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THE CONTRIBUTION OF RADIOACTIVITY IN THE IRISH SEA TO THE RADIATION EXPOSURE OF THE IRISH POPULATION DURING 1982-'83

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THE CONTRIBUTION OF LIQUID DISCHARGES

FROM SELLAFIELD

TO THE RADIATION EXPOSURE OF THE IRISH PUBLIC

DURING 1982-1983

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1. INTRODUCTION.

The Nuclear Energy Board undertakes a monitoring programme of the radioactivity levels of the Irish Sea. The programme includes the sampling and analysis of fish, seaweeds, sediments and seawater. This report presents an estimate of the exposure of members of the Irish public during the period of May 1982 to June 1983 due to the consumption of fish and shellfish, the most important route by which exposure of the Irish public could occur from radioactivity, in particular radiocaesium, in the Irish Sea. Radiation exposure from other pathways, such as external radiation, is negligible. The results are examined in terms of the dose limits recommended by the International Commission on Radiological Protection and the basic radiation safety standards of the European Community.

2. SOURCE OF RADIOACTIVITY IN THE IRISH SEA.

The principal source of radioactivity in the Irish Sea is the discharge of low level radioactive liquid effluents from Sellafield, Cumbria, in the United Kingdom to the north-east Irish Sea. Discharges from other sources are, by comparison, negligible. The location of Sellafield is shown in Figure 1 and its facilities include the Windscale nuclear fuel reprocessing works and the Calder Hall magnox-type nuclear power station. The prototype Advanced Gas Cooled Reactor, which was also sited there, has been closed down. The radioactivity discharges arise almost entirely from the reprocessing activities and particularly from the used nuclear fuel storage ponds. Virtually 100% of the radioactive wastes separated from the reprocessed fuel are stored on site and only extremely small quantities are discharged to the Irish Sea via a pipeline which terminates 2.1 km beyond the low-water mark.

While a variety of radionuclides is present in the effluents discharged to the Irish Sea, the radionuclide of principal interest here is caesium as it is the dominant contributor to the exposure of members of the Irish public. Restrictions have been placed on the quantities of radionuclides which may be discharged annually by the United Kingdom authorities (HUNT 1983). These discharge authorisations, which are summarised in Table 1, are set so that,

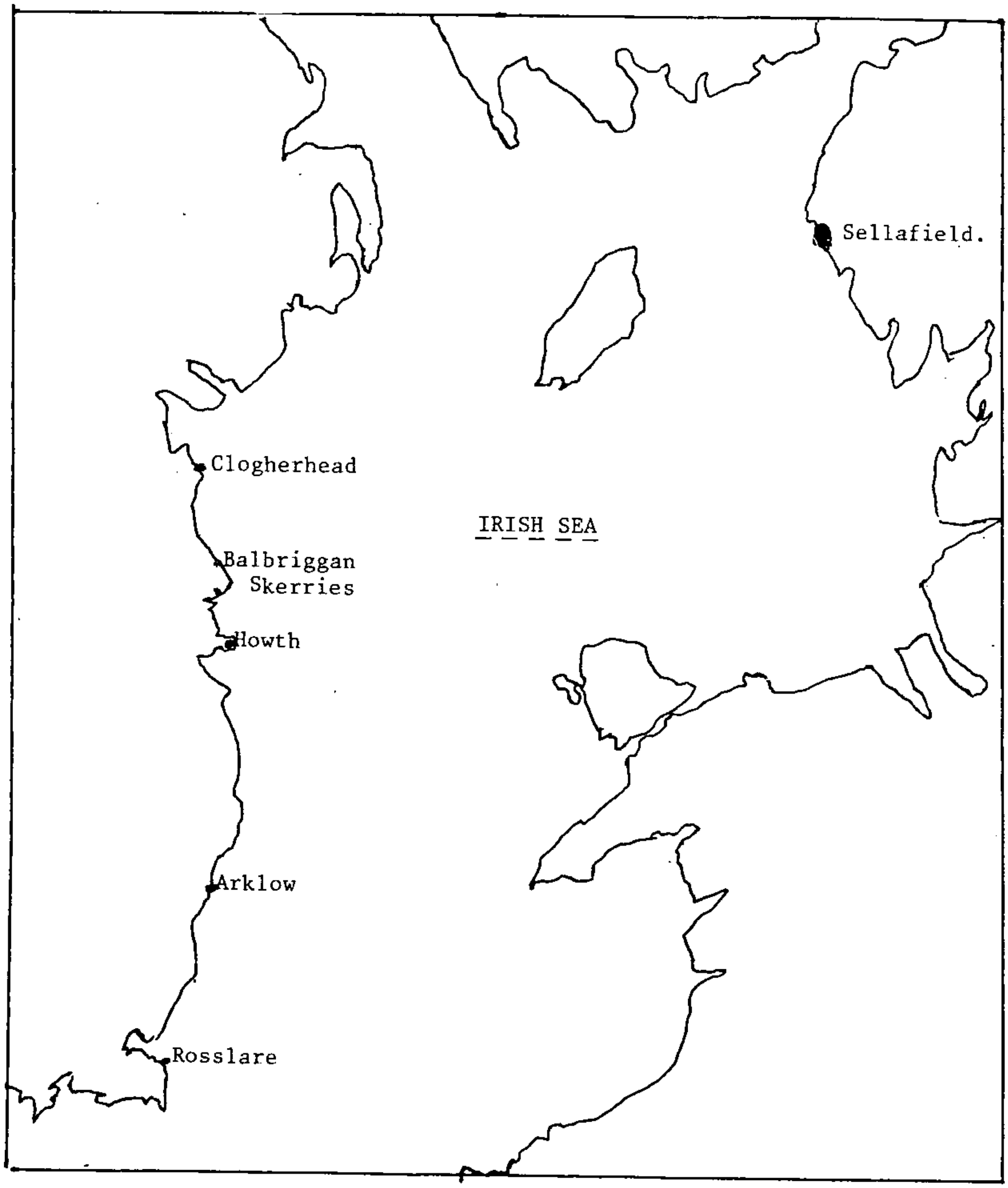

FIGURE 1. THE IRISH SEA SHOWING THE LOCATIONS OF SELLAFIELD AND THE SAMPLING POINTS.

SCALE: 1cm = 20 km

if they are observed, the dose limits recommended by the International Commission on Radiological Protection (ICRP) for members of the public (ICRP 1977) will not be exceeded. These latter limits have been included in the European Community Directive on the protection of members of the public and workers against the dangers of ionizing radiation (CEC 1980). The discharge authorisation for Sellafield was amended recently to require discharges to be kept as low as reasonably achievable (ALARA) within the authorised discharge limits.

There was a major increase in 1974 in the quantities of radionuclides being discharged to the Irish Sea. This was due to operating difficulties at the reprocessing plant which necessitated prolonged storage of magnox-type used fuel under water in the used fuel storage ponds. This resulted in corrosion of the fuel and the release of radionuclides, notably caesium, to the pond water. Pond water treatment facilities were inadequate and the quantities of caesium discharged to the Irish Sea increased as indicated in Figure 2. Since then the quantities discharged have been gradually reduced primarily by the use of zeolites to absorb radioactivity from the pond water. The quantity discharged in 1974 amounted to about 50% of the annual total beta radioactivity limit and in 1983 about 20% of this limit. A further significant reduction is expected during 1984 when a new ion exchange effluent treatment plant is due to be brought into service.

TABLE 1

SELLAFIELD LIQUID DISCHARGES.

Radioactivity	Annual Discharge Limit	1982 Discharges
Total alpha emitters	2.22×10^2 TBq	2.85 TBq
Total beta emitters including caesium	1.11×10^4 TBq	3.53×10^3 TBq

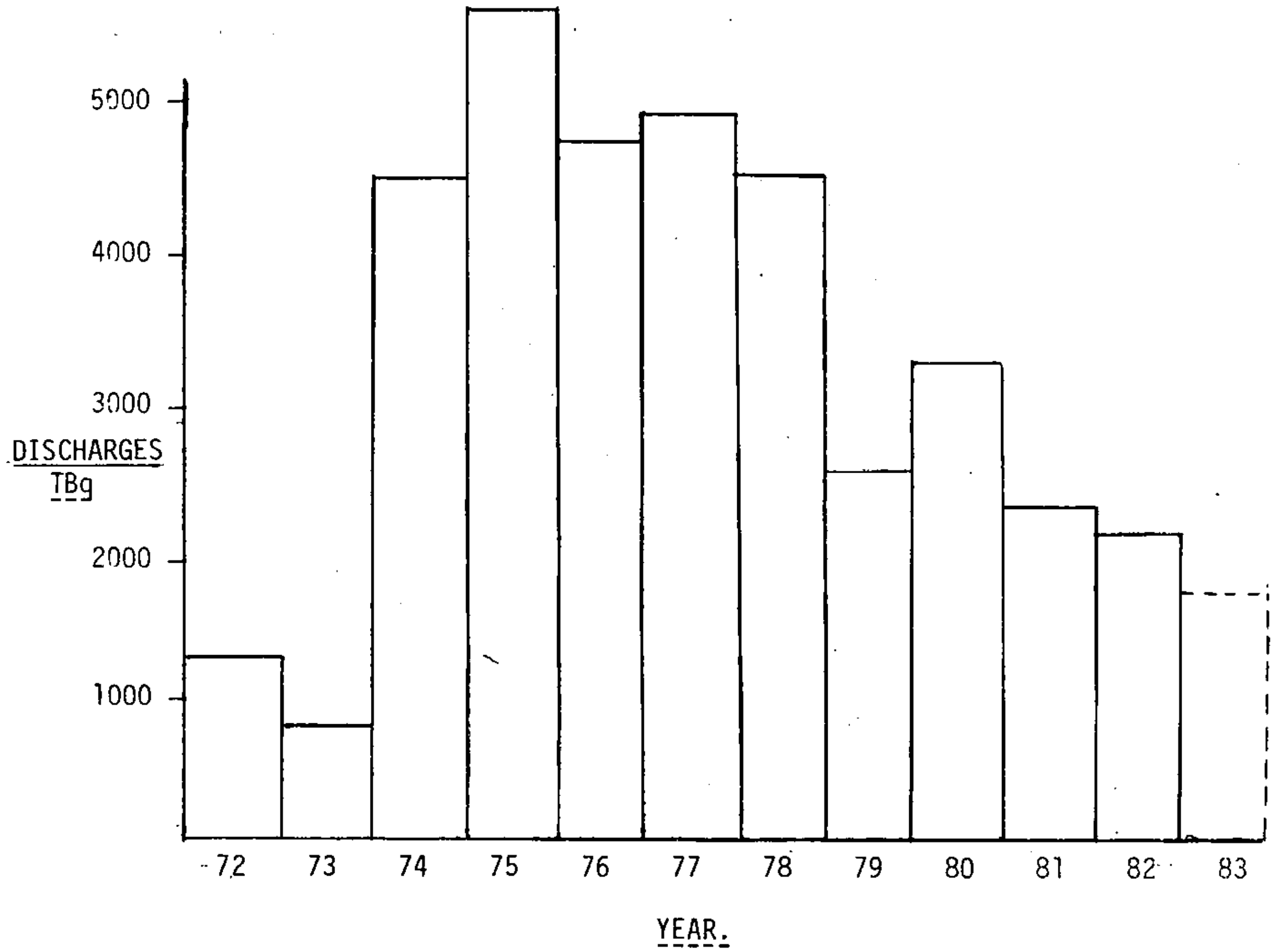

FIGURE 2. DISCHARGES OF RADIOCAESIUM FROM SELLAFIELD TO THE IRISH SEA.

Data are presented in the SI (Systeme Internationale) radiological units which are summarised in Table 2. This table also includes some useful conversion factors.

TABLE 2

RADIOLOGICAL UNITS

Quantity	SI Unit	Conversion Factors
Radioactivity	Becquerels (Bq)	1 TBq = 10^{12} Bq
Dose Equivalent	Sievert (Sv)	1 Sv = 1000 mSv 1mSv = 1000 μSv
Collective Dose	Man-sievert (man-Sv)	

3. METHODOLOGY.

(i) Sampling and Analysis

Caesium-134 and -137 concentrations are measured in plaice, whiting, cod, herring and prawns. These species constitute the major proportion of the catches from the fishing grounds of the Irish Sea and are representative of the types of fish and shellfish consumed by the Irish public. In addition these species represent the demersal and the pelagic types of fish i.e., those found near the bottom of the sea and those living in the middle depths and surface waters of the sea.

Samples of fish and shellfish are obtained primarily at the Dublin and Howth fish markets and are taken from catches landed at the east coast ports of Clogherhead, Skerries, Howth and Arklow. The frequency of sampling is selected to enable a reasonable estimate to be made of the radiological dose to the public as a result of eating seafood from the Irish Sea. Each sample weighing about 2 kg is prepared for analysis by cleaning and filleting one to about five fish depending on their size. The edible flesh is dried to a constant weight and ground to a fine powder.

The fish and shellfish samples are analysed by conventional gamma spectrometry using a 75 mm by 75 mm sodium iodide (Tl) detector coupled to a multichannel analyser. The detector is housed in a 100 mm thick lead shield and is calibrated using suitable reference sources. The energy resolution is about 13% and the spectra are recorded over 512 channels which cover the gamma energy range from zero to 1.8 MeV. Two counting configurations are used, an array of polystyrene tubes placed symmetrically around the detector or a 75 mm diameter container placed above the detector.

The spectral data are analysed to derive radioactivity concentrations using a computer programme. The data inserted into the programme include the sample weight, the percentage dry weight, the configuration, the counting time and the counts in the energy channels of interest. The programme carries out background subtraction, corrections for potassium-40, which is abundantly present as a naturally occurring radionuclide, and for radioactive decay of caesium -134 and -137 leading to the estimation of the caesium radioactivity concentrations from the nett counts in the appropriate energy channels.

Intercalibration checks were carried out with the Department of Pure and Applied Physics, Trinity College Dublin and the Department of Experimental Physics, University College, Dublin. Samples of fish and reference sources analysed in the three laboratories show good agreement which provides an independent basis for confidence in the reliability of the measurements presented here.

(ii) Presentation of Results

Variations in radiocaesium concentrations are observed between samples of the same fish species and between the different species. These are due to a combination of such factors as residence times in areas of seawater of different radiocaesium concentrations, different feeding habits and different fishing areas. The variations found are typical of those normally observed.

Radiation doses are estimated by combining radiocaesium concentrations with fish and shellfish consumption data to determine the radiocaesium intake and then using the ICRP factors on weighted committed dose equivalent per unit intake of Caesium-134 and -137 to determine the dose equivalent (ICRP 1979). As detailed dietary information is not available for the Irish public it is necessary to assume representative consumption rates in determining individual doses. It is also assumed that an individual consumes an equal mix of the fish species analysed. The population dose on the other hand is estimated from the total intake of fish based upon the statistics published on total landings at the east coast ports (DFF 1983). Although the ICRP conversion factors, given in Table 3, were derived for exposed workers they provide, in the case of radiocaesium, a reliable basis for the estimate of doses to members of the public.

TABLE 3

DOSE EQUIVALENT CONVERSION

FACTORS FOR RADIOCAESIUM

Radionuclide	Factor, Sv Bq^{-1}
Caesium-137	1.4×10^{-8}
Caesium-134	2.1×10^{-8}

(iii) Interpretation of results

The estimated radiation doses to members of the public are compared with the dose limit recommended by the ICRP by expressing them as a percentage of the dose limit of 5000 μSv for members of the public (ICRP 1977) and of the European Community basic radiation safety standards (CEC 1980). While the ICRP does not recommend a limit for collective doses to populations, it recommends that collective doses should be kept as low as are reasonably achievable.

4. RESULTS.

(i) Radiocaesium Concentrations

The radiocaesium concentrations of fish and shellfish are summarised in Table 4. Whiting, of the fish species, has the highest concentration at 77.7 Bq kg^{-1} of caesium-137 and plaice the lowest at 35.7 Bq kg^{-1}. The mean radiocaesium concentrations in fish are 54.9 Bq kg^{-1} for caesium-137 and 2.5 Bq kg^{-1} for caesium-134. The concentrations in prawns are lower at 28.9 and 1.3 Bq kg^{-1}, respectively. These values are slightly lower than those of samples analysed in 1981 by the U.K. Ministry of Agriculture Fisheries and Food (Hunt. 1983) and during 1980-'82 by the Department of Pure and Applied Physics of Trinity College, Dublin (McAulay 1983). The values obtained are in good agreement with those obtained by TCD (McAulay 1983) and UCD (Mitchell 1983) for the samples they analysed during 1982-'83.

TABLE 4.

RADIOCAESIUM CONCENTRATIONS IN FISH.

Species	Number of Observations	Radiocaesium Bq kg^{-1} (wet)	
		Cs-137	Cs-134
Plaice	12	35.7	1.9
Cod	10	44.6	1.8
Whiting	10	77.7	2.9
Herring	5	61.5	3.4
Prawns	6	28.9	1.3

It is important to note that the seas contain quantities of radionuclides, some of which are naturally occurring, while others orginate from fallout due to the atmospheric testing of nuclear weapons. The most abundant naturally occurring radionuclide is potassium-40. Other naturally occurring radionuclides are uranium and thorium and their radioactive decay products. The radionuclides produced by the testing of nuclear weapons include long lived fission and activation products such as a caesium-137, strontium-90 and plutonium-239 and -240. A typical activity of caesium-137 in cod from this source would be about 0.5 Bq kg^{-1}. Their contribution to the radiological risk is small.

(ii) Individual Radiation Doses

The estimated radiation doses arising from the consumption of fish and shellfish from the Irish Sea are summarised in Table 5. Three consumption rates are assessed, consumers of 100 g. and 20 g., respectively, of the edible portions of wet fish and shellfish daily, of 40 g. of fish daily and of 15 g. of fish daily. 40 $g.d.^{-1}$ is considered as average for persons for whom fish is a regular part of their diet (Hunt 1983). 15 $g.d.^{-1}$ was the overall average per capita consumption of fish by members of the Irish public during 1982.

The effective dose equivalents obtained were 33.1, 12.0 and 4.5 μSv^{y-1} respectively. These doses are less than 1% of the annual dose limit of 5000 μSv for members of the public and less than 2% of the dose due to naturally occurring radiation (UN 1983).

TABLE 5

ANNUAL INDIVIDUAL RADIATION EXPOSURES DUE TO THE CONSUMPTION OF IRISH SEA FISH AND SHELLFISH

Consumption rates of edible portions	Radionuclide	Effective dose equivalent μSv	% of the ICRP dose limit of 5000 μSv for members of the public
$100 g.d.^{-1}$ fish $20 g.d.^{-1}$ shellfish	Cs - 137 Cs - 134 Total	31.0 2.1 33.1	0.62 0.04 0.66
$40 g.d.^{-1}$ fish	Cs - 137 Cs - 134 Total	11.2 0.8 12.0	0.22 0.02 0.24
$15 g.d.^{-1}$ fish	Cs - 137 Cs - 134 Total	4.2 0.3 4.5	0.08 0.01 0.09

(iii) Population Radiation Doses

The collective effective dose equivalent, i.e. the population dose, from the consumption of fish and shellfish provides a measure of the total impact to the Irish population from radioactivity in the Irish Sea. It is also a useful benchmark for observing trends over the years and comparing practices. The collective effective dose equivalent is simply the sum of all the individual doses. It can also be estimated by combining data on fish and shellfish landings from the Irish Sea with their mean radiocaesium concentrations. The quantities landed at the main east coast ports are summarised in Table 6 in which it is assumed that the annual demersal fish landings at Wexford, Rosslare, Arklow and Dun Laoghaire are divided between flat and round fish in the ratio of 1:9.

TABLE 6

QUANTITIES OF FISH (TONNES) LANDED AT
MAIN EAST COAST PORTS IN 1982

PORT	DEMERSAL FISH		PELAGIC FISH	TOTAL	SHELLFISH	TOTAL
	FLAT	ROUND				
Clogherhead	109	868	213	1190	1379	2569
Greencastle	195	4201	0	4396	124	4520
Balbriggan	46	278	31	355	468	823
Skerries	77	1155	936	2168	1689	3857
Howth	186	4379	513	5078	739	5817
Dunlaoire	33	299	16	348	68	416
Arklow	27	238	33	298	49	347
Wexford	1	12	0	13	3317	3330
Rosslare	30	274	3	307	19	326
Totals	704	11704	1745	14153	7852	22005

Some corrections must be made to enable the quantities of fish and shellfish actually consumed to be determined. It is assumed that 80% of the total catch is exported and that 50% of the gross weights of fish and shellfish are lost through cleaning and filleting. The quantities of fish and shellfish consumed by the Irish population are therefore 1417 and 785 tonnes, respectively. The results, summarised in Table 7, show that the collective effective dose equivalent to the Irish population from fish and shellfish caught in the Irish Sea and landed at east coast ports is 1.6 man-Sv. This collective dose may be compared with a value of 2.0 man-Sv yr^{-1} reported for the period of 1980-'82 (McAulay). The corresponding dose due to naturally occurring radiation would be about 3000 man-Sv for the same population.

TABLE 7

COLLECTIVE DOSES TO THE IRISH POPULATION
FROM
FISH AND SHELLFISH

Fish Type	Consumption Tonnes	Mean Activity Bq kg^{-1} (wet) Cs-137	Cs-134	Collective Effective Dose Equivalent man-Sv
Demersal flat	70	35.7	1.9	.037
Demersal round	1170	61.2	2.4	1.061
Pelagic	177	61.5	3.4	.165
Shellfish	785	28.9	1.3	.339
Total	2202	--	--	1.602

5. CONCLUSIONS.

The results show that the radiation doses of members of the Irish public arising from the consumption of fish and shellfish from the Irish Sea, are very small and are likely to be less than 1% of the dose limits recommended by the ICRP and of the European Community basic radiation safety standards. The doses are less than 2% of the dose arising from naturally occurring radiation.

The results show a small decrease on the levels of recent years and indicate a decreasing trend probably reflecting the reduction in the quantity of radiocaesium being discharged annually from Sellafield. The monitoring programme enables the radioactivity levels of the Irish Sea to be kept under review and will be continued to enable trends to be indentified.

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REFERENCES

1. COMMISSION OF THE EUROPEAN COMMUNITIES, 1980. Council directive of 15th July, 1980 amending the directives laying down the revised basic safety standards for the health protection of the general public and workers against the dangers of ionising radiation. Official Journal of the European Communities, 23(L246) 1 - 2.

2. DEPARTMENT OF FISHERIES AND FORESTRY, 1983. Sea and Inland Fisheries Statistical Abstract 1982. Sea Fisheries Division, Department of Fisheries and Forestry, August 1983.

3. HUNT G.J. 1983. Radioactivity in surface and coastal waters of the British Isles 1981. Aquatic Environment Monitoring Report. Ministry of Agriculture Fisheries and Food, Directorate of Fisheries Research, Lowestoft (9) 33pp.

4. INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, 1977. Recommendation of the International Commission on Radiological Protection. (Annal. ICRP 1 (3)). Pergamon Press, Oxford, 53pp. (ICRP, Publication 26).

5. INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, 1979. Limits for Intakes of Radionuclides by Workers (Annal. ICRP 3 (1-4)) Pergamon Press, Oxford, 555pp (ICRP, Publication 30. Supplement to Part 1).

6. McAULAY, I.R. and DOYLE. C. 1983, to be published.

7. MITCHELL, P.I., GONZALO, M., and VIDAL-QUADRAS, A., 1983. Levels of radioactive caesium and potassium in the marine environment of Ireland. Proc IX Reunion Anual de la Sociedad Nuclear Espanola, Sevilla, Diciembre, 1983.

8. UNITED NATIONS SCIENTIFIC COMMITTEE ON THE EFFECTS OF ATOMIC RADIATION, 1982. Ionising Radiation: Sources and Biological Effects, United Nations, New York, 1982.