Radioactivity Monitoring of the Irish Environment 2003-2005

Radiological Protection Institute of Ireland
An Institiúid Éireannach um Chosaint Raideolaíoch

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Summary

This report presents the results of the environmental radioactivity monitoring programme carried out by the Radiological Protection Institute of Ireland (RPII) between 2003 and 2005. This programme aims to assess the exposure of the Irish population to anthropogenic radioactivity in the environment, to review the temporal and geographical distribution of contaminating radionuclides and to maintain systems and procedures, which would allow a rapid assessment of environmental contamination to be made in the event of a radiological emergency.

Radioactivity is present in the environment due to natural processes, the testing of nuclear weapons in the atmosphere, past nuclear accidents such as that at Chernobyl and the routine licensed discharge of radionuclides from nuclear installations. Liquid discharges from the British Nuclear Group reprocessing plant at Sellafield in Cumbria in the North West of England continue to be the dominant source of anthropogenic radioactivity in the Irish marine environment.

The key elements of the monitoring programme implemented by the RPII during the reporting period include:

- assessment of ambient radioactivity based on measurements of radioactivity in air and external gamma dose rate at permanent monitoring stations located throughout the country;
- assessment of levels of radioactivity in drinking water;
- assessment of levels of radioactivity in foodstuffs based on measurements of total diet, milk and miscellaneous ingredients;
- assessment of levels of radioactivity in the marine environment based on sampling and measurements of seawater, sediment, seaweed, fish and shellfish.

The RPII monitored airborne radioactivity at eleven stations located throughout the country. One station is equipped with a high volume sampler, which allows global fallout concentrations to be measured, and one is equipped to detect the presence of the gas krypton-85. Krypton-85 is released into the environment primarily as a result of the reprocessing of nuclear fuel. During the reporting period, levels of radionuclides in airborne radioactivity were low and consistent with measurements in previous years. External gamma dose rates were monitored continuously at twelve stations. No abnormal levels were observed during the period.

In accordance with the RPII's drinking water monitoring protocol, major public water supplies from each county are sampled at least every four years while supplies to certain major population centres are sampled annually. During the period 2003 to 2005, water supplies from 14 counties were sampled and all of the waters tested were found to be within the parametric values for radioactivity set out in the relevant national standards.

The RPII sampled and measured levels of radioactivity in mixed diet, milk and miscellaneous other foodstuffs including milk products, baby foods, beef, lamb, poultry and vegetables. These measurements show that levels of anthropogenic radioactivity in the Irish diet continue to be low.

Approximately 300 samples of fish, shellfish, seaweed, seawater and sediment were collected in each of the years covered by this report. The samples were analysed for a range of radionuclides. The main pathway contributing to the exposure of the Irish public to anthropogenic radioactivity from the marine environment was found to be the consumption of seafood. Between 2003 and 2005, the mean annual committed effective dose to a heavy consumer of seafood from the Irish Sea was 0.85 μSv. Caesium-137 was the dominant radionuclide, accounting for approximately 60-70% of the total dose. The dose to the Irish population due to this radionuclide has declined significantly over the last two decades corresponding to the reduction in discharges of this radionuclide from Sellafield. Along the Irish coastline the highest activity concentrations observed are in the north-east.

The doses incurred by the Irish public as a result of anthropogenic radioactivity in the environment do not constitute a significant health risk and are small compared with the dose received as a result of background radiation.

1 Introduction

This report presents the results of the environmental radioactivity monitoring programme carried out by the RPII between 2003 and 2005. It is the first report by the RPII to bring together the results of monitoring in the Irish marine, terrestrial and atmospheric environments. Previously, results were published separately in the Marine Monitoring and Environmental Radioactivity Surveillance Series by the RPII.

The aims of the RPII's monitoring programme are to assess the exposure of the Irish population to anthropogenic radioactivity in the environment, to review the temporal and geographical distribution of contaminating radionuclides and to maintain systems and procedures, which would allow a rapid assessment of environmental contamination to be made in the event of a radiological emergency. The monitoring programme involves the sampling and testing for radioactivity in air, drinking water, foodstuffs, fish, shellfish, seaweed, sediments and seawater as well as the continuous measurement of external gamma radiation.

Radioactivity in the Environment

Radioactivity from both natural and anthropogenic origins exists throughout the environment. Natural radioactivity has been present since the formation of the earth. Inputs of artificial origin have come from the testing of nuclear weapons in the atmosphere, events such as the Chernobyl accident and the routine licensed discharge of radionuclides from nuclear installations. Once present in the environment, these radionuclides are available for uptake by crops, animals and water and so make their way into the food chain.

Natural Radioactivity in the Environment

Natural radioactivity in the terrestrial environment has two principal components, namely the cosmic and the primordial. Cosmic rays, originating in outer space, strike the earth's atmosphere generating a cascade of ionising particles. The intensity of cosmic radiation decreases with decreasing altitude and at sea level accounts for approximately 10% of the total dose received by a typical member of the Irish public from all natural sources. The interaction between cosmic radiation and atoms in the earth's atmosphere produces a range of cosmogenic radionuclides including beryllium-7 and hydrogen-3 (tritium).

At the time of the formation of the earth a range of long-lived radionuclides were present and many of these are still detectable. These are collectively known as primordial radioactivity and include radionuclides of the uranium and thorium decay series. The most significant contribution to human exposure due to primordial radioactivity comes from radon, which is a naturally occurring gas produced as a result of the decay of uranium present in rocks and soil. Because radon is a gas it can seep up from the ground and may accumulate in buildings giving rise to human exposure. Radon concentrations in Irish dwellings have been investigated extensively and the results reported by Fennell *et al.* [2002]. A comprehensive study of natural radionuclides in Irish soil has been carried out by McAulay and Moran [1988].

The activity concentrations of some of the naturally occurring radionuclides most commonly found in seawater are summarised in **Table 1**. Of these, polonium-210 is known to make the most significant contribution to radiation exposure through the consumption of marine foodstuffs [Pollard *et al.*, 1998].

Potassium-40, a naturally occurring radionuclide, is present in relatively large activity concentrations in the environment. However, it is controlled by homeostatic processes in the human body [Eisenbud and Gessell, 1997] which means its equilibrium activity concentration is normally independent of the amount consumed. Therefore, while the activity concentrations of this radionuclide in food are considerably higher than many other natural radionuclides, its presence does not result in an increased radiological hazard.

Artificial Radioactivity in the Environment

A total of 543 atmospheric nuclear weapons tests, which took place from 1945 until 1980, released artificial radioactive materials directly into the atmosphere [UNSCEAR, 2000]. These included tritium, carbon-14, strontium-90, caesium-137, plutonium-238, plutonium-239 and plutonium-240. The inventories and deposition patterns in Ireland of weapons derived radionuclides have previously been published [Ryan, 1992; Ryan *et al.*, 1993].

Past accidents at nuclear installations are also an important source of anthropogenic radionuclides in the environment. For example, radio-caesium was widely dispersed in the Irish environment following the Chernobyl accident in 1986 [McAulay and Moran, 1989; Ryan, 1992; European Commission, 1998a].

During the routine operation of nuclear installations such as nuclear power plants and reprocessing plants, radioactive material is released under authorisation to the environment. The most significant of these sources in the Irish environment is from the Sellafield nuclear fuel reprocessing plant situated in Cumbria on the northwest coast of England. The principal activities at Sellafield include fuel reprocessing, spent fuel storage, vitrification of high level radioactive wastes, decommissioning of obsolete plants, fabrication of mixed oxide (MOX) fuel for nuclear reactors, storage of reprocessed plutonium and, until 2003, the generation of nuclear power. These activities result in aerial discharges and the discharge of low-level liquid radioactive waste into the Irish Sea [Colgan *et al.*, 2005], which are authorised within prescribed limits by the UK Environment Agency. The quantity of various radionuclides discharged from Sellafield into the Irish Sea between 2003 and 2005 are presented in **Table 2**.

Typical aerial discharges from Sellafield include krypton-85, a radioactive noble gas that is released primarily during the reprocessing of nuclear fuel. Arising from its low capacity to react with other materials, krypton-85 distributes uniformly throughout the earth's atmosphere within a few years after release [Howett and O'Colmáin, 1998].

Liquid discharges from Sellafield to the marine environment began in the early 1950s and were relatively low until the early to mid 1970s, when considerably larger discharges occurred [Gray *et al.*, 1995]. Discharges then decreased during the late 1970s and early 1980s when the practice of discharging the 'medium active concentrate' and cooling pond water directly to sea was halted. The commissioning of the Site Ion Exchange Effluent Plant and the Salt Evaporator waste treatment facility resulted in a substantial reduction in discharges in the mid-1980s. This is illustrated in the discharges of caesium-137 between 1952 and 2005, which are presented in **Figure 1**.

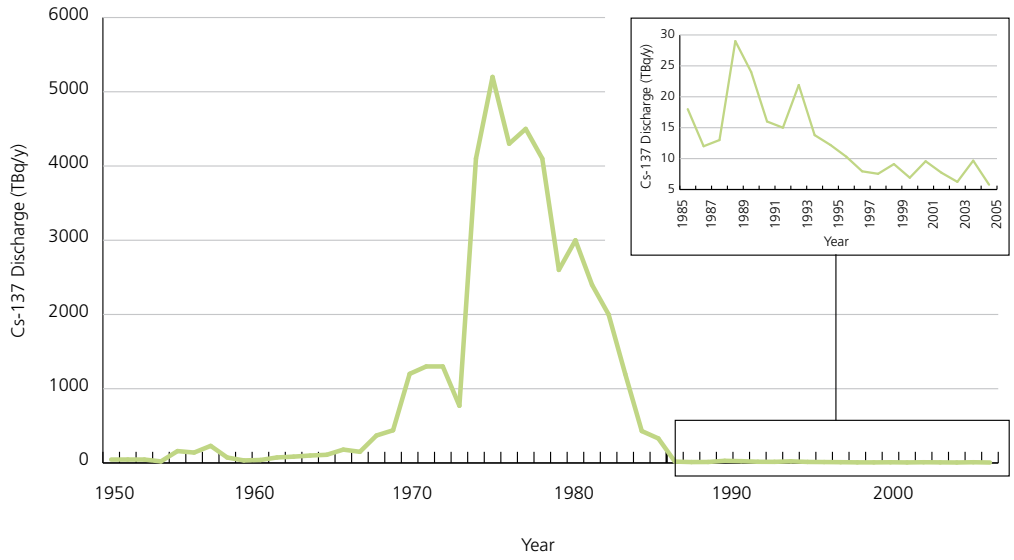

Figure 1. Marine discharges of caesium-137 from Sellafield, 1952-2005

Discharges of technetium-99 from Sellafield into the Irish Sea increased significantly in the mid-1990s, reached a peak in 1995, and were subsequently reduced. By the end of 2005 technetium-99 discharges had returned to pre-1994 levels **(Figure 2)** [RIFE, 2006]. The increased discharges of technetium-99 were due mainly to the processing of a backlog of liquid waste through the Enhanced Actinide Removal Plant at Sellafield. While it is convenient to represent such discharges averaged over a year, in reality month on month discharge rates varied significantly throughout the reporting period. In 2004, a new treatment process based on a chemical called tetraphenylphosphonium bromide (TPP) was implemented at Sellafield that removed approximately 97% of technetium-99 from liquid waste during trials. Consequently, the annual limit for technetium-99 discharges from Sellafield was reduced from 90 terabecquerels (TBq) per year to 20 TBq per year in October 2004 **(Table 2)**.

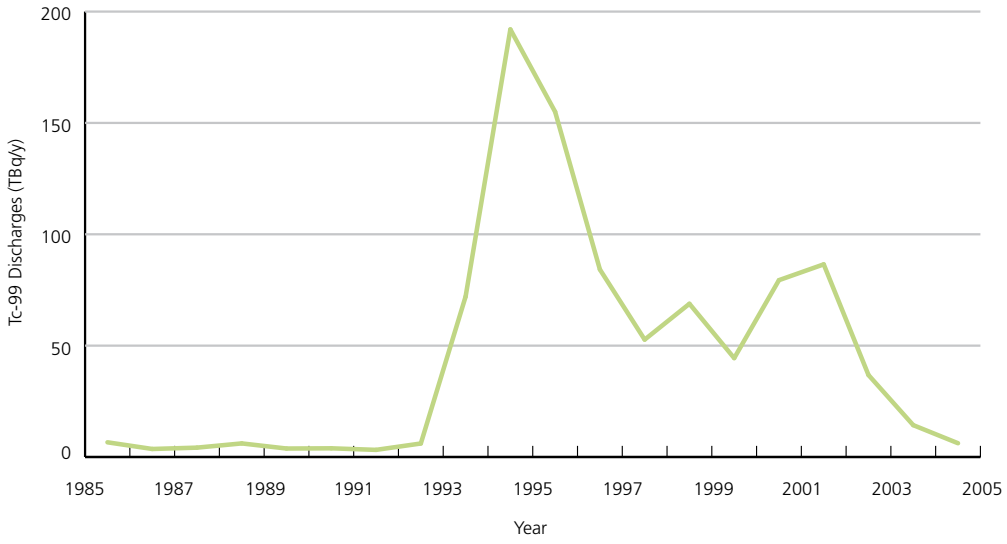

Figure 2. Marine discharges of technetium-99 from Sellafield, 1986-2005

Because of its location within the Irish Sea and the amount of radioactivity involved, the impact of Sellafield discharges on the Irish marine environment is very much greater than those resulting from other nuclear installations in the UK and elsewhere in western Europe (for example, La Hague on the northwest coast of France).

Some hospitals use short-lived radionuclides (for example, iodine-131) for medical and scientific research purposes, which are subsequently released to the environment via the sewage system. As these radionuclides are predominantly short-lived, their contribution to the inventory of artificial radionuclides in the marine environment is small.

Legislative Framework

Radiological Protection Act, 1991

The RPII is the national organisation with regulatory, monitoring and advisory responsibilities in matters pertaining to ionising radiation and was established in 1992 under the Radiological Protection Act, 1991 [Stationery Office, 2000a]. Article 7 (1) (a) of the Act assigns responsibility to the RPII for monitoring levels of radioactivity in the environment.

Articles 35 and 36 of the EURATOM Treaty

Under Article 35 of the EURATOM Treaty, each Member State of the European Union is required to establish the facilities necessary to carry out continuous monitoring of the levels of radioactivity in the environment. In addition, Article 36 of the EURATOM Treaty requires that data arising from this programme be communicated periodically to the European Commission. In fulfilment of this requirement, the RPII transmits the results of its monitoring programme to the Commission on an annual basis. The database of Member States' environmental radioactivity measurements is maintained on behalf of the Commission by the Joint Research Centre at Ispra in Italy and compilations of the data submitted are published periodically in the EU Environmental Radioactivity Series [European Commission, 2005]. Further guidelines on the application of Article 36, specifying the recommended structure of monitoring networks, recommended sampling media, types of measurements and frequency of sampling are provided by the Commission Recommendation 2000/473/EURATOM [European Commission, 2000].

2 Sampling and Analysis

A strong emphasis is placed on quality assurance and best practice is ensured by accreditation of test procedures through the Irish National Accreditation Board to International Standard ISO 17025 [INAB, 2006]. Analytical techniques are validated both through participation in intercomparison exercises and by analysis of certified reference materials. Details regarding the analytical techniques used are given in **Table 3**.

Airborne Radioactivity

Between 2003 and 2005, the RPII, with the assistance of Met Éireann, measured airborne radioactivity at eleven permanent monitoring stations of which nine were equipped with low volume particulate samplers and one with high volume particulate sampler **(Figure 3)**. Low volume particulate samples were routinely assessed for total beta activity while high volume particulate samples were assessed for gamma emitting radionuclides such as caesium-137 and beryllium-7. In addition, gaseous krypton-85 was sampled by the RPII at Clonskeagh in Dublin. The sampling stations and types of samples taken are outlined in **Table 4**.

Low volume particulates were collected over a period of approximately one week by using a pump to draw air continuously through a glass microfibre filter with a diameter of 47 mm. The airflow rate for these systems ranged between 0.1 and 0.15 m^3/h. The glass microfibre filters were stored in a dust-free environment for five days before analysis to ensure that short-lived naturally occurring radionuclides such as bismuth-214 and lead-214 had decayed below detectable levels prior to measurement. The filters were then analysed for gross beta activity using a gas-flow proportional counter.

High volume samples were collected at Beggars Bush (Dublin) during 2004 over a sampling period of two weeks per filter with a typical airflow rate of 50 - 60 m^3/h. During 2004, a new high volume particulate sampler with improved sensitivity was installed at the School of Physics Building at University College Dublin (Belfield) and subsequently measurements at the Beggars Bush site were phased out. The airflow rate of the new unit ranged between 2,000 and 2,500 m^3/h, while the sampling period was increased to four weeks. Typically the filters were bulked on either a monthly or bimonthly basis and were analysed by high resolution gamma spectrometry.

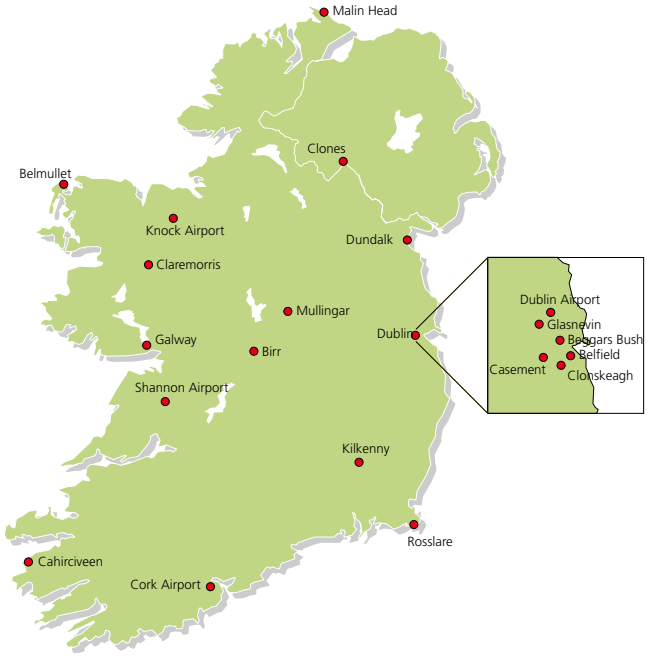

Figure 3. Airborne radioactivity sampling locations, 2003-2005

The krypton-85 sampling system used at the RPII was designed and built by the Subatomic and Radiation Physics Group at the University of Gent in Belgium. Krypton-85 was sampled using a pump to draw air over an activated charcoal trap maintained at the temperature of liquid nitrogen for approximately two hours. The krypton sample was transferred by distillation from the charcoal trap to a copper coil containing a molecular sieve. The copper coil was then sent to Belgium for analysis, which involved gas chromatographic separation followed by liquid scintillation counting to determine the krypton-85 concentration.

Terrestrial Radioactivity

Rainwater

Rainwater was collected continuously with the assistance of Met Éireann at 12 stations as indicated in **Table 4** so that in the event of an accidental release of radioactivity into the atmosphere, concentrations in rainwater could quickly be assessed. It was not considered necessary to analyse any of these samples during the reporting period.

Drinking Water

All drinking water supply zones serving populations in excess of 10,000 are sampled at least once every four years and analysed for tritium, gross alpha and gross beta activities (see **Annex**). There are 60 zones falling into this category [Environmental Protection Agency, personal communication]. Those supplies serving the major population centres are sampled annually while the other supplies falling into this category are sampled on a four-year rotational-basis. Where possible, drinking water was sampled at the point at which the treated water was released into the distribution network. Sampling was carried out on behalf of the RPII by the relevant local authority.

Drinking water samples were acidified with nitric acid as soon as practicable after sampling to minimise the adsorption of radioactivity on the walls of the sample container. An aliquot of between 100 and 500 ml (depending on the concentration of dissolved solids) from each sample was evaporated to dryness and analysed for both naturally and artificially occurring radionuclides by measuring the gross alpha and gross beta activities. Samples were also analysed for tritium by liquid scintillation counting.

Foodstuffs

During the reporting period, samples of complete meals (mixed diet) were collected from selected restaurant facilities around the country and homogenised and measured for gamma-emitting radionuclides. The radioactivity content of individual ingredients was investigated by the RPII in a study carried out between 2003 and 2004 in collaboration with the Food Safety Authority of Ireland. Foodstuffs (including grains, dairy products, vegetables, fruit, meat, seafood, beverages, preserves, oils and takeaway foods) were collected in Dublin and subsequently analysed for gamma-emitting radionuclides. Furthermore, a wide variety of other foodstuffs was supplied to the RPII for testing and certification by food processors, the Health Service Executive and the Department of Agriculture and Food. These foodstuffs (dairy produce, beef, grains, lamb, pork, and poultry) were analysed for the presence of gamma-emitting radionuclides.

Milk was given particular attention due to its high consumption by children and the fact that radionuclides such as caesium-137 and strontium-90 may concentrate in it following contamination of soil and grass. Sampling was conducted at milk processing plants, to which milk was collected from a wide geographic area. Samples were bulked and analysed on a quarterly basis for strontium-90 and gamma-emitting radionuclides.

In the years following the 1986 Chernobyl accident, the RPII carried out an extensive programme of research into the transfer of radiocaesium into the food chain via sheep grazing on upland areas [Colgan *et al.*, 1990; McGee *et al.*, 1993a; McGee *et al.*, 1993b; Pearce *et al.*, 1995]. In addition, routine assessment of radioactivity levels in sheep was conducted through in-vivo monitoring of sheep at slaughterhouses and testing of meat samples from lamb sourced in upland areas. In-vivo monitoring was continued by officers of the Department of Agriculture and Food in association with RPII staff up until 2003. Sampling of lamb meat was continued during 2004 and 2005.

External Gamma Dose Rate (Terrestrial)

The RPII, with the assistance of Met Éireann, operates a permanent network of twelve external gamma dose rate monitoring stations located throughout Ireland (**Table 4** and **Figure 3**). The dose rate is recorded every twenty minutes and automatically transmitted to the RPII's database at Clonskeagh. Recent data from each station can be viewed on line (www.rpii.ie/radiation/ConstantMonitoring.aspx). Each station is fitted with an alarm, which is triggered in the event of a high reading. Arrangements are in place to immediately notify the RPII's Duty Officer of such an occurrence. Between 2003 and 2005, the external gamma dose rates were continuously monitored.

Marine Radioactivity

Between 2003 and 2005, samples of a wide range of fish and shellfish species were collected from commercial landings at major Irish fishing ports and aquaculture areas. Particular attention was given to collecting samples from the north-east ports of Carlingford, Clogherhead and Howth where the highest concentrations of Sellafield-derived radionuclides have been found. Seawater, sediment and seaweed were also collected from coastal sites while seawater and sediment samples were taken at offshore sites in the western Irish Sea using the Marine Institute's research vessel, the *Celtic Voyager*. The external gamma dose rate at coastal sites was measured in 2003 and 2004 using an energy-compensated Geiger Müller detector.

The coastal sampling locations are shown in **Figure 4** and offshore locations in **Figure 5**. The range of samples collected at each location, are given in **Table 5**. The sampling frequency for each site, which ranged from monthly to once every two years, reflected the resolution judged to be necessary to assess the population dose and to identify important trends.

Figure 4. Main coastal sampling locations, 2003-2005

Figure 5. Off-shore sampling locations, 2003-2005

In 2003, a study commissioned by Greenpeace (UK) and carried out by Southampton University found traces of technetium-99 discharged from Sellafield in fresh and smoked salmon farmed in Scotland [Greenpeace, 2003]. In light of public concern in Ireland over these findings, samples of Irish and Scottish smoked salmon, smoked mackerel and fresh salmon were sourced from Irish supermarkets and analysed for their technetium-99 content.

Initial preparation of fish and shellfish samples included cleaning and separation of the edible portion for analysis. Seaweed samples were washed to remove all sediment and other extraneous material. Fish, shellfish, seaweed and sediment samples were then dried to constant weight, pulverised and thoroughly mixed. Samples were analysed individually for caesium-137 and other gamma-emitting radionuclides. Selected individual and bulked samples were analysed for carbon-14, technetium-99, iodine-131, plutonium-238 and plutonium-239,240. Seawater (coastal and offshore) was analysed for caesium-137 and technetium-99 using techniques outlined in **Table 3**.

3 Results

All results quoted are decay corrected to the date of sampling, while bulked samples are decay corrected to the middle of the bulking period. Seaweed samples because of the variability in moisture content are quoted on a dry weight basis while all other solid marine samples are quoted on a fresh weight basis. Typical detection limits and uncertainties for each analytical technique are detailed in **Table 3**. Uncertainties are calculated in accordance with the ISO Guide to the Expression of Uncertainty in Measurement [ISO, 1995]. Where calculated, mean activity concentrations relate to samples with activities above the limit of detection.

Airborne Radioactivity

The monthly range of gross beta activity concentrations in low volume airborne particulates at each of the nine monitoring stations between 2003 and 2005 are presented in **Tables 6-8**. The activity concentrations were consistent with the pattern of background radioactivity established in previous years [RPII Environmental Radioactivity Surveillance Series].

The activity concentrations of caesium-137 and beryllium-7 present in high volume airborne particulates sampled in the Beggars Bush site are presented in **Table 9** and those sampled at Belfield in **Table 10**. Beryllium-7 is a naturally occurring radionuclide and was measured for quality control purposes. The data was consistent with measurements made in previous years [RPII Environmental Radioactivity Surveillance Series]. In particular, caesium-137 concentrations were consistent with expected concentrations arising from global circulation of weapons test fallout [European Commission, 2005].

The individual results for krypton-85 measurements, corrected to standard temperature and pressure, carried out at Clonskeagh (Dublin) between 2003 and 2005 are presented in **Tables 11-13**. A linear trend line fitted to the measured concentrations **(Figure 6)** indicated an overall increasing trend up to approximately 2003, after which concentrations appear to decrease.

In order to allow a more meaningful comparison of year on year data, the geometric mean concentration values for krypton-85 between 2003 and 2005 were calculated **(Table 14)**. The use of the geometric mean reduces the impact of short term fluctuations on the data, which, for example, may occur when wind blows directly from the source of the release.

The concentrations in 2003, 2004 and 2005 were broadly similar to those reported for the period 2001 and 2002 [Long *et al.*, 2005]. In order to compare data with previous years, baseline concentrations were calculated for the years 1993 to 2002. Baseline concentrations are calculated according to Howett and O'Colmáin [1998] and are the mean of all concentrations excluding those that are greater than 1.1 times this mean. The baseline concentrations over Dublin mirrored the trend of the discharges of krypton-85 from La Hague with a time lag of approximately one year (**Figure 7**). It should be noted that La Hague had higher emissions of krypton-85 than Sellafield due principally to its larger nuclear fuel throughput. The krypton-85 discharges from Sellafield increased after 1994 following the commencement of operations at the Thermal Oxide Reprocessing Plant (THORP). Note that the krypton-85 discharges from Sellafield in 2005 declined due to an enforced shutdown of THORP. This was reflected in reduced baseline concentrations for that year.

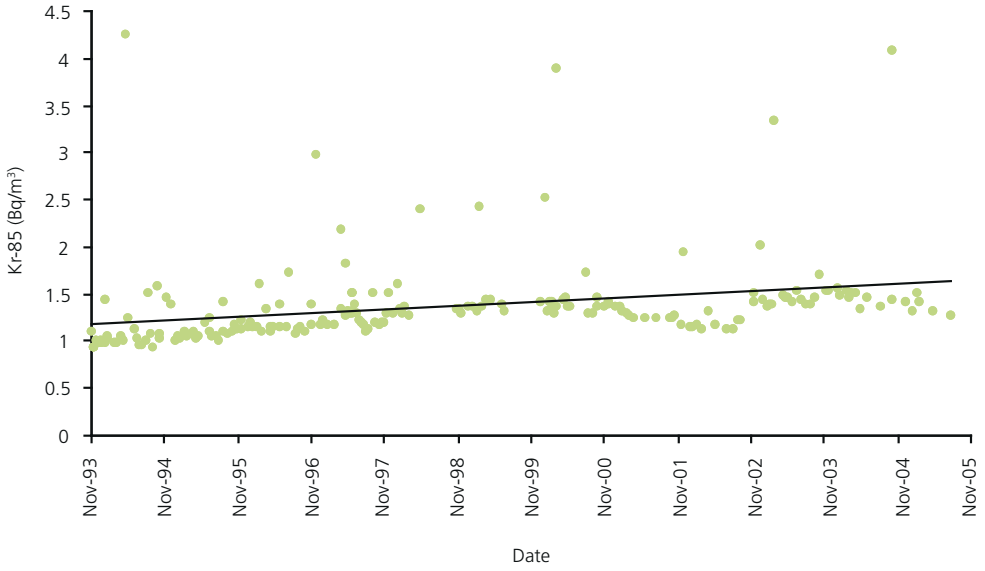

Figure 6. Krypton-85 activity concentrations (Bq/m³) in air at Clonskeagh, 1993-2005

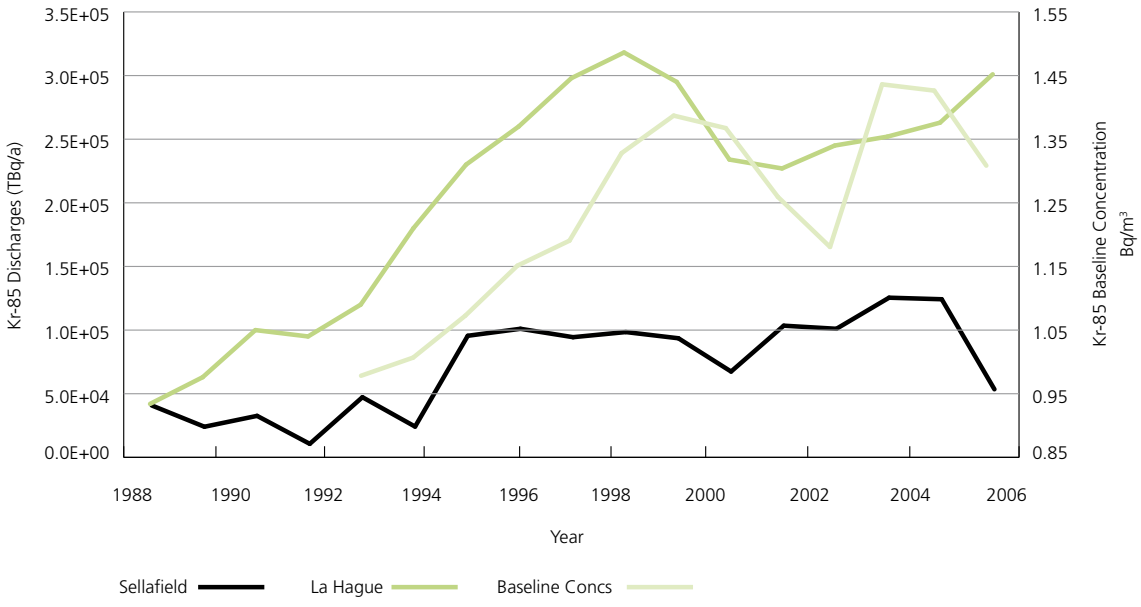

Figure 7. Krypton-85 discharges to the atmosphere from Sellafield and La Hague and baseline concentrations over Dublin, 1989 to 2005

Terrestrial Radioactivity

Drinking Water

The results of gross alpha, gross beta and tritium activity measurements carried out between 2003 and 2005 are presented in **Tables 15-17**. In accordance with the WHO methodology for screening drinking water adopted by the RPII (see **Annex**), if the gross alpha and gross beta are less than 100 mBq/l and 1000 mBq/l respectively then the water may be considered to be in compliance with the standard for total indicative dose set out in S.I. 439 of 2000 (which implements the EU Drinking Water Directive). As all the measured radioactivity concentrations in drinking water samples were below the screening levels for total alpha and total beta and below the parametric value for tritium, the drinking water was considered in full compliance with the requirements of S.I. 439 of 2000.

Foodstuffs

The results of the radioactivity measurements in complete meals (mixed diet) and individual ingredients between 2003 and 2005 are shown in **Tables 18-20**. Caesium-137 was detected in 3 of the 15 samples measured during 2003, 1 of the 17 samples measured during 2004 and 1 of the 4 samples measured in 2005. The maximum caesium-137 concentrations measured in a range of foodstuffs for export during the reporting period are presented in **Table 21**. The majority of these samples had activity levels below the limit of detection. The results of the radioactivity measurements in individual ingredients, carried out in collaboration with the Food Safety Authority of Ireland, are listed in **Table 22**. Caesium-137 was detected in 11 of the 104 ingredients analysed. Caesium-137 detected in terrestrial foodstuffs is most likely to be due to residual fallout from the Chernobyl accident or earlier nuclear weapons testing.

Table 23 presents the results of measurements of radioactivity in milk samples for 2003-2005. Caesium-137 was not detected in any of the 68 composite milk samples analysed during the reporting period. Strontium-90 was detected in some samples with activity concentrations ranging from the detection limit of 0.02 to 0.07 Bq/l. It should be noted that, because of the difference in analytical techniques, the detection limit for strontium-90 is lower than the detection limit for caesium-137. In general, the results were similar to those for 2001 and 2002 [Long *et al.*, 2005].

In 2003, in-vivo monitoring was carried out on 1,108 sheep at upland farms and in slaughterhouses. Of these, 95% were found to contain radiocaesium concentrations below 200 Bq/kg and 5% were found to be in the range 200 to 600 Bq/kg. The maximum measured concentrations and the number of samples tested for sheep meat samples conducted between 2003 and 2005 are given in **Table 21**. In all cases sheep meat samples were found to have caesium-137 concentrations below 20 Bq/kg. Since 1988, the measured levels of radiocaesium have decreased and the number of sheep exceeding the above limits has declined [RPII Environmental Radioactivity Surveillance Series].

External Gamma Dose Rate (Terrestrial)

The minimum and maximum external gamma dose rate readings for each month, at each of the 12 stations around the Republic of Ireland, between 2003 and 2005 are presented in **Tables 24-26**. The ranges were similar to those observed in previous years [RPII Environmental Radioactivity Surveillance Series]. No abnormally high readings were observed at any of the twelve stations during the reporting period.

The external gamma dose rate is a measurement of ambient gamma radiation, which is dominated by primordial radionuclides and cosmic radiation. The measurements were subject to variation arising from changes in the concentration of radon daughters and variability in the radioactive content of underlying rocks and soils. During heavy rainfall, radon daughters present in the atmosphere were brought to ground level resulting in increased dose rate readings, a phenomenon known as 'radon washout'. This increase in dose rate tended to persist for a few hours and gave rise to significant variability in the recorded data.

Marine Radioactivity

Seawater

The results of the analyses of caesium-137 and technetium-99 in coastline and offshore (western Irish Sea) seawater between 2003 and 2005 are presented in **Tables 27-29**.

The mean activity concentrations of caesium-137 at each coastal location between 2003 and 2005 (**Figure 8**) illustrates the previously established geographical distribution of caesium-137 around the Irish coastline with the highest concentrations of Sellafield-derived caesium-137 being found on the north-east coast, consistent with the known water circulation patterns in the Irish Sea. The caesium-137 concentrations on the west coast of Ireland are comparable to those found in north Atlantic waters (2.7 mBq/l) between 1990 and 1997 [Ólafsdottir *et al.*, 1999].

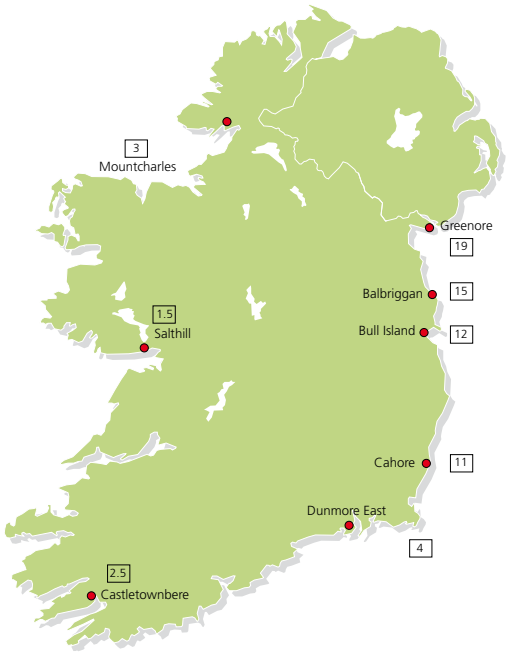

Figure 8. Mean caesium-137 activity concentrations (mBq/l) in coastline seawater, 2003-2005

The mean caesium-137 activity concentrations in seawater from Balbriggan on the east coast of Ireland between 1993 and 2005 are shown in **Figure 9**. The data reveals a downward trend in the period 1993-2000, which reflects the reduction in caesium-137 discharges from Sellafield during this period (**Figure 1**). Given the low discharge rates from Sellafield in recent years, remobilisation from sediments of historic discharges is now an important source of caesium-137 in seawater from the western Irish Sea [Leonard *et al.*, 2004, Hunt and Kershaw, 1990]. As a result, concentrations have remained relatively steady since 2000. The trend observed in caesium-137 activity concentrations in seawater at offshore locations in the Irish Sea (Stations N1-N6 inclusive) since 1985 is shown in **Figure 10**. The caesium-137 activity concentrations measured along the south and west coasts between 2003 and 2005 were similar to those measured in 2002 and are now relatively constant [McMahon *et al.*, 2005a].

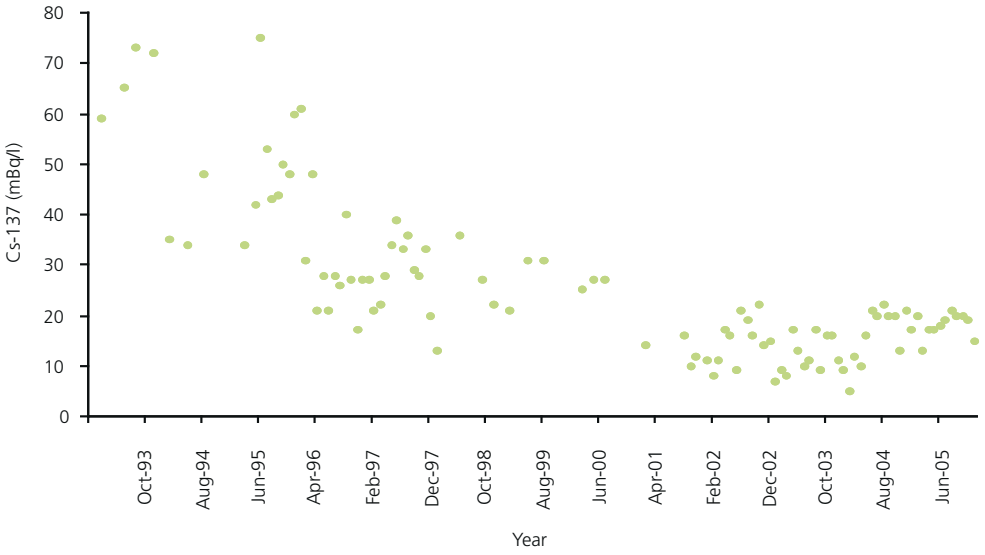

Figure 9. Mean caesium-137 activity concentrations in seawater from Balbriggan, 1993-2005

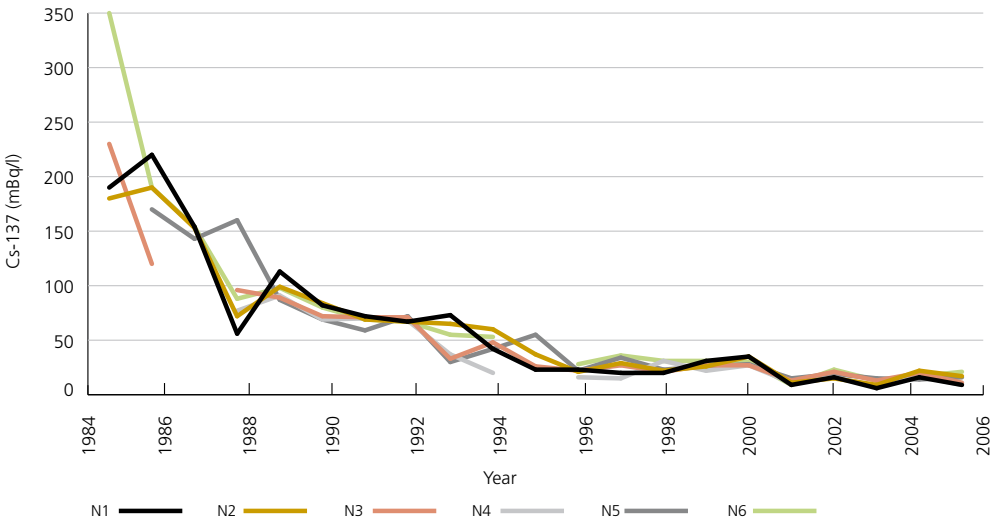

Figure 10. Caesium-137 activity concentrations in seawater from locations N1-N6 in the Irish Sea, 1985-2005

The distribution of soluble radionuclides such as technetium-99 discharged from Sellafield is influenced predominantly by the movements of the major tidal and residual currents in the Irish Sea. Discharges of technetium-99 from Sellafield peaked in 1995 following the commissioning of the Enhanced Actinide Removal Plant in 1994 and peak concentrations in seawater from Balbriggan (**Figure 11**) were found 18-24 months later [Long *et al.*, 1998]. Following the implementation of the TPP waste treatment process at Sellafield in 2004, reductions in concentrations in seawater in the western Irish Sea were seen in the 2005 data for Balbriggan.

Figure 11. Technetium-99 activity concentrations in seawater (mBq/l) from Balbriggan, 1995-2005

Sediment

The results for caesium-137 activity concentrations in sediment samples collected between 2003 and 2005 are shown in **Tables 30-32**. The mean activity concentrations in coastline sediments for 2003-2004, shown in **Figure 12**, were similar to those measured during 2002 and show the same geographical trend as the seawater data [McMahon *et al.*, 2005a]. All other artificial gamma emitting radionuclides were below the detection limit.

The relatively high activity concentrations of caesium-137 measured in sediments from offshore locations between Dundalk Bay and the Isle of Man (N3–N6 inclusive) were associated with areas of mud and silt accumulation that tended to concentrate radionuclides to a greater degree than coarser sediments (**Figure 13**). To illustrate the effect of smaller grain size on radioactivity concentrations, sediment was taken from two different locations on Bull Island (Dublin) in 2003 and 2004. The caesium-137 activity in the sediment comprising of fine silt at Bull Wall was higher than that comprising of sand at Dollymount Strand (**Tables 30-31**).

Figure 12. Mean caesium-137 activity concentrations in coastline sediments (Bq/kg, dry), 2003-2004

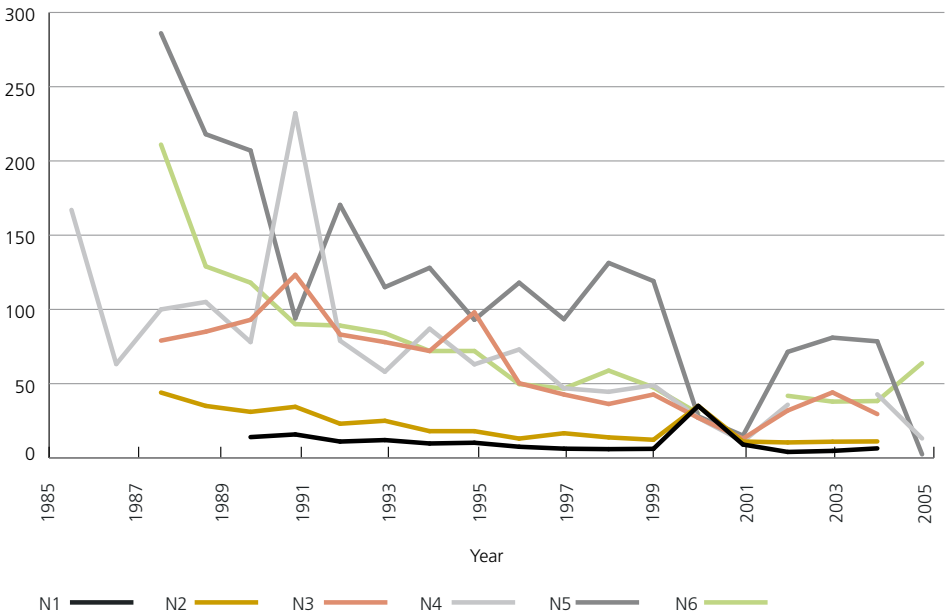

Figure 13. Caesium-137 activity concentrations (Bq/kg, dry) in sediment from locations N1-N6 in the Irish Sea, 1986-2005

Seaweed

The results for caesium-137, carbon-14, iodine-131 and technetium-99 activity concentrations in seaweed between 2003 and 2005 are given in **Tables 33-35**. The mean activity concentrations of caesium-137 in seaweed (*Fucus vesiculosis*) around the Irish coastline during the reporting period are presented in **Figure 14**.

All results are presented on a dry weight basis and an estimate of the fresh weight activity concentration may be obtained using the mean dry to fresh weight ratio of 0.18 established between 2003 and 2005.

Figure 14. Mean caesium-137 activity concentrations in seaweed (*F. vesiculosis*, Bq/kg, dry), 2003-2005

Caesium-137 activity concentrations in seaweed sampled from Balbriggan on the east coast of Ireland (**Figure 15**) have remained relatively constant since the mid 1990s, which is consistent with sediment and seawater data [RPII Marine Monitoring Series]. **Figure 16** shows the technetium-99 activity concentrations in seaweed from Balbriggan and Greenore for the period June 1988 to December 2003 [RPII Marine Monitoring Series]. These data demonstrate that technetium-99 activity concentrations in seaweed from the north-east coastline peaked between late 1997 and early 1998, in line with seawater activity concentrations and have slowly reduced in subsequent years. Mean carbon-14 activity concentrations in seaweed from Balbriggan in 2003 and 2004 were similar to those measured in 2002 and 2003 [McMahon *et al.*, 2005a; Keogh *et al.*, 2004].

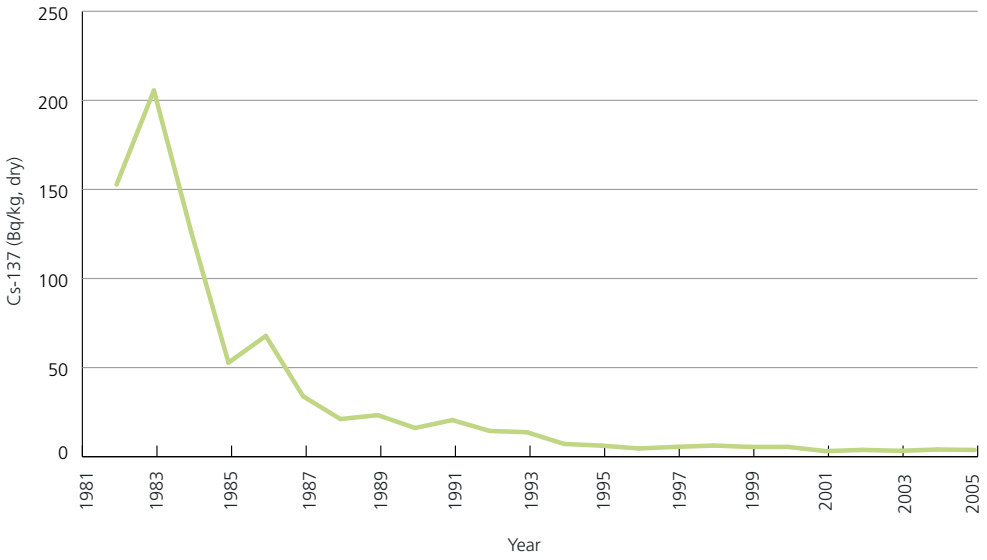

Figure 15. Mean caesium-137 activity concentrations in seaweed (*F. vesiculosis*, Bq/kg, dry) from Balbriggan, 1982 to 2005

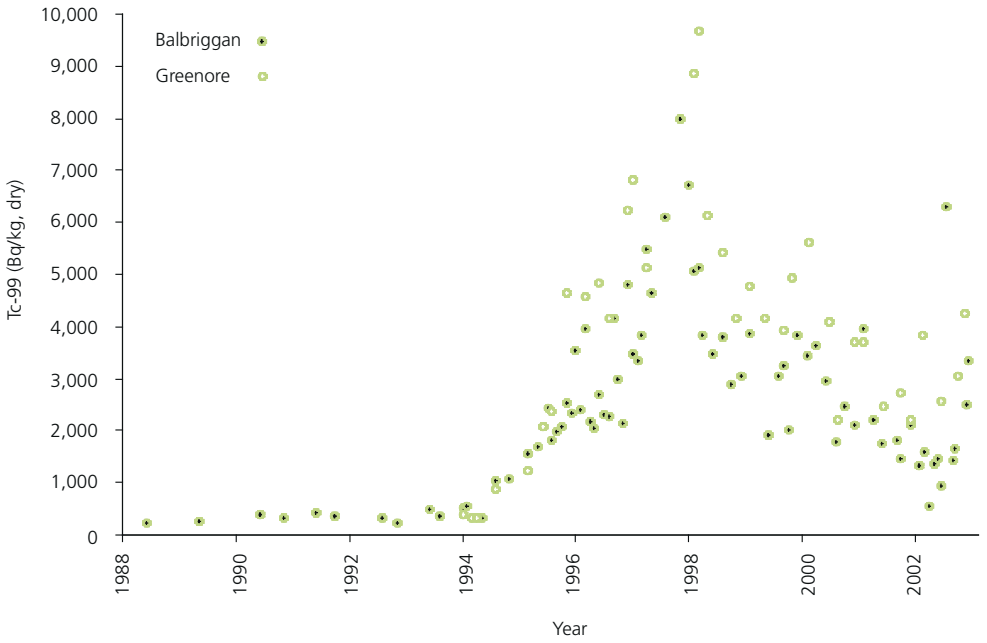

Figure 16. Technetium-99 activity concentrations in seaweed (*F. vesiculosis*, Bq/kg, dry) from Balbriggan and Greenore, 1988-2003

Data on Iodine-131 in seaweed (*Fucus vesiculosis* and *Ascophyllum nodusum*), which is discharged via the sewage system as a result of its use in medical procedures, are presented in **Tables 33** and **34**. The data show large fluctuations from month to month, which are expected due to the intermittent use of the radionuclide in such procedures and its dilution following discharge. This variability is evident from the concentrations of iodine-131 observed in samples of *Fucus vesiculosus* collected from Bull Island (Dublin) between 1991 and 2004 (**Figure 17**). Both *Ascophyllum nodosum* and *Fucus vesiculosis* were collected from Bull Island between 2003 and 2004 and the results of these analyses are shown in Figure 18. All other artificial gamma emitting radionuclides were below the detection limits of the measurement system.

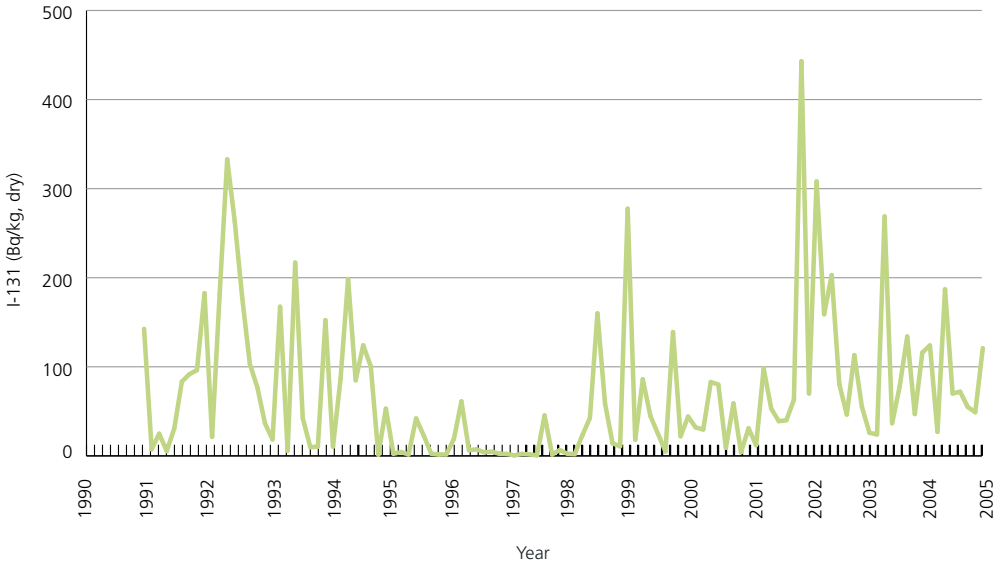

Figure 17. Iodine-131 activity concentrations in seaweed (*F. vesiculosis*, Bq/kg, dry) from Bull Island, 1991-2004

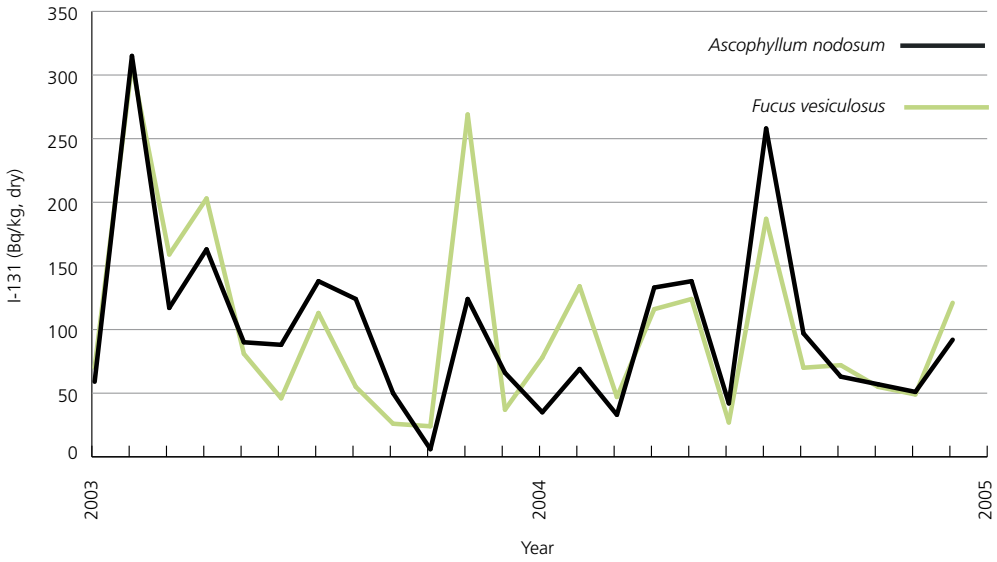

Figure 18. Iodine-131 activity concentrations in seaweed (Bq/kg, dry) from Bull Island, 2003-2004

Fish and Shellfish

The results of radioactivity measurements in fish and shellfish collected from major Irish fishing ports and aquaculture areas between 2003 and 2005 are shown in **Tables 36-44**. All results are presented on a fresh weight basis.

The caesium-137 concentrations in fish and shellfish were similar to those detected in 2002 [McMahon *et al.*, 2005a]. All other artificial gamma emitting radionuclides were below detection limits of the system. Technetium-99 activity concentrations were generally observed to be higher in prawns than in farmed mussels and higher in mussels than in fish, which was consistent with the concentration factors reported for this radionuclide [IAEA, 2004]. Plutonium-238 and plutonium-239,240 activity concentrations were higher in shellfish than in fish, a feature that was consistent with the concentration factors reported for plutonium [IAEA, 2004]. The mean activity concentrations of artificial radionuclides in fish and shellfish landed at North East ports between 2003 and 2005 is presented in **Table 45**.

In 2003, the RPII carried out a survey to determine the levels of technetium-99 in a number of salmon samples bought in Dublin. Technetium-99 was detected (0.18 Bg/kg, wet wt.) in one of the nine samples of salmon analysed.

External Gamma Dose Rate (Coastal)

In 2003 and 2004, external ambient gamma dose rate readings were taken at nine and six locations, respectively, around the country (**Table 46**). While the data are consistent with that recorded in 2002 [McMahon *et al.*, 2005a], differences in readings from location to location can be largely attributed to differences in local geology. The mean dose rates measured at Balbriggan on the east coast were 0.066 µGy per hour in 2003 and 0.065 µGy per hour in 2004. This is equivalent to an exposure of 0.056 µSv per hour in 2003 and 0.055 µSv per hour in 2004 using a mean conversion factor of 0.85µSv per µGy for gamma rays in the energy range 0.05 MeV to 2 MeV [ICRP, 1996b].

4 Assessment of Radiation Exposure

Dose Assessment

The radiation dose due to inhalation of airborne caesium-137 (measured in high volume airborne particulates) was calculated using committed dose coefficients set out in the Basic Safety Standards Directive [European Commission, 1996]. The annual equivalent skin dose and the whole body effective dose due to krypton-85 was calculated using the ICRP 30 dose coefficient for submersion in a semi-infinite cloud [ICRP, 1979] and the ICRP 68 effective dose rates for inert gases [ICRP, 1994], respectively. The doses were calculated on the basis of the annual geometric mean concentration of krypton-85 in air measured at Clonskeagh (**Table 14**).

The committed effective dose to infants and adults from the consumption of milk was estimated for strontium-90 and its daughter product yttrium-90, which is assumed to be in equilibrium and therefore to be numerically equal in terms of activity concentration. The dose from caesium-137 was not estimated as the levels of caesium-137 in every milk sample analysed between 2003 and 2005 were below the detection limit. Ingestion doses were calculated using ICRP 72 age-dependent dose coefficients [ICRP, 1996a] (**Table 47**) and the mean annual strontium-90 activity concentrations for the whole country (**Table 50**). Milk consumption rates were obtained from two sources. The North/South Ireland Food Consumption Survey [NSIFCS, 2001] was used for adults while the 1993 UNSCEAR report on the Sources and Effects of Ionizing Radiation [UNSCEAR, 1993] was used for infants. Based on these sources the mean full milk consumption for an adult male and an infant in Ireland is 178 kg/y and 120 kg/y, respectively.

The committed effective dose due to the consumption of seafood was estimated using the mean activity concentrations for artificial radionuclides in fish, crustaceans and molluscs from north-east ports between 2003 and 2005 (**Table 45**). Americium-241 activity concentrations were estimated using mean americium/plutonium ratios in fish, prawns and mussels [Ryan *et al.*, 1999]. The consumption rates used were those used in previous reports and are a notional estimate of the quantities eaten daily by 'typical' and 'heavy' consumers of seafood and were 40g of fish and 5g of shellfish for a typical consumer and 200g of fish and 20g of shellfish for a heavy consumer. Shellfish consumption was assumed to be divided equally between crustaceans and molluscs and activity concentrations in prawns and mussels were considered to be representative of crustaceans and molluscs, respectively. Dose conversion factors used were those recommended by ICRP 72 [ICRP, 1996a] as presented in **Table 47**.

The effective dose from beach occupancy was estimated from the caesium-137 activity concentration in inter-tidal sediments using the sandy beach model described by Hunt [1984]. It was calculated for an individual spending one hour per day in the inter-tidal zone and was based on the mean caesium-137 activity concentrations in sediments for two sampling locations in the north-east of Ireland, namely Balbriggan and Greenore.

Population Doses

The committed effective dose due to inhalation of airborne particulate caesium-137 for the years 2003, 2004 and 2005 (**Table 48**) was calculated to be 4.3×10^{-4} µSv (microSievert), 8.9×10^{-5} µSv and 7.5×10^{-5} µSv, respectively. These doses were similar to the average committed effective dose of 5.8×10^{-4} µSv measured during 2001 and 2002 [Long *et al.*, 2005].

The skin dose from exposure to krypton-85 in 2003 (0.81 µSv), 2004 (0.80 µSv) and 2005 (0.56 µSv) was comparable with the mean skin dose of 0.55 µSv observed in the period 1993 to 2002 (**Table 49**). The annual skin dose to the Irish population from exposure to krypton-85 between 1993 and 2005 has remained constant [RPII Environmental Radioactivity Surveillance Series]. Similarly the whole body effective dose from krypton-85 exposure estimated for 2003 (0.016 µSv), 2004 (0.016 µSv) and 2005 (0.011 µSv) was similar to the mean effective dose of 0.011 µSv observed in the period 1993 to 2002 [RPII Environmental Radioactivity Surveillance Series]. It should be noted that the whole body effective dose was significantly less than the skin dose arising from the inability of krypton-85 to participate in metabolic processes [Howett and O'Colmáin, 1998].

The committed effective doses from strontium-90 and yttrium-90 in milk between 2003 and 2005 are presented in **Table 50**. Infants under the age of one were the most sensitive group, receiving doses from strontium-90 of 1.1 µSv each year. These doses were similar to previous years [RPII Environmental Radioactivity Surveillance Series].

The committed effective doses from artificial radionuclides for typical and heavy consumers of seafood landed at Irish north-east ports between 2003 and 2005 are given in **Table 51**. These doses included contributions from the artificial radionuclides technetium-99, caesium-137, plutonium-238,239,240 and americium-241. The total doses for 2003 were estimated to be 0.16 and 0.71 μSv to typical and heavy consumers, respectively. Similarly, in 2004 these doses were 0.17 and 0.75 μSv to typical and heavy consumers, respectively. In 2005, the doses were 0.24 and 1.10 μSv to typical and heavy consumers, respectively. Between the early 1980s and the late 1990s annual doses have decreased steadily (**Table 52**), reflecting the overall reduction in discharges of these radionuclides from Sellafield during this period. Annual doses since then have remained relatively constant.

Caesium-137 continues to be the dominant radionuclide, accounting for approximately 60-70% of the total dose due to artificial radionuclides in the Irish marine environment. Although there are significantly higher activity concentrations of technetium-99 than caesium-137 in shellfish, technetium-99 accounts for less than 15-20% of the dose. This reflects the fact that the dose received per becquerel of technetium-99 ingested is approximately 20 times less than that received per becquerel of caesium-137 ingested.

Of the dose attributable to caesium-137, more than 90% is due to the consumption of fish. This is in contrast to the dose due to technetium-99, where more than 90% of the dose is attributable to consumption of shellfish, reflecting the significantly higher activity concentrations of this radionuclide in crustaceans and molluscs than in fish. The committed effective dose to heavy consumers due to radiocaesium is shown in **Figure 19** for the period 1982 to 2005 [RPII Marine Monitoring Series]. A strong downward trend is evident during the mid to late 1980s, which was followed by a period of less pronounced reductions. Since 1997, the dose has remained essentially unchanged.

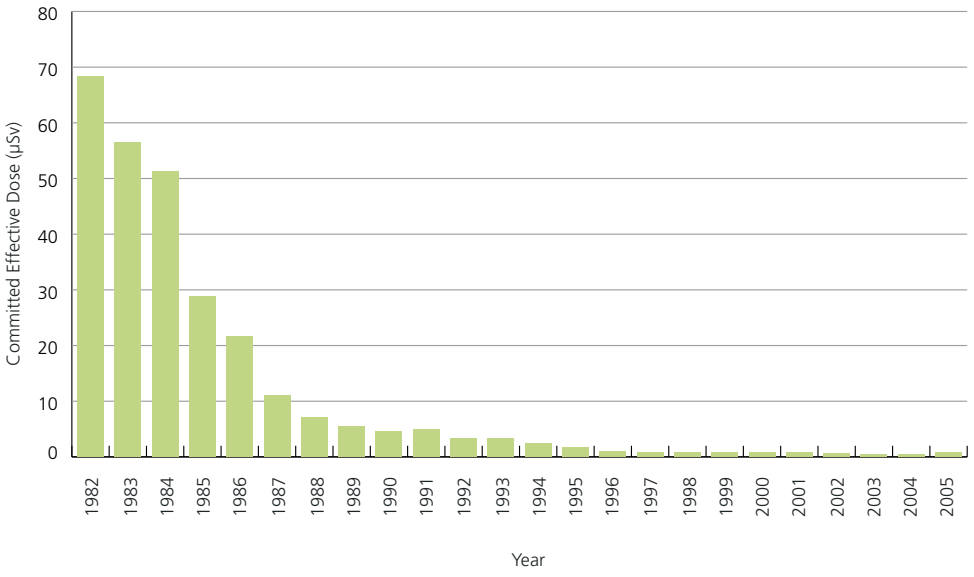

Figure 19. Committed effective doses to heavy seafood consumers due to caesium-137, 1982-2005

The effective dose from beach occupancy due to the presence of caesium-137 in marine sediments was estimated to be approximately 0.3 μSv for 2003-2004. This may be compared with the mean annual dose due to ambient gamma radiation of 480 μSv as estimated from the permanent gamma dose monitoring stations. The beach occupancy dose was similar in value to the annual committed dose to the typical seafood consumer from artificial radionuclides. However, in the absence of detailed habit surveys, it was assumed that the actual number of people who spend 365 hours per year in the inter-tidal zone was considerably smaller than the number of typical seafood consumers. The ingestion pathway was therefore still considered to be the dominant one affecting the Irish public. Other external exposure pathways such as swimming in the sea or boating were considered to be of lesser significance.

The committed effective doses detailed above may be compared with those attributable to the presence in seafood of the naturally-occurring radionuclide, polonium-210, which were estimated to be 32 μSv and 148 μSv for typical and heavy consumers, respectively [Pollard *et al.*, 1998]. The doses from artificial radionuclides may also be compared with the annual dose limit of 1000 μSv for members of the public from practices involving controllable sources of radiation [Stationery Office, 2000a]. Thus, between 2003 and 2005, typical seafood consumers received about 0.02% of this limit while heavy consumers received about 0.07-0.11% of the limit. If the doses from air exposure and milk consumption are taken into account, then between 2003 and 2005, typical seafood consumers received about 0.04-0.05% of the limit while heavy consumers received about 0.09-0.14% of the limit.

Comparison can also be made with the annual average dose of approximately 3620 μSv from all sources of radiation received by members of the Irish public [Ryan *et al.*, 2003b]. Of this, approximately 90% is due to naturally occurring radiation and the remainder is mainly due to medical uses of radiation. It can be seen, therefore, that the doses arising from exposure to air, consumption of milk and the consumption of fish and shellfish, even by heavy consumers, are a very small fraction of those received from other sources.

Risk Estimates

Evaluation of the risks associated with radiation exposure is based on the assumption that there is a linear relationship between radiation dose and the risk of a fatal cancer. The probability of a fatal cancer occurring in an exposed population is estimated to be 5×10^{-2} per sievert, that is, there is a chance of 1 in 20 of developing a fatal cancer after exposure to a radiation dose of 1 Sv [ICRP, 1991].

The radiation induced risk for a typical Irish seafood consumer in 2003, 2004 and 2005 was about one in 127 million, one in 119 million and one in 85 million, respectively. For a heavy Irish seafood consumer the radiation induced risk in 2003, 2004 and 2005 was one in 28 million, one in 27 million and one in 18 million, respectively.

When the dose contribution from air and milk is combined with that from seafood, the radiation induced risk for a typical consumer in 2003, 2004 and 2005 becomes about one in 52 million, one in 50 million and one in 40 million, respectively. For a heavy consumer the radiation induced risk in 2003, 2004 and 2005 becomes one in 21 million, one in 20 million and one in 15 million, respectively.

These compare with a general risk of death from cancer in Ireland of 1 in 522 during this period [CSO, 2005]. These risks have reduced over the past number of years [RPII Marine Monitoring Series].

5 Research

National Environmental Monitoring Programme (2003)

In 2003, the RPII participated in a multi-agency review of existing and proposed environmental monitoring in Ireland's estuarine, coastal and marine waters carried out by the Environmental Protection Agency (EPA) in association with the Marine Institute, National Parks and Wildlife and Met Éireann. '*The National Environmental Monitoring Programme for Transitional, Coastal and Marine Waters*' was published as a discussion document [Environmental Protection Agency, 2003]. This document outlined the existing and future monitoring and reporting roles of national, regional and local bodies, in order to guide the protection of the Irish marine environment and to safeguard its quality for human use. The requirements of EU Directives and of other commitments, such as those arising from the OSPAR Convention were taken into account in the programme to ensure increased efficiency, communication and collaboration in marine monitoring in Ireland.

Radioactivity in Drinking Water (2003)

During 2003, the RPII published the results of a pilot study of radon in drinking water in Co. Wicklow [Ryan *et al.*, 2003a]. Wicklow was chosen primarily on the basis that parts of the county are known to have high instances of radon in air in homes and many residents use private supplies for their drinking water. Radon activity concentrations were measured in the private drinking water supplies of 166 houses in the county. Four houses had activity concentrations in excess of the recommended European Commission reference level of 1000 Bq/l above which remediation is recommended [European Commission, 2001]. The overall results of the survey are illustrated in **Figure 20**.

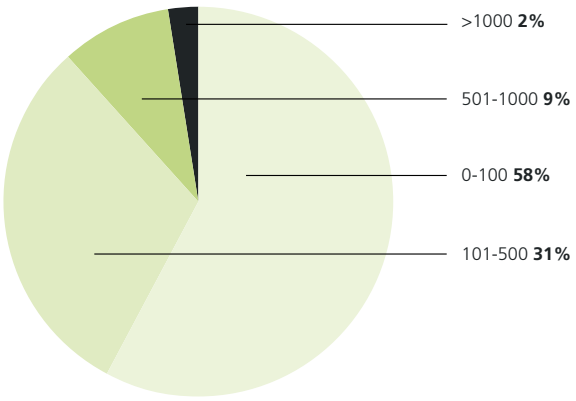

Figure 20. Radon levels (Bq/l) in 166 private drinking water supplies, Co. Wicklow, 2003

Dose estimates based on the measurements made in this study demonstrate that radon in drinking water may pose a significant additional health risk, in the longer term, to some consumers who depend on the supplies as their primary source of water. Following this study, the RPII issued an advice note to all local authorities regarding radon in water.

Marine Radioecology Research (2003)

Although discharges of radiocaesium and plutonium from Sellafield have decreased significantly since the peak discharges in the 1970s, the concentrations in the water of the Irish Sea have not dropped as quickly. This is as a result of a significant proportion of the radionuclides which had accumulated on seabed sediments being slowly released back into the water. The processes involved in such remobilisation were the focus of a four year international research project entitled REMOTRANS in which the RPII participated. The project, which was partially funded by the European Union and involved 12 laboratories in eight countries, concluded at the end of 2003.

A fundamental step in understanding the potential impact on Irish coastal waters of this 'source' of radionuclides was to determine the total amount of radionuclides deposited in western Irish Sea sediments. To achieve this, 23 sediment cores were collected from the western Irish Sea and analysed for radiocaesium and plutonium content. From the results of the analysis, it was estimated that approximately 120 terabecquerels (TBq) of caesium-137 and 20 TBq of plutonium-239,240 were deposited in the sediments of the western Irish Sea. The results showed the highest concentrations of radioactivity resided in the mud banks off the north-east coast and were consistent with previous studies in the Irish Sea [McMahon *et al.*, 2005b].

Also, as part of the REMOTRANS project transit times of radionuclides from the point of discharge to different locations on the Irish coast were estimated from direct measurements. Using these data, it has been estimated that a pulse of soluble radionuclides leaving Sellafield will be first measurable on the east coast of Ireland after approximately six months, and in about four years will be detected on the west coast [McMahon *et al.*, 2005b].

Environmental Impact Assessment of Iodine-131 Discharged From Hospitals (2003 and 2004)

The main source of discharges of radioactivity to the marine environment from Irish facilities is disposal via the sewage system of radioisotopes administered to patients in the nuclear medicine departments of hospitals. Of the several radionuclides used, iodine-131 is the only one that is present in measurable quantities.

Between 2003 and 2004, an environmental impact assessment was carried out on iodine-131 discharges from hospitals to the Dublin Bay area. To this end, a sampling campaign was carried out to collect influent, effluent and processed sludge samples from the Waste Water Treatment Works (WWTW) at Ringsend and seaweed samples from Dublin Bay. Sampling was timed to coincide with administrations of iodine-131 to thyroid ablation patients at two Dublin hospitals. The RPII collected and analysed seaweed samples on a monthly basis. Analysis of these samples showed that approximately 80% of the iodine-131 activity estimated to have been discharged from the hospitals was detected at the WWTW, of which approximately one quarter was associated with the sludge and approximately three quarters was ultimately discharged to Dublin Bay. The remaining 20% of the iodine-131 was likely to have been retained in the sewer pipes, possibly bound to organic matter which builds up in these pipes.

Concentrations of iodine-131 of up to approximately 600 Bq/kg (dry weight) were measured in the sludge, which ultimately is used as an organic fertiliser. However, because of its short half-life of eight days, contamination of the foodchain was not of concern. The wastewater contained up to 20 Bq/l. Analysis of iodine-131 concentrations in two seaweed species (*Ascophyllum nodosum* and *Fucus vesiculosus*) indicated that the impact of individual administrations were measurable (**Figure 18**), with concentrations ranging from 17.6 Bq/kg to 62.0 Bq/kg (wet weight). The temporal pattern of iodine-131 uptake by the two species was followed by analysis of daily samples collected over a two-week period.

Doses to sewer workers repairing a blockage on the premises of a disposer and staff at the WWTW were also calculated. These groups were considered to be at the highest risk of exposure to the discharges. For the worst case scenario, doses received by the sewer workers were estimated to be significantly less than the annual dose limit to members of the public from exposure to all controlled sources of ionising radiation of 1 mSv/y [Akinmboni *et al.*, 2005].

6 Conclusions

Between 2003 and 2005, the RPII monitored radioactivity in a wide range of environmental samples and foodstuffs.

Activity concentrations of radionuclides in airborne particulates and krypton-85 were low and consistent with measurements made in recent years. No abnormal external gamma dose rates were observed between 2003 and 2005 at any of the 12 continuous monitoring stations.

All drinking waters tested for gross alpha, gross beta and tritium activities were found to comply with relevant national and EU standards for water quality. Radioactivity levels in milk, mixed diet and a wide range of foodstuffs were low and for the majority of samples, below the detection limits.

The consumption of fish and shellfish from the Irish Sea continued to be the dominant pathway by which radioactive contamination of the marine environment resulted in radiation exposure of the Irish population. Between 2003 and 2005, the mean annual committed effective dose to a heavy consumer of seafood from the Irish Sea was 0.85 μSv, which was similar to that received in 2001 and 2002. Caesium-137 remained the dominant radionuclide accounting for approximately 60-70% of these doses.

The doses incurred by the Irish public as a result of anthropogenic radioactivity in the environment are small by comparison with the doses received as a result of background radiation. The doses from the consumption of fish and shellfish, for example, were small compared with the estimated annual dose of 148 μSv received by the same consumer due to the presence of the naturally occurring radionuclide polonium-210 in seafood and with the average annual dose to a person in Ireland from all sources of radioactivity of 3620 μSv.

In general, levels of radioactivity in the Irish environment remained fairly constant over this reporting period and were broadly consistent with levels reported during the previous period. Specifically regarding discharges from Sellafield, the data reported here are consistent with the pattern of slow decline in environmental concentrations which has been observed over a number of decades. It is emphasised that the levels of radioactive contamination present in the marine environment, do not warrant any modification of the habits of people in Ireland, either in respect of consumption of seafood or any other use of the amenities of the marine environment.

The Oslo Paris (OSPAR) Convention sets out a framework for international cooperation on the protection of the marine environment of the North-East Atlantic. Further reductions in anthropogenic radioactivity levels in the marine environment are being pursued through the implementation of the OSPAR Radioactive Substances Strategy. All signatories to the Strategy are committed to progressive and substantial reductions in radioactive discharges from their facilities. Compliance with the objectives of the Strategy should ensure that the radiation doses attributable to the operations at Sellafield are even further reduced in future years. The RPII takes the view that the very highest possible standards of safety and waste management should apply in nuclear facilities including the implementation of the best available techniques for the further reduction of discharges with a view to minimising their environmental impact.

In summary, the results of the monitoring programmes between 2003 and 2005 show that, while the levels of anthropogenic radioactivity in the Irish environment remain detectable, they are low and, on the basis of current scientific knowledge, do not pose a significant risk to human health.

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9 Glossary of Terms

Absorbed Dose

Quantity of energy imparted by the ionising radiation to unit mass of matter such as tissue. It is measured in grays (Gy). One Gy produces different biological effects on tissue depending on the type of radiation (alpha, beta or gamma).

Activity

Activity is a measure of the rate at which nuclear disintegration occurs. The unit of activity is the becquerel (Bq). One Bq is equivalent to one disintegration per second.

Collective Effective Dose

Total dose over a population group exposed to a given source. It is represented by the product of the average effective dose to the individuals in the group by the number of persons comprising the group. It is measured in man sieverts (manSv).

Committed Effective Dose

Total dose gradually delivered to an individual over a given period of time by the decay of a radionuclide following its intake into the body. The integration time is usually taken as 50 years for adults and 70 years for children.

Effective Dose

Weighted sum of the equivalent doses to the various organs and tissues. The weighting factor for each organ or tissue takes account of the fractional contribution of the risk of death or serious genetic defect from irradiation of that organ or tissue to the total risk from uniform irradiation of the whole body. The unit of effective dose is the sievert (Sv).

Equivalent Dose

The quantity obtained by multiplying the absorbed dose by a factor representing the different effectiveness of the various types of radiation in causing harm to tissues. It is measured in sieverts (Sv). One Sv produces the same biological effect irrespective of the type of the radiation.

Half-life

The time taken for the activity of a radionuclide to lose half its value by decay.

Radionuclide

An unstable nuclide that emits ionising radiation. The emissions may be either alpha, beta or gamma radiation.

Radiotoxicity

A measure of the dose per becquerel resulting from the ingestion of a particular radionuclide.

10 Annex

Screening Levels for Drinking Water

The Drinking Water Directive [European Communities, 1998b] on the quality of water intended for human consumption sets out standards for radioactivity in drinking water. With regard to radioactivity, the directive sets parametric standards for tritium and total indicative dose as set out below. This Directive has been transposed into Irish law in Statutory Instrument 439 of 2000 [Stationery Office, 2000b]. Practical arrangements for monitoring compliance with these standards are to be set out in Annexes to the Directive, which are currently being finalised by the European Commission. In the absence of these Annexes, the RPII has applied the methodology for screening drinking water as set out by the World Health Organisation recommendations on drinking water [WHO, 1993] to monitor compliance with the standards set by the Directive.

Table A. Parametric values for radioactivity from S.I. 439 of 2000

Parameter	Parametric Value
Tritium	100 Bq/l
Total indicative dose*	0.10 mSv/year

**Excluding tritium, potassium-40, radon and radon decay products. Assessment method will be set in the Annexes to the Directive.*

In accordance with the WHO scheme the recommended screening levels for gross alpha and gross beta activity are 100 and 1000 mBq/l, respectively, while the level for tritium is 100 Bq/l. If the radioactivity concentrations of water supplies are below the screening values then the water is considered to be in compliance with Statutory Instrument 439, which states that the dose arising from one year's consumption of drinking water should not exceed 0.1 mSv. Hence the drinking water is considered acceptable for human consumption and any action to reduce the radioactivity is deemed unnecessary. If the radioactivity concentrations exceed these screening levels then individual radionuclide concentrations should be determined and, if necessary, the dose arising from each component calculated.

It should be noted that the dose calculation should include contributions from all natural and artificial radionuclides with the exception of tritium, potassium-40, radon and radon decay products. This dose represents less than 5% of the average effective dose normally attributable annually to natural background radiation. The methodology applied by the Institute assumed a consumption rate of 2 litres per day.

It is important to emphasise that the above requirements apply to routine operational conditions of existing or new water supplies. They are not intended to apply to a water supply contaminated during an emergency involving the release of radionuclides into the environment.

11 Radiation Quantities and Units

Table B. Activity and dose units

Quantity	Unit and Symbol
Activity	Becquerel (Bq)
Activity Concentration	Becquerel per unit mass or volume (Bq/kg or Bq/l)
Absorbed Dose	Gray (Gy)
Effective Dose	Sievert (Sv)
Committed Effective Dose	Sievert (Sv)
Equivalent Dose	Sievert (Sv)
Collective Effective Dose	Man Sievert (manSv)

Table C. Commonly used activity and dose unit multiples and sub-multiples

Activity	Dose
1 millibecquerel (1 mBq) = 1 x 10^{-3} Bq	1 nanosievert (1 nSv) = 1 x 10^{-9} Sv
1 kilobecquerel (1 kBq) = 1 x 10^{3} Bq	1 microsievert (1 μSv) = 1 x 10^{-6} Sv
1 megabecquerel (1 MBq) = 1 x 10^{6} Bq	1 millisievert (1 mSv) = 1 x 10^{-3} Sv
1 terabecquerel (1 TBq) = 1 x 10^{12} Bq	1 nanogray (1 nGy) = 1 x 10^{-9} Gy
	1 microgray (1 μGy) = 1 x 10^{-6} Gy

Table D. Radionuclide symbols, principal emissions and half-lives

Radionuclide	Symbol	Principal Emission	Half-life
Tritium	H-3	β	12.35 years
Carbon-14	C-14	β	5,730 years
Potassium-40	K-40	β	1.28 x 10^{9} years
Cobalt-60	Co-60	β	5.27 years
Krypton-85	Kr-85	β	10.7 years
Strontium-90	Sr-90	β	29.12 years
Niobium-95	Nb-95	β	35.15 days
Zirconium-95	Zr-95	β	63.98 days
Technetium-99	Tc-99	β	213,000 years
Ruthenium-106	Ru-106	β	368.2 days
Iodine-131	I-131	β	8.04 days
Caesium-134	Cs-134	β	2.06 years
Caesium-137	Cs-137	β	30 years
Cerium-144	Ce-144	β	284.3 days
Polonium-210	Po-210	α	138.38 days
Plutonium-238	Pu-238	α	87.74 years
Plutonium-239	Pu-239	α	24,065 years
Plutonium-240	Pu-240	α	6,537 years
Plutonium-241	Pu-241	β	14.4 years
Americium-241	Am-241	α	432.2 years

12 Tables

Table 1. Naturally occurring radionuclides in seawater

Radionuclide	Activity Concentration (mBq/l)
Tritium	0.6[1]
Carbon-14	4.3[1]
Potassium-40	11,000[2]
Lead-210	5.0[1]
Polonium-210	3.7[1]
Bismuth-214	0.7[1]
Radon-222	0.7[1]
Uranium-234	47[3]
Uranium-238	41[3]
Radium-226	3.6[1]

Notes: [1] Source: Walker and Rose [1990].
[2] RPII measurement.
[3] Source: Smith [2001].

Table 2. Annual discharge limits[1] (TBq) and actual discharges[2] (TBq) from Sellafield to the Irish Sea, 2003-2005

Radionuclide	2003		2004		2005	
Category	Limit	Discharge	Limit	Discharge	Limit	Discharge
Total Alpha	1	0.407	1	0.291	1	0.248
Total Beta	400	83.3	400	73.3	220	42.9
Tritium	25,000	3,900	25,000	3,170	20,000	1,570
Carbon-14	20.8	17.0	20.8	16.3	21	5.26
Cobalt-60	13	0.43	13	0.775	3.6	0.663
Strontium-90	48	14.0	48	18.0	48	12.7
Zirconium-95 + Niobium-95	9	0.306	9	0.231	3.8	0.162
Technetium-99	90	37.0	90	14.3	20	6.7
Ruthenium-106	63	11.5	63	4.42	63	1.85
Iodine-129	1.6	0.554	1.6	0.650	2.0	0.298
Caesium-134	6.6	0.392	6.6	0.401	1.6	0.164
Caesium-137	75	6.24	75	9.67	34	5.86
Cerium-144	8	0.885	8	0.819	4.0	0.542
Plutonium (alpha)	0.7	0.358	0.7	0.292	0.7	0.203
Plutonium-241	27	10.1	27	8.10	25	5.5
Americium-241	0.3	0.0590	0.3	0.0372	0.3	0.0337
Uranium (kg)[3]	2,040	484	2,040	436	2000	369

Notes: [1] Annual equivalent discharge limits as set by UK authorities for 2003-2005.
[2] From the sea pipeline.
[3] The limit and the discharge are expressed in kg.

Table 3. Analytical techniques used in the determination of radionuclide concentrations, typical minimum detectable activities and typical counting uncertainties

Measurements	Sample Types	Analytical Techniques	Typical Minimum Detectable Activities	Typical Counting Uncertainties
K-40, Cs-137	Foodstuffs	High resolution gamma spectrometry using high purity germanium detectors	0.5 Bq/kg (5 h count)	15% or better
Cs-137	Air filters (Belfield)	High resolution gamma spectrometry using high purity germanium detectors	1 x 10^{-7} Bq/m^3 (4 day count)	15% or better
Cs-137	Air filters (Beggars Bush)	High resolution gamma spectrometry using high purity germanium detectors	1 x 10^{-6} Bq/m^3 (4 day count)	30% or better
Cs-137	Milk	High resolution gamma spectrometry using high purity germanium detectors	0.3 Bq/kg (24 hour count)	15% or better
Sr-90	Milk	Radiochemical separation followed by liquid scintillation counting	0.02 Bq/l (2 h count)	40%
Gross beta	Air filters	Gas flow proportional counting	0.05 mBq/m^3 (2 h count)	10%
Gross alpha Gross beta	Drinking water	Evaporation and gas flow proportional counting	5 mBq/l (24 h count) 5 mBq/l (24 h count)	40% 30%
Gamma dose rate	Ambient	Continuous monitoring station	40 nSv/h (20 minute count)	20%
Tritium	Drinking water	Liquid scintillation counting	12 Bq/l (30 minute count)	20%
K-40, I-131, Cs-137 and other gamma emitting radionuclides	Fish, shellfish, seaweed and sediment	High resolution gamma spectrometry using high purity germanium detectors	1.0 Bq/kg (I-131) 0.3 Bq/kg (Cs-137)	15% or better
Kr-85	Air	Grab sampling onto activated charcoal trap at liquid nitrogen temperature. Measurement at University of Gent by gas chromatography and liquid scintillation counting	For a 2 hour grab sample background levels can be measured to an accuracy of ± 5%	5%
C-14	Seaweed	High temperature catalytic combustion to carbon dioxide followed by liquid scintillation counting	1.0 Bq/kg	15% or better
Cs-137	Seawater	Radiochemical separation techniques in accordance with the method described by Baker [1975] followed by high resolution gamma spectrometry	0.8 mBq/l	15% or better
Tc-99	Fish, shellfish, seaweed and seawater	Radiochemical separation techniques in accordance with the method described by Harvey *et al.* [1991] followed by beta spectrometry using a gas flow proportional counter	0.1 Bq/kg	30% or better for fish 10% or better for remainder
Pu-238, Pu-239,240	Fish and shellfish	Radiochemical separation techniques followed by alpha spectrometry using silicon surface barrier detectors	0.001 Bq/kg	15% or better

Table 4. Fixed monitoring network, 2003-2005

Sampling Location	Sample Types
Belmullet, Co. Mayo	Rainwater
Dublin Airport, Co. Dublin	Rainwater
Cork Airport, Co. Cork	External gamma dose rate
Knock Airport, Co. Mayo	External gamma dose rate
Birr, Co. Offaly	Rainwater, external gamma dose rate
Casement, Co. Dublin	Rainwater, external gamma dose rate
Kilkenny, Co. Kilkenny	Rainwater, external gamma dose rate
Malin Head, Co. Donegal	Rainwater, external gamma dose rate
Shannon Airport, Co. Clare	Rainwater, external gamma dose rate
Cahirciveen, Co. Kerry	Rainwater, external gamma dose rate, airborne particulates
Clones, Co. Monaghan	Rainwater, external gamma dose rate, airborne particulates
Rosslare, Co. Wexford	Rainwater, external gamma dose rate, airborne particulates
Mullingar, Co. Westmeath	Rainwater, airborne particulates
Dundalk, Co. Louth	External gamma dose rate, airborne particulates
Galway, Co. Galway	Airborne particulates
Glasnevin, Co. Dublin	Airborne particulates
Cork Airport, Co. Cork	Airborne particulates
Beggars Bush/ Belfield, Co. Dublin[1]	Airborne particulates (high volume sampler, operational 2003 & 2004)
Clonskeagh, Co. Dublin	Rainwater, external gamma dose rate, airborne particulates, krypton-85

Notes: [1] The high volume air sampling site was moved from Beggars Bush to a new site at Belfield in 2004.

Table 5. Marine monitoring programme, 2003-2005

Sampling Point	Location	Sample Types
Blackrock	Louth	Sediment, external gamma dose rate
Carlingford	Louth	Sediment, Shellfish
Greenore	Louth	Seawater, sediment, seaweed, external gamma dose rate
Dundalk Bay	Louth	Shellfish, Sediment
Clogherhead	Louth	Fish, shellfish
Balbriggan	Dublin	Seawater, sediment, seaweed, external gamma dose rate
Howth	Dublin	Fish, shellfish
Bull Island	Dublin	Seawater, sediment, seaweed, external gamma dose rate
Cahore	Wexford	Seawater, sediment, seaweed, external gamma dose rate
Dunmore East	Waterford	Fish, seawater, sediment, seaweed, external gamma dose rate
Castletownbere	Cork	Fish, shellfish, seawater, sediment, seaweed, external gamma dose rate
Galway/Salthill	Galway	Fish, shellfish, seawater, sediment, seaweed, external gamma dose rate
Killybegs Mountcharles	Donegal	Fish, seawater, sediment, seaweed, external gamma dose rate
Irish Sea - N1	53:25N 6:01W	Seawater, sediment
Irish Sea - N2	53:36N 5:56W	Seawater, sediment
Irish Sea - N3	53:44N 5:25W	Seawater, sediment
Irish Sea - N4	53:52N 5:14W	Seawater, sediment
Irish Sea - N5	53:53N 5:33W	Seawater, sediment
Irish Sea - N6	53:52N 5:53W	Seawater, sediment
Irish Sea – S1	53:20N 6:00W	Seawater, sediment
Irish Sea – S2	53:20N 5:22W	Seawater, sediment
Irish Sea – S3	53:04N 5:31W	Seawater, sediment
Irish Sea – S4	53:00N 5:55W	Seawater, sediment
Irish Sea – S5	53:10N 6:00W	Seawater, sediment

Table 6. Radioactivity in airborne particulates (low volume), 2003

Month	Gross Beta Activity Range (mBq/m³)				
	Cahirciveen	Clones	Clonskeagh	Dundalk	Galway
Jan	0.14 (1)	0.07 - 0.42 (6)	0.17 - 0.27 (3)	0.11 - 0.32 (5)	0.15 - 0.38 (3)
Feb	0.10 - 0.60 (3)	0.11 - 0.12 (2)	0.15 (2)	0.10 - 0.11 (2)	0.11 - 0.49 (4)
Mar	0.15 - 0.95 (4)	0.13 - 1.19 (6)	0.23 (1)	0.18 (1)	0.24 - 0.79 (2)
Apr	0.37 - 0.83 (4)	0.33 - 0.95 (4)	0.25 - 0.76 (4)	0.22 - 0.89 (4)	0.32 (1)
May	0.11 - 0.17 (5)	0.09 - 0.22 (5)	0.12 - 0.20 (4)	0.06 - 0.15 (4)	0.12 - 0.19 (2)
Jun	0.10 - 0.26 (4)	0.15 - 0.33 (4)	0.18 - 0.29 (4)	0.14 - 0.52 (4)	0.30 - 0.70 (2)
Jul	0.08 - 0.32 (5)	0.14 - 0.36 (5)	0.11 - 0.29 (5)	0.18 - 0.41 (4)	0.22 - 0.46 (4)
Aug	0.18 - 0.35 (4)	0.16 - 0.42 (4)	0.17 - 0.38 (4)	0.22 - 0.67 (4)	nm
Sep	0.16 - 0.48 (4)	0.20 - 0.55 (4)	0.18 - 0.36 (4)	0.17 - 0.31 (3)	nm
Oct	0.24 - 0.55 (5)	0.16 - 0.36 (4)	0.19 - 0.36 (5)	0.19 - 0.39 (5)	nm
Nov	0.10 - 0.36 (4)	0.10 - 0.53 (4)	0.09 - 0.27 (4)	0.13 - 0.33 (4)	0.10 (2)
Dec	0.23 - 0.32 (4)	0.19 - 0.34 (3)	0.10 - 0.31 (5)	0.18 - 0.36 (3)	0.18 (2)

Notes: nm = not measured.
Figure in brackets indicates number of samples measured.

Table 6. Radioactivity in airborne particulates (low volume), 2003 (continued)

Month	Gross Beta Activity Range (mBq/m³)			
	Glasnevin	Cork Airport	Mullingar	Rosslare
Jan	0.09 - 0.37 (4)	0.10 - 0.34 (5)	0.08 - 0.33 (5)	0.17 - 0.38 (4)
Feb	0.13 - 1.14 (4)	0.09 - 0.69 (4)	0.12 - 0.73 (4)	0.25 (1)
Mar	0.17 - 0.43 (4)	0.11 - 0.79 (4)	0.13 - 0.23 (2)	nm
Apr	0.37 - 0.87 (4)	0.43 - 0.54 (4)	0.13 - 0.82 (4)	0.61 - 0.62 (2)
May	0.11 - 0.26 (4)	0.10 - 0.14 (5)	0.09 - 0.19 (5)	0.23 - 0.26 (4)
Jun	0.17 - 0.28 (3)	0.12 - 0.26 (4)	0.20 - 0.28 (3)	0.15 - 0.28 (4)
Jul	0.11 - 0.40 (6)	0.12 - 0.31 (4)	0.19 - 0.40 (4)	0.14 - 0.24 (4)
Aug	0.19 - 0.46 (3)	0.13 - 0.37 (4)	0.12 - 0.41 (5)	0.20 - 0.69 (4)
Sep	0.20 - 0.38 (3)	0.27 - 0.58 (2)	0.20 - 0.45 (5)	0.27 - 0.49 (5)
Oct	0.22 - 0.46 (4)	0.19 - 0.56 (5)	0.18 - 0.40 (4)	0.48 - 0.52 (2)
Nov	0.13 - 0.15 (2)	0.09 - 0.24 (4)	0.08 - 0.14 (3)	0.22 - 0.28 (3)
Dec	0.19 - 0.39 (5)	0.15 - 0.26 (4)	0.10 - 0.20 (3)	0.38 - 0.41 (3)

Notes: nm = not measured.
Figure in brackets indicates number of samples measured.

Table 7. Radioactivity in airborne particulates (low volume), 2004

Month	Gross Beta Activity Range (mBq/m³)				
	Cahirciveen	Clones	Clonskeagh	Dundalk	Galway
Jan	0.15 - 0.22 (4)	0.12 - 0.25 (5)	0.09 - 0.25 (4)	0.11 - 0.25 (4)	0.12 - 0.13 (2)
Feb	0.14 - 0.36 (4)	0.14 - 0.24 (4)	0.10 - 0.31 (4)	0.17 - 0.52 (3)	0.14 - 0.44 (4)
Mar	0.13 - 0.23 (4)	0.15 - 0.23 (3)	0.16 - 0.19 (5)	0.14 - 0.22 (5)	0.14 - 0.17 (2)
Apr	0.14 - 0.35 (5)	0.15 - 0.24 (2)	0.13 - 0.21 (3)	0.15 - 0.19 (3)	0.16 - 0.26 (3)
May	0.27 - 0.29 (3)	0.23 - 0.40 (3)	0.21 - 0.33 (3)	0.17 - 0.51 (3)	0.14 - 0.20 (2)
Jun	0.17 - 0.19 (2)	0.12 - 0.15 (2)	0.13 - 0.25 (4)	0.10 - 0.30 (3)	0.13 - 0.23 (3)
Jul	0.10 - 0.23 (5)	0.11 - 0.32 (6)	0.09 - 0.16 (2)	0.12 - 0.30 (4)	0.12 - 0.16 (2)
Aug	0.16 - 0.20 (3)	0.16 - 0.36 (4)	0.14 - 0.19 (4)	0.17 - 0.51 (5)	0.15 - 0.25 (2)
Sep	0.21 - 0.42 (5)	0.11 - 0.24 (5)	0.13 - 0.22 (4)	0.16 - 0.25 (4)	0.13 - 0.19 (2)
Oct	0.10 - 0.25 (4)	0.13 - 0.30 (3)	0.11 - 0.23 (4)	0.17 - 0.27 (4)	0.17 (2)
Nov	0.18 - 0.34 (4)	0.12 - 0.18 (3)	0.12 - 0.23 (6)	0.19 - 0.22 (2)	0.34 (1)
Dec	0.17 - 0.76 (5)	0.10 - 0.42 (4)	0.10 - 0.45 (3)	0.18 - 0.25 (2)	0.12 - 0.38 (2)

Note: Figure in brackets indicates number of samples measured.

Table 7. Radioactivity in airborne particulates (low volume), 2004 (continued)

Month	Gross Beta Activity Range (mBq/m³)			
	Glasnevin	Cork Airport	Mullingar	Rosslare
Jan	0.12 - 0.18 (3)	0.09 (1)	0.08 - 0.13 (4)	0.18 - 0.34 (4)
Feb	0.19 - 0.20 (2)	nm	0.07 - 0.21 (3)	0.17 - 0.33 (2)
Mar	0.09 - 0.20 (5)	nm	0.19 - 0.24 (2)	0.14 - 0.21 (2)
Apr	0.16 - 0.29 (4)	nm	0.14 - 0.25 (5)	0.08 - 0.22 (4)
May	0.26 - 0.37 (3)	nm	0.26 - 0.39 (3)	0.18 - 0.41 (4)
Jun	0.14 - 0.31 (4)	nm	0.15 - 0.22 (3)	0.13 - 0.25 (4)
Jul	0.10 - 0.26 (4)	nm	0.11 - 0.24 (4)	0.11 - 0.18 (4)
Aug	0.20 - 0.24 (3)	0.15 - 0.17 (2)	0.20 (1)	0.11 - 0.27 (4)
Sep	0.20 - 0.30 (5)	0.13 - 0.25 (3)	0.12 - 0.40 (3)	0.12 - 0.24 (5)
Oct	0.16 - 0.27 (4)	0.06 - 0.21 (5)	0.08 - 0.21 (5)	0.11 - 0.29 (4)
Nov	0.14 - 0.21 (3)	0.13 - 0.27 (4)	0.14 - 0.21 (4)	0.10 - 0.23 (4)
Dec	0.13 - 0.80 (3)	0.07 - 0.54 (4)	0.12 - 0.27 (5)	0.10 - 0.74 (5)

Notes: nm = not measured.
Figure in brackets indicates number of samples measured.

Table 8. Radioactivity in airborne particulates (low volume), 2005

Month	Gross Beta Activity Range (mBq/m³)				
	Cahirciveen	Clones	Clonskeagh	Dundalk	Galway
Jan	0.13 - 0.15 (4)	0.09 - 0.15 (4)	0.09 - 0.12 (4)	0.15 (1)	nm
Feb	0.11 - 0.30 (4)	0.07 - 0.22 (4)	0.07 - 0.16 (4)	0.05 (1)	nm
Mar	0.14 - 0.50 (5)	0.07 - 0.49 (5)	0.12 - 0.31 (5)	0.10 - 0.32 (4)	nm
Apr	0.13 (1)	0.32 (1)	0.29 (1)	0.18 (1)	nm
May	0.23 (1)	0.26 (1)	0.16 (1)	0.21 (1)	nm
Jun	0.08 - 0.14 (2)	0.10 (1)	0.13 (1)	0.11 (1)	nm
Jul	0.08 (1)	0.12 (1)	0.12 (1)	0.18 (1)	nm
Aug	nm	0.19 (1)	0.16 (1)	0.51 (1)	nm
Sep	0.26 - 0.37 (3)	0.18 - 0.36 (2)	0.12 (1)	0.18 - 0.19 (2)	0.18 (1)
Oct	0.13 (1)	0.28 (1)	0.44 (1)	0.34 (1)	0.27 (1)
Nov	0.14 (1)	0.19 (1)	0.25 (1)	0.12 (1)	0.14 (1)
Dec	0.10 (1)	0.07 - 0.22 (2)	0.11 (1)	nm	0.11 (1)

Notes: nm = not measured.
Figure in brackets indicates number of samples measured.

Table 8. Radioactivity in airborne particulates (low volume), 2005 (continued)

Month	Gross Beta Activity Range (mBq/m³)			
	Glasnevin	Cork Airport	Mullingar	Rosslare
Jan	0.16 - 0.17 (3)	0.07 - 0.11 (4)	0.12 - 0.20 (3)	0.08 - 0.13 (4)
Feb	0.10 - 0.24 (4)	0.08 - 0.18 (4)	0.15 - 0.25 (3)	0.10 - 0.18 (3)
Mar	0.17 - 0.42 (4)	0.06 - 0.29 (4)	0.05 - 0.54 (4)	0.15 - 0.21 (5)
Apr	0.41 (1)	0.33 (1)	0.57 (1)	0.10 - 0.37 (3)
May	0.19 (1)	0.23 (1)	0.09 (1)	0.31 (1)
Jun	0.17 (1)	0.11 (1)	0.21 - 0.22 (2)	0.15 (1)
Jul	0.18 (1)	0.5 (1)	0.07 (1)	nm
Aug	*nm*	*0.12 (1)*	*0.18 (1)*	*0.06 (1)*
Sept	0.18 - 0.41 (2)	nm	0.16 - 0.28 (2)	0.18 - 0.27 (2)
Oct	0.26 (1)	nm	0.20 (1)	0.32 (1)
Nov	0.30 (1)	nm	0.11 (1)	0.13 (1)
Dec	0.13 (1)	nm	0.14 (1)	0.07 (1)

Notes: nm = not measured.
Figure in brackets indicates number of samples measured.

Table 9. Radioactivity in airborne particulates (high volume), Beggars Bush, 2003-2005

	Sampling Period		Activity Concentration in Air (Bq/m^3)	
Year	Start Date	End Date	Cs-137	Be-7
2003	20 Mar	09 Apr	2.8×10^{-6}	3.60×10^{-3}
	23 Apr	04 Jun	0.5×10^{-6}	2.22×10^{-3}
	04 Jun	15 Jul	1.0×10^{-6}	2.67×10^{-3}
	15 Jul	13 Aug	0.8×10^{-6}	1.91×10^{-3}
	13 Aug	24 Sep	1.8×10^{-6}	2.09×10^{-3}
	08 Oct	05 Nov	2.0×10^{-6}	2.34×10^{-3}
	05 Nov	22 Dec	2.6×10^{-6}	2.33×10^{-3}
		Mean	**1.64×10^{-6}**	**2.45×10^{-3}**
2004	22 Dec 2003	04 Feb	1.1×10^{-6}	2.25×10^{-3}
	04 Feb	18 Feb	1.1×10^{-6}	2.29×10^{-3}
	10 Mar	21 Apr	1.1×10^{-6}	2.72×10^{-3}
	21 Apr	19 May	nd	1.98×10^{-3}
	19 May	30 Jun	nd	2.38×10^{-3}
	30 Jun	30 Aug	nd	2.25×10^{-3}
	06 Oct	17 Nov	1.5×10^{-6}	2.12×10^{-3}
		Mean	**1.2×10^{-6}**	**2.28×10^{-3}**
2005	23 Mar	04 May	nd	2.67×10^{-3}
	04 May	10 Aug	5.61×10^{-7}	1.75×10^{-3}
		Mean	**0.6×10^{-6}**	**2.21×10^{-3}**

Notes: nd = not detected (sample analysed but radionuclide below detection limit).

Table 10. Radioactivity in airborne particulates (high volume), Belfield (Dublin), 2004-2005

	Sampling Period		Activity Concentration in Air (Bq/m^3)	
Year	Start Date	End Date	Cs-137	Be-7
2004	06 May	13 May	7.68×10^{-7}	2.49×10^{-3}
	13 May	27 May	3.63×10^{-7}	nm
	27 May	10 Jun	5.52×10^{-7}	3.37×10^{-3}
	10 Jun	28 Jun	nd	nm
	28 Jun	08 Jul	3.65×10^{-7}	1.01×10^{-3}
	08 Jul	26 Jul	2.03×10^{-7}	1.44×10^{-3}
	26 Jul	11 Aug	4.13×10^{-7}	nd
	11 Aug	02 Sep	1.87×10^{-7}	1.74×10^{-3}
	02 Sep	20 Sep	nd	nd
	20 Sep	06 Oct	nd	1.26×10^{-3}
	06 Oct	22 Oct	1.84×10^{-7}	nm
	22 Oct	10 Nov	4.08×10^{-7}	1.76×10^{-3}
	10 Nov	24 Nov	2.66×10^{-7}	nd
	24 Nov	09 Dec	1.64×10^{-7}	nd
	09 Dec	30 Dec	2.17×10^{-7}	1.76×10^{-3}
		Mean	**3.38×10^{-7}**	**1.85×10^{-3}**
2005	30 Dec 2004	13 Jan	1.80×10^{-7}	nm
	13 Jan	26 Jan	nd	nm
	26 Jan	18 Feb	2.10×10^{-7}	nm
	18 Feb	03 Mar	1.38×10^{-7}	nm
	03 Mar	22 Mar	1.85×10^{-7}	1.48×10^{-3}
	31 Mar	13 Apr	nd	nd
	13 Apr	28 Apr	5.24×10^{-7}	5.94×10^{-3}
	28 Apr	11 May	2.70×10^{-7}	5.35×10^{-3}
	11 May	25 May	2.17×10^{-7}	2.56×10^{-3}
	14 Jun	30 Jun	2.97×10^{-7}	3.20×10^{-3}
	30 Jun	13 Jul	5.05×10^{-7}	2.04×10^{-3}
	27 Jul	10 Aug	2.67×10^{-7}	1.27×10^{-3}
	10 Aug	24 Aug	2.35×10^{-7}	2.09×10^{-3}
	16 Sep	26 Oct	2.95×10^{-7}	3.03×10^{-3}
	26 Oct	24 Nov	3.94×10^{-7}	2.89×10^{-3}
	24 Nov	07 Dec	2.81×10^{-7}	1.25×10^{-3}
		Mean	**2.85×10^{-7}**	**2.85×10^{-3}**

Notes: nd = not detected (sample analysed but radionuclide below detection limit).
nm = not measured.
This high volume sampler was installed at Belfield in May 2004.

Table 11. Krypton-85 measurements at Clonskeagh (Dublin), 2003

Sampling Date	Activity Concentration (Bq/m^3) (Corrected to STP)[1]
09 Jan	2.03
15 Jan	1.44
05 Feb	1.38
21 Feb	1.40
05 Mar	1.40
20 Mar	3.34[2]
16 Apr	24.81[2]
30 Apr	1.48
15 May	1.47
28 May	1.46
18 Jun	1.42
03 Jul	1.53
30 Jul	1.45
20 Aug	1.39
11 Sep	1.40
03 Oct	1.46
24 Oct	1.71
11 Nov	9.73[2]
26 Nov	1.54
10 Dec	1.55

Notes: [1] STP is 0° C and 760 mm of Hg.

[2] This elevated activity was attributed to a specific wind pattern.

Table 12. Krypton-85 measurements at Clonskeagh (Dublin), 2004

Sampling Date	Activity Concentration (Bq/m^3) (Corrected to STP)[1]
30 Jan	1.56
05 Feb	1.50
11 Mar	1.53
25 Mar	1.47
05 Apr	1.51
30 Apr	1.52
14 May	1.36
28 May	28.44[2]
17 Jun	1.46
03 Sep	1.38
23 Sep	1.38
22 Oct	1.45
27 Oct	4.08[2]
31 Dec	1.41

Notes: [1] STP is 0° C and 760 mm of Hg.

[2] This elevated activity was attributed to a specific wind pattern.

Table 13. Krypton-85 Measurements at Clonskeagh (Dublin), 2005

Sampling Date	Activity Concentration (Bq/m^3) (Corrected to STP)[1]
31 Jan	1.32
25 Feb	1.51
03 Mar	1.41
13 May	1.32
09 Aug	1.27

Notes: [1] STP is 0° C and 760 mm of Hg.

Table 14. Krypton-85 geometric mean concentrations, 1993-2005

Year	Geometric Mean (Bq/m^3)
1993	1.05
1994	1.25
1995	1.19
1996	1.37
1997	1.41
1998	1.43
1999	1.47
2000	1.51
2001	1.32
2002	1.22
2003	1.96
2004	1.94
2005	1.37

Table 15. Gross alpha and beta activities in drinking water, 2003

County	Supply	Sampling Date	Activity Concentration (mBq/l)		
			Gross Alpha	Gross Beta	H-3
Cork	Ballincollig	08 Sep	16	86	nd
	Bandon	08 Sep	nd	839	nd
	Clonakilty	09 Sep	nd	144	nd
	Cobh	08 Sep	54	142	nd
	Cork	03 Sep	12	87	nd
	Inishannon	08 Sep	16	525	nd
	Mallow	02 Sep	nd	7	nd
	Whitegate	08 Sep	28	160	nd
Dublin	Ballyboden	03 Dec	7	37	nd
Galway	Galway	23 Sep	nd	102	nd
	Galway	29 Sep	29	99	nd
Kerry	Ballyduff	02 Sep	nd	582	nd
	Kerry	02 Sep	6	22	nd
	Killarney	02 Sep	9	23	nd
Kildare	Ballymore-Eustace[1]	03 Dec	17	44	nd
	Leixlip	03 Dec	21	90	nd
Limerick	Limerick	04 Sep	nd	122	nd
Tipperary	Tipperary	25 Sep	nd	2	nd
Waterford	Dunmore-East	01 Sep	9	123	nd
	Waterford	02 Sep	24	78	nd
Wexford	Enniscorthy	02 Sep	24	65	nd
	Gorey	29 Aug	nd	3	nd
	Rosslare	15 Mar	48	93	nd
	Wexford	09 Sep	54	113	nd
Wicklow	Annagolan	09 Oct	nd	44	nd
	Arklow	09 Oct	nd	51	nd
	Bray	09 Oct	12	50	nd
	Croneroe	09 Oct	6	46	nd
	Greystones	09 Oct	nd	44	nd
	Roundwood	29 Sep	29	99	nd
	Wicklow	09 Oct	6	46	nd

Notes: nd = not detected (sample analysed but radionuclide below detection limit).

[1] Main Dublin supply.

Table 16. Gross alpha and beta activities in drinking water, 2004

County	Supply	Sampling Date	Activity Concentration (mBq/l)		
			Gross Alpha	Gross Beta	H-3
Cavan	Cavan	02 Nov	nd	167	nd
Clare	Ennistymon	05 Aug	13	85	nd
Cork	Cork	11 Aug	nd	43	nd
Donegal	Lough Mourne	14 Sep	12	60	nd
	Letterkenny	14 Sep	12	68	nd
	Rosses Region	14 Sep	10	61	nd
Kildare	Ballymore-Eustace[1]	05 Aug	11	32	nd
Laois	Portloaise	13 Aug	60	81	nd
Wicklow	Newtownmountkennedy	10 Aug	nd	39	nd

Notes: nd = not detected (sample analysed but radionuclide below detection limit).
[1] Main Dublin supply.

Table 17. Gross alpha and beta activities in drinking water, 2005

County	Supply	Sampling Date	Activity Concentration (mBq/l)		
			Gross Alpha	Gross Beta	H-3
Kildare	Leixlip	24 Jan	58	141	nd
Galway	Galway (New)	07 Dec	nd	79	nd
	Galway (Old)	07 Dec	40	115	nd
Cork	Clonakilty	08 Dec	39	108	nd
	Cobh	08 Dec	21	88	nd
	Clashaboy	06 Dec	22	105	nd
	Newmarket	08 Dec	69	52	nd
	Innishcarra	08 Dec	23	97	nd
	Cork	14 Dec	nd	74	nd
Wicklow	Roundwood	08 Dec	27	80	nd
Limerick	Rathbane	07 Jun	nd	83	nd
	Park Road	07 Jun	nd	79	nd
	Moyross	26 Jul	nd	59	nd
Dublin	See note 1	6 Dec	nd - 83	nd - 325	nd

Notes: nd = not detected (sample analysed but radionuclide below detection limit).
[1] range of results given for 22 samples collected by Dublin City Council.

Table 18. Radioactivity in complete meals (mixed diet), 2003

Location	Food Type	Cs-137 Activity Concentration (Bq/kg, fresh weight)
Dublin	Mixed Diet	nd
	Mixed Diet	nd
	Mixed Diet	nd
	Mixed Diet	nd
Louth	Mixed Diet	0.95
	Mixed Diet	nd
	Mixed Diet	nd
	Mixed Diet	nd
	Mixed Diet	nd
	Mixed Diet	nd
	Mixed Diet	0.21
	Mixed Diet	0.34
	Mixed Diet	nd
	Mixed Diet	nd
	Mixed Diet	nd

Notes: nd = not detected (sample analysed but radionuclide below detection limit).
Mixed Diet comprises a typical 3 course prepared meal.

Table 19. Radioactivity in complete meals (mixed diet), 2004

Location	Food Type	Cs-137 Activity Concentration (Bq/kg, fresh weight)
Dublin	Mixed Diet	nd
	Mixed Diet	nd
	Mixed Diet	nd
Galway	Mixed Diet	nd
	Mixed Diet	nd
	Mixed Diet	nd
	Mixed Diet	nd
	Mixed Diet	nd
	Mixed Diet	nd
	Mixed Diet	nd
	Mixed Diet	nd
	Mixed Diet	nd
	Mixed Diet	nd
	Mixed Diet	nd
	Mixed Diet	nd
Wicklow	Blackberries	nd
	Honey	1.7

Notes: nd = not detected (sample analysed but radionuclide below detection limit).
Mixed Diet comprises a typical 3 course prepared meal.

Table 20. Radioactivity in complete meals (mixed diet), 2005

Location	Food Type	Cs-137 Activity Concentration (Bq/kg, fresh weight)
Dublin	Mixed Diet	nd
	Mixed Diet	nd
	Mixed Diet	nd
	Fish (Pike)	2.16

Notes: nd = not detected (sample analysed but radionuclide below detection limit).
Mixed Diet comprises a typical 3 course prepared meal.

Table 21. Maximum Caesium-137 activity concentrations in a range of foodstuffs, 2003-2005

Year	Sample Type	Number of Samples	Max Cs-137 (Bq/kg, fresh weight)
2003	Dairy products	405	5.90
	Grain	114	nd
	Beef	48	1.40
	Lamb	62	11.94
	Pork/Poultry	56	nd
	Miscellaneous foodstuffs	327	28.90
2004	Dairy products	423	nd
	Grain	58	nd
	Beef	35	8.06
	Lamb	96	8.67
	Pork/Poultry	48	nd
	Miscellaneous foodstuffs	451	30.70
2005	Dairy products	463	5.13
	Grain	6	nd
	Beef	36	nd
	Lamb	36	16.90
	Pork/Poultry	11	nd
	Miscellaneous foodstuffs	371	nd

Note: nd = not detected (sample analysed but radionuclide below detection limit).

Table 22. Radioactivity in foodstuffs (FSAI survey), 2003-2004

Food Type	Cs-137 Activity Concentration (Bq/kg, fresh weight)
White Bread Rolls	nd
Brown Bread	nd
Plain Biscuit	nd
Chocolate Biscuit	nd
Cakes (Madeira)	nd
Spaghetti (Boiled)	nd
White Rice (Boiled)	nd
Cornflakes	nd
Bran Flakes	nd
Breakfast Cereal (Wheat Type)	nd
Muesli	nd
Oatflakes (Boiled)	nd
Breakfast Cereal (Rice Type)	nd
Pork (Grilled)	0.23
Minced Beef (Fried)	nd
Beef Steak (Grilled)	nd
Chicken (Roasted)	0.33
Turkey (Roasted)	nd
Lamb (Roasted)	0.75
Offal (Fried)	0.60
Mussels (Boiled)	nd
Prawns	nd
Crab	nd
Eggs (Fried)	nd
Whole Milk	nd
Skimmed Milk	nd
Semi-Skimmed Milk	nd
Cream	nd
Cheese	nd
Soft Cheese	0.24
Yoghurt	nd
Custard	nd
Vanilla Ice Cream	nd
Butter	nd
Dairy Spreads	nd
Potato Without Skin (Boiled)	nd
Potato With Skin (Micro-waved)	nd
Onions (Fried)	nd

Note: nd = not detected (sample analysed but radionuclide below detection limit).

Table 22. Radioactivity in foodstuffs (FSAI survey), 2003-2004 (continued)

Food Type	Cs-137 Activity Concentration (Bq/kg, fresh weight)
Tomatoes (Raw)	nd
Carrots (Boiled)	nd
Frozen Peas (Boiled)	nd
Cabbage (Boiled)	nd
Brocolli (Boiled)	nd
Cauliflower (Boiled)	nd
Lettuce Varieties (Raw)	nd
Mushrooms (Fried)	nd
Peppers (Raw)	nd
Celery (Raw)	nd
Swede (Boiled)	nd
Cucumber (Raw)	nd
Sweetcorn (Boiled)	nd
Green Beans (Boiled)	nd
Carrots (Raw)	nd
Cabbage (Raw)	nd
Pork Sausages (Grilled)	nd
White/Black Pudding (Fried)	nd
Bacon Rashers (Grilled)	0.41
Ham (Raw)	nd
Beefburgers (Grilled)	nd
Cod (Baked)	1.04
Salmon (Grilled)	0.32
Smoked Salmon	0.49
Canned Tuna	nd
Chips (As bought)	nd
Beefburger (Whole as bought)	nd
Fried Chicken Pieces (Whole as bought)	nd
Pizza	nd
Quiches/Pies	nd
Battered Fish (Whole as bought)	1.15
Apples	nd
Oranges	nd
Bananas	nd
Grapes	nd
Pears	nd
Raisins (Dried)	nd
Peaches	nd

Note: nd = not detected (sample analysed but radionuclide below detection limit).

Table 22. Radioactivity in foodstuffs (FSAI survey), 2003-2004 (continued)

Food Type	Cs-137 Activity Concentration (Bq/kg, fresh weight)
Plums	nd
Canned Peas	nd
Baked Beans	nd
Chips (Frozen)	nd
Canned Sweet Corn	nd
Potato Crisps	nd
Canned Tomato	nd
Canned Peaches	nd
Lager	nd
Stout	nd
Wine	nd
Spirits	nd
Carbonated Soft Drinks	nd
Fruit Squashes	nd
Black Tea	nd
Coffee (Instant)	nd
Coffee (Percolated)	nd
Water (Bottled)	nd
Apple Juice	nd
Orange Juice	nd
Marmalade	nd
Fruit Jam	0.8
Honey	nd
Tomato Sauce	nd
Mayonnaise	nd
Olive Oil	nd
Vegetable Oil	nd
Gravy (Instant Granules)	nd

Note: nd = not detected (sample analysed but radionuclide below detection limit).

Table 23. Radioactivity in milk, 2003 to 2005

Year	County	Activity Concentration (Bq/l)							
		Jan - Mar		Apr - Jun		Jul - Sep		Oct -Dec	
		Cs-137	Sr-90	Cs-137	Sr-90	Cs-137	Sr-90	Cs-137	Sr-90
2003	Cavan	nd	nd	nd	nd	nd	nd	nd	nd
	Cork	nd	0.04	nd	nd	nd	nd	nd	nd
	Dublin	nd	nd	nd	0.03	nd	nd	nd	nd
	Kerry	nd	nd	nd	nd	nd	nd	nd	nd
	Kilkenny	nd	nd	nd	nd	nd	nd	nd	nd
	Louth	nd	nd	nd	nd	nd	nd	nd	nd
	Monaghan	nd	nd	nd	0.04	nd	nd	nd	nd
	Roscommon	nd	nd	nm	nm	nm	nm	nm	nm
	Tipperary	nd	nd	nd	0.03	nd	nd	nd	0.06
	Waterford	nd	0.05	nd	0.03	nd	nd	nd	nd
2004	Cavan	nd[1]	nd[1]	nm	nm	nm	nm	nm	nm
	Cork	nd[1]	nm[1]	nm	nm	nm	nm	nm	nm
	Dublin	nd	nd	nm	nm	nd	0.04	nd	0.04
	Kerry	nd[1]	0.04[1]	nm	nm	nm	nm	nm	nm
	Kilkenny	nd[1]	nd[1]	nm	nm	nm	nm	nm	nm
	Louth	nd[1]	nd[1]	nm	nm	nm	nm	nm	nm
	Monaghan	nd[1]	nd[1]	nm	nm	nm	nm	nm	nm
	Roscommon	nd	nd	nd	nm	nd	nd	nd	nd
	Tipperary	nd[1]	nd[1]	nm	nm	nm	nm	nm	nm
	Waterford	nd[1]	nd[1]	nm	nm	nm	nm	nm	nm
2005	Cavan	nd	0.04	nd	0.04	nd	0.02	nd	0.03
	Cork	nd	0.07	nd	0.05	nd	0.03	nd	0.05
	Dublin	nd	0.05	nd	0.04	nd	0.03	nd	0.04
	Roscommon	nd	0.03	nd	0.04	nd	0.05	nd	0.04

Notes: nm = not measured.
nd = not detected (sample analysed but radionuclide below detection limit).
[1] Annual composite sample.

Table 24. External gamma dose rates (terrestrial), 2003

Month	Monthly Ranges (nSv/h)			
	Birr	Cahirciveen	Casement	Clones
Jan	52 - 70	74 - 97	60 - 77	60 - 82
Feb	53 - 71	75 - 138	60 - 87	61 - 80
Mar	53 - 71	74 - 106	59 - 76	60 - 78
Apr	54 - 78	74 - 115	60 - 80	58 - 78
May	53 - 69	72 - 105	59 - 73	59 - 76
Jun	53 - 80	74 - 104	61 - 96	57 - 86
Jul	54 - 87	80 - 109	61 - 101	58 - 92
Aug	56 - 82	nm	56 - 85	59 - 75
Sep	58 - 75	nm	62 - 89	59 - 82
Oct	57 - 79	nm	59 - 87	61 - 76
Nov	55 - 74	nm	60 - 114	60 - 79
Dec	56 - 74	64 - 80	62 - 100	60 - 80

Note: nm = not measured.

Table 24. External gamma dose rates (terrestrial), 2003 (continued)

Month	Monthly Ranges (nSv/h)			
	Clonskeagh	Cork Airport	Dundalk	Kilkenny
Jan	71 - 91	76 - 98	77 - 97	59 - 78
Feb	72 - 92	75 - 113	78 - 101	60 - 79
Mar	72 - 86	78 - 100	77 - 97	59 - 78
Apr	73 - 90	78 - 114	80 - 112	60 - 94
May	72 - 86	78 - 93	76 - 96	59 - 76
Jun	72 - 106	77 - 109	77 - 107	60 - 93
Jul	72 - 100	70 - 110	78 - 110	60 - 80
Aug	73 - 92	78 - 103	77 - 101	59 - 77
Sep	73 - 92	81 - 101	82 - 103	62 - 80
Oct	73 - 95	81 - 100	81 - 104	62 - 82
Nov	72 - 92	78 - 127	79 - 113	59 - 82
Dec	72 - 100	81 - 103	79 - 102	60 - 83

Table 24. External gamma dose rates (terrestrial), 2003 (continued)

Month	Monthly Ranges (nSv/h)			
	Knock Airport	Malin Head	Rosslare	Shannon Airport
Jan	57 - 77	54 - 88	59 - 77	56 - 71
Feb	57 - 78	56 - 82	54 - 82	57 - 80
Mar	57 - 76	56 - 76	60 - 84	56 - 76
Apr	56 - 79	56 - 79	60 - 87	57 - 76
May	56 - 75	55 - 70	59 - 90	53 - 71
Jun	55 - 83	54 - 74	59 - 107	56 - 96
Jul	56 - 77	56 - 81	61 - 93	57 - 78
Aug	56 - 74	54 - 99	58 - 83	61 - 73
Sep	56 - 75	56 - 77	64 - 90	61 - 75
Oct	56 - 74	59 - 78	58 - 97	60 - 78
Nov	56 - 93	57 - 74	61 - 89	59 - 77
Dec	55 - 80	57 - 74	53 - 99	58 - 72

Table 25. External gamma dose rates (terrestrial), 2004

Month	Monthly Ranges (nSv/h)			
	Birr	Cahirciveen	Casement	Clones
Jan	56 - 73	63 - 88	61 - 93	62 - 80
Feb	56 - 72	64 - 89	60 - 86	60 - 79
Mar	57 - 74	63 - 94	72 - 91	60 - 80
Apr	59 - 78	63 - 83	73 - 89	61 - 116
May	59 - 89	60 - 81	51 - 89	60 - 116
Jun	66 - 104	66 - 86	62 - 101	62 - 93
Jul	63 - 105	65 - 90	72 - 89	61 - 97
Aug	63 - 79	64 - 78	63 - 95	62 - 107
Sep	61 - 82	64 - 88	70 - 97	62 - 93
Oct	62 - 88	66 - 90	62 - 110	70 - 93
Nov	61 - 84	63 - 100	62 - 88	68 - 81
Dec	62 - 76	61 - 91	76 - 85	69 - 85

Table 25. External gamma dose rates (terrestrial), 2004 (continued)

Month	Monthly Ranges (nSv/h)			
	Clonskeagh	Cork Airport	Dundalk	Kilkenny
Jan	72 - 88	75 - 106	80 - 101	61 - 78
Feb	72 - 88	78 - 98	78 - 96	61 - 77
Mar	72 - 92	80 - 108	83 - 92	61 - 85
Apr	72 - 92	80 - 107	79 - 95	59 - 82
May	71 - 90	79 - 101	81 - 100	61 - 77
Jun	73 - 95	80 - 114	82 - 110	60 - 83
Jul	71 - 89	82 - 114	81 - 99	61 - 78
Aug	73 - 89	69 - 124	81 - 101	62 - 83
Sep	72 - 91	82 - 109	81 - 135	60 - 79
Oct	73 - 98	86 - 126	80 - 107	62 - 90
Nov	71 - 87	84 - 118	79 - 110	60 - 81
Dec	73 - 90	85 - 108	80 - 98	60 - 79

Table 25. External gamma dose rates (terrestrial), 2004 (continued)

Month	Monthly Ranges (nSv/h)			
	Knock Airport	Malin Head	Rosslare	Shannon Airport
Jan	55 - 82	58 - 76	61 - 79	58 - 75
Feb	55 - 78	57 - 72	58 - 75	58 - 72
Mar	55 - 77	57 - 72	61 - 82	52 - 73
Apr	56 - 77	57 - 77	61 - 81	43 - 65
May	56 - 74	58 - 75	62 - 78	43 - 104
Jun	57 - 83	58 - 89	61 - 83	49 - 71
Jul	56 - 73	60 - 80	63 - 80	49 - 62
Aug	57 - 80	61 - 93	64 - 82	49 - 68
Sep	56 - 92	51 - 118	63 - 83	50 - 65
Oct	57 - 81	54 - 89	62 - 102	52 - 70
Nov	57 - 73	53 - 72	62 - 87	50 - 68
Dec	56 - 80	56 - 84	59 - 86	50 - 68

Table 26. External gamma dose rates (terrestrial), 2005

Month	Monthly Ranges (nSv/h)			
	Birr	Cahirciveen	Casement	Clones
Jan	60 - 76	62 - 82	74 - 85	68 - 83
Feb	60 - 74	61 - 79	74 - 92	68 - 80
Mar	62 - 89	83 - 102	76 - 92	69 - 89
Apr	62 - 73	83 - 91	75 - 85	69 - 83
May	61 - 73	84 - 92	74 - 85	68 - 83
Jun	67 - 78	83 - 101	75 - 99	74 - 92
Jul	68 - 80	85 - 95	77 - 102	75 - 85
Aug	67 - 82	85 - 94	76 - 88	74 - 110
Sep	65 - 77	83 - 101	75 - 95	73 - 95
Oct	66 - 87	83 - 116	76 - 98	75 - 95
Nov	66 - 76	83 - 99	75 - 87	76 - 89
Dec	66 - 94	84 - 111	75 - 108	75 - 104

Note: During the first half of 2005, the RPII upgraded its gamma-monitoring network.

Table 26. External gamma dose rates (terrestrial), 2005 (continued)

Month	Monthly Ranges (nSv/h)			
	Clonskeagh	Cork Airport	Dundalk	Kilkenny
Jan	71 - 89	77 - 118	79 - 97	60 - 76
Feb	72 - 88	100 - 108	79 - 100	60 - 78
Mar	73 - 93	101 - 150	79 - 105	61 - 90
Apr	nm	100 - 121	77 - 101	59 - 75
May	nm	99 - 111	77 - 98	60 - 76
Jun	nm	98 - 123	80 - 103	75 - 96
Jul	100 - 114	100 - 127	111 - 130	76 - 87
Aug	100 - 110	99 - 111	111 - 127	74 - 87
Sep	101 - 119	98 - 111	107 - 153	75 - 89
Oct	102 - 118	99 - 153	106 - 127	74 - 115
Nov	103 - 112	97 - 119	105 - 116	74 - 85
Dec	103 - 126	97 - 119	103 - 143	74 - 94

Note: nm = not measured.

Table 26. External gamma dose rates (terrestrial), 2005 (continued)

Month	Monthly Ranges (nSv/h)			
	Knock Airport	Malin Head	Rosslare	Shannon Airport
Jan	56 - 74	62 - 109	60 - 80	75 - 98
Feb	58 - 71	51 - 92	75 - 90	81 - 89
Mar	57 - 88	50 - 76	75 - 98	81 - 105
Apr	58 - 73	57 - 69	74 - 90	80 - 93
May	57 - 74	69 - 78	74 - 82	80 - 89
Jun	72 - 87	69 - 79	75 - 108	79 - 93
Jul	70 - 84	70 - 79	77 - 114	80 - 92
Aug	70 - 82	69 - 95	76 - 87	80 - 91
Sep	68 - 85	68 - 84	75 - 89	79 - 90
Oct	69 - 93	69 - 125	75 - 136	78 - 107
Nov	70 - 86	69 - 82	73 - 90	79 - 92
Dec	68 - 107	68 - 117	73 - 97	78 - 101

Table 27. Radioactivity in seawater, 2003

Sampling Location	Month	Activity Concentration (mBq/l)	
		Tc-99	Cs-137
Greenore	Mar	20	19
	May	17	14
	Sep	28	11
	Dec	29	17
	Mean	**24**	**15**
Balbriggan	Jan	11	7
	Feb	nm	9
	Mar	12	8
	Apr	nm	17
	May	9	13
	Jun	nm	10
	Jul	29	11
	Aug	nm	17
	Sep	26	9
	Oct	31	16
	Nov	nm	16
	Dec	nm	11
	Mean	**20**	**12**
Bull Island	Jan	8	10
	Feb	7	9
	Mar	8	10
	Apr	11	12
	May	7	8
	Jun	7	9
	Jul	11	12
	Aug	12	-
	Sep	10	11
	Oct	9	15
	Nov	16	11
	Dec	**11**	**7**
	Mean	**10**	**10**
Cahore	Jun	1	3
	Oct	2	6
Dunmore East	Sep	nd	nm
Castletownbere	Sep	nd	1
Salthill	Sep	nm	1
Mountcharles	Sep	nd	nd
Irish Sea – N1	Jun	10	6
Irish Sea – N2	Jun	nm	9
Irish Sea – N3	Jun	26	13
Irish Sea – N4	Jun	14	8
Irish Sea – N5	Jun	nm	15
Irish Sea – N6	Jun	27	13

Notes: nd = not detected (sample analysed but radionuclide below detection limit).
nm = not measured.

Table 28. Radioactivity in seawater, 2004

Sampling Location	Month	Activity Concentration (mBq/l)	
		Tc-99	Cs-137
Greenore	Mar	19	15
	Jun	26	18
	Sep	nm	21
	Nov	nm	22
	Mean	**23**	**19**
Balbriggan	Jan	16	9
	Feb	nm	5
	Mar	18	12
	Apr	nm	10
	May	20	16
	Jun	nm	21
	Jul	26	20
	Aug	nm	22
	Sep	nm	20
	Oct	nm	20
	Nov	nm	13
	Dec	nm	21
	Mean	**20**	**16**

Note: nm = not measured.

Table 28. Radioactivity in seawater, 2004 (continued)

Sampling Location	Month	Activity Concentration (mBq/l)	
		Tc-99	Cs-137
Bull Island	Jan	6	7
	Feb	13	9
	Mar	9	9
	Apr	12	12
	May	36	19
	Jun	16	20
	Jul	16	15
	Aug	nm	14
	Sep	nm	14
	Oct	nm	13
	Nov	nm	14
	Dec	nm	19
	Mean	**15**	**14**
Cahore[1]	Apr	2	2.7 (3)
	Aug	nm	9 (5)
Dunmore East	Aug	nm	4
Castletownbere	Aug	nm	4
Salthill	Oct	nm	2
Mountcharles	Nov	nm	3
Woodstown	Aug	nm	nd
Irish Sea – N1	Jul	nm	16
Irish Sea – N2	Jul	nm	22
Irish Sea – N3	Jul	nm	20
Irish Sea – N4	Jul	nm	17
Irish Sea – N5	Jul	nm	14
Irish Sea – N6	Jul	nm	17
Irish Sea – S1	Jul	nm	15
Irish Sea – S2	Jul	nm	16
Irish Sea – S3	Jul	nm	14
Irish Sea – S4	Jul	nm	17
Irish Sea – S5	Jul	nm	14

Notes: [1]Sample collected at pier. Value in bracket refers to sample collected on beach.
nd = not detected (sample analysed but radionuclide below detection limit).
nm = not measured.

Table 29. Radioactivity in seawater, 2005

Sampling Location	Month	Activity Concentration (mBq/l)	
		Tc-99	Cs-137
Greenore	Jan	nm	17
	May	nm	19
	Aug	16	28
	Oct	nm	30
	Mean	**16**	**24**
Balbriggan	Jan	13	17
	Feb	nm	20
	Mar	nm	13
	Apr	nm	17
	May	15	17
	Jun	8	18
	Jul	16	19
	Aug	14	21
	Sep	nm	20
	Oct	nm	20
	Nov	nm	19
	Dec	nm	15
	Mean	**13**	**18**
Cahore[1]	Mar	nm	(12)
	Nov	3	7 (6)
Irish Sea – N1	Jun	nm	9
Irish Sea – N2	Jun	nm	17
Irish Sea – N3	Jun	nm	11
Irish Sea – N4	Jun	nm	9
Irish Sea – N5	Jun	nm	16
Irish Sea – N6	Jun	nm	21

Notes: [1]Sample collected at pier. Value in bracket refers to sample collected on beach.
nm = not measured.

Table 30. Radioactivity in marine sediments, 2003

Sampling Location	Month	Cs-137 Activity Concentration (Bq/kg, dry weight)
Greenore	Mar	5.6
	May	14.0
	Sep	13.2
	Dec	6.6
	Mean	**9.9**
Carlingford	Sep	17.2
Blackrock, Co. Louth	Sep	6.0
	Dec	5.5
Balbriggan	Jan	6.6
	Feb	7.5
	Mar	8.9
	Apr	7.3
	May	9.8
	Jun	8.1
	Jul	6.8
	Aug	7.5
	Sep	9.7
	Oct	8.3
	Nov	8.0
	Dec	7.9
	Mean	**8.0**

Table 30. Radioactivity in marine sediments, 2003 (continued)

Sampling Location	Month	Cs-137 Activity Concentration (Bq/kg, dry weight)
Bull Island[1]	Jan	2.0 (5.5)
	Feb	2.0 (2.6)
	Mar	1.6 (3.2)
	Apr	1.9
	May	1.8
	Jun	1.9
	Jul	2.0
	Aug	2.2 (3.4)
	Sep	3.7
	Oct	2.4
	Nov	1.9 (2.4)
	Dec	2.3
	Mean	**2.1 (3.6)**
Cahore	May	0.5
	Sep	0.6
Dunmore East	Sep	0.4
Castletownbere	Sep	nd
Salthill	Jul	0.4
	Sep	0.3
Mountcharles	Sep	0.6
Irish Sea – N1	Jun	4.7
Irish Sea – N2	Jun	10.9
Irish Sea – N3	Jun	44.1
Irish Sea – N5	Jun	81.0
Irish Sea – N6	Jun	37.9

Notes: nd = not detected (sample analysed but radionuclide below detection limit).

[1] Samples collected on Dollymount Strand. Values in brackets refer to samples collected at Bull Wall.

Table 31. Radioactivity in marine sediments, 2004

Sampling Location	Month	Cs-137 Activity Concentration (Bq/kg, dry weight)
Greenore	Mar	7.5
	Jun	2.2
	Sep	11.9
	Nov	7.0
	Mean	**7.2**
Carlingford	Mar	27.4
Dundalk Bay	Mar	4.9
Blackrock, Co. Louth	Jun	3.7
	Sep	6.7
	Nov	5.2
	Mean	**5.2**
Balbriggan	Jan	7.8
	Feb	8.7
	Mar	9.1
	Apr	4.4
	May	6.6
	Jun	8.6
	Jul	8.5
	Aug	9.9
	Sep	7.4
	Oct	10.9
	Nov	5.7
	Dec	8.9
	Mean	**8.0**

Table 31. Radioactivity in marine sediments, 2004 (continued)

Sampling Location	Month	Cs-137 Activity Concentration (Bq/kg, dry weight)
Bull Island[1]	Jan	2.7 (2.7)
	Feb	2.7 (2.5)
	Mar	2.0 (2.0)
	Apr	1.7 (2.3)
	May	1.4 (2.6)
	Jun	1.9
	Jul	2.0 (3.1)
	Aug	2.2 (2.8)
	Sep	2.6
	Oct	(1.9)
	Nov	(1.9)
	Dec	(2.1)
	Mean	**2.1 (2.4)**
Cahore[2]	Aug	0.5 (0.5)
Dunmore East	Aug	0.5
Castletownbere	Aug	nd
Woodstown	Aug	nd
Salthill	Oct	0.1
Mountcharles	Nov	1.6
Irish Sea – N1	Jul	6.4
Irish Sea – N2	Jul	11.1
Irish Sea – N3	Jul	29.5
Irish Sea – N4	Jul	42.8
Irish Sea – N5	Jul	78.5
Irish Sea – N6	Jul	38.3
Irish Sea – S1	Jul	2.3
Irish Sea – S3	Jul	0.4
Irish Sea – S4	Jul	1.6
Irish Sea – S5	Jul	5.0

Notes: nd = not detected (sample analysed but radionuclide below detection limit).

[1] Samples collected on Dollymount Strand. Values in brackets refer to samples collected at Bull Wall.

[2] Sample collected at pier. Value in bracket refers to sample collected on beach.

Table 32. Radioactivity in marine sediments, 2005

Sampling Location	Month	Cs-137 Activity Concentration (Bq/kg, dry weight)
Irish Sea – N4	Jun	13.1
Irish Sea – N5	Jun	2.4
Irish Sea – N6	Jun	63.8

Table 33. Radioactivity in seaweed, 2003

Sampling Location	Sample Type	Month	Activity Concentration (Bq/kg, dry weight)			
			Tc-99	I-1311	Cs-137	C-142
Greenore	*Fucus vesiculosis*	Mar	6181	nm	2.5	nm
	Fucus vesiculosis	May	4938	nm	4.2	nm
	Fucus vesiculosis	Sep	4002	nm	5.5	nm
	Fucus vesiculosis	Dec	4864	nm	3.0	nm
		Mean	**4996**	-	**3.8**	-
Balbriggan	*Fucus vesiculosis*	Jan	4795	nm	3.2	296
	Fucus vesiculosis	Feb	nm	nm	2.9	276
	Fucus vesiculosis	Mar	2446	nm	2.6	272
	Fucus vesiculosis	Apr	nm	nm	4.2	263
	Fucus vesiculosis	May	1192	nm	2.3	257
	Fucus vesiculosis	Jun	nm	nm	3.6	258
	Fucus vesiculosis	Jul	1018	nm	4.4	259
	Fucus vesiculosis	Aug	nm	nm	4.0	280
	Fucus vesiculosis	Sep	609	nm	5.1	255
	Fucus vesiculosis	Oct	nm	nm	3.0	313
	Fucus vesiculosis	Nov	nm	nm	3.7	279
	Fucus vesiculosis	Dec	nm	nm	2.8	299
		Mean	**2012**	-	**3.5**	**276**

Notes: nm = not measured.

[1] Analysis performed on wet sample but results quoted on a dry weight basis for ease of comparison.

[2] Source: [Keogh *et al.*, 2004].

Table 33. Radioactivity in seaweed, 2003 (continued)

Sampling Location	Sample Type	Month	Activity Concentration (Bq/kg, dry weight)			
			Tc-99	I-1311	Cs-137	C-14
Bull Island	*Fucus vesiculosis*	Jan	nm	70	2.3	nm
	Fucus vesiculosis	Feb	2833	308	2.7	nm
	Fucus vesiculosis	Mar	2128	159	2.8	nm
	Fucus vesiculosis	Apr	664	203	1.9	nm
	Fucus vesiculosis	May	512	81	2.2	nm
	Fucus vesiculosis	Jun	535	46	1.6	nm
	Fucus vesiculosis	Jul	612	113	2.0	nm
	Fucus vesiculosis	Aug	1340	55	3.1	nm
	Fucus vesiculosis	Sep	1763	26	3.6	nm
	Fucus vesiculosis	Oct	nm	24	nm	nm
	Fucus vesiculosis	Nov	2127	269	2.8	nm
	Fucus vesiculosis	Dec	1111	37	2.5	nm
		Mean	**1363**	**116**	**2.5**	-
	Ascophyllum nodosum	Jan	nm	59	1.4	nm
	Ascophyllum nodosum	Feb	nm	315	1.9	nm
	Ascophyllum nodosum	Mar	nm	117	2.2	nm
	Ascophyllum nodosum	Apr	nm	163	1.9	nm
	Ascophyllum nodosum	May	nm	90	1.3	nm
	Ascophyllum nodosum	Jun	nm	88	1.4	nm
	Ascophyllum nodosum	Jul	nm	138	2.0	nm
	Ascophyllum nodosum	Aug	nm	124	2.3	nm
	Ascophyllum nodosum	Sep	nm	50	1.8	nm
	Ascophyllum nodosum	Oct	nm	6	nm	nm
	Ascophyllum nodosum	Nov	nm	124	1.7	nm
	Ascophyllum nodosum	Dec	nm	66	1.6	nm
		Mean	-	**112**	**1.8**	-
Cahore	*Fucus vesiculosis*	Sep	183	nm	0.5	nm
Castletownbere	*Ascophyllum nodosum*	Sep	10	nm	nd	nm
Dunmore East	*Fucus serratus*	Sep	nm	nm	0.3	nm
Mountcharles	*Fucus vesiculosis*	Sep	8	nm	0.4	nm
Salthill	*Fucus vesiculosis*	Jul	7	nm	0.4	nm
	Fucus vesiculosis	Sep	nm	nm	0.4	nm
	Ascophyllum nodosum	Sep	nm	nm	0.8	nm
Killybegs	*Fucus vesiculosis*	Nov	9	nm	0.3	nm

Notes: [1] Analysis performed on wet sample but results quoted on a dry weight basis for ease of comparison.
nm = not measured.

Table 34. Radioactivity in seaweed, 2004

Sampling Location	Sample Type	Month	Activity Concentration (Bq/kg, dry weight)	
			Cs-137	C-141
Greenore	*Fucus vesiculosis*	Mar	3.4	nm
	Fucus vesiculosis	Jun	5.4	nm
	Fucus vesiculosis	Sep	4.3	nm
	Fucus vesiculosis	Nov	4.4	nm
		Mean	**4.4**	-
Balbriggan	*Fucus vesiculosis*	Jan	2.6	288
	Fucus vesiculosis	Feb	2.2	274
	Fucus vesiculosis	Mar	3.0	245
	Fucus vesiculosis	Apr	3.7	272
	Fucus vesiculosis	May	4.0	294
	Fucus vesiculosis	Jun	3.7	270
	Fucus vesiculosis	Jul	4.8	328
	Fucus vesiculosis	Aug	5.9	nm
	Fucus vesiculosis	Sep	4.7	nm
	Fucus vesiculosis	Oct	5.4	nm
	Fucus vesiculosis	Nov	5.0	nm
	Fucus vesiculosis	Dec	3.3	nm
		Mean	**4.0**	**282**

Notes: nm = not measured.

[1] Source: [Keogh *et al.*, 2004].

Table 34. Radioactivity in seaweed, 2004 (continued)

Sampling Location	Sample Type	Month	Activity Concentration (Bq/kg, dry weight)		
			I-1311	Cs-137	C-14
Bull Island	*Fucus vesiculosis*	Jan	78	2.3	nm
	Fucus vesiculosis	Feb	134	1.9	nm
	Fucus vesiculosis	Mar	47	2.4	nm
	Fucus vesiculosis	Apr	116	2.7	nm
	Fucus vesiculosis	May	124	2.9	nm
	Fucus vesiculosis	Jun	27	3.3	nm
	Fucus vesiculosis	Jul	187	4.6	nm
	Fucus vesiculosis	Aug	70	3.7	nm
	Fucus vesiculosis	Sep	72	2.8	nm
	Fucus vesiculosis	Oct	55	2.1	nm
	Fucus vesiculosis	Nov	49	2.4	nm
	Fucus vesiculosis	Dec	121	2.6	nm
		Mean	**90**	**2.8**	-
	Ascophyllum nodosum	Jan	35	2.4	nm
	Ascophyllum nodosum	Feb	69	1.5	nm
	Ascophyllum nodosum	Mar	33	2.0	nm
	Ascophyllum nodosum	Apr	133	3.6	nm
	Ascophyllum nodosum	May	138	2.3	nm
	Ascophyllum nodosum	Jun	42	2.0	nm
	Ascophyllum nodosum	Jul	258	3.0	nm
	Ascophyllum nodosum	Aug	97	3.5	nm
	Ascophyllum nodosum	Sep	63	2.5	nm
	Ascophyllum nodosum	Oct	57	2.2	nm
	Ascophyllum nodosum	Nov	51	2.3	nm
	Ascophyllum nodosum	Dec	92	2.1	nm
		Mean	**89**	**2.5**	-
Cahore	*Fucus vesiculosis*	Apr	nm	0.8	nm
	Fucus vesiculosis	Aug	nm	1.1	nm
Castletownbere	*Fucus vesiculosis*	Aug	nm	0.5	nm
Dunmore East	*Fucus vesiculosis*	Aug	nm	0.6	nm
Monkstown	*Fucus vesiculosis*	Aug	nm	0.9	nm
Mountcharles	*Fucus vesiculosis*	Nov	nm	2.9	nm
Passage West	*Fucus vesiculosis*	Aug	3	nd	nm
	Ascophyllum nodosum	Aug	nm	0.5	nm
Salthill	*Fucus vesiculosis*	Oct	nm	0.2	nm
	Ascophyllum nodosum	Oct	nm	0.3	nm

Notes: nm = not measured.

nd = not detected (sample analysed but radionuclide below detection limit).

[1] Analysis performed on wet sample but results quoted on a dry weight basis for ease of comparison.

Table 35. Radioactivity in seaweed, 2005

Sampling Location	Sample Type	Month	Activity Concentration (Bq/kg, dry weight) Cs-137
Greenore	*Fucus vesiculosis*	Jan	3.8
	Fucus vesiculosis	May	3.6
	Fucus vesiculosis	Aug	7.9
	Fucus vesiculosis	Oct	4.0
		Mean	**4.8**
Balbriggan	*Fucus vesiculosis*	Jan	4.2
	Fucus vesiculosis	Feb	3.4
	Fucus vesiculosis	Mar	3.4
	Fucus vesiculosis	Apr	3.5
	Fucus vesiculosis	May	4.4
	Fucus vesiculosis	Jun	3.9
	Fucus vesiculosis	Jul	4.2
	Fucus vesiculosis	Aug	3.8
	Fucus vesiculosis	Sep	5.6
	Fucus vesiculosis	Oct	3.5
	Fucus vesiculosis	Nov	3.0
	Fucus vesiculosis	Dec	2.4
		Mean	**3.8**
Cahore	*Fucus vesiculosis*	Mar	1.4
	Fucus vesiculosis	Nov	1.0

Note: nm = not measured.

Table 36. Caesium-137 activity concentrations in fish, 2003

Sampling Location	Month	Activity Concentration (Bq/kg, fresh weight)							
		Whiting	Cod	Plaice	Ray	Herring	Mackerel	Lemon Sole	Monk-fish
Clogherhead	Mar	0.3	0.5	0.5	nm	nm	nm	nm	nm
	May	0.2	0.9	0.3	0.6	nm	nm	nm	nm
	Sep	0.3	1.6	0.5	0.2	nm	0.2	nm	nm
	Dec	0.2	3.0	nm	nm	0.3	nm	0.2	nm
	Mean	**0.3**	**1.5**	**0.4**	**0.4**	**0.3**	**0.2**	**0.2**	-
Howth	Jan	0.4	0.2	0.2	0.8	nm	0.1	0.2	nm
	Feb	0.3	0.5	0.2	0.4	nm	0.1	nm	0.5
	Mar	0.4	0.2	0.2	0.3	nm	0.1	nm	nm
	Apr	0.2	1.3	0.2	nm	nm	0.1	0.2	nm
	May	0.3	0.3	nm	0.7	nm	nm	nm	0.2
	Jun	0.4	1.1	0.1	0.7	nm	0.1	nm	nm
	Jul	0.4	0.5	0.3	0.3	nm	nm	nm	nm
	Aug	0.4	1.6	0.5	0.3	nm	nm	nm	0.3
	Sep	0.3	2.4	0.3	0.7	nm	0.2	nm	nm
	Oct	0.3	0.2	0.2	0.2	0.3	0.3	0.1	nm
	Nov	nm	0.7	0.1	0.9	0.2	0.1	nm	0.5
	Dec	0.3	0.7	0.1	0.6	0.1	0.2	nm	nm
	Mean	**0.3**	**0.8**	**0.2**	**0.5**	**0.2**	**0.1**	**0.2**	**0.4**
Dunmore	Jun	nm	nm	0.2	0.3	nm	nm	nm	nm
East	Dec	nm	0.3	0.3	nm	nm	nm	nm	nm
Castletownbere	May	0.4	0.8	0.1	0.2	nm	nd	nm	nm
	Jan	nm	nm	nm	nm	0.3	nm	nm	nm
Galway	Jul	nm	nm	nm	nm	nm	0.1	0.3	nm
	Sep	nm	0.9	0.2	nm	nm	nm	nm	nm
Killybegs	Apr	0.5	0.2	0.1	0.1	nm	0.1	nm	nm
	Sep	0.2	0.4	0.1	0.2	nm	0.2	nm	nm

Notes: nd = not detected (sample analysed but radionuclide below detection limit).
nm = not measured.

Table 37. Caesium-137 activity concentrations in shellfish, 2003

Sampling Location	Month	Activity Concentration (Bq/kg, fresh weight)						
		Prawns	Wild Mussels	Farmed Mussels	Oysters	Scallops	Crab Claws	Lobster
Clogherhead	Mar	0.4	0.3	0.1	0.1	nm	nm	nm
	May	nm	0.4	0.1	0.1	nm	nm	nm
	Sep	0.4	0.3	0.1	0.2	nm	nm	nm
	Dec	0.1	0.4	0.1	0.1	nm	nm	nm
	Mean	**0.3**	**0.4**	**0.1**	**0.1**	-	-	-
Howth	Jan	nm	nm	nm	nm	0.1	nm	nm
	Feb	nm	nm	nm	nm	nm	0.2	0.7
	Mar	0.1	nm	nm	nm	nm	nm	nm
	Apr	0.2	nm	nm	nm	0.1	nm	nm
	May	0.1	nm	nm	nm	nm	0.2	nm
	Jun	0.4	nm	nm	nm	nm	nm	nm
	Jul	0.6	nm	nm	nm	0.1	nm	0.2
	Mean	**0.3**	-	-	-	**0.1**	**0.2**	**0.5**
Bull Wall	Feb	nm	0.3	nm	nm	nm	nm	nm
Castletownbere	Jul	nm	nm	nd	nm	nm	nm	nm
Dundalk Bay	Oct	nm	nm	nm	nm	nm	nm	0.6
Galway	Jul	nm	nm	nd	nm	nm	nm	nm
	Sep	nm	nm	nd	nm	nm	nm	nm
Salthill	Sep	nm	nd	nm	nm	nm	nm	nm

Notes: nd = not detected (sample analysed but radionuclide below detection limit).
nm = not measured.

Table 38. Technetium-99 and plutonium-238, 239 and 240 activity concentrations in fish and shellfish, 2003

Sampling Location	Species	Activity Concentration (Bq/kg, fresh weight)		
		Pu-238	Pu-239,240	Tc-99
Clogherhead	Fish[1]	nd	nd	0.15
	Prawns	nd	0.012	29
	Farmed Mussels	nd	0.028	34
	Wild Mussels	0.016	0.098	29
	Oysters	nd	0.027	6
Howth	Fish[1]	nd	nd	0.11
	Prawns	nd	0.008	21

Notes: nd = not detected (sample analysed but radionuclide below detection limit).
[1] Composite sample.

Table 39. Caesium-137 activity concentrations in fish, 2004

Sampling Location	Month	Activity Concentration (Bq/kg, fresh weight)							
		Whiting	Cod	Plaice	Ray	Herring	Mackerel	Lemon Sole	Monk-fish
Clogherhead	Mar	0.5	1.2	0.1	1.5	nm	0.1	nm	nm
	Jun	0.8	0.9	0.3	0.4	nm	nm	nm	nm
	Sep	0.3	0.8	0.3	0.2	0.4	nd	nm	nm
	Nov	0.3	0.8	nm	0.5	nm	0.1	nm	nm
	Mean	**0.5**	**0.9**	**0.2**	**0.7**	**0.4**	**0.1**	-	-
Howth	Jan	0.3	0.3	0.3	0.3	nm	0.1	nm	nm
	Feb	0.3	0.2	nd	0.4	nm	0.1	nm	0.2
	Mar	0.3	0.6	nd	0.2	nm	nd	nm	nm
	Apr	0.3	1.0	nd	0.1	nm	0.1	0.1	nm
	May	0.4	0.7	0.6	0.2	nm	0.2	nm	nm
	Jun	0.4	1.0	nm	0.5	nm	nm	nm	nm
	Jul	0.4	1.1	nd	0.2	nm	0.1	nm	nm
	Aug	0.4	0.8	nd	0.4	nm	0.1	nm	0.2
	Sep	0.4	nd	nd	0.7	nm	0.3	nm	nm
	Oct	nm	nm	nm	nm	nm	nm	nm	nm
	Nov	0.4	2.1	nd	0.6	0.2	nd	nm	0.8
	Dec	0.3	0.7	nd	0.6	nm	0.1	nm	nm
	Mean	**0.4**	**0.9**	**0.5**	**0.4**	**0.2**	**0.1**	**0.1**	**0.4**
Castletownbere	Feb	0.4	0.3	0.1	nm	0.7	0.1	nm	nm
	Aug	nm	nm	nm	nm	0.1	nm	nm	nm
Galway	Jun	0.1	nm	nd	nm	nm	nm	nm	0.1
	Oct	0.3	nm	nd	nm	nm	nm	nm	nm
Killybegs	Jul	0.5	0.3	0.04	nm	nm	nm	0.2	nm

Notes: nd = not detected (sample analysed but radionuclide below detection limit).
nm = not measured.

Table 40. Caesium-137 activity concentrations in shellfish, 2004

Sampling Location	Month	Activity Concentration (Bq/kg, fresh weight)					
		Prawns	Wild Mussels	Farmed Mussels	Oysters	Scallops	Crab Claws
Clogherhead	Mar	0.1	0.5	nd	0.1	nm	nm
	Jun	0.8	0.3	0.1	0.2	nm	nm
	Sep	nm	0.4	0.1	0.2	nm	nm
	Nov	nd	0.5	0.4	0.1	nm	nm
	Mean	**0.5**	**0.4**	**0.2**	**0.2**	-	-
Howth	Jan	0.4	nm	nm	nm	0.3	nm
	Feb	0.6	nm	nm	nm	nm	0.2
	Mar	0.7	nm	nm	nm	nm	nm
	Apr	0.7	nm	nm	nm	0.2	nm
	May	0.1	nm	nm	nm	nm	0.3
	Jun	0.6	nm	nm	nm	nm	nm
	Jul	0.1	nm	nm	nm	nm	nm
	Aug	0.1	nm	nm	nm	nm	0.2
	Sep	0.1	nm	nm	nm	nm	nm
	Nov	0.1	nm	nm	nm	nm	0.3
	Dec	0.7	nm	nm	nm	nm	nm
	Mean	**0.4**	-	-	-	**0.3**	**0.3**
Castletownbere	Jul	nm	nm	nd	nm	nm	nm
Galway	Jun	nm	nm	nd	nm	nd	nm

Notes: nd = not detected (sample analysed but radionuclide below detection limit).
nm = not measured.

Table 41. Technetium-99 and plutonium-238, 239 and 240 activity concentrations in fish and shellfish, 2004

Sampling Location	Species	Activity Concentration (Bq/kg, fresh weight)		
		Pu-238	Pu-239,240	Tc-99
Clogherhead	Fish[1]	nd	nd	0.23
	Prawns[1]	0.003	0.013	30
Howth	Fish[1]	nd	Nd	0.21
	Prawns[1]	nd	0.009	28
Carlingford	Farmed Mussels[1]	0.006	0.034	13
	Wild Mussels[1]	0.023	0.13	40
	Farmed Oysters[1]	0.006	0.034	4

Notes: nd = not detected (sample analysed but radionuclide below detection limit).
[1] Composite sample.

Table 42. Caesium-137 activity concentrations in fish, 2005

Sampling Location	Month	Activity Concentration (Bq/kg, fresh weight)					
		Whiting	Cod	Plaice	Ray	Herring	Mackerel
Clogherhead	Jan	0.3	1.7	0.5	1.2	nm	nd
	May	0.3	2.4	nm	nm	nm	0.2
	Aug	0.5	2.1	1.2	0.7	nm	0.8
	Oct	0.3	0.2	nm	nm	nm	0.1
	Mean	**0.4**	**1.6**	**0.9**	**1.0**	-	**0.4**
Howth	Feb	0.4	1.8	0.1	0.5	nm	nd
	Apr	0.4	2.3	nd	1.0	nm	nm
	Jul	0.3	1.8	nd	1.1	nm	0.2
	Nov	0.3	0.6	0.1	0.5	nm	nm
	Mean	**0.4**	**1.6**	**0.1**	**0.8**	-	**0.2**
Galway	Nov	0.1	0.1	nd	0.1	nm	0.1
Killybegs	Oct	0.2	0.3	nd	0.2	0.2	0.3

Notes: nd = not detected (sample analysed but radionuclide below detection limit).
nm = not measured.

Table 43. Caesium-137 activity concentrations in shellfish, 2005

Sampling Location	Month	Activity Concentration (Bq/kg, fresh weight)			
		Prawns	Wild Mussels	Farmed Mussels	Oysters
Clogherhead	Jan	0.7	0.7	0.1	0.2
	May	0.1	0.6	0.3	0.2
	Aug	0.6	0.4	0.2	0.5
	Oct	nd	0.3	0.1	0.3
	Mean	**0.5**	**0.5**	**0.2**	**0.3**
Howth	Feb	0.4	nm	nm	nm
	Apr	0.6	nm	nm	nm
	Jul	0.7	nm	nm	nm
	Mean	**0.6**	-	-	-
Castletownbere	Oct	nm	nm	nd	nm
Galway	Nov	0.6	nm	nd	nm

Notes: nd = not detected (sample analysed but radionuclide below detection limit).
nm = not measured.

Table 44. Technetium-99 and plutonium-238, 239 and 240 activity concentrations in fish and shellfish, 2005

Sampling Location	Species	Activity Concentration (Bq/kg, fresh weight)		
		Pu-238	Pu-239,240	Tc-99
Clogherhead	Fish[1]	nd	0.0002	0.10
	Prawns	nm	nm	31
Howth	Fish[1]	nd	nd	nd
	Prawns[1]	0.003	0.0142	55
Carlingford	Farmed Oysters[1]	0.008	0.0465	3
	Farmed Mussels[1]	0.005	0.0332	4
	Wild Mussels	nm	nm	36
Dublin	Mixed Diet	nd	nd	nm

Notes: nd = not detected (sample analysed but radionuclide below detection limit).
nm = not measured.
[1] Composite sample.

Table 45. Mean activity concentrations of artificial radionuclides in fish and shellfish landed at north-east ports, 2002-2005

Year	Species Type	Activity Concentration (Bq/kg, fresh weight)				
		Tc-99	Cs-137	Pu-238	Pu-239,240	Am-241[1]
2003	Fish[2]	0.13	0.46	nd	nd	nd
	Crustaceans (Prawns)	25	0.29	nd	0.01	0.015
	Molluscs (Mussels)	31.50	0.23	0.016	0.063	0.029
2004	Fish[2]	0.22	0.46	nd	Nd	Nd
	Crustaceans (Prawns)	29	0.39	0.001	0.011	0.017
	Molluscs (Mussels)	26.50	0.33	0.015	0.084	0.038
2005	Fish[2]	0.1	0.79	nd	0.002	0.0024
	Crustaceans (Prawns)	43	0.62	0.003	0.014	0.022
	Molluscs (Mussels)	20	0.34	0.005	0.033	0.015

Notes: [1] Estimated using a mean americium/plutonium ratio in fish at Clogherhead [Ryan *et al.*, 1999].

[2] Cod, whiting, plaice, ray, mackerel and herring.

Table 46. External gamma dose rates (coastal), 2003-2004

Sampling Location	Month	Site Description	Gamma Dose Rate (nGy/h)	
			2003	2004
Greenore	Mar	Rocks/Sand	75	58
	May	Rocks/Sand	73	nm
	Jun	Rocks	nm	76
	Sep	Rocks/Sand	75	nm
	Dec	Rocks/Sand	74	nm
		Mean	**74**	**67**
Blackrock, Co Louth	Mar	Fine Sand	60	63
	Jun	Fine Sand	62	66
	Sep	Fine Sand	56	nm
	Dec	Fine Sand	57	nm
		Mean	**59**	**65**
Balbriggan	Jan	Fine Sand	68	61
	Feb	Fine Sand	73	72
	Mar	Fine Sand	72	63
	Apr	Fine Sand	61	64
	May	Fine Sand	67	68
	Jun	Fine Sand	63	nm
	Jul	Fine Sand	61	nm
	Aug	Fine Sand	70	nm
	Sep	Fine Sand	61	nm
	Oct	Fine Sand	73	65
	Nov	Fine Sand	68	59
	Dec	Fine Sand	58	69
		Mean	**66**	**65**

Note: nm = not measured.

Table 46. External gamma dose rate measurements (coastal), 2003-2004 (continued)

Sampling Location	Month	Site Description	Gamma Dose Rate (nGy/h)	
			2003	2004
Bull Island	Jan	Fine Sand	53	57
(Dollymount Strand)	Feb	Fine Sand	62	nm
	Mar	Fine Sand	53	56
	Apr	Fine Sand	52	56
	May	Fine Sand	62	58
	Jun	Fine Sand	59	50
	Jul	Fine Sand	54	nm
	Aug	Fine Sand	52	nm
	Sep	Fine Sand	55	nm
	Oct	Fine Sand	51	53
	Nov	Fine Sand	61	54
	Dec	Fine Sand	55	60
		Mean	**56**	**56**
Cahore	Apr	Stones	nm	75
	Jun	Stones	70	nm
	Sep	Stones	73	nm
		Mean	**72**	**75**
Dunmore East	Sep	Rocks/Sand	71	nm
Dunmore East (Woodstown Beach)	Sep	Fine Sand	58	nm
Castletownbere	Sep	Stones	70	nm
Salthill	Jul	Sand	85	nm
	Sep	Sand	75	nm
	Oct	Sand	nm	81
		Mean	**80**	**81**
Mountcharles	Sep	Fine Sand	66	nm

Note: nm = not measured.

Table 47. Dose coefficients

Nuclide	Category	Dose Coefficient[1] (Sv/ Bq)
C-14	Adult	5.8×10^{-10}
Cs-137	Adult	1.3×10^{-8}
Tc-99	Adult	6.4×10^{-10}
Pu-238	Adult	2.3×10^{-7}
Pu-239	Adult	2.5×10^{-7}
Pu-240	Adult	2.5×10^{-7}
Am-24[1]	Adult	2.0×10^{-7}
Sr-90	Adult	2.8×10^{-8}
Sr-90	Infant	2.3×10^{-7}
Y-90	Adult	2.7×10^{-9}
Y-90	Infant	3.1×10^{-8}

Note: [1] Source: ICRP [1996a].

Table 48. Committed effective dose due to inhalation of airborne particulate caesium-137, 2001-2005

Year	Committed Effective Dose (μSv)
2001	5.8×10^{-4}
2002	5.8×10^{-4}
2003	4.3×10^{-4}
2004	8.9×10^{-5}
2005	7.5×10^{-5}

Table 49. Krypton-85 annual skin and effective doses, 1993-2005

Year	Skin Dose (μSv)	Effective Dose (μSv)
1993	0.43	0.008
1994	0.52	0.010
1995	0.49	0.010
1996	0.56	0.011
1997	0.58	0.011
1998	0.59	0.011
1999	0.61	0.012
2000	0.62	0.012
2001	0.54	0.010
2002	0.50	0.010
2003	0.81	0.016
2004	0.80	0.016
2005	0.56	0.011
Mean	**0.58**	**0.011**

Table 50. Committed effective dose from strontium-90 and yttrium-90 in milk, 2003-2005

Radionuclide	Category	Annual Dose (μSv)		
		2003	2004	2005
Sr-90	Infant	1.10	1.10	1.10
	Adult	0.19	0.19	0.20
Y-90	Infant	0.15	0.15	0.15
	Adult	0.02	0.02	0.02

Table 51. Committed effective doses from artificial radionuclides due to the consumption of fish and shellfish landed at north-east ports, 2003-2005

		Committed Effective Dose (μSv)	
Year	Radionuclide	Heavy consumer	Typical consumer
2003	Tc-99	0.14	0.034
	Cs-137	0.46	0.093
	Pu-238,239,240	0.08	0.02
	Am-241	0.032	0.01
	Total	**0.71**	**0.16**
2004	Tc-99	0.14	0.097
	Cs-137	0.47	0.034
	Pu-238,239,240	0.1	0.025
	Am-241	0.04	0.012
	Total	**0.75**	**0.17**
2005	Tc-99	0.15	0.038
	Cs-137	0.79	0.16
	Pu-238,239,240	0.09	0.012
	Am-241	0.071	0.017
	Total	**1.100**	**0.24**

Table 52. Committed effective doses from selected artificial radionuclides due to the consumption of fish and shellfish, 1982-2005

	Committed Effective Dose (μSv)	
Year	Typical Consumer	Heavy Consumer
1982	13.80	71.20
1983	11.00	58.20
1984	9.40	49.10
1985	5.00	25.40
1986	3.80	19.70
1987	2.20	10.90
1988	1.40	6.80
1989	1.10	5.50
1990	0.94	4.60
1991	1.06	5.19
1992	0.74	3.58
1993	0.67	3.30
1994	0.51	2.50
1995	0.41	2.00
1996	0.34	1.56
1997	0.32	1.43
1998	0.32	1.42
1999	0.30	1.33
2000	0.26	1.17
2001	0.27	1.20
2002	0.17	0.79
2003	0.16	0.71
2004	0.17	0.75
2005	0.24	1.10

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