Pa, pCi/g (dry)	Gamma dose rate, μR/h
Pipeline outlet	331 ± 183	16 ± 1.4
Upstream		
90 metres	368 ± 456	14 ± 1.4
460 metres	370 ± 257	16 ± 1.4
Downstream		
90 metres	266 ± 195	13 ± 1.2

3.3. Chapelcross, Dumfriesshire

Liquid radioactive waste is discharged from this site into the upper reaches of the Solway Firth under authorizations granted by the Scottish Development Department. The monitoring carried out by the laboratory has been concentrated on the two major exposure pathways associated with this discharge, namely internal exposure due to the consumption of local fish and shellfish, principally shrimps, and external exposure from the occupancy of the intertidal areas. The results of the monitoring are shown in Table 12.

The interpretation of the data in relation to the radicactivity discharged from Chapelcross is impossible because of the contribution of Windscale-derived activity in this area. Nevertheless the monitoring has shown that the radiation dose received by any member of the general public from the consumption of fish and shellfish or from regular occupancy of intertidal areas did not exceed 1% of the ICRP dose limit, and it is clear that the contribution of Chapelcross to the total dose is small.

Table 12 Radioactivity in materials from the Solway estuary in the vicinity of Chapelcross, 1974

Material and sampling site	Concentration of radioactivity, pCi/g (wet)*					
	Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce
Shrimps						
Seafield	8.1 ± 1.7	not detected	1.3 ± 0.2	0.5 ± 0.4	2.4 ± 1.7	0.1 ± 0.1
<u>Fucus vesiculosus</u>						
Waterfoot	33 ± 10	0.4 ± 0.1	0.8 ± 0.2	0.5 ± 0.4	2.7 ± 1.9	0.4 ± 0.1
Seafield	28 ± 2.8	0.4 ± 0.1	0.9 ± 0.1	0.4 ± 0.4	2.6 ± 1.7	0.5 ± 0.2
Sediment						
Seafield	399 ± 540	3.7 ± 7.3	38 ± 40	2.6 ± 1.1	13 ± 4	19 ± 21

Gamma dose rate over intertidal area at Seafield = 11 ± 1 μR/h

*Except sediment, pCi/g (dry).

4. UNITED KINGDOM ATOMIC ENERGY AUTHORITY

Monitoring programmes have been conducted in association with two sites operated by the UKAEA, the Atomic Energy Establishment at Winfrith in Dorset, and the Dounreay Experimental Reactor Establishment in Caithness, Scotland; the work at the Scottish site has been done on behalf of the Departments of the Scottish Office.

No monitoring is undertaken by the laboratory in connection with any of the discharges into the rivers of the Thames catchment area from establishments such as the Atomic Energy Establishment, Harwell. The critical pathway for these discharges is drinking water and the lead is taken by the Department of the Environment rather than by the Ministry of Agriculture, Fisheries and Food. However, an assessment of the consequences of the discharges in terms of collective dose has been included in section 11 of this report for the sake of completeness.

4.1. Atomic Energy Establishment, Winfrith, Dorset

This site has an authorization to discharge liquid waste via a pipeline into Weymouth Bay. The amounts discharged during the year were small (see Table 2), and most of the beta activity was tritium. The effluent has however contained small quantities of the metal activation products cobalt-60 (^{60}Co) and zinc-65 (^{65}Zn) and it is the reconcentration of these radionuclides by crustacean shellfish which constitutes the critical exposure pathway for this discharge. Because contamination of the critical material is too low to be readily measurable, the monitoring effort is concentrated more on the indicator materials such as <u>Fucus</u> seaweed and molluscan shellfish which have the added advantage of being much more easily obtainable than the critical materials themselves. The results are summarized in Table 13 and these show that cobalt-60 is present in practically all the materials examined. The concentrations are, however, very low and, since those in the crustacean species will be even lower, the public radiation exposure due to these discharges is extremely small.

Table 13 Radioactivity in indicator materials from the vicinity of Winfrith, 1974

Material	Sampling site	Concentration of radioactivity, pCi/g (wet)		
		Total beta	^{60}Co	^{65}Zn
Limpet flesh	Chapman's Pool	2.1 ± 0.4	0.5 ± 0.2	0.1 ± 0.1
	Osmington Mills	2.0 ± 0.6	0.2 ± 0.1	<0.1
Fucus serratus	Chapman's Pool	9.1 ± 0.3	4.7 ± 1.4	not detected
	Osmington Mills	7.2 ± 1.1	2.1 ± 1.0	"
	Weymouth	7.7 ± 1.3	2.4 ± 1.1	"
	Swanage	9.6 ± 0.9	4.4 ± 2.0	"
	Portland	9.4 ± 1.4	1.6 ± 0.8	"

As well as demonstrating the safety of this existing discharge, the monitoring of this area has another important objective. Since the waste from this site comes primarily from the experimental steam generating heavy water reactor (SGHWR), it gives an insight into the effluents which may be expected to arise from the commercial reactors of this type presently being designed for construction in this country. So the opportunity is being taken of collecting as much information as possible on the environmental behaviour of the major components of the Winfrith effluent in order to provide information on which to base the control of commercial SGHWR effluents when they become operational.

4.2. Dounreay, Caithness

Environmental monitoring in connection with this establishment has been continued on behalf of Departments of the Scottish Office, and the results of the measurements made on a range of indicator materials are presented in Table 14. In addition, the laboratory has continued to investigate the principal pathway for public radiation exposure for these discharges, which is the beta irradiation of the hands and forearms of the local people as they handle their fishing gear. Measurements of the dose rates from fishing nets have been made and these results, together with observations on the fishing effort in the area, have shown that the maximum exposure during 1974 was equivalent to about 1% of the ICRP dose limit.

The other significant pathway, that due to the deposition on the foreshore of spume contaminated by fission product nuclides, has been monitored by the UKAEA themselves, who have published their own results (Ref. 7).

Table 14 Radioactivity in environmental materials from the vicinity of Dounreay, 1974

Material and sampling site	Concentration of radioactivity, pCi/g (wet)				
	Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{137}Cs	^{144}Ce
Limpet flesh					
Sandside Bay	40 ± 16	2.4 ± 1.6	3.2 ± 1.6	not detected	11 ± 5
Winkle flesh					
Sandside Bay	14 ± 3	2.4 ± 0.6	2.8 ± 1.4	0.1 ± 0.1	13 ± 7
<u>Fucus vesiculosis</u>					
Sandside Bay	27 ± 10	6.5 ± 5.8	0.7 ± 0.4	0.4 ± 0.1	7.7 ± 3.7
<u>Fucus serratus</u>					
Pipeline outlet	85 ± 29	28 ± 7	3.2 ± 0.8	0.8 ± 0.4	34 ± 14
Oigin's Goe (1.6 km east)	135 ± 6	30 ± 4	3.5 ± 0.8	0.6 ± 0.1	48 ± 10
Sandside Bay East (1.6 km west)	43 ± 3	15 ± 7	2.0 ± 0.7	0.5 ± 0.2	18 ± 2
Borrowston (3.2 km east)	92 ± 26	20 ± 1	2.5 ± 0.1	0.2 ± 0.4	42 ± 13
Holborn Head (12.1 km east)	24 ± 10	2.4 ± 1.3	0.4 ± 0.1	not detected	5.4 ± 4.3

5. NUCLEAR POWER STATIONS OPERATED BY THE CENTRAL ELECTRICITY GENERATING BOARD

The discharges of liquid radioactive waste from nuclear power stations operated by the Central Electricity Generating Board during 1974 are summarized in Table 2 and were all within the authorized limits. In most cases, and particularly for those sites discharging directly into the sea, these limits are well below the limiting environmental capacities of the water masses to which the discharges are made. It is therefore not surprising that it is not usually possible to detect anything more than a trace of artificial radioactivity in environmental materials collected from the vicinity of the stations; this itself is often due to weapons test fallout rather than station operations.

Results for the individual sites are given below. The measurements of radioactivity in both the critical materials and the principal indicator materials are reported, together with the results of gamma dose rate surveys over the intertidal areas in each case. The radioactivity measurements have been expressed in terms of total beta activity together with specific nuclide data where appropriate. All results have been expressed in terms of public radiation exposure by relating them to the appropriate derived working limit. Information concerning the actual exposure pathways themselves has not been repeated in this report. This information may be obtained from previous reports in this series which should also be consulted for further details about the monitoring programmes.

5.1. Berkeley, Gloucestershire and Oldbury, Avon

Results from the joint monitoring programme for these stations are given in Table 15. Traces of radiocaesium nuclides were detectable in both critical and indicator materials. The concentrations were barely distinguishable from weapons fallout and far below the derived working limits. The gamma dose rates were not distinguishable from natural background levels.

Table 15 Radioactivity in environmental materials around Berkeley and Oldbury nuclear power stations in 1974

Material	Concentration of radioactivity, pCi/g (wet)*			% of DWL
	Total beta	^{137}Cs	^{134}Cs	
Flounders	2.6	<0.1	not detected	<0.01
Eels	1.7	<0.1	<0.01	<0.01
Shrimps	2.5 ± 0.3	<0.1	<0.02	<0.01
Fucus vesiculosus	6.5 ± 0.9	<0.1	not detected	-
Mud	24.9 ± 1.5	1.4 ± 0.2	0.16 ± 0.05	-
Background mud	20.9 ± 3.2	0.3 ± 0.1	not detected	-

Gamma dose rate over intertidal mud = 7.2 ± 0.4 μR/h

*Except mud, pCi/g (dry).

5.2. Bradwell, Essex

Discharges of both silver-110m (^{110m}Ag) and zinc-65, which have been the critical nuclides discharged from this station in the past, were extremely small in 1974. Consequently they were only just detectable in oysters and indicator materials. Traces of caesium radionuclides were also detected, but the total public radiation exposure from the consumption of oysters amounted to no more than 0.1% of the ICRP dose limit. Gamma dose rates are not distinguishable from natural background levels (see Table 16).

Table 16 Radioactivity in environmental materials around Bradwell nuclear power station in 1974

Material	Concentration of radioactivity, pCi/g (wet)*				% of DWL
	Total beta	^{137}Cs	^{65}Zn	^{110m}Ag	
Oysters	2.6 ± 0.6	0.07 ± 0.04	0.3 ± 0.1	0.7 ± 0.2	0.1
Fucus vesiculosus	5.9 ± 0.7	0.1 ± 0.01	not detected	<0.1	-
Mud	29.5 ± 3.7	1.6 ± 1.4	not detected	0.2 ± 0.1	-

Gamma dose rate over intertidal mud = 7.0 ± 0.3 μR/h

*Except mud, pCi/g (dry).

5.3. Dungeness, Kent

Monitoring of plaice flesh and sand in the Dungeness area continued to show no more than the merest traces of caesium-137. The gamma dose rate readings were not distinguishable from background levels and public radiation exposure due to the discharges from this station were less than 0.1% of the ICRP dose limit (see Table 17).

Table 17 Radioactivity in environmental materials around Dungeness nuclear power station in 1974

Material	Concentration of radioactivity, pCi/g (wet)*		% of DWL
	Total beta	^{137}Cs	
Plaice	not analysed	< 0.05	< 0.1
Sand	11.5 ± 0.9	< 0.05	-

Gamma dose rates over intertidal sand = 4.3 ± 1.0 μR/h

*Except sand, pCi/g (dry).

5.4. Hinkley Point, Somerset

Flatfish and shrimps, which are the critical materials at this site, continued to show only traces of caesium-137 (see Table 18). The concentrations were equivalent to less than 0.1% of the derived working limit and were probably due to weapons fallout rather than to the operations of the power station. Small amounts of fission products were detected in indicator materials collected from the immediate vicinity of the outfall, particularly sediment, but the gamma dose rates over muddy areas were indistinguishable from natural background levels.

Table 18 Radioactivity in environmental materials around Hinkley Point nuclear power station in 1974

Material	Concentration of radioactivity, pCi/g (wet)*				% of DWL
	Total beta	^{137}Cs	^{144}Ce	^{106}Ru	
Flatfish	1.9	<0.1	not detected	not detected	<0.03
Shrimps	2.7	<0.1	"	"	<0.01
Fucus vesiculosus (outfall)	10.6 ± 1.5	0.8 ± 0.4	"	<0.2	-
Fucus vesiculosus (elsewhere)	8.5 ± 1.7	0.2 ± 0.03	"	not detected	-
Mud (outfall)	34.2 ± 7.9	4.2 ± 3.8	1.2 ± 1.6	0.7 ± 1.0	-
Mud (elsewhere)	27.0 ± 0.9	1.7 ± 0.7	0.9 ± 0.4	not detected	-

Gamma dose rate over intertidal mud = 7.6 ± 1.2 μR/h

*Except mud, pCi/g (dry).

5.5. Sizewell, Suffolk

Fish and crustaceans caught in the vicinity of Sizewell contained only traces of caesium-137 and these were consistent with weapons fallout levels, as would be expected from the continuation of low discharges and good dispersion. The gamma dose rates over the sandy areas of the foreshore are very low, and indistinguishable from natural background (see Table 19).

Table 19 Radioactivity in environmental materials around Sizewell nuclear power station in 1974

Material	Concentration of radioactivity, pCi/g (wet)		% of DWL
	Total beta	^{137}Cs	
Roundfish	3.1 ± 0.4	< 0.1	< 0.1 (Roundfish and Flatfish)
Flatfish	2.1 ± 0.1	< 0.1	
Crab	2.1	< 0.1	< 0.01 (Crab and Lobster)
Lobster	2.0 ± 0.2	< 0.03	

Gamma dose rate over intertidal sand = 3.2 ± 0.3 μR/h

5.6. Trawsfynydd, Gwynedd

At Trawsfynydd, where discharges are made to a freshwater lake, public radiation exposure from the consumption of fish is higher than would be the case for a similar discharge to coastal waters. Even so, the data given in Table 20 show that the public radiation exposure from the consumption of trout and perch caught from the lake amounted to only about 7% of the ICRP dose limit, the exposure being due almost entirely to radiocaesium nuclides. The concentration of radioactivity in rainbow trout, which in terms of total catch from the lake is a more important species, is less than that in brown trout. The results demonstrate that the discharges have continued to be controlled satisfactorily. The remaining data presented in the table have been collected as a part of the continuing radioecological research programme aimed at a better understanding of the behaviour of artificial radioactivity in a freshwater environment.

Table 20 Radioactivity in environmental materials around Trawsfynydd nuclear power station in 1974

Material	Concentration of radioactivity, pCi/g (wet)*								% of DWL
	Total beta	^{60}Co	^{90}Sr	^{106}Ru	^{125}Sb†	^{134}Cs	^{137}Cs	^{144}Ce	
Trout	17.4 ± 4.8	not detected	0.06	not detected		2.4 ± 0.8	17.6 ± 3.9	<1	7 (Trout and Perch)
Perch	36.6 ± 7.4	"	0.17	"		5.4 ± 1.8	36.6 ± 9.5	not detected	
Mud	44 ± 12	<1	not analysed	<1	6.9 ± 4.1	1.1 ± 0.5	17.4 ± 8.8	<5	-
Peat	123 ± 32	0.7 ± 0.1	"	3.2 ± 1.3	70 ± 16	3.1 ± 0.9	18.3 ± 3.8	not analysed	-
Fontinalis (Afon Prysor)	9.8 ± 2.2	not detected	"	1.1 ± 0.4	0.2 ± 0.1	not detected	0.1 ± 0.1	1.1 ± 0.5	-
Fontinalis (Gwylan Stream)	69 ± 51	3.7 ± 2.6	"	9.2 ± 8.7	35 ± 36	1.9 ± 1.0	6.8 ± 3.1	<2	-
Water* (Hot Lagoon)	not analysed	not analysed	3.7 ± 0.6	not analysed	not analysed	1.5 ± 0.5	12.7 ± 4.8	not analysed	-
Water* (Main Lagoon)	"	"	not analysed	"	"	1.4 ± 0.5	12.0 ± 4.7	"	-

*Except peat and mud, pCi/g (dry); and water, pCi/l.
†^{125}Sb, antimony-125.

5.7. Wylfa, Gwynedd

Traces of artificial radioactivity at levels greater than those corresponding to weapons fallout are generally detectable in environmental materials in the vicinity of Wylfa, as may be seen from the data of Table 21. They are, however, due to the increased radioactivity of Irish Sea water caused by discharges from Windscale, and not to discharges from the power station, which are minimal. Public radiation exposure from the consumption of fish was around 0.3% of the ICRP dose limit, and gamma dose rates over intertidal mud are not distinguishable from background values.

Table 21 Radioactivity in environmental materials around Wylfa nuclear power station in 1974

Material	Concentration of radioactivity, pCi/g (wet)*				% of DWL
	Total beta	^{137}Cs	^{106}Ru	^{144}Ce	
Pollack and bass	5.8 ±1.3	2.1 ±1.7	not detected	not detected	0.2
Lobster	4.7 ±1.2	0.2 ±0.1	"	"	0.03
Crab	4.9	0.3 ±0.1	"	"	0.05
Winkles	3.9 ±0.9	0.2 ±0.1	0.2 ±0.1	"	-
Porphyra	6.3 ±1.1	<0.2	not detected	"	-
Fucus vesiculosus	19.0 ±4.9	0.6 ±0.1	0.1 ±0.1	"	-
Mud	41.7 ±5.3	9.3 ±2.3	2.7 ±0.4	1.4 ±1.0	-

Gamma dose rates over intertidal mud = 10 ±2 μR/h

*Except mud, pCi/g (dry).

6. NUCLEAR POWER STATIONS OPERATED BY THE SOUTH OF SCOTLAND ELECTRICITY BOARD

The power station at Hunterston in Ayrshire is the only site in this category, and monitoring there has been conducted on behalf of Departments of the Scottish Office. The results of this programme are summarized in Table 22. In addition to the sampling of cockles, which constitutes the principal source of internal exposure, both sea water and indicator materials have been monitored. The sea water has been analysed for radiocaesium as part of the wider study of the movement of activity discharged from Windscale. The critical material continued to show traces of fission products. These are mainly attributable to weapons fallout, with Hunterston itself contributing a very small fraction. Public radiation exposure from these discharges remained a very small fraction of the ICRP dose limit.

Table 22 Radioactivity in the vicinity of Hunterston, 1974

Material	Concentration of radioactivity, pCi/g (wet)*					% of DWL
	Total beta	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce	
Cockle flesh	2.4 ±0.6	0.3 ±0.1	<0.1	0.2 ±0.1	<0.1	<0.01
Crab flesh	4.9	0.1	<0.1	0.2	0.1	<0.01
Fucus spiralis	12 ±1.0	0.4 ±0.2	0.2 ±0.1	1.0 ±0.4	0.2 ±0.1	-
Sand	12 ±3.9	not detected	0.1 ±0.1	0.4 ±0.1	0.3 ±0.1	-
Sea water	not detected	"	4.4 ±2.2	25 ±8.9	not detected	-

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

7. SITES OPERATED BY MINISTRY OF DEFENCE (NAVY DEPARTMENT)

Small amounts of radioactivity were discharged during the year from the naval bases at Chatham, Devonport, Faslane and Rosyth, and environmental monitoring has been continued in each of these areas. In the case of Faslane and Rosyth the work has been carried out on behalf of Departments of the Scottish Office.

It so happens that the principal exposure pathway associated with all of these discharges is external exposure following the uptake of radioactivity by intertidal sediments. The monitoring is concentrated mainly on gamma dose measurement backed up by analyses of samples of sediment together with a small number of samples of indicator materials. The results are summarized in Table 23. They show that the sediments contained traces of cobalt-60, as would be expected since this is the principal nuclide discharge from these establishments. The concentrations were very small, however, and the resultant dose rates were not significantly different from those due to natural sources expected in these muddy areas. Public radiation exposure has remained negligible, less than 1% of the ICRP dose limit.

Table 23 Results of monitoring surveys in the vicinity of establishments operated by the MOD (Navy Department)

Site and material	Concentration of radioactivity, pCi/g (wet)*			Gamma dose rate, μR/h
	Total beta	^{60}Co	^{137}Cs	
Chatham				
Sediment	28 ± 5.6	0.2 ± 0.1	0.8 ± 0.2	9.1 ± 1.5
Devonport				
Sediment	28 ± 1.2	0.1 ± 0.1	0.3 ± 0.1	10 ± 1.8
Winkle flesh	3.7 ± 1.3	<0.1	<0.1	-
Fucus vesiculosus	7.1 ± 1.2	<0.1	not detected	-
Faslane				
Foreshore sediment	26 ± 5.8	0.3 ± 0.3	1.7 ± 1.4	10
Seabed sediment	38 ± 3.8	0.7 ± 0.2	8.3 ± 2.7	-
Rosyth				
Foreshore sediment	15	<0.1	0.2	11
Seabed sediment	24 ± 1.4	0.5 ± 0.5	0.7 ± 0.4	-

*Except sediment, pCi/g (dry).

8. THE CHANNEL ISLANDS

In surveillance of possible effects of discharges from the fuel reprocessing plant at Cap de La Hague on the mainland of France to the east of the Channel Islands the laboratory has continued its programme of analysis on environmental samples made available by the Channel Islands Governments. The range of materials for which measurements are quoted in Table 24 includes fish, shellfish and sand chosen for their possible significance in relation to public radiation exposure; _Porphyra_ seaweed is also included and fulfils an indicator role. Traces of caesium-137 are found in some of these materials but at levels consistent with fallout from weapons testing. There is also evidence of ruthenium-106, especially in _Porphyra_, though again levels are low and of very little radiological significance. In this case, however, and although a majority of the analyses are consistent with weapons testing fallout, measurements on the shores of Alderney suggest a small contribution from another source, presumably the discharges from the plant at Cap de la Hague.

Table 24 Radioactivity in materials on the coasts of the Channel Islands, 1974

Material	Sampling area		Concentration of radioactivity, pCi/g (wet)*		
			Total beta	^{106}Ru	^{137}Cs
Porphyra	Guernsey	Fort Doyle	6.2 ± 2.7	0.7 ± 0.2	not detected
		Fermain Bay	6.9 ± 2.6	0.5 ± 0.2	"
	Alderney	Corblets Bay	7.7 ± 1.0	1.0 ± 0.8	"
		Telegraph Bay	6.9 ± 2.2	0.8 ± 0.5	"
		Hannain	9.0	not detected	"
		Querard Point	7.8 ± 1.9	2.1 ± 1.7	"
	Jersey	Greve de Lecq	7.4 ± 1.9	0.3 ± 0.3	"
		La Rozel	6.8 ± 0.9	0.4 ± 0.4	"
Ormer flesh	Guernsey		3.3	0.3	< 0.1
Ray wings	Guernsey		2.6	not detected	< 0.1

*Except sand, pCi/g (dry).

9. IRELAND

Monitoring has continued of seaweed indicator materials collected from a series of sites on the Irish Sea coast of the Irish Republic. A variety of seaweeds has been collected, and the results are summarized in Table 25. Traces of fission products have occasionally been found but at such a low level that they carry no radiological significance.

Table 25 Radioactivity in seaweeds from the coastline of Ireland, 1974

Material	Concentration of radioactivity, pCi/g (wet)			
	Total beta	$^{95}Zr/^{95}Nb$	^{106}Ru	^{137}Cs
Porphyra				
Skerries	4.7	0.1	0.3	0.1
Colliemore	7.3	not detected	not detected	<0.1
St Helens	4.0	"	0.1	not detected
Dunmore	4.5	"	not detected	"
Fucus serratus				
St Helens	8.1	not detected	not detected	not detected
Dunmore	5.8	"	"	"
Laminaria digitata and L. saccharina				
Skerries	11.2	0.3	0.1	0.3
Colliemore	15.2	not detected	not detected	0.2
Dunmore	7.9	"	"	not detected
Carlingford	13.8	0.3	0.2	0.3
St Helens	17.4	0.1	not detected	not detected

10. MISCELLANEOUS SURVEYS

As in previous years, a limited programme of work has been undertaken to measure the concentrations of radioactivity in a selection of marine samples from areas remote from any controlled discharge of radioactive waste. This work has shown that traces of fission products such as ruthenium-106 and caesium-137 remain detectable in fish and seaweed at concentrations of the order of 0.1 pCi/g (wet).

11. SUMMARY AND CONCLUSION

The principal purpose of the environmental monitoring surveys summarized in this report is to confirm the adequacy of the procedures for controlling discharges of radioactive waste to coastal and surface waters. For this reason, throughout the report, the monitoring data have been interpreted wherever possible in terms of radiation exposure to members of the public. This has been achieved by the application of the conventional critical pathway approach and for each source of radioactive waste the dose to the critical group (or groups) has been calculated. A summary of the results is presented in Table 26 where the doses are expressed as percentages of the appropriate ICRP dose limits.

Table 26 Estimates of public radiation exposure from liquid radioactive waste disposals in the United Kingdom, 1974

Site	Pathway	Maximum exposure* of an individual (% of ICRP-recommended dose limit)
BRITISH NUCLEAR FUELS LIMITED		
Windscale	Fish	14 (to critical group)
	External dose	7
	Porphyra/laverbread	< 0.2 (to critical group)
Springfields	External dose	< 1
Chapelcross	External dose	< 1
	Shellfish	< 1
UNITED KINGDOM ATOMIC ENERGY AUTHORITY		
Winfrith	Shellfish	< 1
Harwell*	Drinking water	< 1
Dounreay	External dose (foreshore)	< 1
	Beta dose (fishermen)	1
	Shellfish	< 1
CENTRAL ELECTRICITY GENERATING BOARD		
Berkeley/ Oldbury	External dose	< 0.1
	Fish/shellfish	< 0.1
Bradwell	Oyster	0.1
Dungeness	External dose	< 0.1
	Fish	< 0.1
Hinkley Point	External dose	< 0.1
	Fish/shellfish	< 0.1
Sizewell	External dose	< 0.1
	Fish/shellfish	< 0.1
Trawsfynydd	Lake fish	7
Wylfa	Fish/shellfish	0.3
	External dose	< 0.1

Table 26 (continued)

Site	Pathway	Maximum exposure* of an individual (% of ICRP-recommended dose limit)
SOUTH OF SCOTLAND ELECTRICITY BOARD		
Hunterston	External dose	< 0.1
	Fish/shellfish	< 0.1
MINISTRY OF DEFENCE (NAVY DEPARTMENT)		
Chatham	External dose	< 1
Devonport	External dose	< 1
Faslane	External dose	< 1
Rosyth	External dose	< 1

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

As in previous years, the discharges from the British Nuclear Fuels Limited reprocessing factory at Windscale in Cumbria have provided the largest source of public exposure, although even in this case the doses received by the most highly exposed individuals were less than one-sixth of the ICRP dose limit. Of the discharges from the nuclear power stations, only those from Trawsfynydd led to public radiation exposure amounting to more than a small fraction of 1% of the ICRP dose limits; even in that case the maximum dose to any individual was only about 7% of the dose limit.

Although the primary consideration when assessing the impact of radioactive waste discharges is the dose received by individuals, it is necessary, because of the significance of ionizing radiation in genetic terms, also to take account of the collective doses which may arise from waste disposal operations. This is a figure which takes into account not only the individual doses but also the total number of people concerned. However, when this integration is attempted for the sites covered by this report it is found, in fact, that there are only two discharges of liquid waste for which it is possible to quantify a source-related collective dose in a meaningful way. These are the discharge of radiocaesium nuclides from Windscale and the discharge of tritium into the rivers of the Thames catchment area. Details have already been given of the work which has been undertaken by this laboratory in order to measure the collective dose due to the contamination of fish by Windscale caesium (see section 3.1) and it has been shown that the doses to the UK population itself during 1974 was equivalent to 0.2% of the UK limit of 30 millirem per person per year whilst that to the other nations of western Europe was approximately 0.06% of the UK limit.

In the case of tritium releases to the Thames, it may be calculated from the discharge data of Table 2 and the mean flow rate of the river that the average concentration in the water extracted for drinking was approximately 1.5×10^2 pCi/l higher than would have been the case in the absence of these discharges. Regular consumption of water containing this amount of tritium results in a gonad dose of 15 μrem per year; on the assumption that the number of people drinking this water is 7 million, this implies a collective dose of approximately 100 man-rem during 1974, equivalent to < 0.01% of the UK dose limit.

It is possible in theory to calculate the collective dose due to each of the other discharges individually, but, because they are all so small, it is more appropriate to consider them together. This may be done by the following procedure which, although tending to overestimate the actual dose, does permit the upper limit to the total integrated dose from a given discharge into coastal waters to be calculated. When radioactivity is discharged to a volume of water which supports a certain fishing effort which is reasonably homogeneous then the total amount of radioactivity which returns to the human diet through the fish food chain is, to a first approximation, independent of the ways in which the activity disperses. On this basis it is possible to reach a relationship between the rate of input of radioactivity into the continental shelf waters of western Europe and the resultant collective doses to the populations which eat the fish from these areas. In the case of a radionuclide with decay factor λ, discharged at a constant rate into a water mass with mean depth d, from which the rate of extraction of edible fish is F units of mass per unit area, the collective dose per unit input of activity is given by

$$J = \frac{k\,F\,\gamma}{d\,\lambda\,\rho},$$

where k is the factor relating dose to activity ingested, γ the concentration factor for the nuclide concerned by the edible part of the fish, and ρ is the density of water. For the purposes of the calculation it is appropriate to consider only caesium-137. As well as being a nuclide of importance via the fish food chain, it is the predominant constituent of the effluents of most of the nuclear sites. Substitution of the appropriate factors for this nuclide into the above equation gives a value of 0.6 man-rem per Ci for caesium-137 discharges into the European continental shelf waters. Although this is undoubtedly an overestimate of the true figure (it does not for example take account of any mechanisms of loss from the water other than physical decay of the nuclide), it does nonetheless represent an upper limit for total collective dose commitment and one which can be obtained very simply without recourse to complicated processes involving, for example, a cut-off level of contamination which must in any case be arbitrary to one degree or another. Using this relationship, it may be calculated that the annual collective dose from a rate of discharge of caesium-137 equal to that during 1974 from all sources other than Windscale could not have been more than about 10^3 man-rem. When averaged over the total fish-eating population of western Europe, this corresponds to a per capita dose of 5 μrem per year, which is equivalent to less than 0.02% of the United Kingdom limit. The actual collective dose was even less than this and so was of no consequence at all.

It is concluded therefore that during the year under review all discharges of liquid radioactive waste to UK coastal and surface waters have continued to be controlled satisfactorily. The measurement made on samples collected in the course of the environmental monitoring surveys conducted by the Fisheries Radiobiological Laboratory have shown that public radiation exposure has been controlled within the internationally recommended standards of radiological safety. In the majority of cases public radiation exposure has been virtually nil and in no case has the dose exceeded about 15% of the ICRP dose limit.

In order to help readers to appreciate the significance of these low levels of radiation exposure it may be helpful to add some remarks about the ICRP dose limits and the philosophy which underlies them. It has become clear over recent years that these limits have come to be identified in the minds of some people with a threshold of danger and that it is believed that, as radiation exposure approaches the limits, the consequences increase in a catastrophic fashion. This view is wrong and reveals a misunderstanding of the basic views of the Commission. The dose limits are intended as standards for the design and operation of sources of radiation so that individuals of the public will receive no more than a specified dose. This specified dose has been chosen after a careful comparison of the risks associated with radiation exposure with the benefits which are produced by the processes which produce the radiation. Long experience with many sources of ionizing radiation has shown that, provided the specified limits are observed, the associated risks are small compared with other risks of everyday life and that they are justified by the benefits provided by the processes which produce the exposure. During the year, therefore, all the doses received as a consequence of the controlled discharges of radioactive waste have been contained well within the limits which are themselves regarded by the Commission of independent international experts as carrying a risk which is not only very small but is acceptable in relation to the advantages derived from the processes of which radioactive waste is a by-product.

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