Back to the Land:

The Sea-to-Land Transfer of Radioactive Pollution

by

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While the British nuclear lobby have ceased to deny that they have made the seas around Britain the most radioactive in the world, they continue to insist that this is having no impact on the health of those who live or work on or near the sea. But research by the nuclear industry into the effects of the marine discharge of man-made radioactivity has been characterized by the use of inefficient technologies and mischosen sites for monitoring and analysis, and has been undertaken against a background of basic ignorance about the behaviour of radioactivity in the sea.

High incidences of childhood leukaemia found near the coastal nuclear plants at Sellafield, Dounreay and Hinkley Point have been linked to radioactive discharges from these sites. The report by the Independent Committee on Medical Aspects of Radiation in the Environment (Comare) into leukaemia clusters around Sellafield in North West England and Dounreay on the Northern coast of Scotland, decided that there was evidence that "some feature of the nuclear plants . . . lead to an increased risk of leukaemia in young people living in the vicinity of these plants."[1] But, the link is by no means clear-cut; indeed, if *conventional* dose-risk estimates are used, the *reported* levels of radioactivity released from these plants could not be responsible for the leukaemias. As the Somerset Health Authority concluded after their study of leukaemias around Hinkley: "Only if the assumed doses from Hinkley Point are drastically wrong (either by an under-estimation of the emissions or by under-estimation of the amount actually reaching people)", could there be a direct cause and effect relationship between the plant and the leukaemia incidence.[2]

But conclusive epidemiological studies of these clusters rely on absolutely sound data. There must be a definitive understanding of dose-risk estimates, the amount of radioactivity entering the sea and the behaviour of radioactivity in the marine environment, as well as an efficient and coherent programme of monitoring. Unfortunately for epidemiologists, legislators, inquiry inspectors and those who live near the coast, none of these conditions are being fulfilled.

For some 40 years, the British Government has turned logic on its head and allowed the nuclear industry to discharge radioactivity into the sea in complete ignorance of its consequences. The little knowledge that has been acquired about the dilution and dispersal of radioactivity in the sea has been gained only by monitoring the radioactivity after it has been discharged.

Understanding the Marine Environment

The nuclear industry has justified the discharge of radioactive liquid into the seas by claiming that the radioactivity would "dilute and disperse". To understand the dispersal and dilution of radioactivity in coastal waters there must be a thorough knowledge of the system of currents in the relevant sea areas. Yet the definitive *Atlas of the Seas around the British Isles*, published by the Ministry of Agriculture, Fisheries and Food (MAFF), admits that for all British waters "the main overall weakness [in the study of water column movement] is the lack of systematic, long term data collection in almost all areas".[3] For the Irish Sea, this lack of data means that the authors can say no more than "it would appear that more often than not there is a South to North flow to the West of the Isle of Man". Referring to the region to the East of the Isle of Man (in the vicinity of the nuclear installations at Sellafield, Chapelcross, Springfields, Capenhurst and Heysham) this definitive work says "the circulation shown for the region is still a matter for argument."

Knowledge of the residence time of pollutants in any given sea area is similarly vague. According to the International Council for the Exploration of the Seas, the fate of pollutants is dependent on the environmental conditions at the time of release *and for a few months afterwards*.[4] The large variables of wind, current and even river input spread over extended time periods, make estimations of residence time extremely unreliable.

After a large leak of radioactive crud into the Irish Sea from the Sellafield pipelines in 1983, site operators British Nuclear Fuels (BNF) admitted that nothing was known about how the radioactivity was likely to disperse. Following that incident, the Irish Sea Project, an independent research group, conducted a number of studies to test the potential movement of the water column and its associated radioactivity. These showed that radioactivity released from Sellafield could travel further and faster in the sea than had been previously guessed, and that such radioactivity might concentrate and remain in coherent masses over a period of months. These coherent masses could be trapped in certain types of coastal locations for even longer periods.[5]

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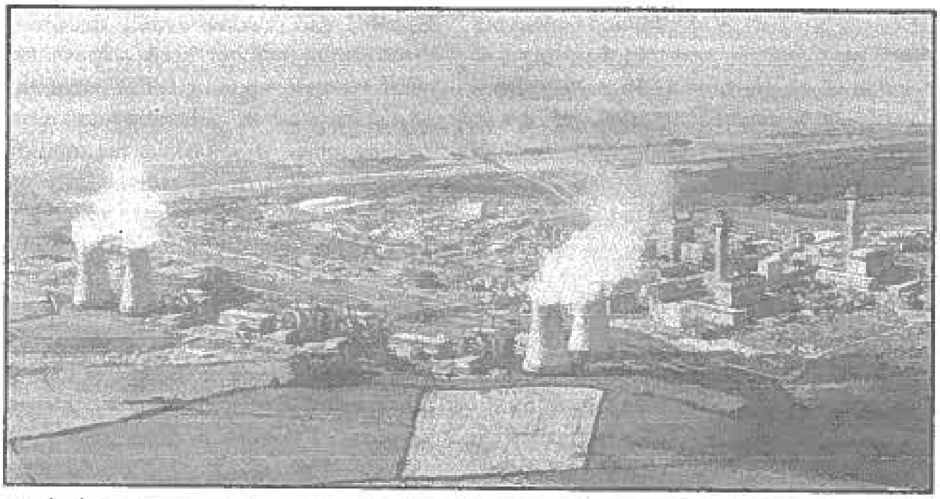
Incomplete Discharge Data

MAFF regularly produce an *Aquatic Environment Monitoring Report*, which contains what purports to be a definitive list of the discharges of liquid radioactive waste from UK nuclear establishments.[6] This data is far from complete.

It is inevitable that sites as complex as nuclear establishments will suffer from accidental leaks. The 1983 pipeline leak at Sellafield was only discovered because Greenpeace protestors were working off the end of the pipeline. BNF and the relevant government agencies were only able to make an approximate assessment of the radioactive contents of the leak. BNF representatives were unable to deny that there had been other such incidents in the past. Beach surveys that have taken place since 1983 make it quite plain that there is contamination on the Cumbrian coast from specific incidents that occurred in years other than 1983.[7]

BNF also discharges solid radioactive wastes into the Irish Sea, including pieces of contaminated work gloves, bits of highly radioactive bitumen (probably from the lining of the pipeline itself) and particles of radioactive stainless steel from nuclear fuel pins or reactor cores. Such items are not included in the computations for liquid radioactive wastes discharged from Sellafield, and since the dumping of solid wastes into the marine environment is currently subject to a moratorium, there is no official record of these wastes.

In February 1979, a serious leak of radioactivity was discovered at the Central Electricity Generating Board (CEGB) installation at Hinkley Point, Somerset. This was escaping via a site drain which was only inspected once every six months.[8] CEGB Hinkley guessed that the leak might have begun on the 8th or perhaps the 17th January. It was not until June that levels of radioactivity escaping from the drain were reduced to close to background levels. The leak may have released approximately 185 million becquerels of mainly caesium-137 onto the beach. No action was taken to clean up the contamination because it was felt that the natural washing action of the sea was sufficient to reduce the radioactivity. Incidents of this nature occur every year at British nuclear establishments, and because of bad site design and lax attitudes to on-site and pipeline monitoring, it is almost always impossible to obtain information on the duration and the radioactivity content of the leaks.



Sellafield nuclear reprocessing plant. A cluster of childhood leukaemias around Sellafield (formerly Windscale) cannot be explained by the reported radioactive discharges from the plant if conventional dose-risk estimates for low level radiation are used. However the official discharge figures are extremely unreliable, and neither the environmental behaviour of radioactive pollution nor its health effects are properly understood. (Photo: University of Cambridge)

There are several other unquantified inputs of man-made radioactivity into the seas around the UK. The Chernobyl plume, for instance, is thought to have deposited some 20,250 curies of radiation into the Irish Sea alone in 1986, and was responsible for an approximately 100-fold increase in radiation in Irish Sea shellfish in only a few days.[9] No attempt has been made to quantify the importance of Chernobyl-derived radioactivity entering coastal waters as a result of run-off from the contaminated highlands of Scotland, Ulster, North West England and North Wales in the years since 1986.

If the "one-off" Chernobyl plume can affect the seas in this way, then it is logical to assume that the regular gaseous discharges from UK nuclear stations are contaminating the seas. But the authorities will not monitor such sources, and have no intention of quantifying their importance. Other contributors to man-made marine radioactivity are the radioactive cargoes lost at sea, as well as the nuclear powered warships which routinely discharge at least six nuclides in significant quantities.[10] There are also "non-nuclear" sites that produce radioactive waste by-products which are flushed into the sea.

Plutonium-241

Plutonium-241, a beta-emitting nuclide, was originally thought to be unimportant in terms of human radiobiology and was consequently discharged into the sea in unlimited and unquantified amounts.[11] It is "guesstimated" that, up to the end of 1982, some 550,000 curies of this substance had been discharged from the Sellafield pipelines alone. It is now accepted that plutonium-241 presents a risk to human health in its own right, and, more seriously, plutonium-241 decays to produce the daughter product americium-241, which is both a beta- and alpha-emitter.[12] Americium-241 is considered to be 2.5 times more hazardous than the most dangerous of the plutoniums.[13] Americium accumulates in marine sediments and silts and in living organisms. It is particularly prone to being incorporated into seaspray and so transferred back to the land.

Americium is discharged from all nuclear stations, but in very small quantities. Because of the late discovery that americium appears in the marine environment as a result of plutonium-241 decay, limits have now been imposed upon discharges of both plutonium-241 and americium-241. In 1988, for example, the total discharge of americium (including that due to plutonium-241 decay) was approximately 45.5 curies. In comparison, it is estimated that americium production in Irish Sea silts resulting from the decay of historically discharged plutonium-241 will peak towards the end of the 21st century, by which time plutonium decay will be contributing approximately 1,300 curies a year into the Irish Sea.[14] On the basis of current authorizations for Sellafield, this will be equivalent to having another 14 reprocessing plants discharging americium into the Irish Sea.

Added to the industry's inefficiency at data collection is a certain economy with the truth over known releases. Sir Douglas Black, for example, when preparing

Comare's report into childhood leukaemia in West Cumbria, was told that only 400 grams of uranium were discharged from Sellafield between 1952 and 1955. It was later revealed by two scientists who had worked at the site in the 1950s that this figure was at least 40 times too low.[15]

Behaviour of Marine Radioactivity

Supposedly "diluted and dispersed" radioactivity is reconcentrated in the marine environment by a number of mechanisms. Some nuclides, such as tritium and caesium, dissolve and become evenly distributed throughout a water-body. These two nuclides make up the greatest percentage of discharges from generating and reprocessing sites. At Sellafield, the total discharge in 1988 of all radioactivity was 1914 Terabecquerels (TBq) of which 1724 TBq was tritium.[16] Tritium is a beta-emitting nuclide which is assumed by the nuclear industry and its regulators to be of little importance to human health. However, tritiated water behaves just like any other water, the human body absorbs 100 per cent of tritium in water through the skin, and 100 per cent of tritium in water or water vapour is inhaled. Tritium reconcentrates in the human body, partic larly in fat cells. In laboratory studies (animals, it has been shown to cause : increase in lymphosarcomas, as well as . important level of incorporation into DN/ RNA and proteins.[17,18] Tritium is difficu and expensive to monitor in environme tal samples so neither the electricity ge erating authorities nor the regulatir agencies undertake such monitoring.

Caesium on the other hand is easy ar cheap to monitor. Like tritium it is ubi uitous throughout the marine environme which it has entered as a result of weapo test fallout, and accidents and gaseous ar liquid discharges from nuclear plant Monitoring by the authorities and ind pendent groups has proved that caesiu reconcentrates in the marine food cha and in estuarine and marine sediments, ar blows ashore with seaspray and water v: pour.[19] Caesium from the sea can be four in grass and lichens at least 10 miles inlar in South Wales and even further inland : Cumbria.[20] Caesium reconcentrates in tl muscle tissue and reproductive organs (marine and land mammals, and is tran: ferred via mother's milk to offspring (wh prior to weaning show much higher bod burdens of caesium despite their short exposure time).[21] The laboratory studie on tritium and the observed behaviour (caesium in the environment (especially i the mammalian system) indicate that th impact of these nuclides on DNA, RN/ proteins, reproductive organs and mother' milk may be relevant to the induction (childhood leukaemia.

Sediment Behaviour

All nuclear plants discharge alpha-emittin actinides — the plutoniums, americiur and curium.[22] Sellafield makes the majc contribution to British waters; its fingerprir can be detected along the Irish Sea coast: down the North Sea as far as the Blackwate Estuary in Essex and even as far away a Scandinavia.[23]

It was originally assumed that actinide would be trapped in the sediments off th end of the discharge pipelines. However i emerged at the Windscale (as Sellafiel was formerly known) Inquiry in 1977 tha the contaminated sediments off the end o the discharge pipelines were subject to : host of phenomena including dredging trawling, earthquakes (several in the Irisl Sea over recent years) and storms.[24] B 1989, the responsible authorities had onl just begun to construct models of marin

Element	Enrichment Factor
Pu 238	291
Pu 239	347
Pu 240	347
Am 241	583

***Table 1:** Enrichment factors for actinides due to bubble burst in open sea 10km from Sellafield pipelines.*

Source: Walker et al., 'Actinide Enrichment in Marine Aerosols', Nature 323, 6084, 11 September, 1986, pp.141-142.

sediment movements; models which do not include any input for specific storms, but only for an "average effect".[25]

The "averaging" of such data irons out the peaks of radioactivity in the environment. Such a peak occurred in February 1990, when extreme storm conditions breached sea defences and deposited hundreds of tonnes of marine sediment in the streets and houses of the town of Towyn in North Wales. Out of 14 samples of this sediment analyzed for radioactivity, eight contained Sellafield-derived actinides at levels which exceeded by more than 10 times the official levels at which further investigation is required.[26] This event has certainly led to the inhalation and possibly the ingestion of actinides. Yet, as far as the official data gatherers are concerned, it remains unrecorded.

When seawater samples from British waters are analyzed for alpha radiation, it is found that almost all of the americium and plutonium present is in the form of radioactivity "adsorbed" or bonded to the surface of sedimentary particles suspended in the water column. The heavier particles will eventually sink to the seabed where they can remain stable for sometime, but are subject to disturbance as described above. Lighter particles will travel through the water column for longer periods and are available for sedimentation out into mud flats and estuarine silts and salt marshes. Because finer particles have a relatively greater surface area available for the adsorption of radioactivity, samples from the silts of the extreme landward end of an estuary will typically have 10 per cent more radioactivity than samples from its seaward end.[27]

Microlayers and Aerosoling

As liquid waste from nuclear installations tends to be warmer than the ambient sea temperature, discharge plumes tend to rise towards the sea surface. The plumes' contents are therefore available for incorporation into the sea surface "microlayer". The microlayering phenomenon occurs when the sea surface layer, only thousandths of a millimetre thick, becomes enriched with very fine sedimentary material. When the sedimentary particles are exposed to radioactive contamination, the microlayer concentrates the surrounding levels of radioactivity. Irish Sea microlayers, for instance, have been observed to be enriched with plutonium and americium by factors of four to five.[28]

Microlayers themselves cause a second set of phenomena called "aerosoling", which allows for the transfer of radioactive materials from the sea to the air by a number of mechanisms including bubbling, evaporation, and wave break in the open sea and in the surf line. Seawater-to-air aerosoling enrichment factors are enormous. The maximum such enrichment observed in the open sea was recorded 10km off the Sellafield pipelines (*see* Table 1). These enrichment factors were observed as a result of "bubble burst". The breaking of waves along the shoreline has been observed to produce aerosols with an enrichment factor of 812 for americium.[29] There do not appear to have been any studies that have considered the enrichment factor potential of evaporation or wave break in the open sea, however it has been calculated that algal blooms in the open sea may concentrate plutonium by factors of up to 26,000.[30]

The CEGB have dismissed the microlayering and aerosol phenomena as being of little importance, insisting that delivered doses from such sources could not represent more than one per cent of International Commission on Radiological Protection (ICRP) limits.[31] The CEGB base this claim on a document published in 1981 using ICRP limits of five millisieverts (mSv).[32] However by 1989, when the CEGB made this assertion, the ICRP limit had been revised downwards to 1mSv, while the UK National Radiological Protection Board (NRPB) was issuing "interim guidance" that the limit should be cut to 0.5mSv.[33] The CEGB's claim refers only to aerosol enrichment factors by bubble burst in the open sea, and completely ignores the even greater enrichment factors observed at the shoreline.

Silt Monitoring

The Ministry of Agriculture, Fisheries and Food, the Department of the Environment, Nuclear Electric (the state-owned company which has taken over the running of the CEGB's nuclear plants), British Nuclear Fuels and the UK Atomic Energy Authority are responsible for monitoring man-made radioactivity in the marine environment. But if there is no understanding of the dispersal patterns of man-made radioactivity in the sea, then there can be no proper assessment of where to monitor.

The village of Garlieston is the only official monitoring site on the coastline of Wigtownshire in South West Scotland. It is on the evidence from this *one* site that MAFF draw their conclusions about the effect of radioactivity on the population of over 120 miles of coastline.[34] Samples taken from silt deposits in the Cree estuary by the environmental group Radioactive Survey for the People of Wigtownshire, gave a maximum reading for americium of 715 becquerels per kilogram (Bq/kg). The maximum activity for the same nuclide a few miles away in the stony-bottomed harbour at Garlieston was only 40.5 Bq/Kg. A similar pattern was noted for plutonium and caesium.[35]

It is therefore likely that some people on the Wigtownshire coast have for many years been exposed to much higher levels

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of radioactivity than official reports indicate. Despite having been fully aware of both the Cree/Garlieston discrepancy and evidence from the Institute of Oceanographic Science that estuaries and mudflats are likely to have the highest marine radioactivity levels, MAFF and the other relevant authorities have failed to adjust their monitoring practices.[36]

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Monitoring of Sea-to-Land Transfer

A study of the UK Atomic Energy Authority's programme of monitoring sea-to-land transfer shows firstly that plutonium and americium are airborne throughout the UK coastal environment; and secondly, that the UKAEA's work dismally fails to give accurate data on the true extent of the sea-to-land transfer of actinides. Most of the Atomic Energy Authority's research has relied on the use of continuous high volume air samplers and muslin screens. Both the technology and the methodology are deeply flawed.

The muslin screens are usually deployed to catch airborne particles on or near the surfline of open coasts. The high volume samplers, which draw air through an aperture positioned one metre above ground level, are sited inland of the screens. Because of the many inaccuracies inherent in the use of muslin screens (especially in winds above force five, when the material in the screen stretches and its porosity increases) a 1982 UKAEA report concluded that they should be used "only as a qualitative tool to compare relative concentrations of actinides in seaspray".[37] Despite this warning, muslin screens have been used repeatedly in recent studies by the UKAEA into human exposure by inhalation to actinides coming off the Irish Sea.

Muslin screens were first used in the early 1980s because the high volume air samplers are "not particularly suited" to sea-to-land transfer studies, "and [are] believed not to be very efficient for the relatively large particles" which may be found in seaspray.[38] Yet, the UKAEA responds to criticism over the use of the muslin screens by arguing that the results from the screens are supported by the use of the high volume air samplers.

The 1982 UKAEA report states that the "enriched spray front" at the shoreline in force five winds is about 10 metres high (the muslin screens are only one metre high and are placed one metre above the ground), and that the behaviour of the spray front as it moves inland has not been studied. Stronger winds will undoubtedly increase both the size of the front and its inland penetration, yet the only inland monitoring is with air samplers which are unreliable for measuring large particles.

Inland Penetration of Seaborne Radioactivity

There is, however, ample evidence that seaborne, man-made radioactivity is penetrating inland and entering the human food chain. In South West Wales, independent analysis by Dyfed County Council and the Irish Sea Project has found caesium-137 from the Sellafield sea discharges on pasture grass and tree lichens more than 10 miles from the coast, presumably having been blown inland in strong winds.[39] A pre-Chernobyl study from the Hebridian island of Uist showed that caesium-137 contamination was present in almost every type of island-produced food. Islanders who consumed a high proportion of local food had higher burdens of caesium than those who were eating imported food.[40] Seaborne radioactive contamination of surface soil and vegetation has been found in the saltmarshes at Ravenglass near Sellafield, with the subsequent reconcentration of caesium-137 and plutonium in the carcasses of sheep that had grazed the area.[41]

In spite of evidence that sea-to-land transfer is affecting crops grown up to 10 miles and more inland from UK coasts, the authorities insist that the only pathway for the ingestion of seaborne radioactivity is through the consumption of seafood.[42] They also disregard the certainty that the population of the coastal zone is breathing in potentially significant doses of radioactivity, particularly in periods of strong winds.

Risk and Dose Estimates

It is central to the nuclear industry's case that it cannot be responsible for the leukaemia clusters around its sites, that there is an adequate understanding of the health effects of exposure to low-level radiation. This is far from being the case.

During the course of the public inquiry into the construction of a third reactor at Hinkley Point, R.H. Clarke of the UK National Radiological Protection Board (NRPB) stated that there was sufficient evidence to recommend a *tenfold* reduction in the current legal annual radioactive dose limit to members of the public.[43] This is of little surprise to anti-nuclear campaigners, because it accords well with the history of radiobiological protection, which has been a long saga of steady reductions in the so-called "safe and acceptable" dose limits.

In 1952, the "safe and acceptable" public dose limit was set by the International Commission on Radiological Protection (ICRP) at 15mSV per year. Five years later this was reduced to 5mSv; in 1986 it was downgraded again to 1mSv. The following year the NRPB gave "interim guidance" that exposures should not be allowed to exceed 0.5mSv per year. Each of these limits was considered in its day to be erring on the side of "safety and acceptability". People born before 1957 were legally allowed to receive doses 30 times greater than those recommended by the NRPB in 1987 — a recommendation which was only an "interim guidance". It is clear that the NRPB are fully aware that there is enormous ignorance about the impact of radioactivity on humans.

A Continuing Experiment

In 1958, John Dunster of the UKAEA openly admitted that the authority had intentionally discharged "substantial amounts of radioactivity" into the Irish Sea to monitor how it would behave in the marine environment. Dunster stated: " . . the aims of this experiment would have been defeated if the level of radioactivity discharged had been kept to a minimum."[44] This experiment is continuing, although it is being grossly mishandled and the resulting data is totally inaccurate.

As the National Radiological Protection Board and the Government press ahead with research into the medical aspects of radiation, the time is ripe for a review of the "experimental" discharges of radioactivity. This would allow the Government to reconsider the safety aspects of marine discharges at the same time as they conduct their promised financial review of the nuclear industry in 1994. If this does not happen, the signs are that after 1994 the industry will be allowed to expand further, in almost complete ignorance of the realities of seaborne radioactivity and its effects on human health. This is what has been happening since the birth of Britain's nuclear industry. There is no need for this to continue.

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