



Radioactivity Monitoring of the Irish Environment 2009



Radiological Protection Institute of Ireland
An Institiúid Éireannach um Chosaint Raideolaíoch

RADIATION UNITS

Radioactivity is measured in units called becquerels (Bq). One becquerel corresponds to one radioactive disintegration per second.

When measuring radioactive discharges to the environment or referring to the content of radioactive sources used in medicine, industry and education, it is more usual to talk in terms of kilobecquerels (kBq), megabecquerels (MBq), gigabecquerels (GBq) or terabecquerels (TBq)

1 kBq = 1000 Bq

1 MBq = 1,000,000 Bq

1 GBq = 1,000,000,000 Bq

1 TBq = 1,000,000,000,000 Bq

Much lower concentrations of radioactivity are normally found in the environment and so the measurement is often reported in units of millibecquerels (mBq). There are one thousand millibecquerels in a becquerel.

1 Bq = 1000 mBq

Radiation Dose When radiation interacts with body tissues and organs, the radiation dose received is a function of factors such as the type of radiation, the part of the body affected, the exposure pathway, etc. This means that one becquerel of radioactivity will not always deliver the same radiation dose. A unit called 'effective dose' has been developed to take account of the differences between different types of radiation so that their biological impact can be compared directly. Effective dose is measured in units called sieverts (Sv).

The sievert is a large unit, and in practice it is more usual to measure radiation doses received by individuals in terms of fractions of a sievert.

1 sievert = 1000 millisievert (mSv)

= 1,000,000 microsievert (μ Sv)

= 1,000,000,000 nanosievert (nSv)

In RPII reports the term 'effective dose' is often referred to as 'radiation dose' or simply 'dose'.

Collective dose is the sum of the radiation doses received by each individual in the population. This allows comparison of the total radiation dose received from different sources. Collective dose is reported in units of man sieverts (man Sv) or man millisieverts (man mSv).

Per caput dose is the collective dose divided by the total population. Per caput dose is reported in units of sieverts, or fractions of a sievert.

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Executive Summary

This report presents the results of the environmental radioactivity monitoring programme carried out by the Radiological Protection Institute of Ireland (RPII) during 2009. The RPII has routinely monitored levels of radioactivity in the Irish environment since 1982 and this is the latest in the RPII's series of environmental monitoring reports. The RPII reviews and updates its environmental programme annually so as to ensure it remains relevant and continues to focus on the most important sources of radioactivity in the environment.

The principal aims of the RPII's monitoring programme are:

- to assess the level of radioactivity to which the Irish population is exposed in the environment,
- to study trends and establish the geographical distribution of contaminating radionuclides so as to better understand the long term behaviour of artificial radioactivity in the food chain and the environment.
- to ensure that any increase in radiation levels resulting from an accidental release of radioactivity to the environment is detected and assessed rapidly.

Exposure of the Population to Radioactivity

There are a number of different routes or pathways by which the public can be exposed to radiation. These include exposure by inhalation, when radioactive material is breathed into the lungs, exposure through ingestion when radioactive material is consumed and direct or external exposure from radioactive material.

Exposure to the Irish population from radioactivity in the environment is assessed by measuring the concentrations of radioactivity in food and the environment and by combining this radioactivity data with food consumption rates and other habit data.

During 2009, radioactivity was measured in a wide range of food and environmental materials including: air, water, milk, seafood, foodstuffs and complete meals.

The most significant source of artificial radioactivity in the Irish marine environment is the discharge of low level liquid radioactive waste from the Sellafield Nuclear Fuel Reprocessing Plant on the north east coast of England. In order to assess the exposure arising from this source, extensive sampling of fish and shellfish landed at ports along the north east coast of Ireland is undertaken. The most exposed group of individuals to discharges from Sellafield have been identified as commercial oyster and mussel farmers working along the north east coastline and their families. Based on this data, the radiation dose to a member of this most exposed group was assessed to be 0.44 $\mu\text{Sv}/\text{year}$ for 2009. This dose may be compared with the average radiation dose to a person living in Ireland of 3950 $\mu\text{Sv}/\text{year}$ from all sources of radiation.

Man-made radioactivity is also present in the terrestrial environment due mainly to residual global fallout, arising primarily from atmospheric testing of nuclear weapons in the 1950s and 1960s, and releases from past nuclear accidents such as Chernobyl. Milk, because it is an important foodstuff for infants and children and is known to concentrate long-lived radionuclides such as caesium-137 and strontium-90, is an important indicator of levels of artificial radioactivity in the terrestrial food chain. The estimated dose due to strontium-90 activity in milk was estimated to be 0.97 μSv for 2009. This was for the most exposed age group, assessed to be infants, children under the age of one year. It is very small compared to the background radiation. Radioactivity measurements on other foodstuffs confirm that levels of artificial radioactivity in the Irish food-chain remain very low and that Irish foodstuffs are free from harmful levels of radioactivity.

The RPII monitors radioactivity in major drinking water supplies in rotation so that major supplies from each county are sampled at least once every four years. During 2009, supplies from Galway, Kerry, Kildare, Kilkenny, Leitrim, Longford, Limerick and Laois were tested. Drinking water samples are assessed for compliance with the radioactivity standards set out in the Drinking Water Directive. All drinking water samples tested during 2009 were found to be in compliance with the radioactivity standards set out in the Drinking Water Directive.

The RPII programme also monitors airborne radioactivity through its network of on-line and off-line samplers. External gamma dose rates are also monitored. No exceptional activity was detected in outdoor air during 2009. The levels were consistent with those recorded in previous years. For 2009, the average annual dose from inhalation of caesium-137 was estimated at 9.0×10^{-5} μSv .

Trends and Geographic distribution

In general, the levels of radioactivity measured in air and terrestrial foodstuffs are very similar to those reported in recent years. This is to be expected since these are influenced primarily by levels of residual global fallout which change very slowly.

Concentrations of radioactivity measured in the Irish marine environment are broadly similar to those reported over the last decade. Figure A shows the radiation dose from artificial radionuclides to the typical seafood consumer over the period 1982 to 2009.

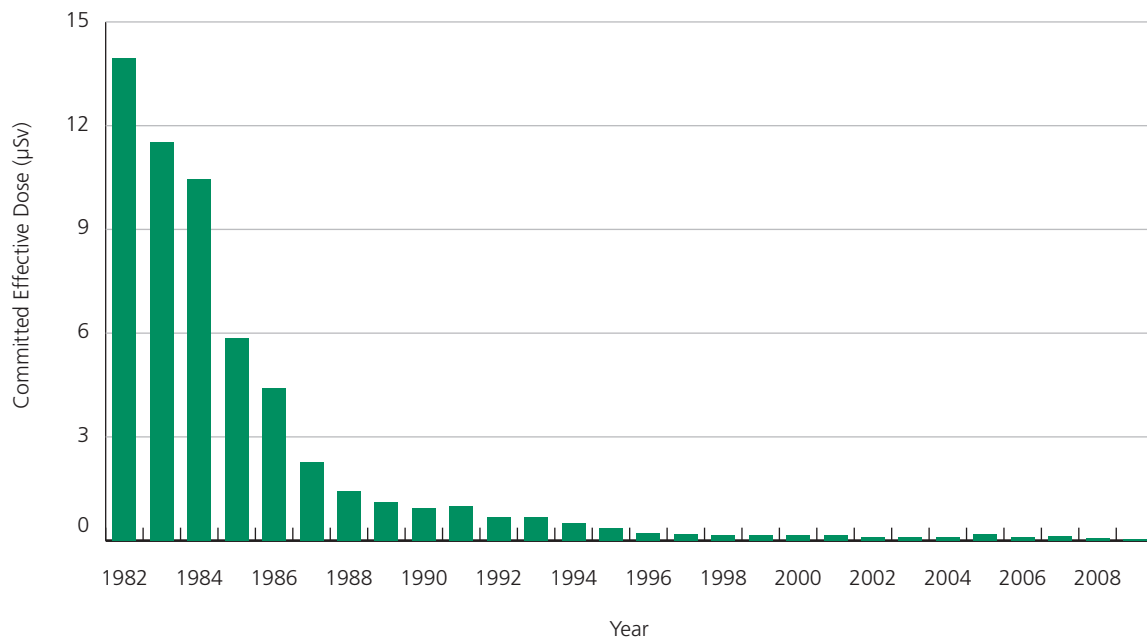


Figure A. Committed effective dose to the typical seafood consumer, 1982-2009

The highest concentrations of Sellafield derived radioactivity in the Irish marine environment are found along the north east coast. Concentrations measured south of Dublin are lower while concentrations measured along the south and west coast are generally consistent with global fallout levels. Figure B shows the mean concentrations of the radionuclide caesium-137 measured in coastal seawater during 2009. Concentrations on the south and west coast are measured biennially; data from 2008 are included in Figure B for comparison purposes.

While in general Sellafield discharges into the Irish Sea have been falling since the 1980s, discharges of the radionuclide technetium-99 increased sharply in 1994 due to changes in waste treatment at the plant. Discharges of this radionuclide peaked in 1995 and reduced substantially after 2004 following the introduction of new waste treatment at the plant. These lower discharges have led to reductions in technetium-99 activity concentrations in seafood landed at Irish ports and in the Irish marine environment. By 2005, levels of technetium in the Irish marine environment had effectively fallen back to those observed in the early 1990s and this continues to be reflected in the concentrations measured in 2009.

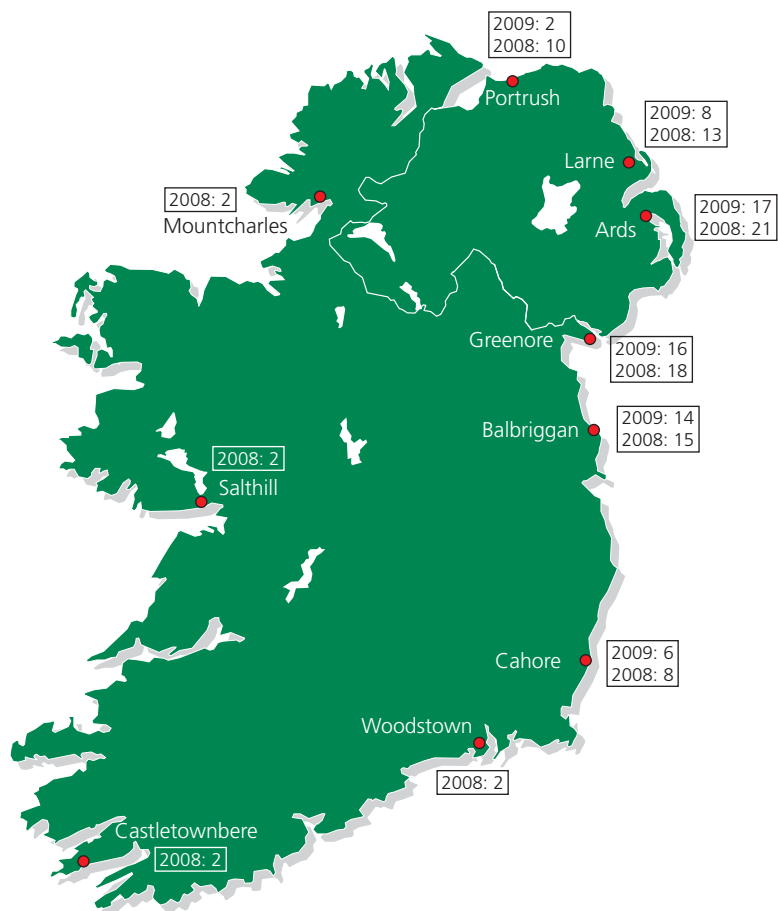


Figure B. Mean caesium-137 concentrations (mBq/l) in coastline seawater, 2008-2009

Monitoring for accidental releases

The RPII operates a national network of permanent monitoring stations which continuously assess the levels of radioactivity in the environment through the collection of aerosol and rainwater samples and the measurement of ambient gamma dose rate. This network is designed to allow a rapid assessment of environmental contamination to be made in the event of a radiological emergency. The locations of the permanent monitoring stations are shown in Figure C. No abnormal levels of radioactivity were recorded at any of the stations during 2009.



Figure C. Permanent monitoring network for radioactivity measurement

Conclusion

The data presented in this report confirm that while the levels of artificial radioactivity in the Irish environment are detectable, they are low. They do not pose a significant risk to the human health of the Irish population.

Activity concentrations of radionuclides in airborne particulates were low and consistent with measurements made in recent years. Radioactivity levels in milk, mixed diet and a wide range of foodstuffs were low and, for the majority of samples, below the detection limits. All drinking waters tested were found to be in compliance with the total indicative dose defined in national and EU legislation.

The doses incurred by the Irish public in 2009 as a result of artificial radioactivity in the marine environment are small when compared to dose limits or to natural radiation doses received by the Irish public. The dose to the most exposed individuals, members of the oyster and mussel farmers critical group, was approximately 0.04% of the annual dose limit of 1000 μSv for members of the public from practices involving controllable sources of radiation. These doses may also be compared with the average annual dose to a person in Ireland from all sources of radioactivity of 3950 μSv .

In general, levels of artificial radioactivity in the Irish environment remain fairly constant and are broadly consistent with levels reported previously. It must be 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.

1 Introduction

This report presents the results of the environmental radioactivity monitoring programme carried out by the RPII in 2009. It is the latest in a series of reports, all of which are available on the RPII's website www.rpii.ie.

The principal aims of the RPII's monitoring programme are:

- to assess the level of radioactivity to which the Irish population is exposed in the environment,
- to study trends and establish the geographical distribution of contaminating radionuclides so as to better understand the long term behaviour of artificial radioactivity in the food chain and the environment.
- to ensure that any increases in radiation levels resulting from an accidental release of radioactivity to the environment is detected and assessed rapidly.

Exposure to the Irish population from radioactivity in the environment is assessed by measuring the concentrations of radioactivity in food and the environment and by combining this radioactivity data with food consumption rates and other habits data. The monitoring programme involves the sampling and testing for radioactivity in air, drinking water, foodstuffs, fish, shellfish, seaweed, sediment and seawater as well as the continuous measurement of external gamma radiation. The sample types and radionuclides measured are reviewed annually to ensure that the aims of the monitoring programme continue to be achieved.

While the routine programme focuses primarily on artificial radionuclides in the environment, investigations of specific natural radiation pathways are undertaken so as to improve the RPII's overall assessment of doses to the Irish public. During 2009, the programme included investigations into natural radioactivity in groundwater and thoron gas in indoor air. A comprehensive assessment of doses to the Irish public was published by RPII in 2008 [Colgan *et al.*, 2008].

Radioactivity in the Environment

Radioactivity from both natural and artificial origins exists throughout the environment. Natural radioactivity has been present since the formation of the earth and is also formed in the earth's atmosphere as a result of interactions with cosmic radiation. Inputs of artificial origin have come from the testing of nuclear weapons in the atmosphere, accidents such as that at Chernobyl and the routine discharge of radionuclides from nuclear installations. Once present in the environment, these radionuclides are available for uptake by fish, shellfish, crops and animals and so make their way into the food chain.

Natural Radioactivity in the Environment

Natural radioactivity in the environment has two principal components, cosmic and 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 [Colgan *et al.*, 2008]. 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 creation 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

More than 500 atmospheric nuclear weapons tests took place from 1945 until 1980, releasing 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 another source of artificial radionuclides in the environment. Radiocaesium, for example, was widely dispersed in the Irish environment and was found to be present in air, soil, vegetation and milk following the Chernobyl accident in 1986 [McAulay and Moran, 1989; Ryan, 1992; European Communities, 1998a].

During the routine operation of nuclear installations such as nuclear power plants and reprocessing plants, radioactive material can be released to the environment. The most significant source of artificial radioactivity in the Irish marine environment is from the Sellafield nuclear fuel reprocessing plant. 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 eastern Irish Sea [Colgan *et al.*, 2005]. These discharges are authorised within prescribed limits by the UK Environment Agency. The quantities of various radionuclides discharged from Sellafield into the Irish Sea in 2009 are presented in Table 2.

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 liquid waste known as medium active concentrate (MAC) 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. Discharges of the main contaminant, caesium-137, since 1953 are presented in Figure 1.

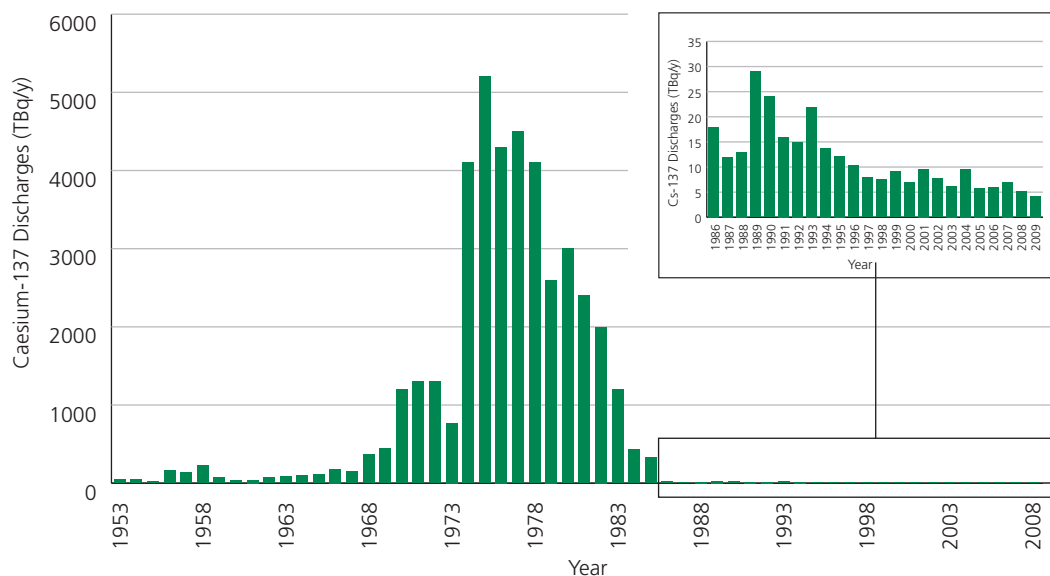


Figure 1. Marine discharges of caesium-137 from Sellafield, 1953-2009

Discharges of technetium-99 from Sellafield into the Irish Sea increased significantly in the mid-1990s due to the processing of a backlog of MAC through the Enhanced Actinide Removal Plant (EARP) and reached a peak in 1995. In 2004, a new treatment process based on tetraphenylphosphonium bromide (TPP) that was effective at removing technetium-99 in liquid waste was implemented. By the end of 2005, technetium-99 discharges had returned to pre-1994 levels (Figure 2).

Some hospitals use short-lived radionuclides for medical and scientific research purposes. These are subsequently released to the environment via the sewage system. The only radionuclide that is present in measurable quantities in the Irish marine environment as a result of discharges from Irish hospitals is iodine-131. A study to assess the environmental impact of these discharges and doses to workers, potentially exposed to them was carried out between 2003 and 2004 [Akinmboni et. al., 2005]. It was found that, since this radionuclide is short-lived and the amounts discharged are relatively small, their impact on the environment was negligible and doses to potentially exposed workers significantly less than the annual dose limit to members of the public from exposure to all controlled sources of ionising radiation of 1000 $\mu\text{Sv}/\text{year}$. Discharges of I-131 from Irish hospitals have been broadly consistent since this study was conducted.

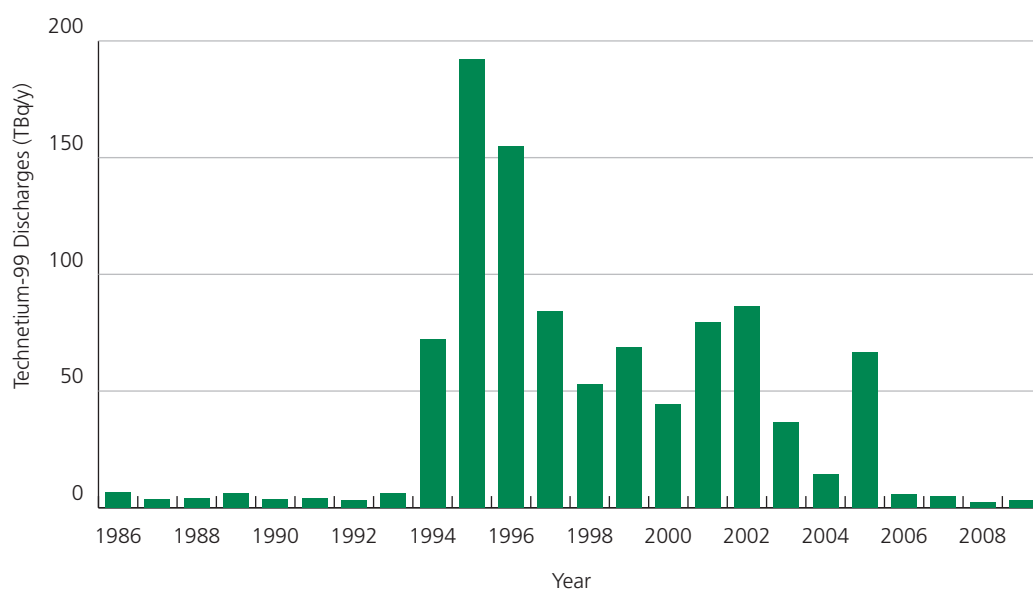


Figure 2. Marine discharges of technetium-99 from Sellafield, 1986-2009

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 [Ireland, 1991]. This Act assigns responsibility to the RPII to monitor levels of radioactivity in the Irish environment, to monitor the exposure of individuals and to provide information to the public and advice to the Government on measures for the protection of individuals in the State from radiological hazards.

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. An independent assessment of Member States' facilities is carried out periodically by the European Commission to verify their operation and efficiency. The most recent assessment of Irish facilities was carried out in 2007 and concluded that the requirements of Article 35 were fully met [European Commission, 2008].

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 Joint Research Centre at Ispra in Italy maintains a database of Member States' environmental radioactivity measurements on behalf of the Commission and publishes compilations of these data periodically in the EU Environmental Radioactivity Series [European Commission, 2005].

Commission Recommendation 2000/473/EURATOM [European Commission, 2000] on the application of Article 36 of the EURATOM treaty gives specific guidance on the monitoring of the levels of radioactivity in the environment for the purpose of assessing the exposure of the population as a whole. This Recommendation gives specific guidance as to the structure of monitoring networks, the media that should be sampled, the types of measurement, the radionuclides to be monitored and the sampling frequencies.

Oslo Paris Convention

The Oslo Paris (OSPAR) Convention sets out a framework for international cooperation on the protection of the marine environment of the North-East Atlantic. OSPAR (www.ospar.org) aims to achieve further reductions in artificial radioactivity levels in the marine environment 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. An essential part of this strategy is an effective monitoring programme for concentrations of radioactive substances in the marine environment so that progress in achieving the OSPAR aims can be measured. This is achieved through collaboration between the Contracting Parties in regular monitoring and assessment of radioactivity in the marine environment. The RPII provides data to this programme annually from its marine monitoring programme.

Drinking Water Directive

Council Directive 98/83/EC [European Communities, 1998b] on the quality of water intended for human consumption, hereafter referred to as the Drinking Water Directive, sets out limit values for microbiological, chemical and radioactivity parameters. The overall objective of this Directive is to protect human health from the adverse effects of any contamination of water intended for human consumption. Practical arrangements for assessing compliance with this Directive are set out in Appendix 1

Quality Assurance and Results

The RPII places a strong emphasis on quality assurance and reliability of data. Best practice is ensured by accreditation of test procedures, through the Irish National Accreditation Board, to International Standard ISO/IEC 17025 [INAB, 2008]. Analytical techniques are validated both through exchange of samples with other laboratories and through analysis of certified reference materials for proficiency testing. The RPII's laboratory participates in an active programme of intercomparison exercises, which provide independent evaluation of the quality and robustness of analyses. During 2009, these included those organised by the International Atomic Energy Agency, the National Physical Laboratory and LGC Standards, a commercial company, both in the UK and the Norwegian Radiation Protection Agency in Norway. Details regarding the analytical techniques used are given in Table 3.

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.

2 Radioactivity in the Atmosphere

The Permanent Monitoring Station Network

The RPII continuously assesses the level of radioactivity in the environment through the collection of aerosol and rain water samples and the measurement of ambient gamma dose rate at a network of permanent monitoring stations located throughout the country. This network is designed to allow a rapid assessment of environmental contamination to be made in the event of a radiological emergency; a core objective of the RPII's monitoring programme. The location of the stations and the measurements undertaken at each are set out in Figure 3 and Table 4 respectively.



Figure 3. Permanent monitoring network for radioactivity measurement

Airborne Radioactivity

The RPII's air sampling network includes both on-line and off-line aerosol samplers. With the on-line system, radioactivity is measured on the air filter at the site and the data is relayed directly to a central computer in the RPII offices in Clonskeagh. With the off-line system, the filters are transported to Clonskeagh for laboratory analysis. The on-line systems automatically correct for the natural radiation component due to radon daughters and so the readings transmitted back to RPII are a direct estimate of the concentrations of airborne artificial radionuclides. The network includes one high volume particulate sampler which allows ambient background levels of radioactivity in air to be measured. The RPII has recently upgraded its air sampling stations; the network now includes 4 on-line and 8 off-line stations.

Low volume particulates from the off-line stations 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 volume of air sampled ranged between 400 and 1900 m³. 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. One filter from each monitoring station was analysed each month for gross beta activity and the gamma emitting radionuclides caesium-137 and beryllium-7. Airborne caesium-137 concentrations arise primarily from residual weapons fallout and aerial discharges from the nuclear fuel cycle, while beryllium-7 is a naturally occurring radionuclide and was measured for quality control purposes. The other filters were archived for analysis if required.

The activity concentrations in low volume airborne particulates measured at the off-line monitoring stations are presented in Tables 5a – 5h. The activity concentrations measured in air in 2009 at these stations were consistent with the pattern of background radioactivity reported in previous years. [Fegan *et al.*, 2010]. Continuous on-line gross alpha and beta radioactivity in air measurements were collected at Clonskeagh in Dublin, Drogheda and Dundalk in Co. Louth and at Kilmeaden in Co. Waterford. No airborne artificial radioactivity was detected at any of the on-line stations during 2009.

High volume particulate samples were collected at Belfield (Dublin) during 2009 over a sampling period of approximately four weeks per filter with a typical airflow rate of between 1,800 and 2,500 m³/h. These filters were analysed by high resolution gamma spectrometry. The activity concentrations of caesium-137 and beryllium-7 are given in Table 6. The data was consistent with measurements made in previous years and with expected concentrations arising from global circulation of weapons test fallout [European Commission, 2005].

The radiation dose due to inhalation of airborne caesium-137 (as measured in high volume airborne particulates) was calculated using committed dose coefficients set out in the Basic Safety Standards Directive [European Commission, 1996]. This was calculated to be 9.0×10^{-5} Sv, which is similar to the values reported in recent years (Table 7).

External Gamma Dose Rate

The external gamma dose rates at fifteen stations were recorded every minute and hourly readings were automatically transmitted to the RPII's database at its Clonskeagh office. This network is an important component of the RPII's early warning arrangements for elevated levels of radioactivity in the atmosphere. Recent data from each station can be viewed on the RPII website (<http://www.rpii.ie/Monitoring-Stations.aspx>). Each station is fitted with an alarm which is triggered in the event of a high reading or technical failure.

The minimum and maximum external gamma dose rate readings for each month, at each of the fifteen stations around the Republic of Ireland, are presented in Tables 8a – 8c. The ranges were similar to those reported in previous years. No abnormally high readings were observed at any of the fifteen stations during the reporting period.

Rainwater

Rainwater was collected continuously at thirteen 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. There were no incidents during the reporting period that warranted the analysis of these samples.

Natural Radioactivity in Air

The dose assessment of the Irish population published in 2008 had recognised that the data available on indoor levels of thoron and thoron decay products in Irish homes was very limited [Colgan *et al.*, 2008]. A notional value of 280 μ Sv/year for the average dose due to thoron decay products was used. Thoron is a naturally occurring radioactive gas, with a short half life of 56 seconds. It is produced from thorium-232, one of the radioactive elements found throughout the earth's crust. Because of its short half life, penetration of thoron into houses from the underlying rock and soil is thought to be very limited and hence the principal source of thoron in indoor air is building materials.

In order to improve the RPII's overall assessment of doses to the Irish public from all sources of radiation, a national population weighted survey of thoron in indoor air in Irish homes recently has been undertaken. This survey was a collaborative project between the RPII, University College Dublin and the National Institute of Radiological Sciences in Japan.

Measurements of thoron gas, thoron decay products and radon gas in 205 Irish homes from around the country were completed in 2009. From this study, the average dose due to thoron decay products was estimated to be 350 μ Sv/year. This represents approximately 10% of the total average dose from all sources to the Irish population. The maximum dose in this study from thoron decay products was 2,800 μ Sv/year. These may be compared to a dose of 5,000 μ Sv/year from indoor radon concentrations of 200 Bq/m³, the national reference level above which remediation is recommended.

3 Radioactivity in Foodstuffs and Drinking Water

Foodstuffs

The Commission Recommendation 2000/473/EURATOM advises the routine measurement of radioactivity in milk and mixed diet. Measurement of caesium-137 and strontium-90 in milk is advised as these radionuclides may concentrate in milk in the event of an accidental release of radioactivity. Milk is also of particular importance as a foodstuff for infants and children.

Sampling of milk was conducted monthly at four processing plants covering a wide geographic area. Samples were bulked quarterly and analysed for strontium-90 and caesium-137.

Table 9 presents the results of measurements of radioactivity in composite milk samples for 2009. In all cases where strontium-90 and caesium-137 were detected in samples the activities were less than 1 Bq/l. It should be noted that, because of the difference in analytical techniques, the detection limit for strontium-90 is lower than that for caesium-137 (Table 3).

Ingestion doses were calculated using age-dependent dose coefficients [ICRP, 1996] (Table 10). 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, the mean full-milk consumption for an adult male and an infant in Ireland is 178 kg/year and 120 kg/year, respectively.

The committed effective dose to infants and adults from the consumption of milk was estimated for strontium-90 and caesium-137. In calculating the dose for strontium-90 it is assumed that its daughter product yttrium-90 is in equilibrium. The calculated dose for consumption of milk is dominated by strontium-90 as can be seen in Table 11. The category, infants (children under the age of one year), received the highest estimated strontium-90 dose of 0.97 μ Sv.

During the reporting period, 5 samples of complete meals (mixed diet) were collected from restaurant facilities in Dublin and Drogheda Co. Louth and analysed for gamma emitting radionuclides. Samples of grain from the main areas of production were supplied by the Department of Agriculture Food and Fisheries and analysed by RPII for gamma emitting radionuclides. In addition a range of meat, dairy and miscellaneous food types were analysed for gamma emitting radionuclides as part of the product certification programme. The maximum caesium-137 concentrations measured in mixed diet, grain and product certification samples during 2009 are presented in Table 12. All other radionuclides were below the limit of detection.

Drinking Water

The RPII has monitored radioactivity in drinking water supplies since 1982. This monitoring has focused primarily on major surface drinking water supplies serving large populations. Currently the RPII routinely measures samples from major water supplies in rotation so that supplies from every county are sampled approximately every four years. Major supplies are defined here as those serving a population of 10,000 or greater or the largest supply in a county.

Where possible, drinking water was sampled at the point at which the treated water was released into the distribution network. 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. Samples were evaporated to dryness and analysed for gross alpha and gross beta activities respectively.

Drinking water samples were assessed for compliance with the total indicative dose (TID), a parametric standard for radioactivity set out in the Drinking Water Directive. The WHO methodology [WHO, 1993] was used as described in Appendix 1. This methodology sets screening limits based on gross alpha and beta activities.

The results of measurements for the RPII's routine monitoring programme of major supplies are presented in Table 13. In 2009 supplies from Galway, Kerry, Kildare, Kilkenny, Leitrim, Longford, Limerick and Laois were tested. All drinking water supplies tested were found to be in compliance with the TID.

In Ireland the majority of drinking water (83.7%) originates from surface water (i.e. rivers and lakes) with the remainder originating from groundwater (8.8%) and springs (7.5%) [EPA, 2009]. At present there is no comprehensive national picture concerning radioactivity in groundwater supplies or private wells in Ireland. To address this, the RPII has undertaken a national survey of radioactivity in groundwater supplies. During the course of this study, approximately 220 groundwater supplies will be assessed for compliance with the radioactivity parameters set out in the Drinking Water Directive by RPII while the Environmental Protection Agency (EPA) will measure chemical parameters including uranium for the same groundwater supplies. The results of this project will be published in 2011 and will also be made available on the RPII website.

4 Radioactivity in the Marine Environment

Marine Radioactivity

The primary focus of the marine monitoring programme is to assess the radiation doses to the Irish population arising from discharges from the Sellafield reprocessing plant and to assess geographic and temporal distribution of artificial radionuclides in the marine environment. The nuclides of greatest concern from a dosimetric point of view are caesium-137, technetium-99 and isotopes of plutonium. These radionuclides are measured in seafood to determine the ingestion dose to the Irish public. Both technetium-99 and caesium-137 are measured in seawater and seaweed to assess geographic and temporal trends. Caesium-137 is also measured in sediment samples from the Irish Sea.

Samples of a wide range of fish and shellfish species were collected from commercial landings at major Irish fishing ports and aquaculture areas. Seawater 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*. In collaboration with the Northern Ireland Environment Agency, three seawater samples from the north and north-east coast were collected from Portrush, Larne and Ards.

The range of samples collected at each location is given in Table 14 and the offshore locations are shown in Figure 4. The sampling frequency for each site, which ranged from monthly to once every two years, reflects the resolution judged necessary to assess the population dose and to identify important trends.

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 for caesium-137. Selected individual and bulked samples were analysed for technetium-99, plutonium-238 and plutonium-239,240. Seawater (coastal and offshore) was analysed for caesium-137 and technetium-99 using techniques outlined in Table 3.



Figure 4. Off-shore sampling locations, 2009

Seawater

The results of the analyses of caesium-137 and technetium-99 in coastline and offshore (western Irish Sea) seawater are presented in Table 15. The mean activity concentrations of caesium-137 at each coastal location in 2009 (Figure 5) are in line with the previously established geographical distribution of caesium-137 around the Irish coastline. The highest concentrations of Sellafield-derived caesium-137 are found on the north-east coast which is consistent with the known water circulation patterns in the Irish Sea. Concentrations at these locations are measured biennially; data from 2008 are included in Figure 5 for comparison purposes.

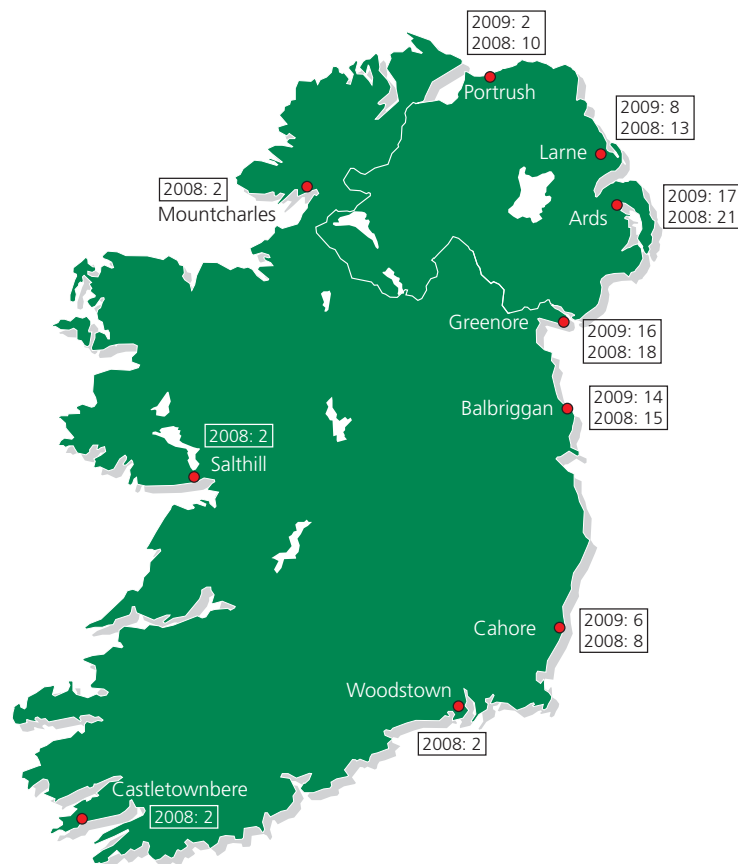


Figure 5. Mean caesium-137 concentrations (mBq/l) in coastline seawater, 2008-2009

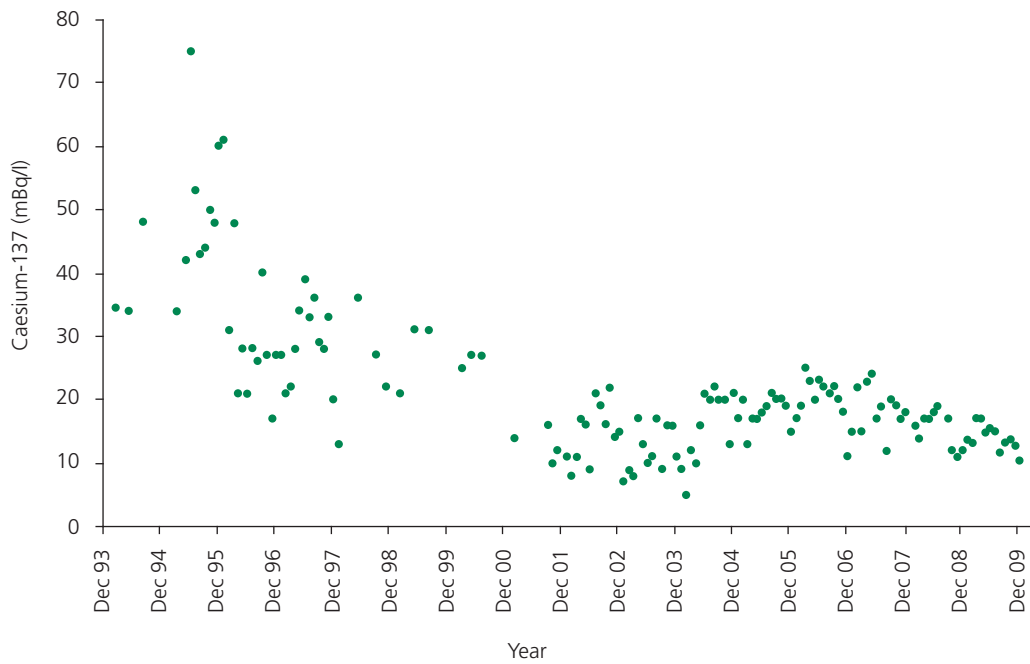


Figure 6. Caesium-137 activity concentrations in seawater from Balbriggan, 1993-2009

Caesium-137 activity concentrations in seawater from Balbriggan between 1993 and 2009 are shown in Figure 6. 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). Since 2000, discharges have remained relatively constant and this is reflected in seawater activity concentrations measured between 2000 and 2009. It has been shown that remobilisation of historic discharges into the water column from sediments is now an important source of caesium-137 in seawater from the western Irish Sea [Poole *et al.*, 1997]. This may also help to explain the levelling off of caesium-137 concentrations observed in recent years. A similar trend is observed in caesium-137 activity concentrations in seawater at offshore locations in the Irish Sea between 1984 and 2009 (Figure 7). The caesium-137 activity concentrations along the south and west coasts are lower than those in the Irish Sea and are now close to global fallout levels. Concentrations in seawater from along these coasts have remained similar since the mid-1990s.

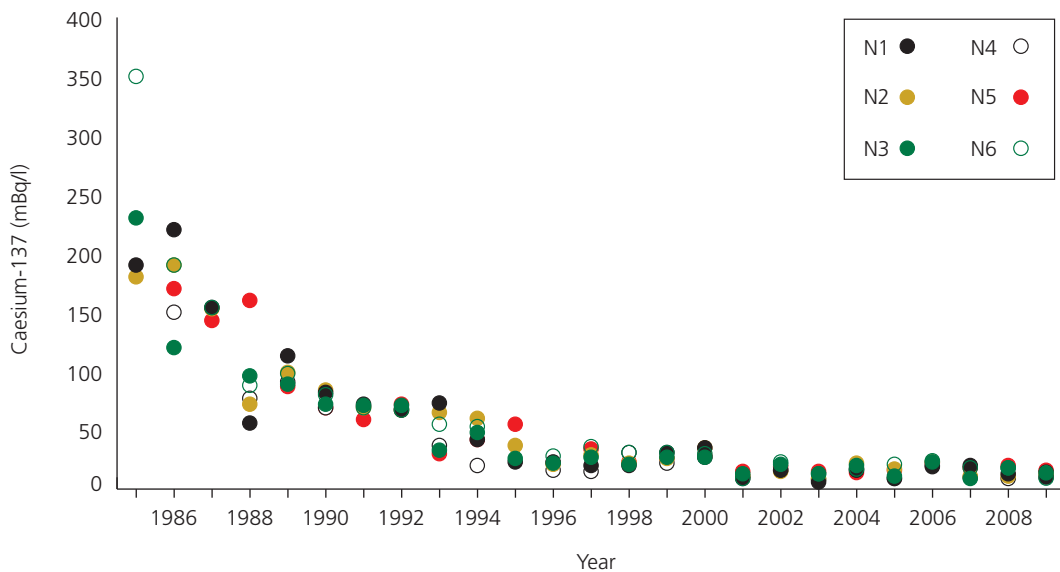


Figure 7. Caesium-137 activity concentrations in seawater from locations N1-N6 in the Irish Sea, 1984-2009

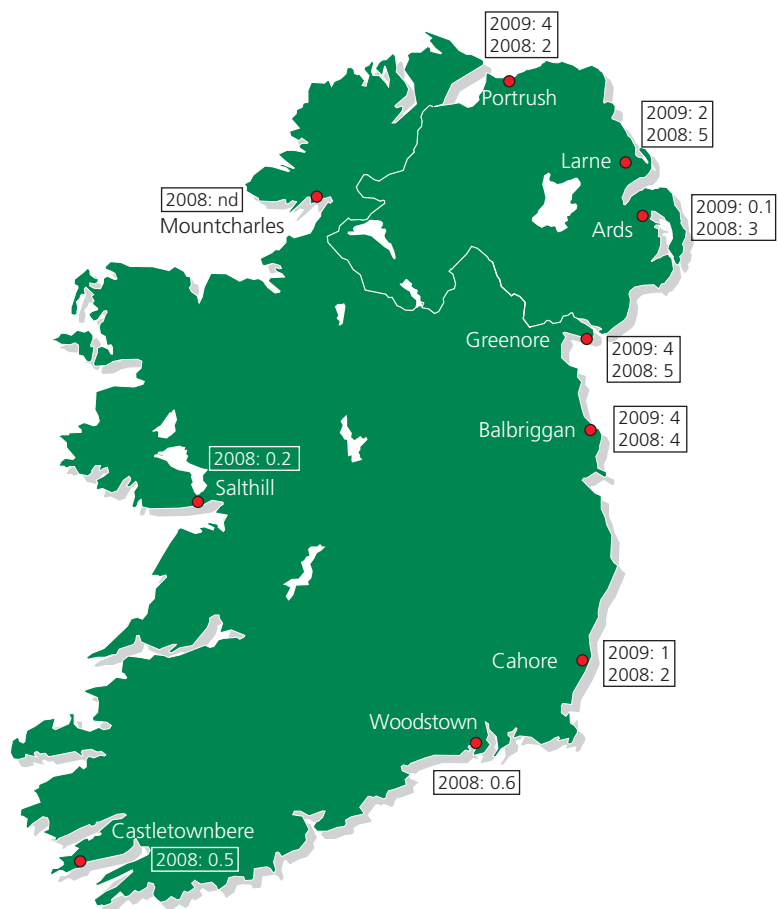


Figure 8. Mean technetium-99 concentrations (mBq/l) in coastline seawater, 2008-2009

The mean activity concentrations of technetium-99 in seawater from around the Irish coastline in 2009 are shown in Figure 8. The geographical distribution is consistent with that of caesium-137 with the highest concentrations on the north-east coast. The mean annual activity concentrations at both Balbriggan and at Greenore in 2009 were 4 mBq/l. Concentrations along the south and west coast are measured biennially; data from 2008 are included in Figure 8 for comparison purposes.

Technetium-99 activity concentrations in seawater from Balbriggan for the period 1995 to 2009 are presented in Figure 9. It can be seen from these data that activity concentrations at this site peaked in 1997 with a mean annual activity concentration of 45 mBq/l. Following the implementation of the tetraphenylphosphonium bromide waste treatment process at Sellafield in 2004 there has been a reduction in the discharges of this radionuclide and corresponding reductions in activity concentrations in seawater can be observed.

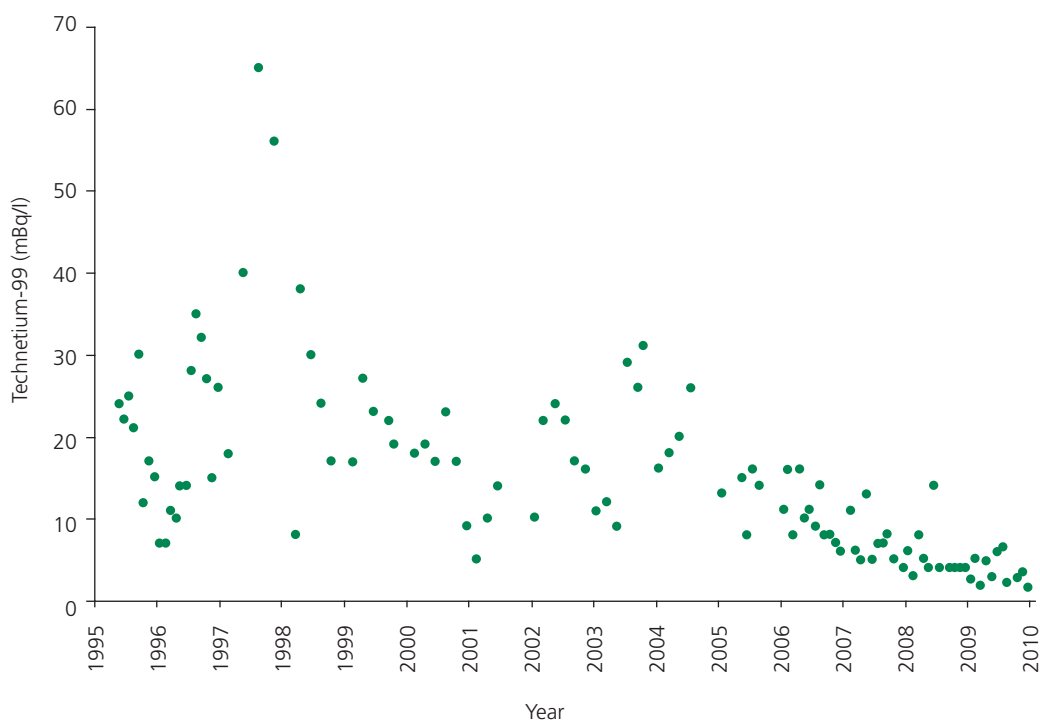


Figure 9. Technetium-99 activity concentrations in seawater (mBq/l) from Balbriggan, 1995-2009

Sediment

Caesium-137 activity concentrations in sediment samples collected at the off-shore sampling sites are shown in Table 16. These measurements are consistent with the data reported for the same stations in recent RPII monitoring reports [Fegan *et al.*, 2010]

Seaweed

The results for caesium-137 and technetium-99 activity concentrations in seaweed (*Fucus vesiculosus*) are given in Table 17. These 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 0.16 calculated for 2009 samples.

Figure 10 presents mean caesium-137 activity concentrations in seaweed sampled from Balbriggan between 1982 and 2009. These data show that concentrations of this radionuclide in seaweed at this site have remained relatively constant since the mid-1990s.

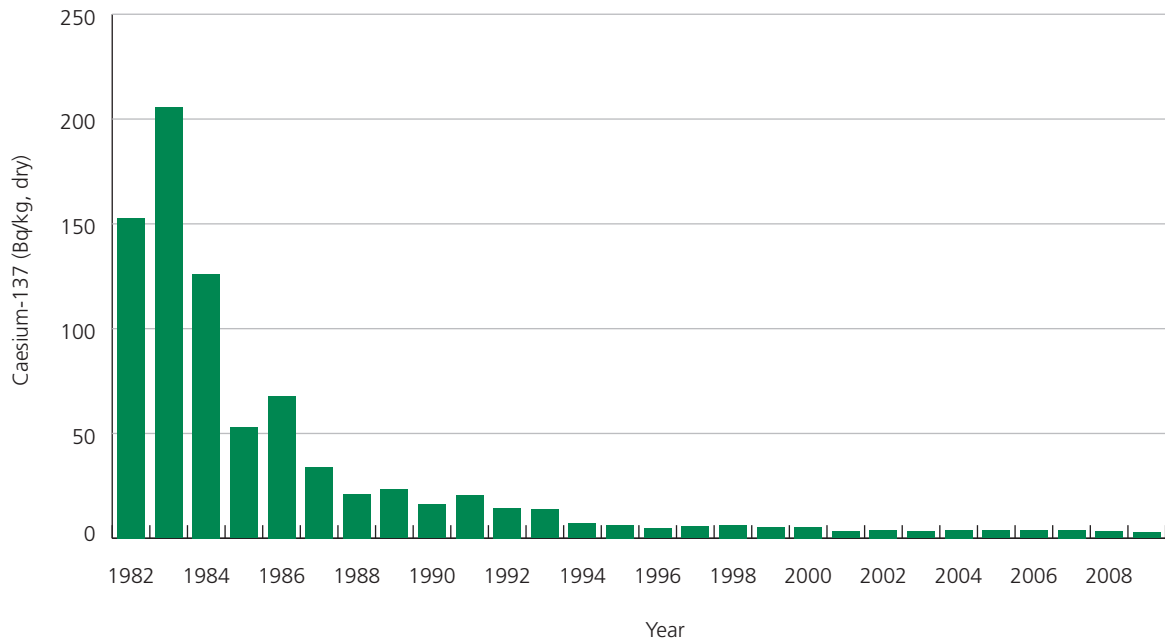


Figure 10. Mean caesium-137 activity concentrations in seaweed (*Fucus vesiculosus*, Bq/kg, dry) from Balbriggan, 1982-2009

Figure 11 presents the technetium-99 activity concentrations in seaweed from Balbriggan for the period 1989 to 2009. A similar pattern is observed to that for seawater (Figure 9) with activity concentrations from the north-east coastline peaking between late 1997 and early 1998 and reducing significantly over the last two to three years.

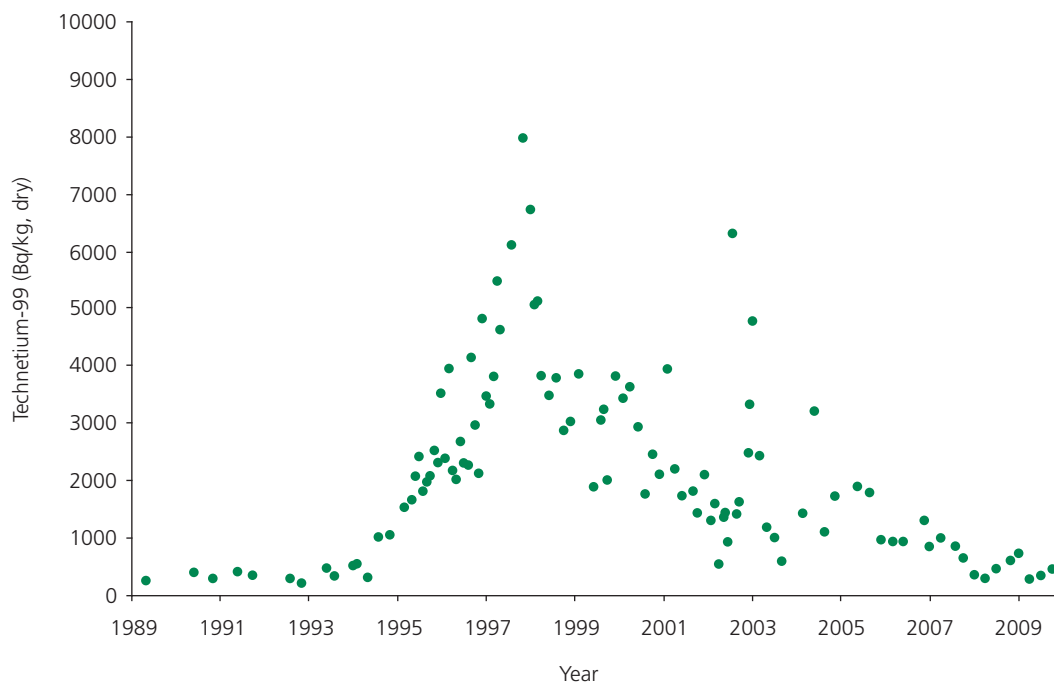


Figure 11. Technetium-99 activity concentrations in seaweed (*Fucus vesiculosus*, Bq/kg, dry) from Balbriggan, 1989-2009

Fish and Shellfish

The results of radioactivity measurements in fish and shellfish collected from major Irish fishing ports and aquaculture areas are shown in Tables 18-20. All results are presented on a fresh weight basis.

The caesium-137 concentrations in fish and shellfish in 2009 were similar to those detected in previous years. Technetium-99, plutonium-238 and plutonium-239,240 activity concentrations in fish samples analysed in 2009 were below detection limits. Americium-241 activity concentrations were estimated using mean americium/plutonium ratios in fish, prawns and mussels [Ryan *et al.*, 1999]. The mean activity concentrations of artificial radionuclides in fish and shellfish landed at north-east ports are presented in Table 21.

A habits survey carried out in 2008 along the north-east coast of Ireland [Cefas, 2008] identified two critical groups: commercial fishermen (Group A), a group of commercial fishermen who consume large amounts of fish and crustaceans; and commercial oyster and mussel farmers (Group B) working along the north-east coast who consume large amounts of molluscs. Dose assessments are carried out for each of these groups. Group A is assumed to consume 26 kg and 10 kg of fish and crustaceans per year respectively while Group B is assumed to consume 25 kg of molluscs per year. The dose assessments relate to adults.

The weighted totalled consumption rates of different fish and mollusc species identified in the Habits Survey and used in the critical group dose assessment are shown in Table 21.

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 in 2009 (Table 22). The north-east coast is the area in which the highest levels of radioactivity attributable to Sellafield are observed. Dose conversion factors used were from ICRP [ICRP, 1996].

The committed effective doses estimated for the commercial fisherman critical group (Group A) and the oyster and mussel farmer critical group (Group B) were 0.24 and 0.44 μ Sv, respectively. These doses include contributions from the artificial radionuclides technetium-99, caesium-137, plutonium-238,239,240 and americium-241.

To allow comparison with previous years, the doses calculated for the notional typical and heavy consumers previously reported in RPII monitoring reports are also included here. The consumption rates for typical and heavy consumers were 40g and 5g of fish and shellfish per day respectively (15 and 1.8 kg per year respectively) and 200g and 20g of fish and shellfish per day respectively (7.3 and 73 kg per year respectively). For both the typical and 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. The committed effective doses estimated for the notional typical and heavy consumer groups are 0.09 μSv and 0.38 μSv , respectively. Dose data for critical and notional consumer groups are summarised in Table 23.

The annual committed effective dose to the notional typical seafood consumer for the period 1982 to 2009 is shown in Figure 12 and Table 24. It can be seen that annual doses have decreased steadily over this period, reflecting the overall reduction in Sellafield discharges.

In 2009, the committed effective dose of 0.24 μSv to Group A consumers is less than 0.03% of the annual dose limit of 1000 μSv for members of the public from practices involving controllable sources of radiation [Ireland, 2000.] The dominant contributors to this dose are caesium-137 (58%) and technetium-99 (33%).

The annual committed effective dose of 0.44 μSv to Group B consumers is less than 0.04% of the annual dose limit to members of the public of 1000 μSv . The dominant contributors to this dose are plutonium-238, 239, 240 (36%), technetium-99 (35%) and americium (18%). The higher dose to this group may be attributed to the relatively high dose coefficients for plutonium-238, 239, 240 and americium-241.

These doses 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 for the notional typical consumers [Pollard *et al.*, 1998].

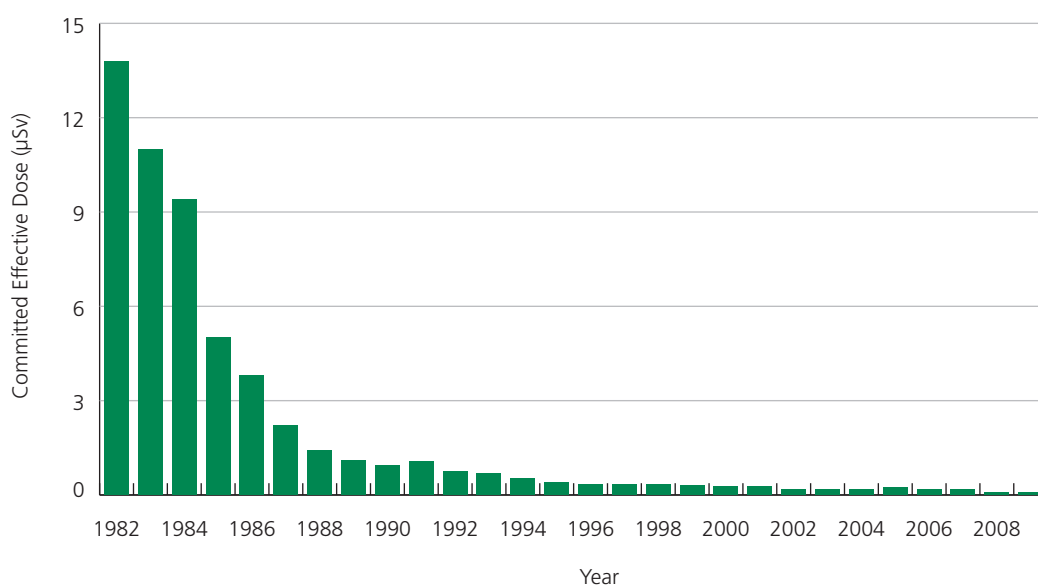


Figure 12. Committed effective dose to the typical seafood consumer, 1982-2009

5 Conclusions

During 2009, the RPII implemented a comprehensive programme of monitoring radioactivity in the Irish environment, which included the measurement of radioactivity in a wide range of foodstuffs and environmental matrices.

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

All drinking waters tested 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. The estimated annual committed effective doses to members of the two critical groups A (commercial fishermen who consume large quantities of fish and crustaceans) and B (commercial oyster and mussel farmers who consume large amounts of molluscs) were 0.24 μSv and 0.44 μSv , respectively.

The doses incurred by the Irish public in 2009 as a result of artificial radioactivity in the environment are small when compared to national dose limits or natural radiation doses received by the Irish public. The dose to the most exposed individuals, members of the oyster and mussel farmers critical group was approximately 0.04% of the annual dose limit of 1000 μSv for members of the public from practices involving controllable sources of radiation. These doses are small in comparison with the dose received (32 μSv) by the notional typical consumer due to the presence of the naturally-occurring radionuclide, polonium-210, in seafood. They may also be compared with the average annual dose to a person in Ireland from all sources of radioactivity of 3950 μSv .

In general, levels of artificial radioactivity in the Irish environment remain fairly constant and are broadly consistent with levels reported previously. It must be 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.

In summary, the results of the 2009 monitoring programme show that, while the levels of artificial radioactivity in the Irish environment remain detectable, they are low and do not pose a significant risk to human health.

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8 Tables

Table 1. Naturally occurring radionuclides in seawater

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

Notes: ^a Source: Walker and Rose [1990].

^b RPII measurement.

^c Source: Smith [2001].

Table 2. Annual discharge limits (TBq) and actual discharges (TBq) from Sellafield to the Irish Sea, 2009

Radionuclide	Limit	Discharge ^a
Category		
Alpha-emitting radionuclides	1.0	0.154
Beta-emitting radionuclides	220	17.8
Tritium	20,000	1,510
Carbon-14	21	8.19
Cobalt-60	3.6	0.083
Strontium-90	48	2.86
Zirconium-95 + Niobium-95	3.8	0.193
Technetium-99	10	3.08
Ruthenium-106	63	3.16
Iodine-129	2.0	0.253
Caesium-134	1.6	0.141
Caesium-137	34	4.27
Cerium-144	4.0	0.498
Plutonium (alpha) ^b	0.7	0.120
Plutonium-241	25	2.87
Americium-241	0.30	0.046
Uranium ^c	2,000	409

Notes: ^a From the sea pipeline.

^b The sum of plutonium-238, plutonium-238 and plutonium-240.

^c 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
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	1×10^{-7} Bq/m ³ (7 day count)	15% 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	Drinking water	Evaporation and gas flow proportional counting	5 mBq/l (24 h count)	40%
Gross beta			5 mBq/l (24 h count)	30%
Gamma dose rate	Ambient	Continuous monitoring station	10 nSv/h	15% (Cs-137)
Cs-137 and other gamma emitting radionuclides	Fish, shellfish and seaweed	High resolution gamma spectrometry using high purity germanium detectors	1.0 Bq/kg (I-131) 0.3 Bq/kg (Cs-137)	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	12% 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. Permanent monitoring network, 2009

Sampling Location	Sample Types
Ballyrichard, Co. Wicklow.	External gamma dose rate
Belfield, Co. Dublin	Airborne particulates (high volume sampler)
Belmullet, Co. Mayo	Rainwater
Birr, Co. Offaly	External gamma dose rate, rainwater
Cahirciveen, Co. Kerry	Airborne particulates, external gamma dose rate, rainwater
Casement, Co. Dublin	External gamma dose rate, rainwater
Clones, Co. Monaghan	External gamma dose rate, rainwater
Clonskeagh, Co. Dublin	Airborne particulates, external gamma dose rate, rainwater
Cork Airport, Co. Cork	Airborne particulates, external gamma dose rate, rainwater
Drogheda Co. Louth	Airborne particulates
Dublin Airport, Co. Dublin	Rainwater
Dundalk, Co. Louth	Airborne particulates, external gamma dose rate
Glasnevin, Co. Dublin	Airborne particulates
Kilkenny, Co. Kilkenny	External gamma dose rate
Kilmeadan, Co. Waterford	Airborne particulates, external gamma dose rate
Kiltrough, Co. Meath	External gamma dose rate
Knock Airport, Co. Mayo	Airborne particulates, external gamma dose rate
Malin Head, Co. Donegal	External gamma dose rate, rainwater
Mullingar, Co. Westmeath	Airborne particulates, rainwater
Rosslare, Co. Wexford	Airborne particulates, external gamma dose rate, rainwater
Shannon Airport, Co. Clare	Airborne particulates, external gamma dose rate, rainwater

Table 5a. Radioactivity in airborne particulates (low volume), Cahirciveen, 2009

Month	Activity Concentration in Air (Bq/m ³)		
	Gross Beta	Cs-137	Be-7
Jan	4.44 X 10 ⁻⁴	nd	6.37 X 10 ⁻³
Feb	1.58 X 10 ⁻⁴	nd	3.00 X 10 ⁻³
Mar	1.25 X 10 ⁻⁴	nd	3.58 X 10 ⁻³
Apr	1.18 X 10 ⁻⁴	nd	3.22 X 10 ⁻³
May	1.91 X 10 ⁻⁴	nd	4.37 X 10 ⁻³
Jun	2.61 X 10 ⁻⁴	nd	5.33 X 10 ⁻³
Jul	1.48 X 10 ⁻⁴	nd	3.03 X 10 ⁻³
Aug	0.64 X 10 ⁻⁴	nd	0.86 X 10 ⁻³
Sep	1.59 X 10 ⁻⁴	nd	2.79 X 10 ⁻³
Oct	1.60 X 10 ⁻⁴	nd	4.08 X 10 ⁻³
Nov	1.02 X 10 ⁻⁴	nd	2.15 X 10 ⁻³
Dec	1.05 X 10 ⁻⁴	nd	3.08 X 10 ⁻³

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

Table 5b. Radioactivity in airborne particulates (low volume), Clonskeagh, 2009

Month	Activity Concentration in Air (Bq/m ³)		
	Gross Beta	Cs-137	Be-7
Jan	2.36 X 10 ⁻⁴	nd	3.33 X 10 ⁻³
Feb	1.86 X 10 ⁻⁴	nd	3.17 X 10 ⁻³
Mar	2.37 X 10 ⁻⁴	nd	5.30 X 10 ⁻³
Apr	3.82 X 10 ⁻⁴	nd	5.13 X 10 ⁻³
May	2.03 X 10 ⁻⁴	nd	4.72 X 10 ⁻³
Jun	2.85 X 10 ⁻⁴	nd	5.46 X 10 ⁻³
Jul	1.19 X 10 ⁻⁴	nd	2.37 X 10 ⁻³
Aug	7.20 X 10 ⁻⁵	nd	1.89 X 10 ⁻³
Sep	2.35 X 10 ⁻⁴	nd	3.47 X 10 ⁻³
Oct	1.72 X 10 ⁻⁴	nd	4.23 X 10 ⁻³
Nov	0.83 X 10 ⁻⁴	nd	2.17 X 10 ⁻³
Dec	1.16 X 10 ⁻⁴	nd	3.25 X 10 ⁻³

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

Table 5c. Radioactivity in airborne particulates (low volume), Cork Airport, 2009

Month	Activity Concentration in Air (Bq/m ³)		
	Gross Beta	Cs-137	Be-7
Jan	5.35 X 10 ⁻⁴	nd	11.3 X 10 ⁻³
Feb	2.33 X 10 ⁻⁴	nd	3.90 X 10 ⁻³
Mar	1.94 X 10 ⁻⁴	nd	4.99 X 10 ⁻³
Apr	1.25 X 10 ⁻⁴	nd	3.66 X 10 ⁻³
May	2.30 X 10 ⁻⁴	nd	5.88 X 10 ⁻³
Jun	2.47 X 10 ⁻⁴	nd	6.33 X 10 ⁻³
Jul	2.92 X 10 ⁻⁴	nd	4.52 X 10 ⁻³
Aug	0.98 X 10 ⁻⁴	nd	1.46 X 10 ⁻³
Sep	1.86 X 10 ⁻⁴	nd	3.93 X 10 ⁻³
Oct	2.31 X 10 ⁻⁴	nd	5.33 X 10 ⁻³
Nov	1.59 X 10 ⁻⁴	nd	3.04 X 10 ⁻³
Dec	0.84 X 10 ⁻⁴	nd	2.96 X 10 ⁻³

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

Table 5d. Radioactivity in airborne particulates (low volume), Glasnevin, 2009

Month	Activity Concentration in Air (Bq/m ³)		
	Gross Beta	Cs-137	Be-7
Jan	3.02 X 10 ⁻⁴	nd	4.96 X 10 ⁻³
Feb	1.62 X 10 ⁻⁴	nd	2.28 X 10 ⁻³
Mar	0.97 X 10 ⁻⁴	nd	2.78 X 10 ⁻³
Apr	1.67 X 10 ⁻⁴	nd	4.02 X 10 ⁻³
May	1.53 X 10 ⁻⁴	nd	3.86 X 10 ⁻³
Jun	2.31 X 10 ⁻⁴	nd	4.01 X 10 ⁻³
Jul	2.34 X 10 ⁻⁴	nd	3.50 X 10 ⁻³
Aug	7.81 X 10 ⁻⁵	nd	1.21 X 10 ⁻³
Sep	1.87 X 10 ⁻⁴	nd	3.38 X 10 ⁻³
Oct	1.75 X 10 ⁻⁴	nd	2.77 X 10 ⁻³
Nov	0.81 X 10 ⁻⁴	nd	1.29 X 10 ⁻³
Dec	0.96 X 10 ⁻⁴	nd	2.72 X 10 ⁻³

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

Table 5e. Radioactivity in airborne particulates (low volume), Knock Airport, 2009

Month	Activity Concentration in Air (Bq/m ³)		
	Gross Beta	Cs-137	Be-7
Jan	0.32 X 10 ⁻⁴	nd	3.45 X 10 ⁻³
Feb	2.29 X 10 ⁻⁴	nd	2.66 X 10 ⁻³
Mar	1.47 X 10 ⁻⁴	nd	4.32 X 10 ⁻³
Apr	1.76 X 10 ⁻⁴	nd	2.74 X 10 ⁻³
May	1.86 X 10 ⁻⁴	nd	3.85 X 10 ⁻³
Jun	3.61 X 10 ⁻⁴	nd	6.28 X 10 ⁻³
Jul	1.45 X 10 ⁻⁴	nd	2.53 X 10 ⁻³
Aug	0.69 X 10 ⁻⁴	nd	1.05 X 10 ⁻³
Sep	2.36 X 10 ⁻⁴	nd	4.29 X 10 ⁻³
Oct	2.32 X 10 ⁻⁴	nd	3.58 X 10 ⁻³
Nov	0.71 X 10 ⁻⁴	nd	2.61 X 10 ⁻³
Dec	1.07 X 10 ⁻⁴	nd	nd

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

Table 5f. Radioactivity in airborne particulates (low volume), Mullingar, 2009

Month	Activity Concentration in Air (Bq/m ³)		
	Gross Beta	Cs-137	Be-7
Jan	2.44 X 10 ⁻⁴	nd	3.70 X 10 ⁻³
Feb	1.37 X 10 ⁻⁴	nd	1.73 X 10 ⁻³
Mar	0.77 X 10 ⁻⁴	nd	2.90 X 10 ⁻³
Apr	0.83 X 10 ⁻⁴	nd	1.78 X 10 ⁻³
May	1.18 X 10 ⁻⁴	nd	2.64 X 10 ⁻³
Jun	2.86 X 10 ⁻⁴	nd	4.64 X 10 ⁻³
Jul	1.17 X 10 ⁻⁴	nd	2.08 X 10 ⁻³
Aug	0.59 X 10 ⁻⁴	nd	1.06 X 10 ⁻³
Sep	1.69 X 10 ⁻⁴	nd	2.01 X 10 ⁻³
Oct	1.91 X 10 ⁻⁴	nd	2.90 X 10 ⁻³
Nov	0.60 X 10 ⁻⁴	nd	1.66 X 10 ⁻³
Dec	System out of service December 2009		

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

Table 5g. Radioactivity in airborne particulates (low volume), Rosslare, 2009

Month	Activity Concentration in Air (Bq/m ³)		
	Gross Beta	Cs-137	Be-7
Jan	4.64 X 10 ⁻⁴	nd	6.60 X 10 ⁻³
Feb	4.12 X 10 ⁻⁴	nd	4.97 X 10 ⁻³
Mar	1.34 X 10 ⁻⁴	nd	4.42 X 10 ⁻³
Apr	2.58 X 10 ⁻⁴	nd	1.86 X 10 ⁻³
May	1.83 X 10 ⁻⁴	nd	3.74 X 10 ⁻³
Jun	2.14 X 10 ⁻⁴	nd	4.70 X 10 ⁻³
Jul	1.27 X 10 ⁻⁴	nd	2.09 X 10 ⁻³
Aug	1.03 X 10 ⁻⁴	nd	1.21 X 10 ⁻³
Sep	2.87 X 10 ⁻⁴	nd	4.71 X 10 ⁻³
Oct	2.81 X 10 ⁻⁴	nd	4.37 X 10 ⁻³
Nov	1.24 X 10 ⁻⁴	nd	nd
Dec	1.07 X 10 ⁻⁴	nd	2.84 X 10 ⁻³

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

Table 5h. Radioactivity in airborne particulates (low volume), Shannon Airport, 2009

Month	Activity Concentration in Air (Bq/m ³)		
	Gross Beta	Cs-137	Be-7
Jan	3.96 X 10 ⁻⁴	nd	6.80 X 10 ⁻³
Feb	1.07 X 10 ⁻⁴	nd	3.94 X 10 ⁻³
Mar	1.66 X 10 ⁻⁴	nd	4.51 X 10 ⁻³
Apr	2.06 X 10 ⁻⁴	nd	3.76 X 10 ⁻³
May	2.58 X 10 ⁻⁴	nd	5.07 X 10 ⁻³
Jun	3.40 X 10 ⁻⁴	nd	8.04 X 10 ⁻³
Jul	2.41 X 10 ⁻⁴	nd	5.09 X 10 ⁻³
Aug	0.92 X 10 ⁻⁴	nd	1.30 X 10 ⁻³
Sep	2.24 X 10 ⁻⁴	nd	4.46 X 10 ⁻³
Oct	3.12 X 10 ⁻⁴	nd	5.47 X 10 ⁻³
Nov	1.13 X 10 ⁻⁴	nd	3.10 X 10 ⁻³
Dec	1.58 X 10 ⁻⁴	nd	3.64 X 10 ⁻³

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

Table 6. Radioactivity in airborne particulates (high volume), Belfield (Dublin), 2009

Sampling Period		Activity Concentration in Air (Bq/m ³)	
Start Date	End Date	Cs-137	Be-7
7 Jan	9 Feb	3.35 x 10 ⁻⁷	2.24 x 10 ⁻³
9 Feb	6 Mar	5.50 x 10 ⁻⁷	2.35 x 10 ⁻³
6 Mar	2 Apr	6.07 x 10 ⁻⁷	3.46 x 10 ⁻³
2 Apr	5 May	4.89 x 10 ⁻⁷	3.65 x 10 ⁻³
5 May	26 May	1.62 x 10 ⁻⁷	2.35 x 10 ⁻³
26 May	29 Jun	1.73 x 10 ⁻⁷	3.52 x 10 ⁻³
29 Jun	27 Jul	0.75 x 10 ⁻⁷	1.88 x 10 ⁻³
27 Jul	9 Sep	1.01 x 10 ⁻⁷	1.78 x 10 ⁻³
9 Sep	29 Sep	1.87 x 10 ⁻⁷	3.68 x 10 ⁻³
29 Sep	2 Nov	2.76 x 10 ⁻⁷	2.66 x 10 ⁻³
2 Nov	2 Dec	2.42 x 10 ⁻⁷	1.79 x 10 ⁻³
2 Dec	25 Jan	4.50 x 10 ⁻⁷	2.15 x 10 ⁻³
	Mean	3.04 x 10⁻⁷	2.63 x 10⁻³

Table 7. Committed effective dose due to inhalation of airborne caesium-137, 2001-2009

Year	Committed Effective Dose (μSv)
2001	5.8 x 10 ⁻⁴
2002	5.8 x 10 ⁻⁴
2003	4.3 x 10 ⁻⁴
2004	0.9 x 10 ⁻⁴
2005	0.8 x 10 ⁻⁴
2006	1.1 x 10 ⁻⁴
2007	1.0 x 10 ⁻⁴
2008	0.8 x 10 ⁻⁴
2009	0.9 x 10 ⁻⁴
Mean	2.4 x 10⁻⁴

Table 8a. External gamma dose rates (terrestrial), 2009

Month	Monthly Ranges (nSv/h)				
	Ballyrichard	Birr	Cahirciveen	Casement	Clones
Jan	92 – 131	68 – 93	84 – 105	75 – 87	77 – 108
Feb	91 – 121	67 – 87	82 – 98	73 – 113	76 – 99
Mar	92 – 102	66 – 78	82 – 92	73 – 86	75 – 87
Apr	92 – 115	67 – 82	83 – 94	73 – 97	77 – 89
May	91 – 118	67 – 80	81 – 93	71 – 101	75 – 87
Jun	94 – 127	68 – 81	83 – 96	73 – 90	76 – 86
Jul	92 – 115	68 – 81	84 – 91	73 – 98	76 – 87
Aug	92 – 100	67 – 78	83 – 93	74 – 83	75 – 86
Sep	89 – 102	64 – 74	81 – 89	71 – 84	74 – 82
Oct	91 – 140	66 – 81	82 – 99	74 – 89	75 – 94
Nov	90 – 113	68 – 85	84 – 107	76 – 92	77 – 92
Dec	90 – 119	67 – 80	82 – 103	74 – 97	76 – 88

Table 8b. External gamma dose rates (terrestrial), 2009

Month	Monthly Ranges (nSv/h)				
	Clonskeagh	Cork Airport	Dundalk	Kilkenny ^a	Kilmeadan
Jan	115 – 126	97 – 116	102 – 127	73 – 101	90 – 127
Feb	112 – 146	96 – 142	101 – 123	72 – 92	88 – 115
Mar	111 – 126	97 – 106	100 – 112	73 – 82	88 – 99
Apr	111 – 131	97 – 120	102 – 117	74 – 96	89 – 124
May	110 – 125	95 – 110	100 – 114	73 – 92	89 – 103
Jun	111 – 128	97 – 121	103 – 115	74 – 90	90 – 107
Jul	111 – 131	97 – 107	102 – 120	73 – 88	89 – 106
Aug	110 – 122	96 – 109	100 – 112	72 – 84	89 – 99
Sep	110 – 123	93 – 103	99 – 110	71 – 86	86 – 97
Oct	114 – 139	96 – 138	102 – 151	72 – 97	89 – 117
Nov	115 – 131	97 – 121	103 – 121	–	89 – 105
Dec	114 – 129	94 – 144	101 – 113	–	87 – 117

Notes: ^a Kilkenny system removed from network in November 2009.

Table 8c. External gamma dose rates (terrestrial), 2009

Month	Monthly Ranges (nSv/h)				
	Kiltrough	Knock Airport	Malin Head	Rosslare	Shannon Airport
Jan	81 – 97	70 – 106	69 – 82	74 – 91	76 – 87
Feb	79 – 104	70 – 90	68 – 107	74 – 108	74 – 91
Mar	81 – 100	70 – 80	68 – 84	75 – 83	74 – 83
Apr	93 – 114	70 – 83	71 – 83	75 – 101	69 – 86
May	87 – 112	70 – 93	71 – 90	74 – 87	60 – 92
Jun	90 – 105	69 – 88	73 – 84	77 – 94	84 – 98
Jul	90 – 110	71 – 85	74 – 85	76 – 87	81 – 90
Aug	91 – 98	70 – 83	72 – 84	75 – 85	81 – 88
Sep	89 – 97	68 – 78	69 – 79	74 – 83	80 – 87
Oct	88 – 117	69 – 112	70 – 93	75 – 112	79 – 98
Nov	88 – 107	71 – 94	72 – 91	75 – 96	81 – 99
Dec	86 – 99	69 – 84	71 – 85	74 – 98	80 – 98

Table 9. Radioactivity in milk, 2009

County	Activity Concentration (Bq/l)							
	Jan – Mar		Apr – Jun		Jul – Sep		Oct – Dec	
	Sr-90	Cs-137	Sr-90	Cs-137	Sr-90	Cs-137	Sr-90	Cs-137
Cavan	0.043	nd	0.035	nd	0.026	nd	nd	nd
Cork	nd	nd	0.034	nd	0.042	nd	0.043	nd
Dublin	nd	nd	nd	nd	0.026	nd	nd	nd
Roscommon	nd	nd	nd	nd	nd	0.06	nd	nd

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

Table 10. Ingestion dose coefficients

Nuclide	Category	Dose Coefficient ^a (Sv/ Bq)
Cs-137	Infant	2.1×10^{-8}
Cs-137	Adult	1.3×10^{-8}
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}
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-241	Adult	2.0×10^{-7}

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

Table 11. Committed effective dose from strontium-90, yttrium-90, caesium-137 in milk, 2009

Radionuclide	Category	Annual Dose (μ Sv)
Sr-90	Infant	0.97
	Adult	0.17
Y-90	Infant	0.13
	Adult	0.02
Cs-137	Infant	0.15
	Adult	0.14

Table 12. Maximum caesium-137 activity concentrations in a range of foodstuffs, 2009

Sample Type	Number of Samples	Max Cs-137 (Bq/kg, fresh weight)	Number of Samples Above Detection Limit
Beef/Pork/Lamb	23	24.42	5
Dairy products	263	1.93	2
Mixed diet samples	5	0.59	2
Grain	65	nd	0
Miscellaneous foodstuffs	170	95.52 ^a	6

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

^a Soft drinks concentrate sample.

Table 13. Gross alpha and gross beta activity concentrations in drinking water, 2009

County	Supply	Sampling Date	Activity Concentration (mBq/l)		Compliance with TID
			Gross Alpha	Gross Beta	
Galway	Lough Corrib	Dec	nd	92.9	Yes
Kerry	Lisarboola	Dec	10.0	38.4	Yes
Kildare	Leixlip	Dec	nd	59.3	Yes
	Ballymore Eustace	Dec	16.5	52.9	Yes
Kilkenny	Radestown	Dec	16.3	134.1	Yes
Laois	Portlaoise	Dec	144.9	181.1	Yes
Leitrim	Leitrim	Dec	nd	70.7	Yes
Limerick	Limerick City	Dec	nd	105.1	Yes
Longford	Lough Forbes	Dec	nd	109.0	Yes

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

Table 14. Marine monitoring programme

Sampling Location	Sample Types	Sampling Frequency
Bantry, Co. Cork	Shellfish	Annually
Balbriggan, Co. Dublin	Seawater, seaweed	Monthly, Quarterly
Cahore, Co. Wexford	Seawater, seaweed	Biannually
Carlingford, Co. Louth	Shellfish	Quarterly
Castletownbere, Co. Cork	Seawater, seaweed	Biennially
Clogherhead, Co. Louth	Fish, shellfish	Quarterly
Galway/Salthill, Co. Galway	Seawater, seaweed	Biennially
Greenore, Co. Louth	Seawater, seaweed	Quarterly
Howth, Co. Dublin	Fish, shellfish	Quarterly
Killybegs/Mountcharles, Co. Donegal	Fish, seawater, seaweed	Annually, Biennially, Biennially
Kilmore Quay, Co. Wexford	Fish	Annually
Woodstown, Co. Waterford	Seawater, seaweed	Biennially
N1 – Irish Sea, 53:25N 6:01W	Seawater	Annually
N2 – Irish Sea, 53:36N 5:56W	Seawater	Annually
N3 – Irish Sea, 53:44N 5:25W	Seawater	Annually
N4 – Irish Sea, 53:52N 5:14W	Seawater, sediment	Annually
N5 – Irish Sea, 53:53N 5:33W	Seawater, sediment	Annually
N6 – Irish Sea, 53:52N 5:53W	Seawater, sediment	Annually

Table 15. Radioactivity in seawater, 2009

Sampling Location	Month	Activity Concentration (mBq/l)	
		Tc-99	Cs-137
Greenore	Jan	-	16.84
	May	4.05	14.54
	Jul	4.18	16.74
	Oct	2.80	14.89
	Mean	3.68	15.75
Balbriggan	Jan	2.57	13.68
	Feb	5.18	13.26
	Mar	1.81	17.01
	Apr	4.87	16.88
	May	2.80	14.86
	Jun	5.82	15.55
	Jul	6.46	15.03
	Aug	2.27	11.79
	Sep	-	13.22
	Oct	2.79	13.72
	Nov	3.30	12.75
	Dec	1.48	10.22
Mean	3.58	14.00	
Cahore	Jun	1.08	7.52
	Aug	0.81	4.07
	Mean	0.95	5.79
Portrush	Oct	3.86	2.24
Larne	Oct	1.91	8.41
Ards	Oct	0.13	17.20
Irish Sea – N1	Aug	1.65	10.21
Irish Sea – N2	Aug	1.53	12.67
Irish Sea – N3	Aug	2.54	13.73
Irish Sea – N4	Aug	3.15	14.33
Irish Sea – N5	Aug	2.88	15.95
Irish Sea – N6	Aug	1.31	9.29

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

Table 16. Radioactivity in marine sediments, 2009

Sampling Location	Month	Cs-137 Activity Concentration
		(Bq/kg, dry weight)
Balbriggan	Oct	3.63
	Dec	5.91
	Mean	4.77
Carlingford	May	15.35
	Jul	14.22
	Oct	19.63
	Mean	16.40
Irish Sea – N4	Aug	47.70
Irish Sea – N5	Aug	68.39
Irish Sea – N6	Aug	29.05

Table 17. Radioactivity in seaweed (*Fucus vesiculosus*), 2009

Sampling Location	Month	Activity Concentration (Bq/kg, dry weight)	
		Tc-99	Cs-137
Greenore	Jan	-	3.50
	May	-	4.14
	Jul	-	3.62
	Oct	-	3.02
	Mean		3.57
Balbriggan	Jan	737	2.64
	Apr	296	2.57
	Jul	357	3.67
	Oct	476	2.23
	Mean	466	2.78
Cahore	Jun	-	1.21
	Aug	-	1.01
	Mean		1.11

Table 18. Caesium-137 activity concentrations in fish, 2009

Sampling Location	Month	Activity Concentration (Bq/kg, fresh weight)					
		Whiting	Cod	Plaice	Ray	Haddock	Mackerel
Clogherhead	Jan	0.30	3.83	0.05	0.58	-	0.09
	May	-	0.46	0.01	1.62	0.65	0.13
	Jul	-	0.91	0.12	0.56	0.08	0.16
	Oct	-	0.41	0.49	0.26	0.10	0.14
	Mean	0.30	1.40	0.17	0.76	0.28	0.13
Howth	Jan	-	0.13	0.04	0.15	-	0.08
	Jun	-	0.12	0.05	0.16	0.14	0.21
	Jul	-	0.12	0.04	0.68	0.05	0.12
	Oct	-	0.14	0.03	0.27	-	0.12
	Mean		0.13	0.04	0.31	0.10	0.13
Kilmore Quay (Celtic Sea)	Jun	-	0.79	0.28	0.11	0.08	0.23
Killybegs (Atlantic Ocean)	Sep	-	0.28	0.09	0.16	0.10	0.23

Table 19. Caesium-137 activity concentrations in shellfish, 2009

Sampling Location	Month	Activity Concentration (Bq/kg, fresh weight)			
		Prawns	Farmed Mussels	Oysters	Lobster
Carlingford	Jan	-	0.06	0.13	-
	May	-	0.10	0.15	-
	Jul	-	0.11	nd	-
	Oct	-	0.08	0.12	-
	Mean		0.09	0.13	
Clogherhead	Jan	0.05	-	-	-
	May	0.41	-	-	-
	Jul	nd	-	-	-
	Oct	0.52	-	-	-
	Mean	0.33			
Howth	Jan	0.09	-	-	-
	Jun	0.12	-	-	-
	Jul	nd	-	-	nd
	Mean	0.11			

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

Table 20. Technetium-99 and plutonium-238, 239 and 240 activity concentrations in composite fish and shellfish, 2009

Sampling Location	Species	Activity Concentration (Bq/kg, fresh weight)		
		Tc-99	Pu-238	Pu-239,240
Clogherhead	Fish ^a	nd	nd	nd
	Prawns	2.58	nd	0.002
Howth	Fish ^a	nd	nd	nd
	Prawns	1.99	nd	nd
Carlingford	Farmed Oysters	0.59	0.004	0.031
	Farmed Mussels	1.47	0.003	0.024

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

^a Cod, whiting, plaice, ray, mackerel and haddock

Table 21. Mean activity concentrations of artificial radionuclides in fish and shellfish landed at north-east ports, 2009

Species Type	Activity Concentration (Bq/kg, fresh weight)				
	Tc-99	Cs-137	Pu-238	Pu-239,240	Am-241 ^a
Fish ^b	nd	0.33	nd	nd	nd
Crustaceans (Prawns)	13.05	0.24	nd	0.002	0.007
Molluscs (Mussels)	11.13	0.09	0.003	0.024	0.018
Oysters	3.74	0.13	0.004	0.031	0.004

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

^b Cod, whiting, plaice, ray, mackerel and herring.

Table 22. Weighted consumption rates from Habits Survey^a

Consumer	Species	Annual consumption rate (kg)
Group A	Cod/Haddock	11
	Mackerel	10
	Plaice	3.5
	Ray	1.0
	Whiting	0.5
	Fish (composite sample)	26
	Prawn (Nephrops)	10
Group B	Mussels	20
	Oysters	5

Notes: ^a Source: Cefas [2008].

Table 23. Committed effective doses from artificial radionuclides due to the consumption of fish and shellfish landed at north-east ports, 2009

Radionuclide	Committed Effective Dose (μSv)			
	Critical Group A	Critical Group B	Notional Typical Consumer	Notional Heavy Consumer
Tc-99	0.081	0.154	0.012	0.048
Cs-137	0.139	0.031	0.067	0.332
Pu-238, 239, 240	0.005	0.177	0.007	0.003
Am-241	0.016	0.078	0.002	0.000
Total^a	0.24	0.44	0.09	0.38

Note: ^a Totals have been rounded to 2 decimal places.

Table 24. Committed effective dose from selected artificial radionuclides due to the consumption of fish and shellfish, 1982-2009

Year	Committed Effective Dose (μSv) Notional Typical Consumer
1982	13.80
1983	11.00
1984	9.40
1985	5.00
1986	3.80
1987	2.20
1988	1.40
1989	1.10
1990	0.94
1991	1.06
1992	0.74
1993	0.67
1994	0.51
1995	0.41
1996	0.34
1997	0.32
1998	0.32
1999	0.30
2000	0.26
2001	0.27
2002	0.17
2003	0.16
2004	0.17
2005	0.24
2006	0.16
2007	0.16
2008	0.09
2009	0.09

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).

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.

Secular equilibrium

Secular equilibrium occurs in a radioactive decay chain where the half life of the daughter radionuclide is much shorter than that of the parent radionuclide. The quantity of radionuclide B builds up until the number of B atoms decaying per unit time becomes equal to the number being produced per unit time; the quantity of radionuclide B then reaches a constant, *equilibrium* value

10 Radiation Quantities and Units

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)

Commonly used activity and dose unit multiples and sub-multiples

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

Appendix 1 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 (TID) as set out below in Table 1. A TID of 0.1 mSv/year represents less than 5% of the average effective dose normally attributable annually to natural background radiation. This Directive has been transposed into Irish law in Statutory Instrument 278 of 2007 [Ireland, 2007]. 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].

Table 1 – Parametric values for radioactivity from S.I. 278 of 2007

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

^a 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 278, 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.

The WHO gross alpha screening level of 100 mBq/l is based on the conservative assumption that all of the alpha activity is due to Po-210, which has the highest ingestion dose coefficient of the radionuclides considered by the WHO. However, it has been shown previously by Sequeira *et al.*, [1999] for Irish groundwater supplies that, where the gross alpha screening level of 100 mBq/l is exceeded, in most cases the gross alpha activity measurement is dominated by uranium. As can be seen from Table 2, the ingestion dose coefficient for uranium is approximately 25 times lower than for Po-210. Therefore, the approach taken by the RPII, where the gross alpha activity exceeds 100 mBq/l, is firstly to estimate the uranium activity concentration from the uranium concentration measured chemically. Where, on the basis of the indicative dose due to uranium and the residual alpha activity with the uranium subtracted, it can be shown that no combination of alpha emitters could result in a TID greater than 100 mBq/l, then the supply is deemed to be in compliance with the standard for TID.

Where it cannot be shown on the basis of the uranium measurements that the supply complies with the standard for TID then individual radionuclide concentrations are determined as necessary and the dose arising from each component is calculated. It should be noted that in accordance with the Drinking Water Directive the dose calculation should include contributions from all natural and artificial radionuclides with the exception of tritium, potassium-40, radon and radon decay products. The methodology applied by the RPII assumes 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. The ingestion dose coefficients used to calculate indicative doses are set out below in Table 2.

Table 2 – Radiological data used to calculate indicative doses for drinking water

Radionuclide	Ingested Dose Coefficient for Adults (Sv/Bq) ¹	Activity per radionuclide (mBq/l) equivalent to 0.1 mSv
Polonium-210	1.2×10^{-6}	117
Radium-226	2.8×10^{-7}	500
Thorium-232	2.3×10^{-7}	600
Uranium-234	4.9×10^{-8}	3000
Uranium-235	4.7×10^{-8}	
Uranium-238	4.5×10^{-8}	

Note ¹ Source: ICRP,1996



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