Radiation: The Facts

A basic guide to the causes and effects of radiation in the environment.

Introduction

This fact sheet is for anyone who wants to get to grips with the basic science behind radiation and its potential effects on human health. This is particularly important in the context of the current political debates about nuclear power and the management of nuclear wastes. Lay people often get confused by the jargon used by trained scientists and feel that, because they are not experts, they cannot understand or contribute to public discussions on technical issues. This is especially true of the nuclear issue, where the processes involved seem far beyond the bounds of everyday experience.

In fact, the basic science of radioactivity and radiation is well within most people's grasp. This fact sheet sets out the principles, explains the main biological effects of radiation, and introduces some of the controversies about the effects of low-level radiation. Terms which may be unfamiliar to you, such as isotope or alpha particle, are introduced in bold type and defined in the glossary at the end of the booklet.

Radioactivity and radiation

Radiation can be thought of as energy, travelling from one place to another. Like all forms of energy, it can be both useful and harmful to human beings. There are three main forms of radiation: mechanical, electromagnetic and particle.

Mechanical radiation occurs when waves pass through air, water or solids, carrying energy. Waves at sea are a good example, as are the vibrations you will feel if you are touching one end of a row of metal railings and someone is banging the other end. Sound is the result of mechanical radiation passing through the air.

Mechanical radiation can be useful. The energy from waves in the sea, for example, can be used to generate electricity. But it can also be dangerous. Excessive noise can damage your hearing; shock waves from earthquakes can cause buildings to collapse. It shares this duality with the other forms of radiation, but in general mechanical radiation is well understood. This is probably because it can be readily detected by human beings and its effects are often immediate.

Electromagnetic radiation, unlike mechanical radiation, can travel through empty space as well as sometimes passing through air, water and solid matter. Like mechanical radiation, electromagnetic radiation travels in waves, each type having its own particular wave length. Radio waves, for example, have wave lengths of between 1 millimetre (short wave) and several hundred kilometres (long wave).
Other types of electromagnetic radiation can be seen below in the diagram of the electromagnetic spectrum. This shows types of radiation ranging from those with very long waves (such as radio waves) to those with short waves (such as X-rays). You will see that visible light forms a very small part of this spectrum.

<table>
<thead>
<tr>
<th>Sources of electromagnetic radiation</th>
<th>Type of radiation</th>
<th>Radiation detector</th>
</tr>
</thead>
<tbody>
<tr>
<td>radio mast</td>
<td>radio waves</td>
<td>radio</td>
</tr>
<tr>
<td>microwave oven</td>
<td>microwaves</td>
<td></td>
</tr>
<tr>
<td>hot objects</td>
<td>infra-red radiation</td>
<td>nerve cells in human skin</td>
</tr>
<tr>
<td>The sun, light bulbs</td>
<td>light</td>
<td>the eye</td>
</tr>
<tr>
<td>the sun</td>
<td>ultra-violet radiation</td>
<td></td>
</tr>
<tr>
<td>X-ray machines</td>
<td>X-rays</td>
<td>photographic plates</td>
</tr>
<tr>
<td>radioactive materials</td>
<td>gamma rays</td>
<td>Geiger counter</td>
</tr>
</tbody>
</table>

Fig. 3 Types of radiation: where they come from and how they can be detected.

The human body is adapted to be sensitive to some types of electromagnetic radiation, such as light. Energy, generated by the sun, or electric light, or fire, travels as radiation from its source and can be detected by the human eye. Similarly, infra-red, or heat radiation can be detected by the heat sensitive nerve endings of the human skin.

Evolution has equipped us to sense these forms of radiation, but other forms were undetectable before technology allowed sensitive equipment to be designed and built. Radio waves can be detected using radio receivers, and equipment exists to detect other forms of electromagnetic radiation, as shown in Figure 3. Gamma rays are a form of electromagnetic radiation which is emitted by radioactive substances, such as those produced by nuclear power stations. One way to detect gamma rays is to use a Geiger counter.

People often use the terms "radioactivity" and "radiation" as if they mean the same thing. Figures 3 and 4 should illustrate the difference. A torch is the source of light radiation and the fire the source of infra-red radiation. In the same way, radioactive substances are the source of gamma radiation.

Some radioactive substances are found naturally, for example in rocks. The granite rocks which lie under the south west of England, for instance, contain high levels of radioactive uranium. This causes background radiation: the implications of this are discussed later in this leaflet. Radioactive substances are also
created inside a nuclear reactor and this is called man-made radiation. Although the initial fuel for a nuclear reactor is only slightly radioactive, the overall radioactivity of the fuel is greatly increased by the nuclear reactions which take place within the reactor.

Particle radiation

Alpha and beta radiation can be emitted when radioactive atoms decay. These are not electromagnetic, but particle radiation. To understand how alpha, beta and gamma radiation are formed it is necessary to consider the structure of atoms and look at the process of radioactive decay.

Isotopes

All solids, liquids and gases are composed of atoms. There are two sorts of atoms: radio-stable (most atoms are radio-stable) and radioactive. As their name suggests, left to themselves radio-stable atoms will remain unchanged ad infinitum. They may undergo chemical reactions, joining with other atoms to form molecules, but the basic structure of the atom does not change. Radioactive atoms, however, are liable to change their structure at any moment because their nucleus (the dense core at the centre of all atoms) is unstable.

A simple example of this is the element hydrogen. Every atom of hydrogen has one positively charged proton in its nucleus and one negatively charged electron in orbit around it. Some atoms of hydrogen also have neutrons in their nucleus. Deuterium, an isotope of hydrogen, has one proton and one neutron. Tritium, another isotope, has one proton and two neutrons.

Because every proton has a positive charge and every electron has a negative charge, the number of electrons in an atom will always equal the number of protons. Neutrons are not charged and therefore do not affect the number of electrons associated with an atom. To other atoms, when undergoing chemical reactions, every atom of hydrogen "looks" the same, as chemical reactions involve interactions between electrons and the nucleus of an atom is not involved. The chemistry of different isotopes of the same element is always the same.

Because protons and neutrons are more or less as heavy as each other, and electrons weigh very little compared to protons, the weight (atomic mass) of a deuterium atom with one proton and one neutron will be twice that of the basic hydrogen atom, and tritium has three times the atomic mass of hydrogen.

Radioactive decay

The isotopes hydrogen and deuterium are radio-stable, but tritium is radio-active. When an atom of tritium undergoes a nuclear reaction, one neutron transforms itself into a proton and an electron. The proton remains in the nucleus and the electron is ejected at high speed. This type of radioactive decay is called beta decay and the electrons emitted are known as beta particles.

The new nucleus now has two protons and one neutron within it and this will quickly attract an additional electron to make a total of two. The resultant atom is an isotope of helium, with a chemistry quite different to that of hydrogen.
Tritium is the smallest and simplest radioactive isotope. Examples of heavier radio-isotopes which also decay by beta emission are given in Table 1. In all of these cases decay occurs when a neutron transforms into a proton and a beta particle (electron) is emitted. You will see that some isotopes emit beta particles and gamma radiation simultaneously. Other isotopes decay with the emission of alpha particles, almost always giving off gamma radiation at the same time. Alpha particles are much heavier than beta particles and consist of two neutrons and two protons bound together. They are formed when a large atomic nucleus splits into two unequal parts: one part is the alpha particle and the other part is the nucleus of an isotope of a new element, containing two fewer protons and two fewer neutrons than the original element.

The isotopes which are products of radioactive decay (daughters) may themselves be radioactive and go on to decay into other elements. This can cause difficulties for the management of radioactive materials as, in order to contain the material, storage and waste facilities have to be designed to cope with the chemical and physical properties of all the daughters as well as the original material.

**Radioactive half lives**

Some radioactive nuclei are more unstable than others, and these will disintegrate at a faster rate. An analogy might be with different designs of china tea set. If used every day, all the cups will eventually be broken. But more delicate designs, with thinner china and weaker handles, will be broken more quickly than tougher designs. The **half-life** of an isotope is way of measuring how quickly it is undergoing radioactive decay. This is the length of time it takes for half the atoms of a particular isotope to undergo radioactive decay. Tritium, for example, has a half-life of 12.26 years. This means that if you started with say, 400 grams of tritium, in just over 12 years half would have undergone radioactive decay and half would still be in its original form. After another twelve and a bit years, 100 more grams would have decayed, and 36 years after the start of the experiment only 50 grams would be left.
Measuring radioactivity

There are two units of radioactivity that you may come across. One is slightly old fashioned now: the Curie (Ci). This unit represents the same amount of radioactivity as one gram of radium-226, which is 37 billion nuclear disintegrations per second. MilliCuries (mCi), microCuries (uCi) and nanoCuries (nCi) represent one thousandth, one millionth and one billionth of these amounts.

More commonly now, radioactivity is measured by the Becquerel (Bq). This is a much smaller unit, representing 1 disintegration per second. There are therefore 37 billion Becquerels in a Curie. You may also come across megaBecquerels (MBq), gigaBecquerels (GBq), teraBecquerels (TBq) and petaBecquerels (PBq) which are a million, a billion, a million million and a thousand million million Becquerels.

Table 1: Some radioactive elements and their properties

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Chemical symbol</th>
<th>Half life</th>
<th>Radiation emitted</th>
</tr>
</thead>
<tbody>
<tr>
<td>iodine-131</td>
<td>131I</td>
<td>8 days</td>
<td>beta; gamma</td>
</tr>
<tr>
<td>tritium</td>
<td>3H</td>
<td>12 years</td>
<td>beta</td>
</tr>
<tr>
<td>strontium-90</td>
<td>90Sr</td>
<td>29 years</td>
<td>beta</td>
</tr>
<tr>
<td>cesium-137</td>
<td>137Cs</td>
<td>30 years</td>
<td>beta; gamma</td>
</tr>
<tr>
<td>carbon-14</td>
<td>14C</td>
<td>5730 years</td>
<td>beta</td>
</tr>
<tr>
<td>plutonium-239</td>
<td>239Pu</td>
<td>24,360 years</td>
<td>alpha; gamma</td>
</tr>
<tr>
<td>uranium-238</td>
<td>238U</td>
<td>4.5 billion years</td>
<td>alpha; gamma</td>
</tr>
<tr>
<td>uranium-235</td>
<td>235U</td>
<td>700 million years</td>
<td>alpha; gamma</td>
</tr>
</tbody>
</table>

Biological effects of radiation

Particle radiation, and some types of electromagnetic radiation, can produce chemical changes when absorbed by matter. Familiar examples are sunlight bleaching curtain material and altering photographic film. For animals, plants and bacteria this means that exposure to radiation can chemically alter components of their tissues. These effects can be both benign and damaging. Exposure to sunlight can cause human skin tissue to produce melanin (the tanning chemical) and to manufacture Vitamin D. However, it can also lead to harmful long term changes such as accelerated ageing of the skin and skin cancer. Similarly, X-rays are tremendously useful medically, but it is also known that they can cause cancer.

Alpha, beta and gamma radiation (and also X-rays) are all examples of ionising radiation. This means that when passing through matter they can cause chemical reactions to take place which otherwise would not. When a living organism is exposed to sufficiently large doses of ionising radiation tissue damage...
may be so severe that death will occur in a few hours or days. However, the cellular chemical changes resulting from even small doses of ionising radiation may still cause severe and life threatening damage, although the effects of this can take months, years or decades to develop. Examples of such effects are:

- **cancerogenesis** - the transformation of a healthy cell into one that will reproduce itself outside the body's normal control mechanisms and form a cancer.
- **teratogenesis** - damage to a developing foetus arising from exposure of a pregnant woman to ionising radiation.
- **genetic damage** - damage transferred to children conceived after a parent's reproductive cells have been exposed to ionising radiation. This damage may be passed on to subsequent generations.

The alpha particle is the most damaging to biological tissue, followed by the beta particle and then gamma radiation. However, alpha particles are not very penetrating - they are too heavy to travel far. External exposure to alpha radiation alone would be unlikely to cause damage (but remember that alpha-emitters are likely also to emit gamma radiation). If, however, an organism has ingested an alpha-emitting isotope, the damaging alpha particles will be emitted wherever in the body the radioactive substance ends up, and may cause serious damage. This might occur if someone breathed in air, or ate food which was contaminated with radioactivity.

Beta particles are more penetrating than alpha, but carry less energy, and therefore have less potential to cause harm. Again, some beta emitting isotopes also give off gamma radiation. Beta particles can penetrate underneath the skin for a short distance, but, as with alpha radiation, the main danger comes from ingestion rather than external exposure. Some accidents at nuclear power stations could result in the release of iodine-131, a beta-emitter, into the air as a gas. If breathed in, iodine can dissolve in the blood stream and then be absorbed by the thyroid gland, where it accumulates. This is why iodine tablets are issued to people living near nuclear sites in the event of accidents. Relatively large quantities of non-radioactive iodine in the blood stream can help block the uptake of radioactive iodine.

Gamma radiation is very penetrating - lead shielding or a thickness of several metres of concrete are needed to absorb gamma rays. These can pass straight through the human body with only a small proportion of the energy in them being absorbed en route. The energy that is absorbed, however, may well damage human tissues. This means that exposure to external sources of gamma radiation can be damaging - you don't have to ingest radioactive material to be at risk.

**Measuring radiation exposure**

Human and animal exposure to radiation is measured in **Grays (Gy)**. This is a measure of the radiation energy absorbed by a given weight of body tissue. However, we have seen that alpha particles are potentially more damaging than beta and gamma radiation. Calculation of the dose equivalent allows for this, by multiplying the alpha radiation dose by 20. Dose equivalent is measured in **Sieverts (Sv)**, also **milliSieverts (mSv)** and **microSieverts (Sv)**. Another unit sometimes used to measure dose equivalent is the **Rem** - there are one hundred Rem to the sievert.
The limit set by the government for the annual exposure of members of the public to man-made radiation is 1 mSv (0.1 rem). Although the National Radiological Protection Board (NRPB) has suggested lowering this to 0.3 mSv, this has been rejected by the government. In general, however, as more has become known about the dangers of radiation exposure, controls aimed at limiting exposure have been tightened.

Forty years ago it was a routine procedure in hospitals to X-ray the bellies of pregnant women. As the fast growing cells of foetal tissue are particularly susceptible to damage by radiation, this practice was discontinued. A link between childhood leukaemia and pre-natal X-ray exposure has also been demonstrated. Similarly, machines in shoe shops, operated by sales assistants with no medical training, were used in the 1950s to X-ray children's feet as part of the fitting process. But increased understanding of the dangers this presented to the staff involved, and their customers, led to the practice being abandoned as unsafe.

**Radiological risks from nuclear power**

The operation of nuclear power stations results in the creation of large quantities of radioactivity. Uranium fuel rods, which were slightly radioactive when loaded into the reactor, are extremely hot when extracted at the end of their useful life. The twin processes of nuclear fission and bombardment with neutrons have transformed the nuclei of the atoms in the fuel. Reprocessing these fuel rods, as happens at Sellafield in Cumbria, does not create further new radioactivity but does result in the contamination of large quantities of materials, thus increasing the volume of the radioactive waste stockpile.

What are the dangers to the public from this material? The most serious risk arises from the possibility of an accidental release of radiation, as happened at Chernobyl in 1986. The explosion there resulted in about 100 million Curies of radioactivity being released into the atmosphere, where it was blown right across Europe. Thirty one people died at the time as a result of the accident and many thousands were evacuated from their homes. The long term health effects of the accident are still being manifested and some estimates suggest the eventual death toll may be as high as 30,000.

Although Western European reactors are designed to a higher standard than Chernobyl, such an accident is statistically possible in the UK, or in neighbouring countries such as France or Belgium.

The operation of nuclear power stations also poses the risk of minor accidents leading to radioactive contamination. According to the regular incident reports produced by the Nuclear Installations Inspectorate (NII) and others, there have been several incidents of this kind at Hinkley Point, leading to contamination of the foreshore and the sidings at Bridgwater station (where spent fuel rods are loaded on to trains) as well as within the site boundary. Some incidents have involved the release of radioactive gases or smoke into the atmosphere.

One of the more worrying incidents showed the way that safety procedures can fail due to human error. In March 1981 it was reported that a worker at Hinkley 'B' had stolen two contaminated paint brushes from the power station and used them to decorate his home. The man's house and car in Bridgwater had to be extensively stripped and decontaminated.

Even if no accidents occur, nuclear power stations discharge some quantities of radioactivity into the local environment through their routine operation. This entails risks for those living near the site. It should also be borne in mind that these risks do not just affect the present generation, who are after all getting the benefit of the electricity generated by Hinkley Point. Sometime in the next decades the nuclear power stations now in use will have to be decommissioned and possibly demolished. The nuclear waste created in the last fifty years will, of course, decay, but it is still likely to need isolation from living creatures for thousands of years. The responsibilities we are bequeathing to our descendants represent an important moral issue, especially as there is still much scientific uncertainty about the long term health effects of radiation.
A report published by Somerset Health Authority in 1988 found that there had been a statistically significant excess of leukaemia among young people living close to Hinkley Point nuclear power station. Although Nuclear Electric deny that this cluster of cases could have been caused by the radioactivity emitted from the site, similar clusters have been found by researchers close to other nuclear installations.

How to cope with the risk

Nuclear power is not the only source of radiation we are exposed to. Radioactive substances are found naturally in soils, rocks, water and air. Background radiation is the term used to describe ambient levels of natural radiation encountered in the everyday environment. Even food contains some natural radioactivity, and some foods, for example brazil nuts, tea and coffee, contain much more than others. The average radiation exposure in the UK from natural radiation is 2.2 mSv, but this varies greatly between different parts of the country.

Decisions we take can increase or decrease this exposure. For example, someone living in a house built on uranium bearing granite rock in Cornwall will be exposed to 6.6 mSv per year - more than two and a half times the average UK exposure of 2.5 mSv per year. This is due to radon gas, a daughter product of the radioactive decay of uranium-238. Once informed about the potential risks to health, however, householders can choose to install ventilation measures to reduce the exposure, or even to move to another area.

Flying in an aeroplane can also result in an increased exposure to cosmic rays, a form of ionising electromagnetic radiation which penetrates the Earth's atmosphere from outer space. Much of this is absorbed by the atmosphere, so the precise dose received depends on the length and height of the flight. A rule of thumb figure is about 0.004 mSv for every hour spent in the air, which can amount to a significant dose per year for airline staff and regular travellers. A medical X-ray can deliver between 0.02 mSv (for a dental X-ray) and 2 mSv (for a spinal X-ray).

Radiation doses received by cancer patients amount to thousands of mSv, as only high doses will kill the cancer cells. All exposure to ionising radiation results in a risk to health, and the public should be given the necessary information to limit their exposure as far as possible. That is why we have published this fact sheet. Literature published by the nuclear industry often seeks to play down the risks of radiation by showing that the exposure of an "average" member of the UK population to radiation from nuclear power is small by comparison to other sources. However, we believe that the nuclear industry's argument does not address the real issues because:

- it concentrates on exposure rates averaged across the population as a whole, ignoring the fact that people living close to nuclear plants receive more than the average dose.
- it ignores the risk of accidents. A study in Gloucestershire showed that local people received a dose of 0.2 mSv as a result of the accident at Chernobyl, which is 2000 km from Britain. For babies the dose was higher - about 0.5 mSv. This is relatively small compared to background radiation, but imagine the effects of an accident of that scale closer to home.
- above all, it ignores the question of choice and the individual's right to balance risks and benefits.

Background radiation is to a large extent unavoidable, but given sufficient information we can then choose to accept or reject other forms of radiation - dental and medical X-rays for example, or the exposure from air travel. With nuclear power we have no choice - the risk is foisted upon us whether we want it or not.
Glossary

alpha decay  the process by which the nucleus of a radioactive atom disintegrates, producing an alpha particle, gamma radiation and the nucleus of a radioactive daughter atom.

alpha particle  a form of ionising particle radiation, emitted when a radioactive nucleus undergoes alpha decay. It consists of two protons and two neutrons, bound together.

atom  the fundamental building block of matter, consisting of a nucleus (containing protons and usually neutrons) and electrons in orbit around the nucleus.

atomic mass  the "weight" of a particular atomic isotope. It can be calculated by adding together the number of protons and the number of neutrons. For uranium-238 the atomic mass is 238, as the nucleus contains 92 protons and 146 neutrons.

background radiation  the level of radiation naturally present in the environment. This will vary between regions of the country.

becquerel  the international unit of radioactivity. One Becquerel equals one disintegration per second.

beta decay  the process by which the nucleus of a radioactive atom disintegrates, producing a beta particle, sometimes gamma radiation and the nucleus of a radioactive daughter atom.

beta particle  a form of ionising particle radiation emitted when a radioactive nucleus undergoes radioactive decay.

curie  old unit of radioactivity. One Curie equals the activity of one gramme of radium.

daughters  the new elements resulting from the decay of radioactive isotopes.

dose equivalent  a measure of radiation dose which takes into account the fact that alpha radiation causes more biological damage than gamma and beta. It is measured in Sieverts (Sv).

dose  the amount of radiation energy absorbed by a given weight of body tissue.

dose equivalent  a measure of radiation dose which takes into account the fact that alpha radiation causes more biological damage than gamma and beta. It is measured in Sieverts (Sv).

electron  a particle found in atoms, orbiting the nucleus.

gamma radiation  a form of ionising electromagnetic radiation produced by the decay of some radioactive isotopes.

gray  international unit of absorbed dose – the amount of radiation energy absorbed by a given weight of body tissue.

half-life  the length of time taken for the amount of radioactivity in a sample of a radioactive isotope to decay to half its original level.
hot
an informal term used to denote radioactivity.

ionising radiation
electromagnetic or particle radiation which is capable of ionising atoms in exposed materials or tissues. This can lead to chemical changes.

isotope
elements are defined by the number of protons in their nucleus. For example, all atoms of uranium have 92 protons. The number of neutrons (and therefore the atomic mass) can vary between different atoms of the same element, and these are called isotopes. Thus uranium-235 and uranium-238 are isotopes of the same element.

mechanical radiation
vibration energy passing through matter: this may be solid (eg earthquakes), liquid (eg waves) or gases (eg sound).

neutron
a particle found in the nucleus of atoms.

NII
the Nuclear Installations Inspectorate, part of the Health and Safety Executive. Together these two bodies are responsible for the safety, licensing and inspection of 35 civil and military nuclear sites in the UK.

NRPB
the National Radiological Protection Board, an advisory body which recommends to the government the limits on radiation exposure for the public and nuclear industry workers. The NRPB joined the Health Protection Agency in 2005.

nuclear reaction
a change in the nuclear structure of an atom which results in a change in the number of protons and therefore the formation of a new element.

nuclear reactor
an engineered structure which enables materials to be bombarded with neutrons, thereby initiating nuclear reactions.

particle radiation
alpha and beta radiation.

proton
a particle found in the nucleus of atoms.

radioactive decay
the process by which radioactive isotopes undergo nuclear reactions.

radioactive isotope
an unstable isotope which will spontaneously undergo radioactive decay.

rem
old unit of dose equivalent, now superceded by the Sievert.

radio-isotope
see radioactive isotope.

sievert
international unit of dose equivalent

wave length
a characteristic of electromagnetic radiation which defines the properties of the radiation. The shorter the wavelength, the higher the amount of energy carried by the radiation. Short wave radiation such as X-rays and gamma radiation are ionising.

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RECOMMENDED READING LIST

'Wolves of Water' by Chris Busby, 2006 publishers Green Audit Books 2006, Aberystwyth, SY23 1DZ, Wales, UK. ISBN 1-897761-26-0. Read this first; it contains everything you need to know about everything nuclear, from atom bomb tests to leukaemia to political cover-up to compromised public health protection.

'Nuclear Power is not the Answer' by Helen Caldicott 2006. ISBN: 978-1-59558-067-2 Read this second; Dr Caldicott covers a more global nuclear power picture, particularly US machinations.

'CERRIE Minority Report 2004' Authors: Richard Bramhall, Chris Busby, Paul Dorfman. ISBN 0-9543081-1-5 This report provides strong biological and epidemiological evidence that current models of hazard from radioactivity inside the human body underestimate risks by at least 100 and possibly up to 1000 times.

'ECRR 2003: Recommendations of the European Committee on Radiation Risk' ISBN: 1 897761, Health Effects of Ionising Radiation Exposure at Low Doses for Radiation Protection Purposes. Covers the problems with using Hiroshima data to set current health risk levels now that we know internal exposure to low radiation levels by inhalation and ingestion disrupt cell replication cycles and interfere with human DNA.

'ECRR Chernobyl: 20 Years On - Health Effects of the Chernobyl Accident' ISBN: 1-897761-25-2, Editors: C C Busby and A V Yablokov An invaluable archive of contributions from Russian and European scientists on the true effects the Chernobyl accident had and continues to have on the exposed populations, including those in Scandinavia and the UK.

'Wings of Death - Nuclear Pollution and Human Health' by Chris Busby 1995. Publishers: Green Audit, Aberystwyth ISBN: 1-897761-03-1. This book has some eye opening ideas on nuclear pollution, the links to cancer and a very credible hypothesis about the initiation of cancers. It is a very important book.

'Still fighting for Gemma' by Susan D'Arcy & Rob Edwards 1995. ISBN 978-0747521860. At the age of three, Gemma D'Arcy was diagnosed as having a rare and incurable form of leukaemia. Her mother Susan became convinced that radiation from the nearby Sellafield plant where her husband worked was the cause.

'The non-cancer mortality experience of male workers at British Nuclear Fuels plc, 1946-2005' Authors: Dave McGeoghegan, Keith Binks, Michael Gillies, Steve Jones and Steve Whaley. International Journal of Epidemiology 4 March 2008, Westlakes Scientific Consulting: This large study of 65,000 men employed at Sellafield reprocessing plant between 1946 and 2002 found the risks of death from heart attacks and strokes increased with exposure to higher levels of radiation.

'Infant and Perinatal Mortality and Stillbirths near Hinkley Point Nuclear Power Station in Somerset, 1993-2005' Authors Dr Chris Busby, Mirielle de Messieres, Saoirse Morgan.

'Cancer Mortality and Proximity to Hinkley point Nuclear Power Station in Somerset 1995-1998' Authors: Chris Busby PhD, Paul Dorfman BSc, Helen Rowe BA
'Part 1: Breast Cancer'
'Part 2: Prostate Cancer'
'Part 3: All malignancies, lung and stomach cancer. Summary'

'Cancer Mortality and Proximity to Oldbury Nuclear Power Station in Gloucestershire 1995-1999'. Chris Busby PhD, Paul Dorfman BSc, Helen Rowe BA, Bruce Kocjan BSc

'Leukaemia Incidence in Somerset with Particular Reference to Hinkley Point Nuclear Power Station' Taunton: Somerset Health Authority: Bowie C and Ewings P D 1988 Referred to in the above 'All malignancies...' paper by Dr Busby.


See [www.stophinkley.org\Health\ReadList.htm](http://www.stophinkley.org\Health\ReadList.htm) to obtain copies of the above.