

The Management of Nuclear Waste

FOREWORD

This is one in a series of briefing notes prepared by SONE, in consultation with scientists and engineers, on controversial energy topics. Arguably, none of these has generated more myths and scare stories than nuclear waste.

This briefing sets out the facts and puts them in perspective. It explains the nature of nuclear radiation and of the waste created by nuclear operations, how these wastes have been handled for more than 50 years and what now needs to be done to cope with a surprisingly small residue.

In the process, the briefing demonstrates:

1. there is no technical problem in handling various kinds of nuclear waste in the short, medium or long-term.
2. after 500-600 years the radioactivity of the most irradiated waste will have decayed to the relatively harmless levels found in nature in the form of uranium.
3. nuclear operations are responsible for only a tiny part of the radioactivity or radiation we experience in our daily lives – and up to 140 times less than is created by medical treatments.
4. the extent to which nuclear's so-called "Green" opponents have used nuclear waste as a scare tactic to try to stop the development of nuclear power, even though it emits next to no greenhouse gases; this begs the question as to whether or not they are serious about trying to contain climate change.

Radioactivity/Radiation - What is it?

Radiation is a fact of nature from the dawn of time. It is defined as the emission of radiant energy as particles or waves and occurs in various forms – e.g. heat and light. This note is concerned with only one particular form of radiation: **ionising radiation**. This consists of particles, X-rays or gamma rays that produce ions – electrically charged atoms or groups of atoms – in whatever they pass through. Consequently, it is necessary to take precautions where people may be exposed to ionising radiation.

Radioactivity is the process by which the atoms of some elements disintegrate and emit ionising radiation.



Exterior of waste encapsulation plant at Sellafield

There are many naturally-occurring elements which do so, including uranium (found in the form of ores and just about as prevalent as tin in the Earth's crust), radon (a gas), and many radioactive forms, called radioisotopes, of non-radioactive elements. Artificial radioisotopes can be produced by inducing changes in non-radioactive elements, generally in nuclear reactors.

Whether natural or artificial, they share two properties. One is their radioactivity – i.e. the more or less rapid disintegration of unstable atoms. The other is their half-life, as it is called – the time in which the strength of a radioactive source decays to half its original value.

Half-lives vary enormously. Uranium-238 has a half-life of 4.5 billion years but some, such as lithium-5, have a half-life measured in microseconds or even less. Those with a long half-life emit low amounts of radiation whereas those with short half-lives emit higher amounts, though, of course, over a shorter period.

Half-life alone is not a measure of the relative danger from a radioactive element. For example, potassium-40, a naturally occurring element in our bodies, has a half-life of 1.3 billion years but its concentration is so low that it poses no danger to health.

The extent to which we are exposed to natural radiation varies widely even within a country. Areas with a granite base – e.g. parts of Scotland and Cornwall - may emit at least twice as much radiation as the Home Counties, which are built on chalk. In Kerala, India, with its thorium sands, natural radiation can be as much as ten times that in London. There is no evidence of any ill-effects from these higher levels.

This table shows the sources of radiation in Britain:

Source	%
Radon and thoron gas seeping from the ground	50.0
Medical X-rays	14.0
Gamma rays from rocks and soils	13.5
Cosmic (from outer space)	12.0
From chemicals within our bodies (e.g. potassium)	10.0
Fall-out from nuclear weapons tests and Chernobyl	0.2
Occupational (medical and industrial)	0.2
Waste from nuclear industry	<0.1
Radioactive products	<0.1

In other words, 85 per cent of all the radiation we absorb as ordinary citizens occurs naturally - and increasingly from air travel since radiation from outer space rises with altitude. Medical treatment provides virtually all the rest – 70 times as much as that arising from nuclear tests and the Chernobyl disaster in the Ukraine in 1986, and up to 140 times as much as from the British nuclear industry.

Types of radiation

There are three main types of ionising radiation – alpha, beta and gamma. Depending on the dose, each can be damaging to health and therefore people have to be shielded from excessive exposure. Since they have different penetrations, the amount of shielding required varies – alpha rays can be stopped by an ordinary sheet of paper or plastic bag and beta by a sheet of aluminium foil. Gamma rays need a block of concrete, lead or steel. The thickness of the shielding is dictated by the density of the material used, the intensity of the source and the closest approach of an individual to that source.

The prime objective of managing nuclear waste is therefore to ensure that those working in the nuclear industry and the public are properly protected from the radiation being emitted by the materials used in the course of nuclear operations.

The British nuclear power industry's record is enviable. There is no recorded case of a death resulting from a radiation accident in the whole of its 50 years' operation.

It is often said that 'no level of radiation is safe'. The reason for this is that the likelihood of radiation causing cancer or hereditary effects is related to the dose and its rate of absorption – the larger the dose the greater the risk and the smaller the dose the smaller the risk. For precautionary reasons, it has been assumed that there is an ever decreasing, but still positive risk, as the dose approaches zero, and that the risk is greater if the exposure is brief than if the dose is accumulated over a long period.



Low level waste repository at Drigg in Cumbria



ILW grouted drum (encapsulation)



Intermediate level waste (ILW) store at Sellafield

As might be expected when most of the radiation absorbed by people is from nature, there is no evidence for this. Indeed, the precautionary linear no threshold (LNT) theory, as it is described, is contradicted by the hormesis theory which, loosely translated, argues that a little radiation does you good in the sense that, as with other toxic substances, small doses can stimulate the immune system. The issue is the subject of much scientific debate.

Nuclear waste - What is it?

Nuclear waste is radioactive waste (radwaste) generated by military, medical, industrial, research and civil nuclear power and its related nuclear operations. Not all of it can properly be described as waste. 'Spent fuel', for example, taken from nuclear reactors can be reprocessed to recover 96 per cent of the uranium, plus a small amount of plutonium, for re-use as new nuclear fuel. As uranium prices rise with worldwide development of nuclear power, reprocessing will become an increasing feature of the nuclear industry.

There are three categories of nuclear waste and more than 90 per cent of it is only slightly radioactive. This is called **low-level waste (LLW)**. It consists of slightly contaminated materials such as air filters, paper, rags, tools and clothing containing small amounts of mostly short-lived radioactivity. It does not require shielding during handling or transport and can be disposed of by shallow burial. Its volume can be reduced by compaction or incineration. Most LLW in the UK is held at an engineered land burial site at Drigg, a few miles from Sellafield in Cumbria. This site is expected to be full by 2050. While accounting for the vast bulk of nuclear waste

across the world, LLW represents only one per cent of the total radioactivity in radwaste.

The second category, **intermediate-level waste (ILW)**, is about 1,000 times more radioactive than LLW and requires remote handling and shielding by lead, concrete or water to give protection against the most penetrative radiation from gamma rays. It takes the form of metal cladding from fuel rods, resins, chemical sludges and contaminated materials from the decommissioning of old, retired reactors and comes from both military and civil nuclear operations, R&D establishments, hospitals and industry. It is immobilised in concrete or bitumen inside special steel drums and stored where it arises until longer-term disposal is available. ILW represents about six per cent of the total volume of nuclear waste generated and about four per cent of total radioactivity.

The third category is **high-level nuclear waste (HLW)**, which is about 1,000 times more radioactive than ILW. It consists mainly of products resulting from nuclear fission – the process that produces the heat to generate steam to drive turbines in power stations. These products have widely differing half-lives and include actinides with very long half-lives that are created in reactors by neutron bombardment of uranium. In the UK much of the HLW comes from the reprocessing of 'spent fuel', mainly at Sellafield. It differs from LLW and ILW in that it produces substantial amounts of heat. It is stored for a time as liquid in water-cooled tanks and then vitrified – that is, cast into glass blocks – to immobilise the waste and reduce its volume while the greater part of its heat-generating capacity decays. These glass blocks are kept in ventilated stores for at least 50 years while they cool.



Aerial view of SFR, Sweden's underground repository for the final disposal of low and intermediate level waste



Rock vault in SFR divided into shafts. Here, intermediate level waste is kept in drums or moulds (containers made from concrete walls). When the shafts are full, they are sealed with concrete blocks. This is done by remote controlled cranes



Placement of container in rock cavern in SFR



Transport underground in SFR

The only 'problem'

It will now become clear that the only "problem" associated with nuclear waste is where to store ILW and HLW long term.

More than 20 years ago, the industry reached its preferred conclusion: deep disposal in a vault drilled into a stable rock formation about 500 metres underground.

This option was recommended in 2006 by the Committee on Radioactive Waste Management (CoRWM), advising the Government. Action is now awaited from the Government and the Nuclear Decommissioning Authority, which has, among other things, responsibility for the disposal of long-term wastes.

In short, the disposal of nuclear waste is not a scientific, engineering, technological or financial problem – as nations such as Finland and Sweden are demonstrating. It is a political problem and in Britain political action on designating a site is overdue.

How much waste?

The popular impression that has been assiduously cultivated is that Britain is awash with nuclear waste and does not know what to do with it. This is nonsense. Indeed, the nuclear industry – even broadly defined – produces little more than **one per cent** of all the chemically toxic waste generated in the UK each year. And modern designs of nuclear power reactor produce one-tenth of the waste currently generated by Britain's first and second generations of reactors – Magnox and AGR – which are being closed on grounds of age.

This puts in perspective the CoRWM claim that there is enough nuclear waste in Britain without a long-term strategy for its disposal to fill the Royal Albert Hall five times over. To achieve such a figure requires estimates to be made of the waste arising in future and that in turn requires certain assumptions to be made. But even if that were the amount in store today, around 94 per cent of it is LLW, which can - and is - disposed of by shallow burial.

Types of radiation

In fact, the records show that so far, after 50 years' nuclear generation of electricity – and taking in everybody else's dirty washing from military, medical, industrial and research establishments – there is barely enough to fill just ONE Royal Albert Hall.

The figures, taken from a CoRWM report in 2004, show the following

Accumulation after 50 years:

This 50-YEAR total of 74,400 cubic metres contrasts sharply with the 4 MILLION cubic metres of chemically toxic waste produced ANNUALLY in the UK.

Source	Current quantity cubic metres
Sellafield and Calder Hal	48,000
Magnox stations	11,800
UKAEA Dounreay	5700
UKAEA Harwell	1700
UKAEA Windscale	200
Aldermaston	2000
Submarines	900
AGR stations	2700
Others	1400
Total	74,400

The volumes of nuclear waste arising each year to 2030 are officially put as follows:

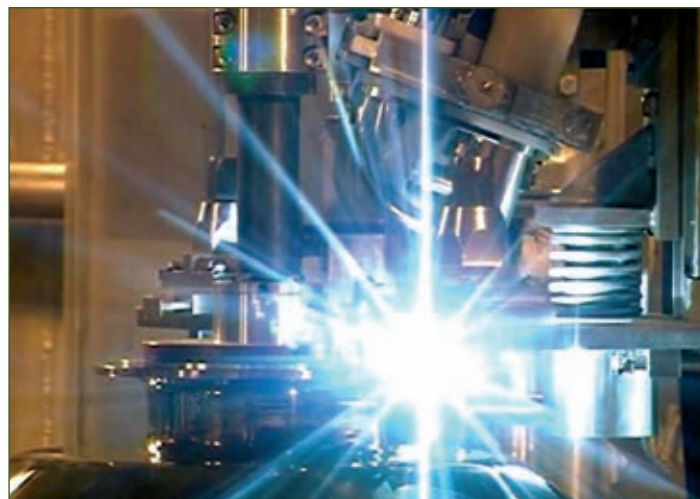
Level	Cubic metres/yr
LLW	40,000
ILW	5,000
HLW	70

Wider context

To put the nuclear industry's waste production in wider context, we know from Government statistics that the UK generated 330.4m tonnes of mostly inert waste in

2002-3 and that the construction industry (122.1mt), mining and quarrying (95.9mt) and households (30.9mt) produced 75 per cent of it.

Convert that to volume and we also know that, while the rest of industrial and domestic activity produces enough waste every year to bury Westminster from Victoria Station to County Hall out of sight, the nuclear industry produces only the equivalent in ILW of a row of buses and a mere taxi-full of HLW.



Remote welding of vitrified product container lid after filling

Managing HLW waste

Obviously, the management of HLW presents the most stringent task. It has to be treated before disposal and is vitrified for ease of handling, transport and storage in corrosion resistant canisters. In reprocessing, the 'spent fuel' is dissolved in nitric acid, the uranium and plutonium extracted, and the remaining liquor contained in stainless steel tanks equipped with cooling systems until it is dried and vitrified. The containers are held for anything up to 50 years to allow radioactivity and heat to decay.

Some idea of how the volume of nuclear waste can be reduced is illustrated by the treatment of Magnox and AGR fuel rods. A tonne of Magnox fuel contains 52 litres of fuel rods that end up as 15 litres of vitrified glass and the 92 litres of fuel pins required for a tonne of AGR fuel reduces to 44 litres on vitrification.

Overseas contracts

BNFL's reprocessing contracts with overseas customers have, since 1976, included options for the return of wastes and, in 1986, the Government admitted the possibility of waste substitution – e.g. returning HLW in lieu of ILW but with the same level of radioactivity. The DTI approved of this in 2004. This meant that the return of overseas waste could be completed ten years earlier, with a six-fold reduction in the number of shipments. The effect was to increase the amount of LLW and ILW retained in Britain, but not the radioactivity.

The cost

The effects on the cost of generating electricity from the management of waste from nuclear power stations is very small - so small, in fact, that it is generally subsumed within overall fuel costs.

Moreover, nuclear is unique among the methods of generating electricity for reflecting the cost of its environmental impact in the current price of power supplied through the National Grid. Around four per cent of the price paid by the consumer for nuclear-generated electricity has long been and continues to be set aside to cover waste management and also decommissioning (see the separate SONE briefing on decommissioning).

For the future, for example, costs have been worked out for a programme of 10 new PWR stations - the Sizewell B type - from which the 'spent fuel' would be stored for many decades before final treatment by either direct disposal (with all the 'spent fuel' becoming HLW) or reprocessing to recover uranium and plutonium (where only the fission products would become HLW).

The income required to be set aside during a station's 50-60 year operating life to fund the necessary facilities (surface stores, vitrification or 'spent fuel' encapsulation plants, and deep disposal) represents less than 0.1 pence/kWh of generating costs - in other words, about four per cent of the total price per unit.

This 'green' provision by nuclear power should be taken into account when comparisons are made of the economics of the various methods of electricity generation.

Environmental impact

As with all industries, standards governing the safe operation and environmental impact of the nuclear industry have improved over the years. In its various processes and at its plants, it has always sought to comply with the prevailing requirements. Its success can be measured by its ability to demolish a host of myths that have been propagated over the years. Below we set out ten familiar myths and the factual response to them.

MYTH - The Irish Sea is the most radioactive in the world (as a result of Sellafield operations)

In fact, the radioactivity of the Irish Sea is almost exactly the average of that of the world's oceans. There are several much more radioactive and the Dead Sea, 13 times more radioactive than the Irish Sea, is used for health cures.

Alternatively, passengers flying from London Heathrow to Dublin would absorb more radiation in an hour from cosmic sources than they would if they ate an Irish Sea fish lunch every day for a year.

Or, if this serves your purpose better, to absorb the amount of maritime radiation arising from Sellafield, you would have to eat seven Irish Sea lobsters in one go. You would then ingest only the same amount of radiation as you would from eating one Brazil nut.

MYTH - Plutonium is the most toxic substance known to man

In fact, radium, which was used for years on watch dials, is more radioactive than plutonium. The danger from plutonium comes mostly from inhaling or ingesting it but there is no evidence that those who have done so have suffered in consequence. Plutonium is, in fact, ten times less chemically toxic than many ingredients found in herbicides and pesticides and about as chemically toxic as uranium and lead.

MYTH - Plutonium is man made and does not exist in nature

In fact, traces are found in uranium ore. Moreover, the remnants of a natural nuclear reactor of nearly two billion years ago were found in Gabon in Africa in 1972 at the Oklo uranium mine. The fuel was a large concentration of uranium in sedimentary rocks. The reactions produced several tonnes of HLW, including plutonium. The HLW is

contained within a 10-metre zone around the point of origin – that is, it has remained securely locked up in its natural repository. Virtually all the plutonium has decayed and left stable products.

MYTH – British civil nuclear power stations make plutonium for weapons

In fact, while they do produce a small amount of plutonium, as explained in the briefing above, it is unsuitable for military because, after six years in a reactor, it is not pure enough to make weapons.

MYTH – Nuclear waste remains deadly for 240,000 years

In fact, even the most irradiated elements will have decayed to levels of radioactivity found in nature – e.g. uranium – in 500-600 years. Plutonium, with a half-life of 24,000 years, would have virtually disappeared after 240,000 years. It would certainly not be deadly, though dioxins and various other substances such as lead, mercury and arsenic would. Their toxicity never decays.

MYTH – Nuclear installations cause leukaemia clusters

In fact, investigation has produced no evidence to support this contention. In some cases, the so-called clusters are imaginary. Where they do exist, a viral agent is suspected.

MYTH – The nuclear industry should be closed down to reduce the public's exposure to radiation

In fact, closing down the industry would have next to no measurable effect on the public's exposure because the radiation arising from the nuclear industry is only 0.1 per cent of that to which they are exposed naturally.

MYTH – Britain is awash with toxic nuclear waste

In fact, nuclear waste represents only one per cent of the toxic chemical waste produced in the UK each year and 94 per cent of it is low-level waste that requires no shielding and is disposed of by burial.

MYTH – Britain hasn't a clue what do with its nuclear waste

In fact, it has been managing all levels of nuclear waste very successfully for 50 years but the time has now come for it to be disposed of permanently. The Committee on Radioactive Waste Management has confirmed the nuclear industry's conclusion of 20 years ago that it

should be buried in stable rock underground. When the Government designates a site for such a store, disposal can proceed. The problem is politicians, not science, engineering, technology or cost.

MYTH – Ah yes but, decommissioning and waste disposal cost an arm and a leg

In fact, the electricity consumer has already paid part of the bill because the nuclear industry, unlike all other electricity generators, has always and still does include a charge of about four per cent in its current price of electricity to cover the cost. The cost figures may look big – and nuclear opponents always inflate them – but, over the course of 50-60 years, a nuclear power station generates a vast amount of electricity and therefore a huge fund to meet these costs. Decommissioning and waste disposal are perfectly manageable.

Conclusion

You should not believe all you hear, see and read about nuclear waste management or decommissioning. Much of it will be silly, ignorant and prejudiced nonsense. This briefing note gives you a flavour of the hysteria.

Hysteria should not be allowed to block the development of nuclear power when – cheaply and competitively - it can increase the security of our electricity supplies, minimise the use of fossil fuels and, by emitting next to no CO₂, help to combat global warming.

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