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The Radioactivity of the Seas Around Ireland

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Introduction

The radioactivity of Irish waters has long been a contentious topic. In 1998, Greenpeace declared that there was more plutonium present in the Irish Sea than at the Novaya Zemlya underwater nuclear weapons test site. [1]
This project seeks to investigate the current status of the waters surrounding Ireland, what radioactive isotopes are present there, and if these radioisotopes pose any harm to the inhabitants of Ireland.

Radiation Background

Radiation is the emission or transmission of energy in the form of waves or particles through space or through a material medium. Ionising radiation is radiation that has sufficient energy to ionise atoms or knock off electrons, creating ions. [2]

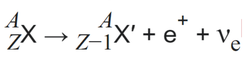

Fig 1. Beta decay

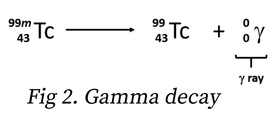

Fig 2. Gamma decay

This radiation is of particular concern because it can alter molecules within our bodies and increase the probability of the formation of cancerous cells. Due to this potential danger, the presence and abundance of radioisotopes are monitored in the waters around Ireland.

Marine Radiation

While there are radionuclides in the ocean produced from natural processes such as the erosion of rocks, the majority arise from artificial sources such as nuclear weapons tests, or nuclear reactors.

The presence of technetium-99 is often used as an indicator for the presence of nuclear waste because it is produced in bulk quantities in nuclear reactors due to it being a fission product of both uranium-235 and plutonium-239, while only occuring naturally in trace concentrations.

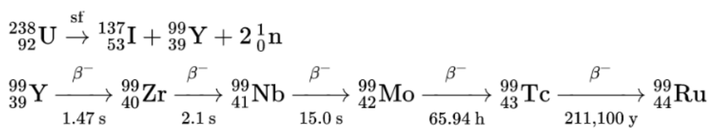

Fig 3. The production of Tc-99 by nuclear fission

According to the Radiological Protection Institute of Ireland, 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. [3]
Because the processes involved in removing fission products from nuclear plant waste are aimed at cationic species such as strontium-90 and caesium-137, technetium-99 often escapes into the water, as seen in Table 1.

These are measurements obtained from both the Irish Environmental Agency (EPA) and British Environmental Agency (EA) of radioactivity in the seaweed species of bladder wrack.
Nethertown is one of the closest monitoring points to Sellafield and shows a much higher quantity of both caesium-137 and technetium-99 than its counterpart of Ballagan in County Louth.
Both the south coast of Ireland at Dunmore East (Co. Waterford) and west coast of Ireland at Salthill (Co. Galway) show a much lower level of both of these elements in their samples.

Location	Radioactivity in Seaweed (Bq/kg)	
	Cs-137	Tc-99
Ireland - Ballagan 2014 Mean	1.20	137.90
Ireland - Dunmore East 2014 Mean	0.20	N/A
Ireland - Salthill 2014 Mean	0.12	N/A
United Kingdom - Nethertown 2016 Mean	2.50	1700

Table 1. Radioactivity of seaweed aross Ireland and the UK

Elements discharged	Sellafield Annual Discharge of Radioactive Materials (TBq)				
	2012	2013	2014	2015	2016
Tritium	1100	1400	1300	1500	2000
Caesium-137	3.60	3.20	2.60	3.10	3.70
Iodine-139	0.21	0.29	0.36	0.36	0.52
Strontium-90	1.20	1.10	1.60	1.60	2.00
Technetium-99	0.93	1.10	1.30	1.70	1.90
Plutonium-241	3.00	3.20	2.90	2.40	3.00

Table 2. Annual Discharge of Radioactive Materials from Sellafield (2012-2016)

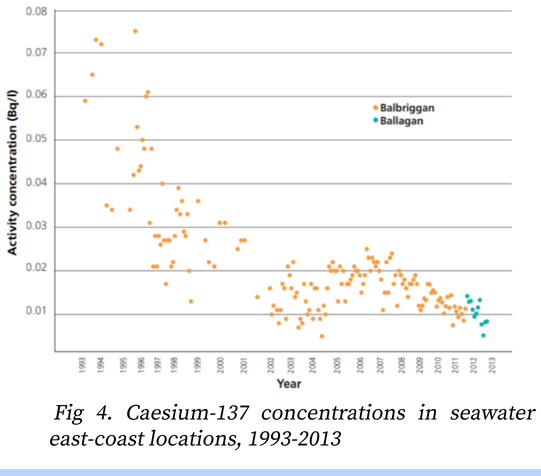

Fig 4. Caesium-137 concentrations in seawater from east-coast locations, 1993-2013

The amount of nuclear waste discharged into the Irish Sea by Sellafield has been a concern since it began operation, with organisations such as Greenpeace heavily criticising the management and disposal of the waste generated at this facility.
However, improvements in the treatment of this waste have greatly reduced the quantities of radioactive isotopes over the past few decades [Fig 4].

References

Radiation Measurements

Gamma-ray (γ-ray) spectroscopy is used to identify radioactive isotopes in water. In γ decay, to return an excited nucleon to a lower energy state, excess energy is released in the form of a quantized photon, known as a γ ray. Due to the discrete nature of nuclear energy levels, transitions between energy levels are fixed for a particular transition. Therefore, by measuring the energy of incident gamma-rays and comparing these measurements to the known γ-ray energy produced by specific radioisotopes, the emitter can be identified. [5]

Effects of Radiation

Exposure to ionising radiation has the same biological effects for the same amount of dose regardless of the source and the effects are cumulative over a person's entire life.
It is difficult to distinguish between cancer caused by other environmental, chemical, or biological factors and cancer that might develop from radiation exposure usually does not appear until 2-10 years after the exposure.

Radioisotope	Health Effects
Technetium-99* Half-Life: 215000 years	Concentrates in thyroid and upper GI tract - produces beta radiation which causes cancers, but is constantly excreted by the body once ingested
Tritium Half-Life: 12 Years	Treated by body the same way as regular water - produces beta radiation which damages cells, causing cancer
Caesium-137 Half-Life: 30 Years	Treated by body the same way as potassium and concentrates in muscles uniformly across the body - produces beta and gamma radiation, causing heavy cell damage and cancers
Strontium-90 Half-Life: 29 Years	Absorbed into the bloodstream and deposited into bone and soft tissue - beta decay in bone marrow causes tumours in bone marrow and other blood-producing organs
Plutonium-240 Half-Life: 6537 Years	Rarely a health hazard unless ingested or inhaled as it undergoes low energy beta decay. Absorption into the body is very low but exposure to high levels of plutonium to lungs, lymph nodes, liver and bones have caused decreased life spans, diseases of the respiratory tract and cancer but these effects are rarely seen in exposure to trace amounts.

*Not to be confused with technetium-99m, the shorter lived form of technetium-99, which due to its far shorter half life (6 hours) is used as a medical diagnostic tool.

Table 3. The health effects of radioisotopes

The vast difference in half-lives between isotopes is due to the varying stability of the atoms.

The dominant pathway for radiation exposure of the Irish population from the marine environment is via the consumption of fish and shellfish from the Irish sea.

Elements discharged	Annual committed effective dose (μSv)			
	Group A - consumed quantities of fish (26 kg)and crustaceans (10 kg) annually	Group B - consumed large quantities of molluscs (25 kg) annually	Notional typical consumer	Notional heavy consumer
Technetium-99	0.017	0.021	0.004	0.017
Caesium-137	0.094	0.094	0.053	0.260
Plutonium-238	0.017	-	0.003	0.013
Plutonium-239,240	0.099	0.003	0.010	0.042
Americium-241	0.007	0.210	0.008	0.031
Total	**0.23**	**0.33**	**0.08**	**0.36**

Table 4. The Annual committed effective doses from artificial radionuclides due to consumption of fish and shellfish landed at north-east ports, 2013

Even for the very highest consumption group, the effective dose of 0.36 μSv annually is still far lower than the average dose experienced on a 3-hour long plane flight, at 10 μSv, or a single CT scan at 7000 μSv. [Table 4]

Given that for a person in Ireland the average annual dose from all sources of radioactivity is 4037 μSv, the percentage coming from the marine environment makes up less than 0.01% of our yearly exposure.

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