THE RADIOACTIVE IRISH SEA

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The Irish Sea has gained a reputation for its degree of contamination by the radioactive wastes of the nuclear industry. To what extent is this justified?

Firstly, this man-made radioactivity has to be set in the context of natural radioactivity, because, like everything on the Earth, ourselves included, the sea, its sediments and life are radioactive [1,2]. This is mainly from radiopotassium (potassium-40), which emits beta particle radiation together with more penetrating gamma rays. In addition, uranium and thorium and their radioactive daughters are present, producing the more hazardous alpha radiation, as well as beta and gamma radiation. As Table 1 shows, seawater is naturally about as radioactive as our bodies, whereas sand and, especially, mud are much more so. (One Becquerel is one disintegration of an atom per second, or one radiation-producing event per second).

	Radioactivity/Becquerel per kilogram or litre	
NATURAL	**Total alpha**	**Total beta**
Human tissue	0.2	67
Irish Sea water	0.2	12
Mud	100	800
ARTIFICIAL	**Plutonium-239+240**	**Caesium-137**
Cumbria coast:		
Seawater – 1974		100
– 1988		0.5
Mud – 1974	16,000	8,500
– 1988	1,300	1,300
Fish – 1975	0.2	1,900
– 1988	<0.1	32
Mussels – 1975	40	289
– 1988	21	8
References:[1,2,5,7]		

Table 1 – Natural and artificial radioactivity in the Irish Sea.

Radioactive liquid wastes are pumped into the northeast Irish Sea from fourteen nuclear reactors, the nuclear fuel manufacturing plant at Springfields, Preston and the fuel reprocessing plant at Sellafield. The wastes originate from the normal operations of the plants and their discharges are authorised by the Department of the Environment and the Ministry of Agriculture, Fisheries and Food. Mostly, they contain artificial radionuclides (radio-isotopes) formed in the reactors. Quantitatively the most important, and the main discharge from the power stations, is tritium (an isotope of hydrogen), but this emits only very weak beta particle radiation and so is relatively insignificant. More significant are the fission products, consisting of a variety of different radionuclides, such as radiocaesium (caesium-137 and caesium-134) and radiostrontium (strontium-90), which are formed in the fuel containers by the 'burn up' of the uranium fuel and which are only released (normally!) when the containers are opened and the unburnt fuel reprocessed. These fission products emit gamma radiation and/or beta radiation. A third component in the discharges are the transuranic elements, especially plutonium and americium, which are 'bred' in the uranium fuel and, again, only released on reprocessing. This category is particularly important because of their alpha radiation production. In addition to these artificial radionuclides, natural radionuclides, from and including uranium, are discharged at above natural levels at the fuel manufacture and reprocessing plants.

This description of the overall composition of the discharges highlights the importance of the fuel reprocessing stage for generating radioactive liquid wastes and, in fact, Sellafield is responsible for about 80% of them, in terms of their radioactivity. The history of the radioactive contamination of the Irish Sea is, therefore, largely the history of Sellafield [3,4]. Discharges began in 1952, when the plant produced weapons plutonium for the Ministry of Defence, and continued at low levels until it began to reprocess fuel from the first generation of civil nuclear power stations, under the management of British Nuclear Fuels. This new programme resulted in increasing discharges, reaching a peak in the 1970's. Subsequent concern about the levels led to better waste management and investment in waste treatment plant and a decrease in levels to about 1% of the peak values. At the peak, a total of about ten thousand tera-Becquerels of beta/gamma activity and one hundred tera-Becquerels of alpha activity was discharged per year (one tera-Becquerel is a million million Becquerels). Figure 1 shows how the discharges of two

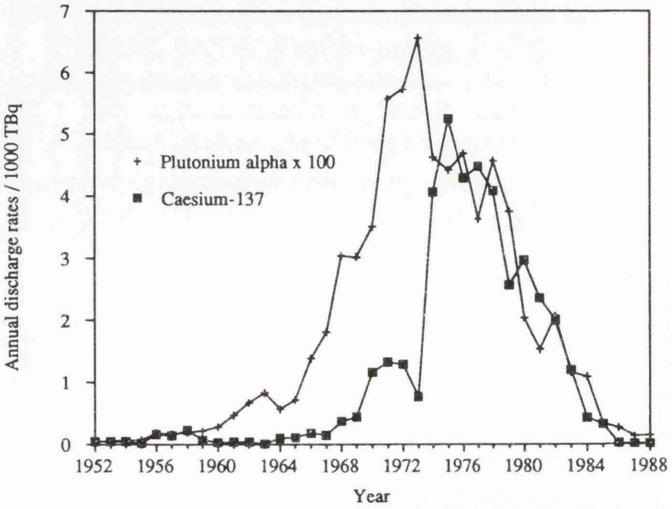

Figure 1 – Sellafield marine discharges (note change of scale for PU)

important components have varied, caesium-137 (beta/gamma radiation emitter) and plutonium-239 (alpha emitter) [3,4]. Whilst these look huge numbers, it only represents a tiny fraction (less than 1%) of the radioactivity of the processed fuel – the rest is still stored at Sellafield awaiting a socio-political decision about the disposal of intermediate and high level wastes. It is also about the same as the quantity of natural radioactivity that is carried in a year by seawater flowing between the Isle of Man and the Cumbrian Coast.

What happens to all this radioactivity? Its fate depends partly on the rate of radioactive decay of the radionuclide – its radioactive half-life, *i.e.* the time taken for radioactivity to decrease to a half its original value. It also depends on the rate of removal of the radionuclide by natural environmental or biological processes, *e.g.* by sea currents, and these can be described by half-lives, environmental or biological. Radioactive half-lives of the important radionuclides vary enormously, from years to a hundred thousand years, and environmental half-lives vary just as widely. Their fate can be illustrated by considering the behavior of caesium-137 (30 y half-life) and plutonium-239 (24,000 y half-life).

When radionuclides are discharged to the sea, two different fates await them – either they dissolve in the seawater or they become adsorbed onto the surface of sediment (sand and mud) particles suspended in the sea. The proportion of each radionuclide which follows these two paths depends on its chemical properties. Thus, more caesium stays in solution than is adsorbed on sediments, and the reverse happens for plutonium.

It is the deliberate intention of this form of waste management, whereby the wastes are discharged to the environment, that they become rapidly diluted and dispersed. This is, eventually, what happens to the radionuclides that are in solution, which are diluted and dispersed by the tidal and oceanographic currents (fig. 2) [5]. This both spreads them throughout the Irish Sea and, ultimately, transports them out of its northern end, around Scotland to the North Sea and into the North Atlantic, where they have been found as far away as Greenland. The currents are strong, so dilution is relatively rapid, and concentrations along the Lancashire coast are about 10% of those on the Cumbrian coast. The northerly flow is less strong and the environmental half-life of the water in the Irish Sea is about one year.

In the peak discharge years, levels of radiocaesium on the Cumbria coast were about a hundred times those of the natural beta/gamma emitter – radiopotassium. Since then they have declined to less than one tenth of the radiopotassium level (Table 1) [7].

Unfortunately, for the sediment-attached radionuclides, the desired dilution and dispersion occur much more slowly and less widely. Consequently, these radionuclides are being stored at relatively high concentrations in parts of the environment. Since radionuclides attach themselves to finer muddy sediments much more readily than sands, it is the behaviour of these muds in the Irish Sea which is important. Again unfortunately, mud deposits form the sea bed off the Cumbrian coast and these deposits have become the site of accumulation of high levels of sediment-attached

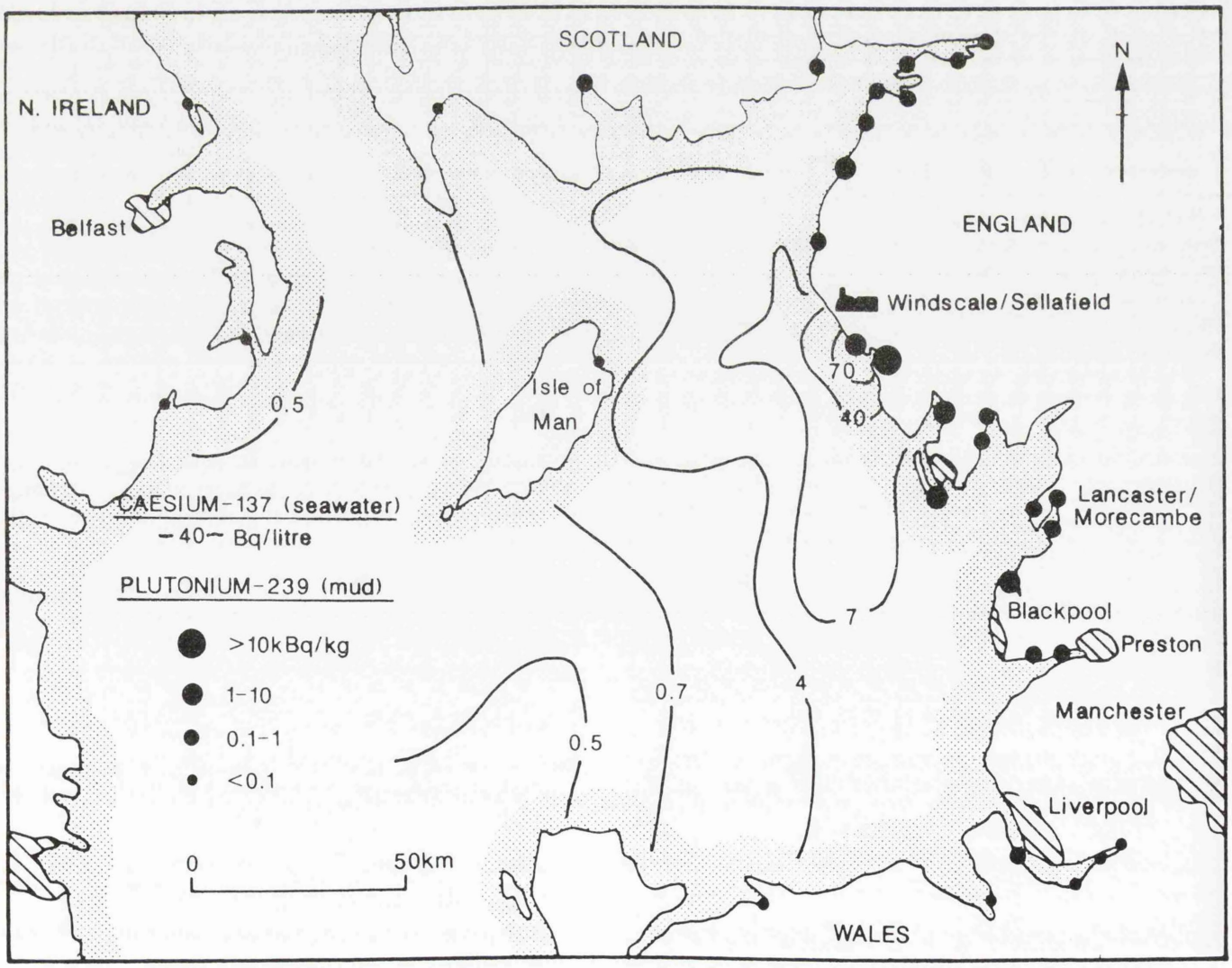

Figure 2 – Distribution of radionuclides in seawater (1974) and mud (1978)

radionuclides, including about half of all the plutonium discharged from Sellafield [6]. Interestingly, it appears that the bulk of the deposits is becoming contaminated by the burial of contaminated surface sediments by the burrowing activity of large marine worms and other organisms. Levels of plutonium-239 in these deposits have reached over a hundred times that of the natural alpha radiation emitters (Table 1).

Contaminated sediments are being spread around the Irish sea by the currents, albeit more slowly [5,7]. The more radioactive muds are found not only offshore but also along the coast in particular environments, especially in estuaries and harbours, where their presence is potentially much more significant because of the greater access to such areas by people. In the 1970's levels of plutonium, with alpha activities exceeding natural levels, could be found as far away from the discharge point as Liverpool (fig. 2) [7]. In these estuaries, where new sediment gradually builds up the deposit, the activity of the surface sediment has changed in keeping with the changes in the discharge levels. Thus, today, levels of artificial radionuclides on the saltmarshes are about the same as natural levels, whereas the more active sediments from the 1970's discharges are buried some tens of centimetres below the surface – where they can still contribute to radiation doses.

The contaminated deposits on the floor of the sea are not locked away but are slowly releasing contaminated sediment back into the water, as storms erode them, and they can then be transported shorewards. Thus, even if discharges were to cease, the long lived radionuclides (e.g. plutonium-239) in the coastal environments would be maintained indefinitely, at a certain level, by these offshore deposits.

The life in the sea will not only be exposed to the radiation from the contaminated water and sediments, but will also become contaminated itself. The microscopic planktonic organisms become contaminated by surface adsorption and also (zooplankton) by food consumption (ingestion), and for higher organisms – fish and shellfish – food is the main source. The level of radionuclides depends not only on the level in the sea but also on the degree of concentration of the activity by the organism, as a whole, and by particular organs within its body. In fish, the main contaminant in edible tissue is radiocaesium and the levels have reflected the changing discharge levels, falling from about 2000 Bq/kg in the 1970's to about 30 Bq/kg today (Table 1) [5]. In contrast, shellfish, which have a well known ability to accumulate toxic metals, also concentrate transuranic metals, with plutonium levels about 100 times higher in mussels than fish in the 1970's.

Is there reason for concern? Assessing the radiological hazard from the contaminated marine environment depends on identifying the pathways for the radiation exposure of people. A great deal of research has gone into trying to identify and quantify the characteristics of these pathways, which include such diverse routes for exposure as:

i) Ingestion of marine foods and foods from areas contaminated by tidal flooding and by windblown spray.

ii) Inhalation of sediment from dust blown from beaches and saltmarshes, and from areas contaminated by vehicles and feet carrying sediment from the intertidal areas, both outdoors (roads, yards, etc.) and indoors (houses, workplaces).

iii) External irradiation by gamma radiation from the ground, on beaches and saltmarshes, and from mud on skin (beta & gamma).

One of the more difficult aspects of these studies is not the measurement of the radioactive materials but, rather, in defining peoples' habits, i.e. foodstuff consumptions, time spent in contaminated areas etc. The aim is to define the worst case exposure for the, so called, critical group of people. Estimates of the doses from the radioactivity in the Irish Sea to critical groups in Cumbria are given in Table 2 [8,9].

Critical Group (no. of people)	Peak*	1980
INGESTION		
Shell fish eaters (10)	7	2.5 (0.3 1987)
Fish eaters (500)	1.2	0.5
INHALATION		
Marine spray (50)	0.1	0.03
Contaminated house dust	0.1	0.04 (1984)
EXTERNAL		
Intertidal areas (10)	1	0.45

*Estimates for mid 1970's, other values from references [8,9]

Table 2 – Doses to critical groups in Cumbria from the marine discharges

These dose estimates can be put into perspective by comparing them with the average UK dose from natural radiation of 2.2 milli-Sieverts per year or 'better' still, with natural critical group doses [10]. These critical groups are people exposed to high levels of radon gas in homes, with doses, for example, of over 100 milli Sieverts per year in granite areas in Cornwall and 70 milli Sieverts per year in limestone areas in northern England. Also, whilst the average medical radiation dose in the UK is 0.3 milli Sieverts, doses over a hundred times larger are received by individuals during treatment. Although the doses due to the radioactive waste discharges to the Irish Sea have been considered as a possible explanation for an enhanced childhood leukaemia incidence in coastal areas, other causes, both nuclear and non-nuclear industry related, have been proposed, including paternal occupational exposure [3,11]. At present, it seems unlikely that the overall consequences of discharging these wastes will be ever be clearly understood.

Meanwhile, the claim that the Irish Sea is the most radioactive sea in the world has to be reconsidered. Although the waters along the Cumbrian coast in the mid-1970's approached this level, the title clearly belongs now to the Dead Sea, with a total natural activity of 177 Becquerel per litre [2]. However, the Irish Sea remains distinguished from other seas by the amount of radioactivity stored in its sediments.

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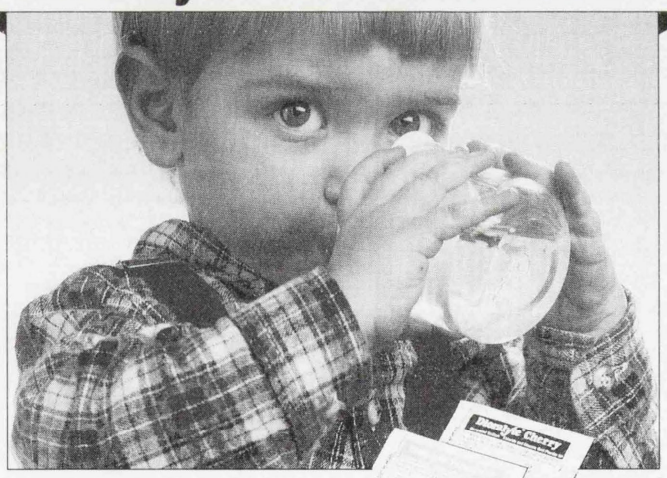

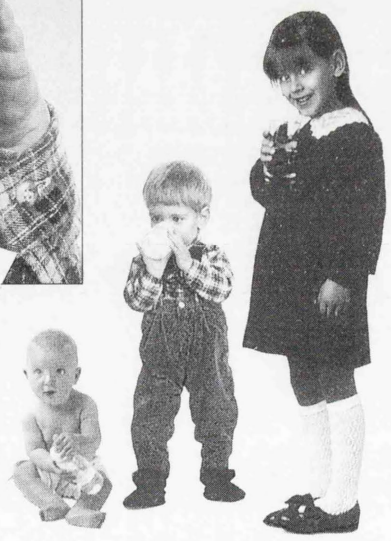

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