Radioactivity Monitoring in Irish Upland Lakes

1988 - 1992

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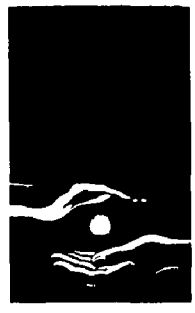

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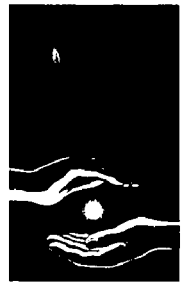


CONTENTS

TABLES

1. INTRODUCTION

Deposition of artificial radionuclides following the serious accident which took place at the Chernobyl nuclear power reactor on the 26th April 1986 resulted in widespread contamination of both the terrestrial and aquatic environments of Europe. Most of the radionuclides deposited had relatively short half-lifes or were deposited in such small amounts as to be of short-term radiological significance. Radioactive caesium, however, was released by the reactor in large quantities of the order of 18.5×10^{15} Bq for caesium-134 and 37.0×10^{15} Bq for caesium-137 [USSR, 1986]. These isotopes have relatively long half-lifes of approximately 2 and 30 years, respectively. In the period 2nd to 4th May, 1986, when the Chernobyl 'cloud' was over Ireland, the prevailing meteorological conditions were characterised by heavy rainfall which varied considerably at regional and local level. This is reflected in a study conducted immediately after the accident which reported total radiocaesium deposition in the range 300-14,200 Bq m^{-2} at different locations across the country. [McAulay and Moran, 1989].

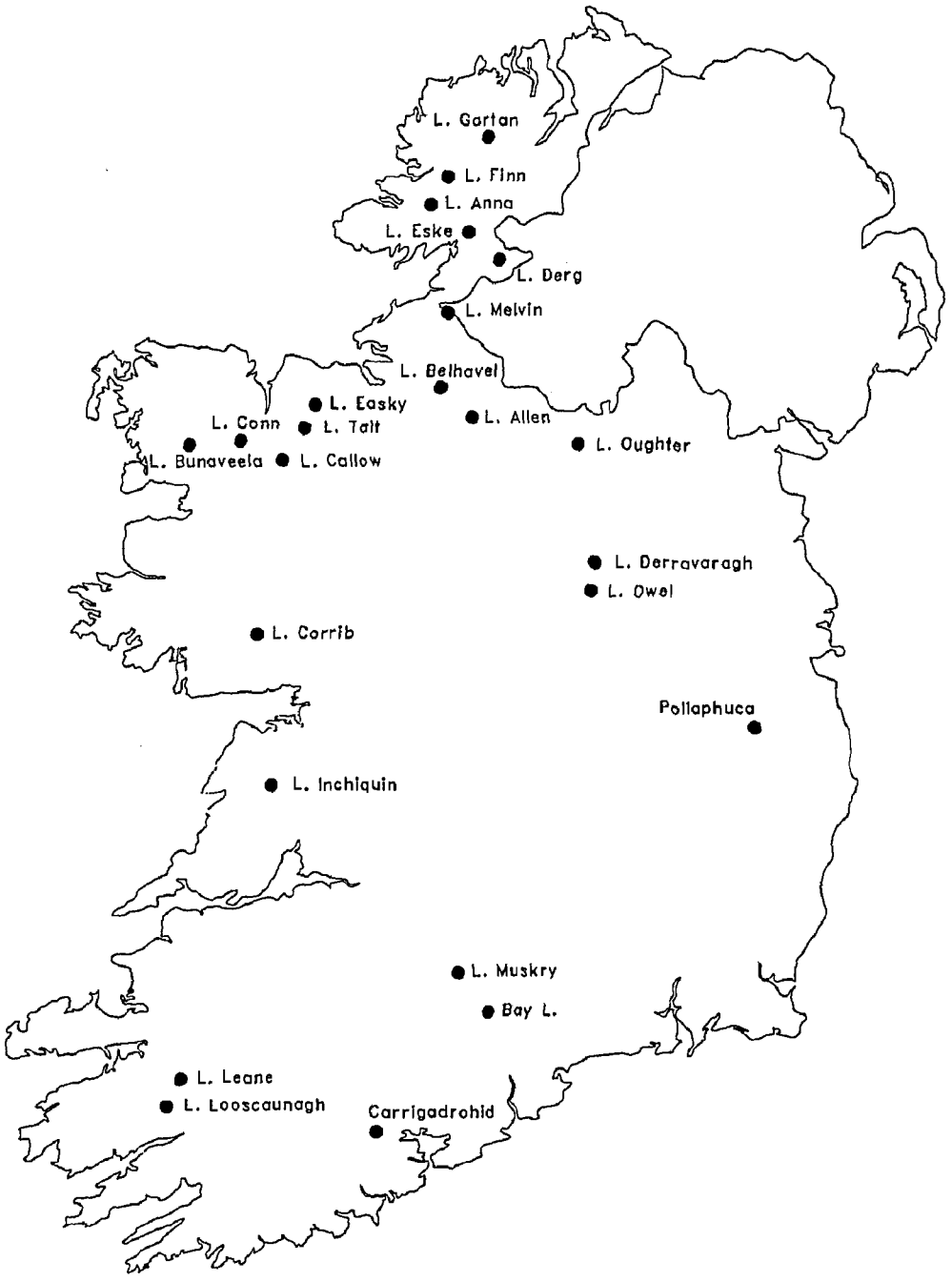
A second source of artificial radioactivity deposition to the terrestrial and aquatic environments is the atmospheric testing of nuclear weapons most of which was carried out in the late 1950s and early 1960s. In this case, the radiocaesium deposition is found to correlate very well with mean annual rainfall [Mitchell *et al.*, 1990], giving rise to highest weapons fallout in areas along the north-west, west and south west coasts of Ireland.

Post Chernobyl monitoring studies undertaken by the Nuclear Energy Board (NEB) to investigate levels of radioactivity in a range of foodstuffs and livestock indicated those areas which had been subjected to highest deposition [Cunningham *et al.*, 1987; Colgan, 1988]. These included upland areas in western and north-western counties as well as a number of locations in the midlands. In 1988, monitoring of radioactivity in upland lakes was initiated in these areas, focusing on counties Donegal, Sligo and Mayo. The monitoring programme was continued in 1989 and extended in 1990 to include twenty-five lakes in thirteen counties. This survey provided a comprehensive national picture of the distribution of Chernobyl contamination in our freshwater lakes. In 1991 and 1992, the monitoring programme concentrated on those lakes which had shown highest levels in the 1990 survey. The geographical characteristics in the vicinity of the lakes monitored are given in Table 1 together with the degree of fishing pressure and an indication of other uses such as water abstraction and amenity. A map of Ireland showing the location of each of the lakes monitored is presented in Figure 1.

This report details the results of the freshwater lake monitoring programme for the years 1988 -1992. The radiocaesium concentrations in freshwater fish species and sediments are given in tabular form and discussed on a county by county basis. Estimates of the Chernobyl/weapons contribution to the total radiocaesium concentration are carried out. An assessment of the radiation doses to those consumers who include relatively large amounts of freshwater fish in their diet is also made.

FIGURE 1

Location of Irish Lakes Monitored



2. METHODS OF SAMPLING AND ANALYSIS

2.1 Rationale

The purpose of the freshwater lake monitoring programme is to keep under review the concentrations of artificial radionuclides in freshwater fish and to estimate the maximum radiation dose to members of the Irish public arising from these concentrations. The programme is, therefore, focused on those lakes where contamination levels are highest and where the fishing pressure is significant.

In Ireland, brown trout *Salmo trutta* is the most commonly eaten freshwater species and this is reflected in the sampling strategy. Other species including pike, perch, roach, bream, rudd and char also accumulate radiocaesium but, as they are eaten only occasionally, sampling of these species was less intensive.

Sediment sampling of the Donegal lakes was included in the 1989 programme as concentrations in this material give a good indication of radionuclide trends within a lake. Samples of sediment were also collected from all of those lakes monitored in 1990, 1991 and 1992.

2.2 Fish

Samples of the main freshwater species were collected each year between May and October by the staff of the Regional Fisheries Boards. Species included brown trout *Salmo trutta*, pike *Esox lucius*, perch *Perca fluviatilis*, char *Salvelinus alpinus*, roach *Rutilus rutilus*, bream *Abramis brama*, rudd *Scardinius erythrophthalmus* and eel *Anguilla anguilla*. In most cases, samples consisted of at least 1 kg wet weight of fish. Upon receipt at the Fisheries Research Centre (FRC) specimens from each lake were grouped according to species and the lengths and weights measured. Scales were removed from selected fish for age determination at the FRC before being forwarded to the Radiological Protection Institute of Ireland (RPII) laboratories for gamma spectrometric analysis. At the RPII, the edible portions were dried at 105°C for 24 hours and ground to a fine powder. In cases where the sample size was particularly small, the fish were not dried before analysis. In general, a sample consisted of a number of individuals, grouped together according to age. The number of individuals per sample varied between 1 and 15. Fish were then packed into standard containers, typically 200 g, for analysis by gamma spectrometry.

2.3 Sediments

Surface sediment samples were collected from selected locations on the lake shore and lake bottom using a grab sampler and stored frozen. Sample size was approximately 500 g. Sediments were dried at 80°C to constant weight and sieved to less than 500 micron (μm) particle size. They were then packed into standard containers for analysis by gamma spectrometry. Selected samples from the 1990 programme were also analysed for their particle size distribution.

2.4 Sediment Size Fractionation

The particle size distribution of selected sediment samples from the 1990 programme was determined by dry sieving. The separates determined included coarse sand (2 - 0.2 mm), fine sand (0.2 - 0.05 mm), silt (50 - 2 μm) and clay (< 2 μm). The organic matter content of each sample was measured using the loss-on-ignition method [APHA, 1992].

2.5 Gamma Spectrometry

All samples were analysed by high resolution gamma spectrometry for their radiocaesium (caesium-137 and caesium-134) and potassium-40 content. Spectra were recorded for periods ranging from about 6 hours to several days using a germanium detector linked to a Nuclear Data microVax based system. Radioactivity concentrations were determined by automatic peak fitting using a Nuclear Data VAX/VMS spectroscopy applications software package and reported at the 95% confidence level with 'less than' values representing minimum detectable activities. Fish activity concentrations are quoted per unit wet weight of fish, while sediment results are given per unit dry weight. Efficiency calibration was carried out using a reference standard (QCY 48) supplied by Amersham International plc (UK). Quality control is maintained by an in-house programme and by participation in national and international intercomparison exercises.

3. RESULTS

The radiocaesium concentrations in freshwater fish and sediments on a county by county basis are given in Tables 2-13 and summarised below.

Co. Cavan *(see Table 2),* ***Co. Clare*** *(see Table 3),* ***Co. Cork*** *(see Table 4),* ***Co. Wicklow*** *(see Table 5)*

Lough Oughter, Lough Inchiquin, Carrigadrohid Reservoir and Pollaphuca Reservoir

Subject to availability, samples of trout, perch, pike, roach and rudd were collected from each of these lakes in 1990. In all cases, the measured radiocaesium concentrations were below 20 Bq/kg. The corresponding sediment concentrations ranged from 6 - 37 Bq/kg.

Co. Donegal *(see Table 6)*

Lough Finn

This lake was one of those most significantly affected by Chernobyl fallout in 1986. Mean radiocaesium levels in trout declined from a maximum of 284 Bq/kg in 1988 to 40 Bq/kg in 1992. Concentrations in char, the only other species sampled in this lake, were lower than those measured in trout in 1991 and 1992. Total radiocaesium concentrations in sediments ranged between 175 - 1,041 Bq/kg in 1989, and between 42 - 440 Bq/kg in 1991. The sediment data indicate considerable variation in the distribution of contamination.

Lough Anna

Radioactivity levels in Lough Anna did not decrease as in Lough Finn. In 1992, maximum radiocaesium concentrations of 188 Bq/kg and 718 Bq/kg were found in trout and sediment, respectively. Both the fish and sediment data showed considerable variation in the degree of contamination within the lake.

Lough Eske

Of the Donegal lakes examined, Lough Eske appears to have been the least affected by the Chernobyl accident. Radiocaesium concentrations in trout were relatively higher in 1990 compared to 1988. Lake sediment concentrations were generally of the order of 150 Bq/kg.

Lough Derg

Concentrations of radiocaesium in trout from Lough Derg were broadly similar to those found in Lough Finn and Lough Anna. The levels in perch did not appear to have varied significantly between 1990 and 1992. The highest caesium levels were recorded from pike, as expected, being at the top of the piscivorous food chain with concentrations in excess of 300 Bq/kg still being detected in 1992. Although the number of measurements are limited, it was evident from the Lough Derg data that pike accumulate caesium to a greater extent than char and trout. Contamination persisted in the lake sediments, with radiocaesium concentrations ranging between 20 and 530 Bq/kg in 1991.

Lough Cartan

In general, the radiocaesium levels measured in trout were similar to those for Lough Finn, Lough Derg and Lough Anna. Concentrations showed no significant decrease over the four years of the sampling programme. Sediment radiocaesium levels remained relatively unchanged between 1989 and 1992, with concentrations ranging from about 100 to 800 Bq/kg.

Co. Galway *(see Table 7)*

Lough Corrib

Radiocaesium concentrations of less than 60 Bq/kg were determined in fish species including trout, perch, pike, roach and eel, all of which were sampled from the lower lake. Levels in sediment were quite varied with values between 2 and 772 Bq/kg. The one very high value of 772 Bq/kg refers to sediment sampled from the middle lake, where mountain runoff was likely to have a greater influence.

Co. Kerry *(see Table 8) and* ***Co. Tipperary*** *(see Table 9).*

Lough Looscaunagh, Lough Leane, Lough Muskry and Bay Lough

Samples of trout and sediment were collected from each of these lakes in 1990, with the exception of Bay Lough which was sampled in 1989. The trout concentration at Bay Lough was about 150 Bq/kg, while in all other cases, the concentrations were below 50 Bq/kg. The sediment values were quite varied with a maximum level of 771 Bq/kg being observed in a sediment from Lough Looscaunagh.

Co. Leitrim *(see Table 10)*

Lough Allen

The levels of radiocaesium in trout, perch and pike were all below 45 Bq/kg. With one exception, levels of less than 5 Bq/kg were reported for rudd, bream and roach. Sediment concentrations were also low, less than 25 Bq/kg.

Lough Belhavel

Radiocaesium levels in the coarse fish species sampled from this lake were low, less than 20 Bq/kg in pike which is at the top of the piscivorous food chain. Sediment values were less than 20 Bq/kg.

Lough Melvin

In agreement with the other lakes monitored in Co. Leitrim, this lake appeared to have been relatively unaffected by Chernobyl radioactivity. Low levels of radiocaesium were recorded in trout (less than 5 Bq/kg) in 1990. The levels in sediments, though variable, were also low with concentrations less than 100 Bq/kg.

Co. Mayo *(see Table 11)*

Lough Callow

This lake was moderately contaminated by Chernobyl radiocaesium with a maximum level of about 140 Bq/kg in trout in 1988. Levels had declined to below 35 Bq/kg in 1992. Sediment concentrations were quite varied with levels of 16 and 165 Bq/kg in 1992, down somewhat on previous levels.

Lough Bunaveela

This lake did not appear to have been contaminated to the same degree as Lough Callow with a maximum radiocaesium level of about 70 Bq/kg present in trout in 1988. This had decreased to below 45 Bq/kg in 1990. Radiocaesium levels in the lake sediments were below 200 Bq/kg in 1990.

Lough Conn

The levels reported for trout and sediments in this lake were generally lower than for other lakes monitored in Co. Mayo. Trout concentrations were less than 40 Bq/kg in 1990.

Co. Sligo *(see Table 12)*

Lough Easkey

Mean radiocaesium levels in trout fell from 111 Bq/kg in 1989 to 42 Bq/kg in 1992. Sediment concentrations also showed a wide variation with one very high level close to 2,000 Bq/kg measured in 1991 compared to a maximum value of 350 Bq/kg in 1992.

Lough Talt

Radiocaesium concentrations in trout in 1991 were approximately one-fifth of those recorded in 1988. The concentration of 316 Bq/kg measured in perch from this lake in 1990 was the highest recorded value for this species in the five year monitoring programme. Measured radiocaesium levels in the lake sediments remained relatively unchanged at about 200 Bq/kg in 1990 and 1991.

Co. Westmeath *(see Table 13)*

Lough Owel

Mean radiocaesium levels in trout caught in this lake remained relatively constant at about 60 Bq/kg between 1990 and 1992. Concentrations in perch and pike were significantly higher, with a maximum value of 275 Bq/kg in pike. Sediment concentrations over the three year period ranged from about 40 - 330 Bq/kg.

Lough Derravaragh

Fish and sediment samples collected in 1990 indicated a lower degree of contamination than observed at Lough Owel. Sediment values were less than 100 Bq/kg.

4. DISCUSSION

(a) Activity Concentrations

The results of the lake monitoring programme for 1988 - 1992 show that lakes in the midlands and north-west of the country were most affected by fallout from the Chernobyl accident. The maximum radiocaesium level in fish of approximately 400 Bq/kg was measured in pike caught in Lough Derg, Co. Donegal in 1991. Sediment concentrations of greater than 500 Bq/kg were measured in a number of lakes with one sediment from Lough Easkey, Co. Sligo showing levels close to 2000 Bq/kg. Lakes in the west, south-west and east were also contaminated but to a noticeably lesser extent. The wide variation in the degree of contamination across the country seen here has been reported previously for the terrestrial environment [McAulay and Moran, 1989; Ryan, 1991].

Since 1988, there appears to have been an overall decrease in radiocaesium concentrations in trout even allowing for the fact that caesium-134 has a half-life of approximately 2 years. In sediments, any corresponding decrease in concentration with time would be masked by the wide variation in concentrations measured.

In addition to the variation in contamination levels between lakes, significantly different radiocaesium concentrations for both fish and sediments were found within the same lake for a given sampling period. In the case of fish, such differences may be explained by differences in the feeding habits of the various species or by differences in age for the same species. A statistical analysis of the results was carried out to determine whether any such correlations existed. In general, the data set was too limited to draw definite conclusions, but there did appear to be some evidence that total radiocaesium increased with age for a particular species.

The range of sediment concentrations within some lakes was very varied, for example in Lough Easkey, Co. Sligo, caesium-137 values of 126 Bq/kg and 1718 Bq/kg were measured in samples taken at the same time. Such variability, while due in part to sediment type, may also be influenced by the method of sampling. In this study, the sediments were grab sampled which cannot discriminate between sediments of different depths. An analysis of the relationship between total radiocaesium concentration and organic matter content showed some correlation, but this alone could not account for the wide variation in radiocaesium concentration observed.

In addition to radiocaesium deposited as a result of the Chernobyl accident, significant amounts were deposited during the atmospheric weapons testing of the late 1950s and early 1960s. The contribution of both of these sources to the total radiocaesium content of fish and sediments can be estimated using a decay corrected Chernobyl fallout caesium-134 to caesium-137 ratio of 0.524. This ratio was determined from a series of measurements made in Ireland immediately following the Chernobyl accident [Mitchell *et al.*, 1990].

This calculation was carried out for all trout and sediments measured in 1991 (Tables 14,15). In general between 70 and 90 per cent of the caesium-137 measured in fish is derived from Chernobyl deposition. In the case of sediments, the division is different with approximately equal amounts of caesium-137 deriving from both sources. It is clear from these results that weapons testing continues to be a significant source of caesium-137 in Irish lakes.

(b) Dose Estimation

Radiation doses (committed effective dose) due to the consumption of fish are calculated by estimating the intake of radiocaesium from the product of the quantity consumed and its activity and converting the intake to dose by the use of standard conversion factors [Phipps *et al.*, 1991]. In this study the radiation dose to a group of freshwater fish consumers has been calculated for the years 1988 - 1992. The mean concentration of radiocaesium in brown trout caught in Donegal lakes has been used in the calculations (Table 16) as brown trout is taken to be representative of the highest concentrations which would be consumed on a regular basis and as the highest levels were, in general, found in Donegal. In the absence of relevant dietary information, a daily intake of 50 g has been assumed for those people who include relatively large amounts of freshwater fish in their diet. The values calculated for each year are shown in Table 17.

Overall, the dose fell from 39 μSv in 1988 to 15 μSv in 1992, although lower doses of 12 and 14 μSv were calculated for 1990 and 1991, respectively. The trend over recent years would appear to indicate a levelling off in radioactivity concentrations. In each year the estimated dose was below 5 per cent of the dose limit for members of the public of 1000 μSv recommended by the International Commission on Radiological Protection [ICRP, 1991]. The calculated doses may also be compared with the annual average dose of approximately 3000 μSv from all sources of radiation received by members of the Irish public of which about 90% is due to naturally occurring radiation and the remainder mainly due to medical uses of radiation.

5. CONCLUSIONS

Some Irish lakes, particularly those in upland areas, were significantly contaminated following the Chernobyl accident. The results of the monitoring programme for 1988 - 1992 indicate that radiocaesium levels in salmonid species have fallen over the five years of the programme.

The radiation doses to freshwater fish consumers fell from 39 μSv in 1988 to 15 μSv in 1992. Such doses are representative of adults who consume relatively large amounts of freshwater fish. For those adults who consume lesser amounts of freshwater fish, the radiation doses received will be proportionately lower.

The estimated doses were less than 5 per cent of the ICRP recommended dose limit of 1000 μSv per year for members of the public. They also represent approximately 1% of the average annual dose of about 3000 μSv received by members of the Irish public from all sources of radiation, natural and artificial and, as such, are of minor radiological significance. The results therefore give reassurance that there is no significant risk to health from the consumption of freshwater fish caught in Irish lakes.

6. ACKNOWLEDGEMENTS

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TABLE 1

Characteristics of the Lakes

County	Lake	Surface Area (ha)	Altitude (m)	Soil Type	Fishing Pressure	Beneficial Uses
Cavan	L. Oughter	1,300	50	Grey brown podzolic/gley	heavy	coarse fishery, amenity
Clare	L. Inchiquin	110	24	Brown earth (shallow)	heavy	water abstraction, game fishery, amenity
Cork	Carrigadrohid Reservoir	981	75	Brown podzolic	medium	water abstraction, mixed fishery, amenity, aquaculture
Donegal	L. Finn	100	133	Blanket peat	seldom fished	amenity
	L. Anna	24	169	Blanket peat	seldom fished	water abstraction
	L. Derg	810	143	Blanket peat	little/moderate	game fishery, amenity
	L. Gartan	190	70	Peaty podzol	medium	water abstraction, game fishery, amenity
	L. Eske	360	31	Blanket peat/Gley	little	game fishery
Galway	L. Corrib	17,000	9	Brown earth (shallow)	medium	water abstraction, game/coarse fishery
Kerry	L. Looscaunagh	40	200	Peaty podzol	little	game fishery
	L. Leane	2,000	20	Brown podzolic	heavy	game fishery, amenity

TABLE 1 (cont'd)

County	Lake	Surface Area (ha)	Altitude (m)	Soil Type	Fishing Pressure	Beneficial Uses
Leitrim	L. Allen	3,500	50	Gley	medium	water abstraction, game/course fishery, aquaculture, amenity
	L. Belhavel	101	65	Gley	seldom fished	course fishery
Mayo	L. Callow	57	42	Podzolic	medium	
	L. Bunaveela	47	121	Blanket peat	little	game fishery
	L. Conn	5,000	13	Degraded grey brown podzolic	heavy	water abstraction, game fishery
Sligo	L. Easkey	120	186	Blanket peat	little	water abstraction, game fishery
	L. Talt	63	138	Blanket peat	little	water abstraction, game fishery
Tipperary	Bay Lough	5	275	Peaty podzolic	seldom fished	
Westmeath	L. Owel	950	99	Grey brown podzolic	heavy	water abstraction, game fishery, amenity
	L. Derravaragh	1,100	63	Grey brown podzolic	heavy	game/course fishery
Wicklow	Pollaphuca Reservoir	1970	186	Brown podzolic	medium	water abstraction, game/course, fishery, amenity

TABLE 2

Radioactivity in County Cavan Lakes

Concentrations in Bq/kg wet weight in fish, dry weight in sediments

Lake	Species	Year	Number of Samples	Cs-137	Cs-134
Lough Oughter	Perch	1990	2	5; 7	<1.7
	Pike	1990	2	4; 4	<1.3
	Roach	1990	2	2; 2	<1.9
	Sediment	1990	1	5	<1.1

TABLE 3

Radioactivity in County Clare Lakes

Concentrations in Bq/kg wet weight in fish, dry weight in sediments

Lake	Species	Year	Number of Samples	Cs-137	Cs-134
Lough Inchiquin	Trout	1990	2	2; 3	<0.7
	Perch	1990	1	2	<0.8
	Pike	1990	1	2	<0.7
	Sediment	1990	2	7; 19	0.7; 2.0

TABLE 4

Radioactivity in County Cork Lakes

Concentrations in Bq/kg wet weight in fish, dry weight in sediments

Lake	Species	Year	Number of Samples	Cs-137	Cs-134
Carrigadrohid Reservoir	Perch	1990	1	3	<1.4
	Roach	1990	1	4	<1.2
	Sediment	1990	2	8; 32	<1.0; 5.2

TABLE 5

Radioactivity in County Wicklow Lakes

Concentrations in Bq/kg wet weight in fish, dry weight in sediments

Lake	Species	Year	Number of Samples	Cs-137	Cs-134
Pollaphuca Reservoir	Perch	1990	4	8 - 19	<2.3
	Rudd	1990	1	9	<2.2
	Roach	1990	4	1 - 6	<1.8
	Sediment	1990	2	11; 20	0.9; 2.2

TABLE 6

Radioactivity in County Donegal Lakes

Concentrations in Bq/kg wet weight in fish, dry weight in sediments

Lake	Species	Year	Number of Samples	Cs-137	Cs-134
Lough Finn	Trout	1988	3	177 - 272	50 - 81
		1989	2	84; 108	17.5; 23.4
		1990	2	63; 72	7.6; 10
		1991	1	94	7.9
		1992	18	18 - 88	<1.2 - 5.2
	Char	1989	1	96	24.2
		1991	1	24	<1.4
		1992	3	17 - 20	<1.8
	Sediment	1989	8	143 - 899	31.5 - 142.0
		1990	4	161 - 596	8.7 - 63.9
		1991	4	42 - 408	<1.6 - 32.0
		1992	1	76	4.2
Lough Anna	Trout	1988	3	225 - 291	59.5 -69.9
		1989	1	133	27.2
		1990	2	72; 123	6.8; 15.7
		1991	2	36; 43	3; 3.5
		1992	15	30 - 180	<1.4 - 8.2
	Sediment	1989	2	329; 373	46.8; 63.5
		1990	1	523	47.8
		1991	2	20; 348	<1.8; 8.1
		1992	2	278; 676	6.9; 41.6
Lough Eske	Trout	1988	3	4 - 29	<7
		1990	2	39; 55	4.4; 5.5
	Char	1990	1	29	2.8
	Sediment	1989	2	133; 150	13.9; 16.8
		1990	2	127; 139	11.3; 11.8

TABLE 6 (Cont'd)

Concentrations in Bq/kg wet weight in fish, dry weight in sediments

Lake	Species	Year	Number of Samples	Cs-137	Cs-134
Lough Derg	Trout	1989	1	130	23.3
		1990	5	46 - 92	5.0 - 9.9
		1991	2	71; 121	4.9; 8.5
	Char	1990	2	35; 39	4.2; 5.6
	Perch	1990	4	46 - 209	5.0 - 24.8
		1991	4	47 - 84	3.0 - 5.7
		1992	12	42 - 162	<1.7 - 7.7
	Pike	1990	1	278	33.2
		1991	1	362	26.2
		1992	7	136 - 330	6.5 - 19.4
	Sediment	1989	2	34; 54	4.9; 6.3
		1990	5	35 - 224	1.8 - 13.1
		1991	3	17 - 503	<0.8 - 25.2
		1992	1	31	1.5
Lough Gartan	Trout	1989	1	99	20.9
		1990	2	100; 110	11.5; 13.5
		1991	5	40 - 91	3.3 - 7.8
		1992	8	59 - 99	3.8 - 6.2
	Char	1990	1	86	9.8
		1991	1	57	4.8
	Sediment	1989	1	232	25.8
		1990	4	68 - 436	8.8 - 43.8
		1991	4	151 - 360	7.9 - 18.0
		1992	4	96 - 774	4.3 - 36.5

TABLE 7

Radioactivity in County Galway Lakes

Concentrations in Bq/kg wet weight in fish, dry weight in sediments

Lake	Species	Year	Number of Samples	Cs-137	Cs-134
Lough Corrib	Trout	1990	2	18; 35	2.2; 3.8
		1991	2	9; 11	<1.0
	Perch	1990	1	31	3.8
		1991	2	43; 53	3.2; 4.6
	Pike	1990	1	40	3.9
		1991	2	29; 20	2.3; 2.5
	Roach	1991	2	8; 15	<0.7; 1.0
	Eels	1990	1	25	2.7
	Sediment	1990	2	92; 168	9.1; 15.8
		1991	5	2 - 754	<0.3 - 17.6

TABLE 8

Radioactivity in County Kerry Lakes

Concentrations in Bq/kg wet weight in fish, dry weight in sediments

Lake	Species	Year	Number of Samples	Cs-137	Cs-134
Lough Looscaunagh	Trout	1989	1	43	6.0
		1990	1	25	<1.4
		1991	2	17; 18	<1.3
	Sediment	1990	1	729	42.4
		1991	2	65; 483	<1.6; 22.4
Lough Leane	Trout	1990	3	3 - 4	<1.1
	Sediment	1990	3	21 - 99	1.5 - <2.5

TABLE 9

Radioactivity in County Tipperary Lakes

Concentrations in Bq/kg wet weight in fish, dry weight in sediments

Lake	Species	Year	Number of Samples	Cs-137	Cs-134
Lough Muskry	Trout	1990	1	20	3.1
	Sediment	1990	2	19; 251	2.0; 25.3
Bay Lough	Trout	1989	1	119	29.0

TABLE 10

Radioactivity in County Leitrim Lakes

Concentrations in Bq/kg wet weight in fish, dry weight in sediments

Lake	Species	Year	Number of Samples	Cs-137	Cs-134
Lough Allen	Trout	1989	1	21	<3
		1990	3	6 - 12	1.2 - 2.2
	Perch	1989	1	15	<4
		1990	2	11; 14	1.6; 2.0
	Pike	1989	1	37	7.5
		1990	2	15; 30	1.8; 4.5
	Rudd	1989	1	4	<1.9
		1990	1	3	<0.7
	Bream	1990	1	4	<0.8
	Roach	1990	2	3; 3	<0.7; <0.8
	Sediment	1990	2	6; 21	0.7; 2.3
Lough Belhavel	Perch	1990	1	17	2.4
	Pike	1990	1	13	<1.3
	Bream	1990	1	4	<1.2
	Sediment	1990	2	15; 17	1.9; 2.1
Lough Melvin	Trout	1990	2	2; 3	<1
	Rudd	1990	1	4	<2.1
	Sediment	1990	2	15; 76	1.9; 10.1

TABLE 11

Radioactivity in County Mayo Lakes

Concentrations in Bq/kg wet weight in fish, dry weight in sediments

Lake	Species	Year	Number of Samples	Cs-137	Cs-134
Lough Callow	Trout	1988	3	95 - 104	28.6 - 33.7
		1990	2	51; 67	6.2; 8.4
		1991	1	24	2.1
		1992	10	8 - 32	<0.4 - 2.0
	Sediment	1990	2	39; 387	5.7; 33.5
		1991	2	285; 296	12.0; 19.8
		1992	2	15; 161	0.7; <2.5
Lough Bunaveela	Trout	1988	3	43 - 50	4.4 - 20.6
		1990	3	18 - 40	2.4 - 3.1
	Sediment	1990	2	62; 175	5.1; 11.2
Lough Conn	Trout	1990	1	33	3.4
	Sediment	1990	2	20; 21	2.2; 2.5

TABLE 12

Radioactivity in County Sligo Lakes

Concentrations in Bq/kg wet weight in fish, dry weight in sediments

Lake	Species	Year	Number of samples	Cs-137	Cs-134
Lough Easkey	Trout	1989	1	92	18.6
		1990	2	50; 54	5.7; 6.5
		1991	2	53; 59	4.3; 4.6
		1992	12	22 - 62	<1.1 - 4.2
	Sediment	1990	2	375; 450	26.7; 41.2
		1991	3	126 - 1718	6.2 - 96.0
		1992	3	138 - 337	<1.5 - 12.2
Lough Talt	Trout	1988	3	79 - 121	25.5 - 33.9
		1989	1	105	18.8
		1990	1	28	3.4
		1991	3	15 - 30	1.2 - 2.6
	Perch	1990	2	74; 280	8.3; 35.7
	Sediment	1990	2	177; 199	14.4; 19.6
		1991	2	116; 251	4.5; 11.8

TABLE 13

Radioactivity in County Westmeath Lakes

Concentrations in Bq/kg wet weight in fish, dry weight in sediments

Lake	Species	Year	Number of Samples	Cs-137	Cs-134
Lough Owel	Trout	1990	1	66	9.5
		1991	22	19 - 91	1.7 - 7.5
		1992	2	43; 58	2.8; 4.0
	Perch	1990	2	6; 193	1.2; 27.3
		1991	6	42 - 149	3.2 - 12.4
		1992	6	65 - 185	<2.1 - 12.4
	Pike	1990	1	81	11.4
		1991	3	55 - 87	4.6 - 7.7
		1992	7	63 - 257	4.0 - 17.5
	Rudd	1991	1	25	2.3
	Roach	1990	3	4 - 5	<2.1
	Sediment	1990	9	36; 298	3.4; 28.6
		1991	3	79 - 193	5.1 - 12.0
		1992	3	67 - 111	3.8 - 5.1
Lough Derravaragh	Roach	1990	1	4	<1.0
	Sediment	1990	2	32; 69	4.1; 9.6

TABLE 14

Radioactivity in Brown Trout (1991) Showing the Amount of the Total Caesium-137 Derived from the Chernobyl Accident and from Weapons Testing

Concentrations in Bq/kg, wet weight

Lake	Number of Samples	Total Cs-134	Total Cs-137	Chernobyl Cs-137	Weapons Cs-137
Lough Owel	22	4.9	59	51	8
Lough Gartan	5	5.1	63	50	13
Lough Derg	2	6.7	96	66	30
Lough Anna	2	3.2	39	31	8
Lough Looscaunagh	2	<1.3	17	13	4
Lough Callow	1	2.1	24	20	4
Lough Corrib	2	<1.0	10	10	0
Lough Easkey	2	4.4	56	43	13
Lough Talt	3	2.1	25	20	5
Lough Finn	1	7.9	94	78	16

TABLE 15

Radioactivity in Sediments (1991) Showing the Amount of the Total Caesium-137 Derived from the Chernobyl Accident and from Weapons Testing

Concentration in Bq/kg, dry weight

Lake	Number of Samples	Total Cs-134	Total Cs-137	Chernobyl Cs-137	Weapons Cs-137
Lough Owel	3	7.5	120	78	42
Lough Gartan	4	14.5	264	143	121
Lough Derg	3	10.2	239	100	139
Lough Anna	2	5.0	184	49	135
Lough Looscaunagh	2	12.0	274	118	156
Lough Callow	2	15.9	291	154	137
Lough Corrib	5	7.2	219	73	146
Lough Easkey	3	37.6	679	366	313
Lough Talt	2	8.2	184	80	104
Lough Finn	4	9.9	155	97	58

TABLE 16

Mean Radioactivity in Brown Trout in Donegal Lakes

Concentrations in Bq/kg wet weight in fish, dry weight in sediments

Year	Cs-137	Cs-134
1988	109	30.7
1989	90	18.6
1990	40	5.0
1991	48	4.6
1992	56	3.2

TABLE 17

Radiation Doses to consumers of fish caught in County Donegal Lakes based on daily intake of 50 g

Year	Radiation Dose (μSv)
1988	38.6
1989	29.4
1990	11.9
1991	13.8
1992	15.3