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MANAGING RADIOACTIVE WASTE ISSUES AND MISUNDERSTANDINGS (RADIATION REALITIES, ENERGY COMPARISON, WASTE STRATEGIES)

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Abstract

The technical specialist is confident that radioactive waste can be safely managed, but many in the public remain totally unconvinced. There are issues and deep-seated misunderstandings that drive public doubts. Currently, a growing concern with pollution from other industrial waste is enabling radioactive waste issues to be debated in a wider context that allows comparisons with other potentially hazardous waste, particularly from energy generation sources. Health effects and time period issues are not unique to radioactive waste. This paper concentrates on 3 topics. The first concerns radiation health effects where the real realities of radiation are covered. The large misunderstandings that exist about radiation and its health effects have led to an almost zero health impact regulatory policy. A policy which must be more fully understood and dealt with. The second topic deals with a few revealing comparisons about the various energy generation systems. Nuclear power's 10 thousand fold lower fuel requirements, compared with a comparable fossil fuelled plant, is a dominating factor decisively minimising environmental impacts. The third topic examines waste disposal strategies. Extraordinarily small radioactive waste quantities permit a confinement strategy for disposal as opposed to the more common dispersion strategy for most toxic waste. The small quantities coupled with radioactive decay, contrary to the public perception, make any potential hazard from both low and high level radioactive waste exceedingly small.

Radiation Realities

Turning to *radiation realities*, there is an "**anxiety about radiation and an *exaggerated perception* of its health effects (that) has resulted in an essentially *zero impact* regulatory policy**".

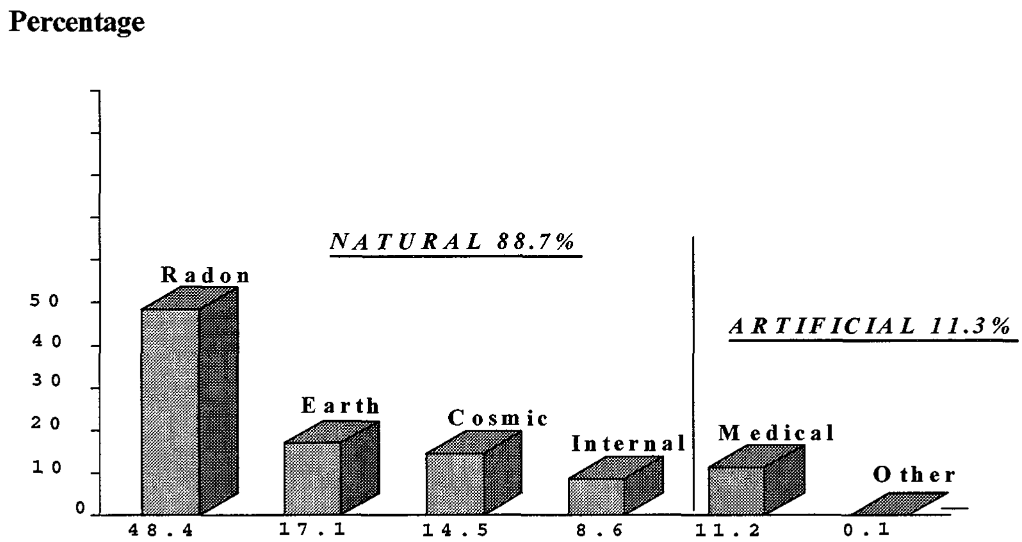
That there is an exaggerated perception of radiation effects is demonstrated in a few figures that follow which put artificial radiation exposures into perspective with the large and very variable natural background radiation, and which also show the known radiation health effects of the atomic bomb survivors since they are the principal bases for current health effects models.

The *zero impact regulatory policy* that we currently live with is rather unique as it actually governs only some small *additions* to the much larger background exposure we receive everyday. In this context, a look at what we do and what we do not regulate is revealing.

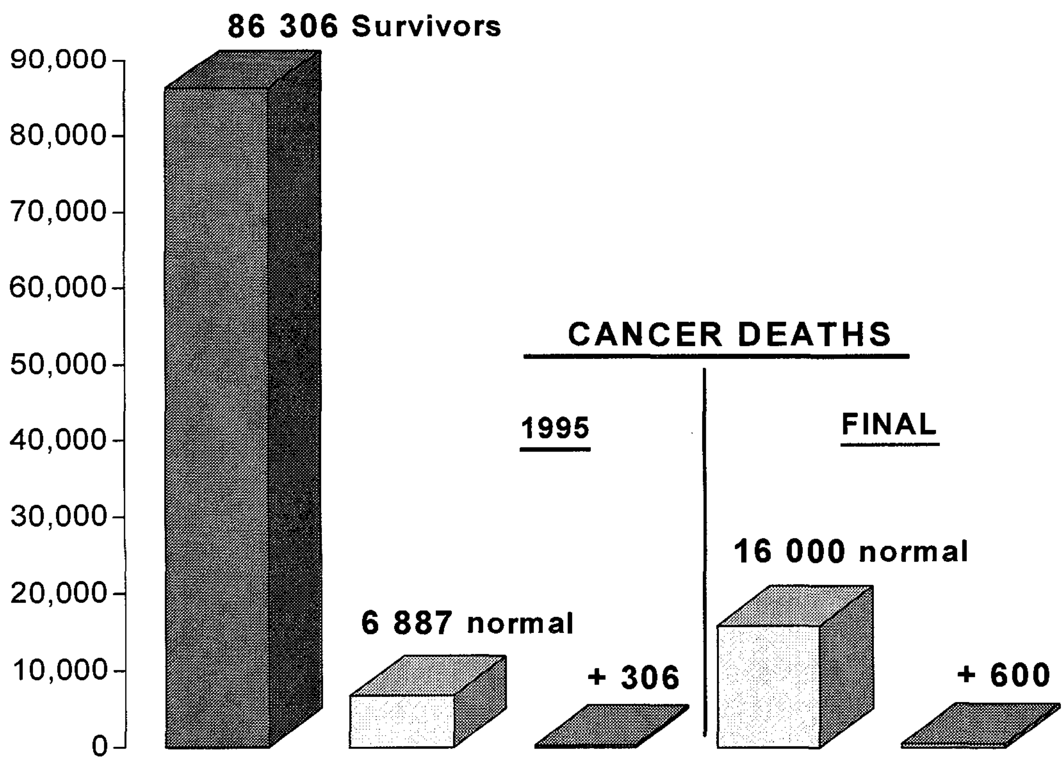
We are all continually exposed to cosmic radiation and natural radioactive elements are in the *air* we breath, the *earth* we walk on, the *homes* we live in and in the *food* we eat as well as in our *bones and tissues*. In comparison to this ongoing and unavoidable exposure from *natural background* sources, exposures from artificial sources are small.

The artificial exposure itself is almost totally medically related, with routine nuclear power activities contributing only a *fraction of one percent* to our total exposure, an addition which can best be characterised as *minor*. As shown later, the natural background is dependent on location and can vary by many multiples of ten, making any nuclear power related exposure even less meaningful.

Annual Individual Radiation Exposure (2.7 mSv total)



Atomic Bomb Survivors

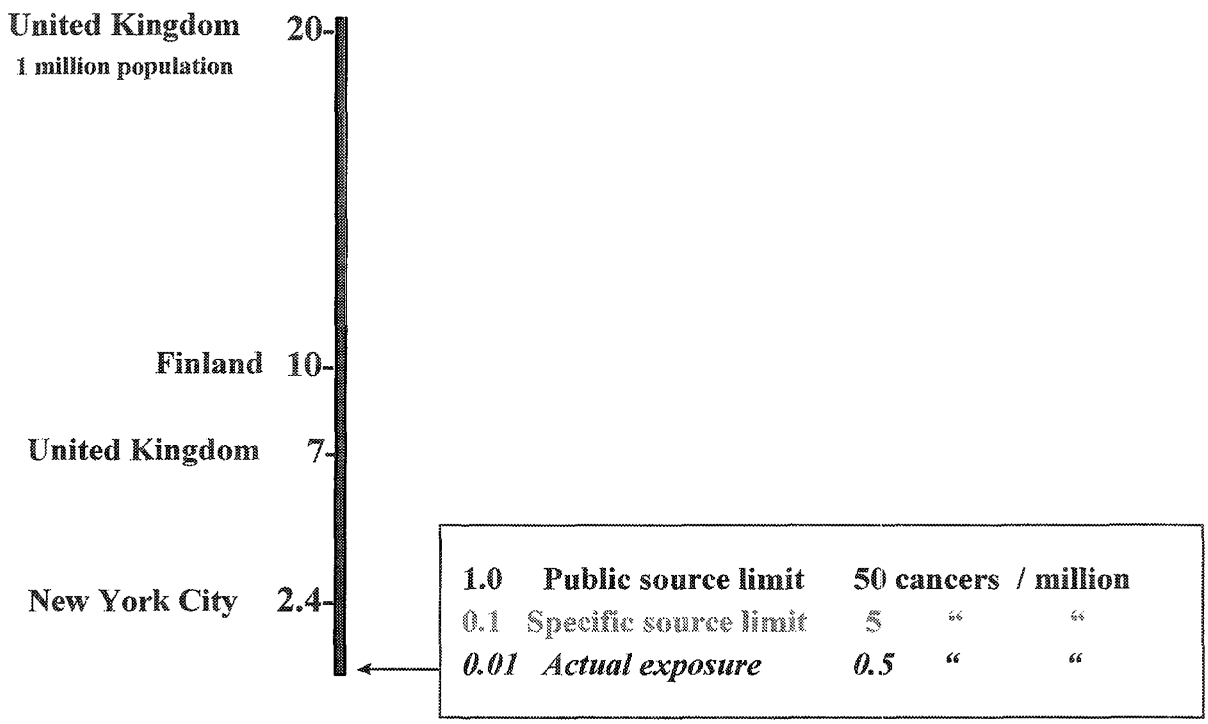


Extreme high radiation exposures of three to four thousand times natural background cause breakdowns in body functions leading to severe disability or death within a short time. Much lower level exposures can cause radiation induced cancers, principally late in life. The Radiation Effects Research Foundation in Hiroshima has over the past 50 years carried out an epidemiological study of 87 000 atomic bomb survivors who were exposed to moderately high radiation levels.

As with all populations, about 20% will die from non-radiation induced or so called normal cancers. The epidemiological studies are indicating additional cancer deaths, currently estimated at some 300. Studies continue with a projected eventual total of some 600 radiation induced cancer deaths that are concentrated in the more highly exposed, an overall addition of 0.7% to the normal 20% rate. An expected several year loss in the survivors' average life expectancy will not materialise as above average health care through early diagnosis and treatment of medical disorders, including cancer, is leading to increased longevity. There are many people in the public and technical community who are not aware of these results and believe that the health effects are considerably greater, and also that considerable abnormalities have occurred in the descendants. But, no above normal number has been demonstrated in the 80 000 children and more than 100 000 grandchildren and great grandchildren.

The RERF study provides a significant perspective. Health effects from moderately high radiation exposure can occur. Nevertheless, when viewed in the larger context of health effects in general and particularly severe incidents, they are relatively small.

Variations in Background Radiation Exposures (mSv annually)

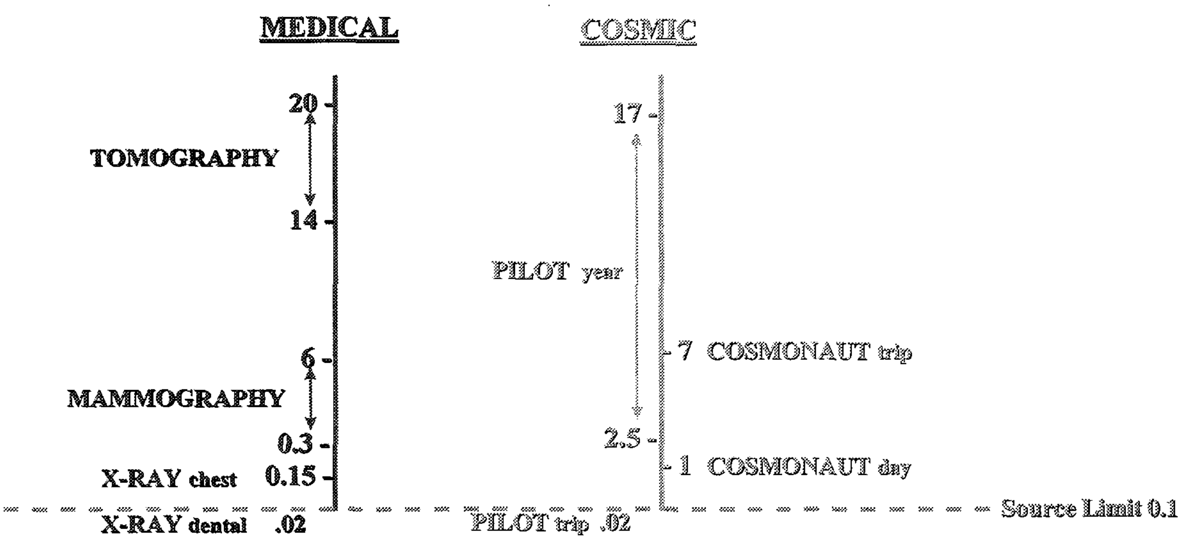


Turning to regulatory policy, today's strict safety regulations deal only with small *additions* to a much larger and unavoidable natural background. The background itself varies significantly by location due to radon gas with multiples of ten not uncommon. This unavoidable background is mostly excluded from regulations as it is simply not feasible to reduce this exposure except through relocation and unacceptable restrictions on individual lifestyles.

For regulated sources, as shown on the left, the *total* additional yearly exposure for the public is limited to 1 mSv or 40% of the world average background. Based on ICRP models, such an exposure of *every* person in a population of 1 million people would add 50 radiation cancer deaths to some 200 000 normally expected in the population's lifetime. For a *specific* regulated source, such as a nuclear power plant, the exposure is limited to as low as 10% of the total. This could lead to 5 cancer deaths if every person were exposed to the limit. However, only a small fraction of the population could possibly be continuously exposed over an entire year to accumulate this limit. Thus, in effect, today's regulatory requirements allow for only a fraction of the estimated 5 cancer deaths, or likely not one. On a probability basis, the individual likelihood of incurring a cancer is comparable to initially drawing all four aces from a full deck of playing cards and having the first card of a second deck also being an ace.

Is such a zero health effects policy reasonable or sensible? If it were applied to other industries, the economic consequences would be enormous. Applied to automobiles, to eliminate the 50 000 deaths that occur each year in Europe and also in the United States, we could require everyone to drive a multi-million dollar steel plated tank down our highways and through our cities.

Unregulated Exposures (mSv)

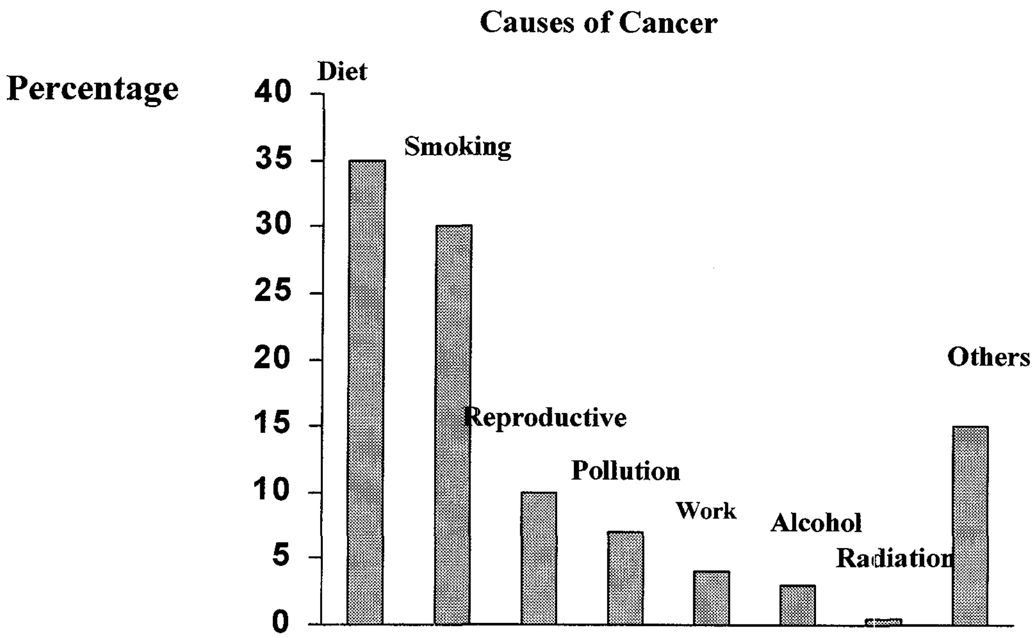


Now for a look at the numerous relatively high exposure situations that are not strictly regulated because control is impractical or they are judged beneficial. In addition to medical exposures, those to airline crew, airline passengers and the relatively large exposures to cosmonauts are not regulated. Actual in flight measurements show that exposures from eight return transatlantic flights or four flights to Asia would exceed the individual public source limit of 1 mSv. One short airline trip in Europe could be equal to one year's actual exposure form living near a nuclear power plant.

Airline pilots commonly receive higher exposures than radiation workers at nuclear power plants, but any attempt to classify them as radiation workers would have serious operational and economic implications for airlines. Cosmonauts receive several times one years' natural background exposure during a typical voyage.

Once again, is such a regulatory policy reasonable or sensible? Whether or not there is an actual threshold for low level radiation effects, a rational and sound regulatory policy may require assuming a realistic exposure level, below which one can assume there is no health effect of concern.

A perspective on radiation cancer effects can be seen by the various causes of cancer deaths. Diet and smoking cause chemically induced cancers accounting for some one-third each of all cancer deaths, with alcohol and environmental pollutants causing an additional few percent each. The remainder is due to a variety of causes with any impact from routine nuclear power activities immeasurably small.



Energy Comparisons

Turning now to the second topic that considers energy comparisons. Huge quantities of a wide variety of waste are produced annually worldwide . Its minimisation is a key element for environmentally sustainable development.

"Nuclear power's *10 000 fold lower* fuel requirements, compared with fossil plants is a dominating factor *decisively minimising* its waste and other environmental impacts". We will rapidly scan a few figures that illustrate the various types of waste being produced, and then turn to some comparisons of the quantity of radioactive waste compared to the quantity of noxious, toxic and polluting waste from fossil fuel sources that currently supply the overwhelming share of world energy, some 87% of primary energy needs.

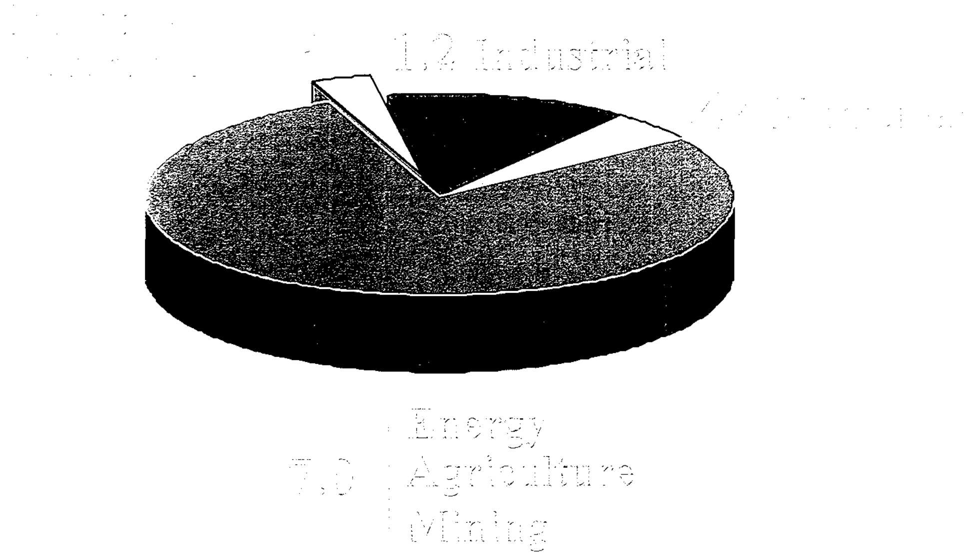
There are some 9 billion tonnes of solid waste in the OECD countries that can be grouped into industrial, energy related, agricultural and mining. There are some 300 million tonnes of hazardous waste from industry.

The small quantity of radioactive waste is seen by the various types and volumes of waste produced in the UK. There is almost 5 million cubic meters of liquid and solid toxic waste compared with some 46,000 cubic meters of all types of radioactive waste.

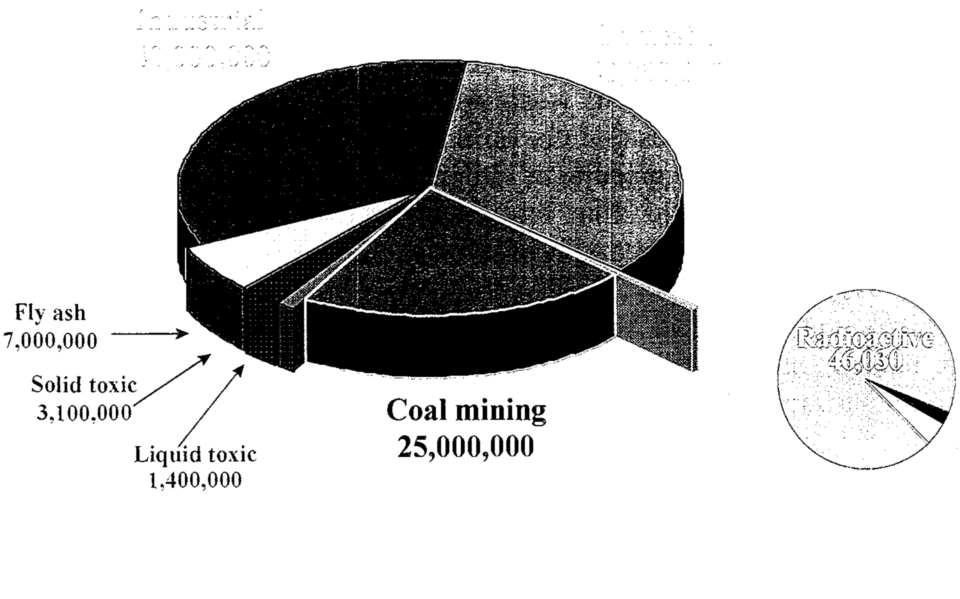
Although varying by type, the quantities of UK waste are not very different in Germany or Japan.

Turning now more directly to a comparison between nuclear and fossil fuels, there are some basic similarities in the fundamental processes. But, what is strikingly dissimilar and not seen on this figure is, as I have already noted, the large 10 000 fold difference in fuel requirements between nuclear and fossil fuels and of course the large resultant difference in waste products for equal amounts of energy generation.

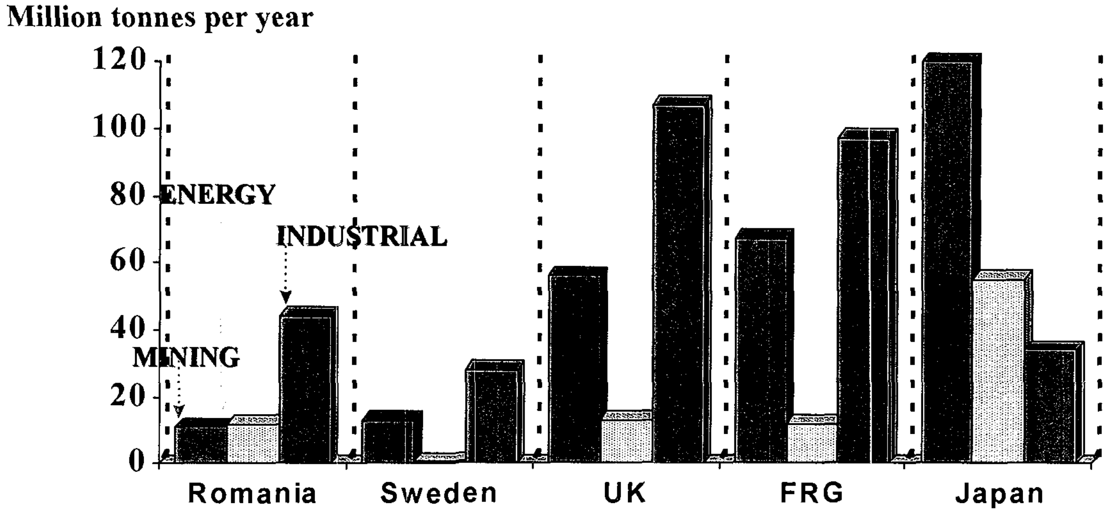
Solid Waste in OECD Countries
(billions of tonnes)



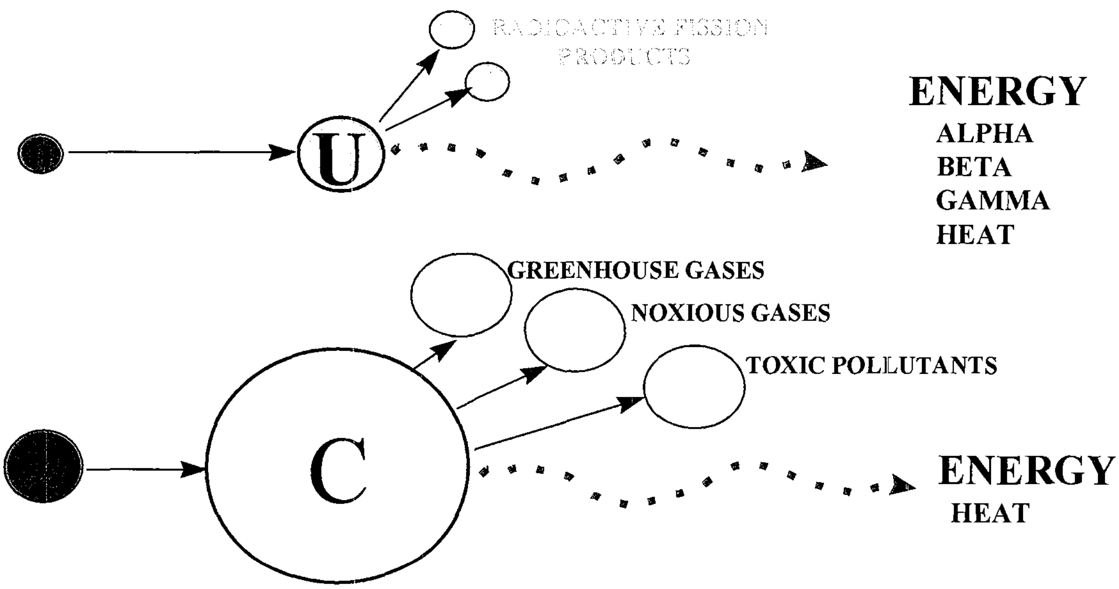
Waste in the United Kingdom
(cubic meters)



Annual Industrial Waste



Energy Comparisons



The large difference in fuel requirements is seen by the figures for a 1000 MWe power plant where *2.6 million tonnes of coal and 2 million tonnes of oil are required, compared with just 30 tonnes of uranium.* Transport requirements are some *2 thousand train cars each with 1300 tonnes of coal, 10 supertankers for oil, and 1/3 of a reactor core for nuclear, which is equal to some 10 cubic meters.*

What makes the vast difference in nuclear fuel requirements a dominating factor for our environment is the ever growing quantity of energy needed, driven in a large part by a rapid growth in population. Today's population of 6 billion is twice the figure only 50 years ago, and is 6 times the 1 billion at the turn of this century. It could double again by the end of the next century.

Although varying considerably by region, the current world average fuel demand per person is 1.6 toe yearly, which when multiplied by 6 billion people is 10 btoe worldwide . This figure will likely be at least 50% higher by mid-century.

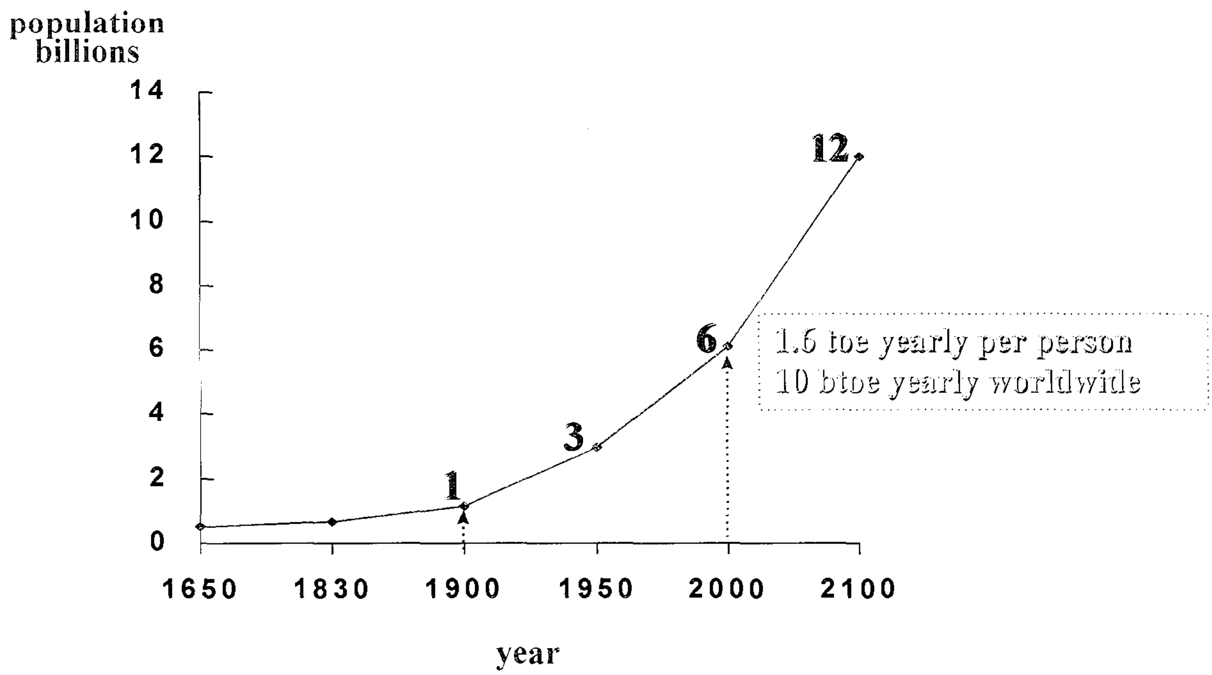
Fuel Required Annually
1000 MWe

COAL ***2,600,000 t*** - **2000 train cars** **(1300 t each)**

OIL *2,000,000 t* - 10 supertankers

URANIUM ***30 t*** - **1/3 reactor core** **(10 m³)**

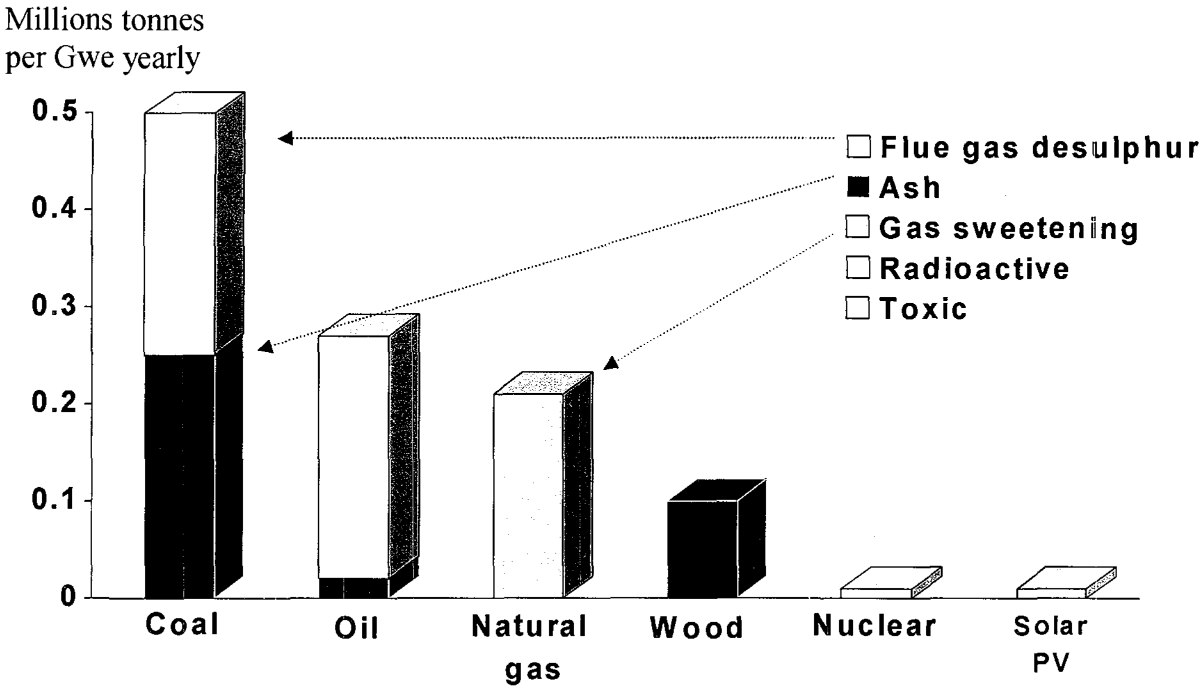
The Population Explosion



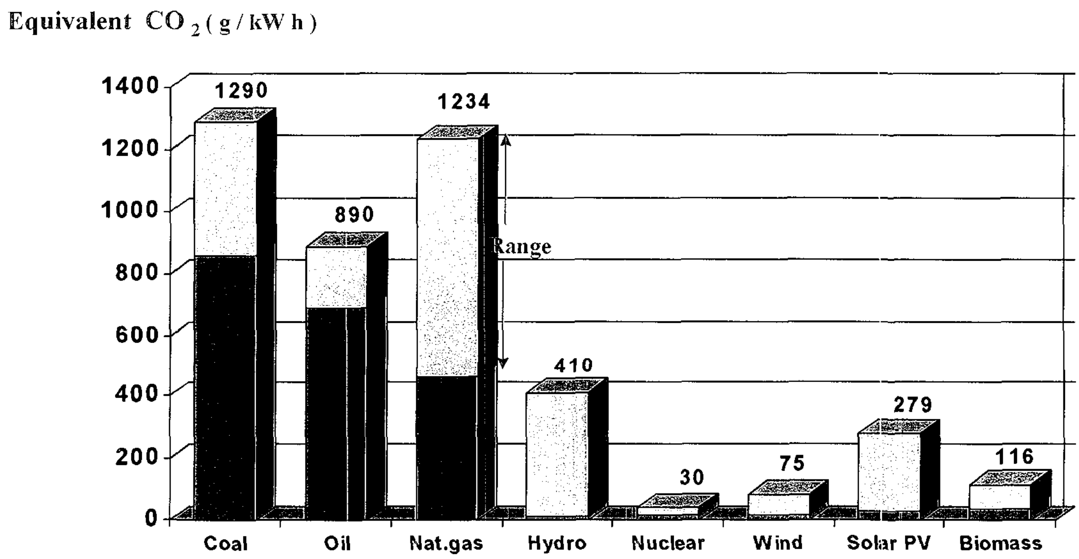
The large quantity of waste including those from noxious gas abatement procedures are shown in this figure. The ash from coal contains some 400 tonnes of chemically toxic substances. There is also some 1000 tonnes of particulates released into the atmosphere.

There are of course large releases of greenhouse gases from fossil fuels, including from natural gas where leakage in recovery and transport can be some 5%.

Waste in Fuel Preparation and Plant Operation



Full Energy Chain CO_2 Emission Factors

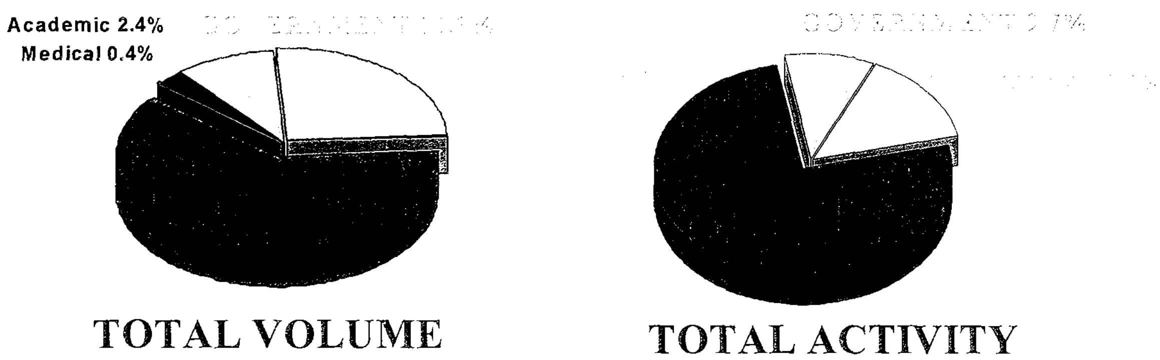


With some insights into the large differences in fuel and waste quantities, we can turn to the final topic on waste disposal strategies. What is strikingly different between the disposal of nuclear and fossil fuel waste, is the basic waste disposal strategy used. The small quantities of nuclear waste permit a *confinement strategy*, beginning with the nuclear fission process and continued to final waste disposal, a strategy essentially isolating the radioactive material from the environment.

Two Alternative Waste Strategies

In sharp contrast, disposal of the large quantities of fossil fuel waste follows an alternative *dispersion strategy*. Most of the waste — the noxious gases and many toxic pollutants are dispersed directly into the atmosphere while some solid waste containing toxic substances is buried in shallow ground, there being no practical alternative.

Low Level Waste in the USA (1996)



The next few figures are concerned with the makeup of radioactive waste — the various sources and quantities and its hazard potential.

As this figure shows, radioactive substances are used extensively in industry and by governments, and in medicine and research centers. A large share of low level waste arises from these non nuclear power activities. In the USA some 60% of the low level waste volume is from utilities operating nuclear power plants with a 25% share from other industries.

Industries with Enhanced NORM Material

PHOSPHATE: fertiliser, phosphoric acid	**URANIUM (feedstock)** **RADIUM (byproduct gypsum)**
ZIRCON SAND for refractories & ceramics	URANIUM
MONAZITE SAND for rare earth elements	URANIUM, THORIUM
OIL & GAS industry	RADIUM (scales)
METAL smelting	BISMUTH, POLONIUM
URANIUM mill tailings	**RADIUM, THORIUM**

During the past years, a radioactive waste source not related to nuclear energy applications has received growing attention. Large quantities of low level waste arise from industrial activities involving raw materials containing **naturally occurring radioactive material** such as uranium, thorium and potassium — so called *NORM* waste. The industrial activities include phosphate ore processing and the production of phosphate fertiliser along with oil and gas extraction.

Although regulatory concerns vary widely, contrary to the approach used for low level waste from nuclear power facilities, the NORM waste generally receives little attention. At the same time, some NORM waste is being managed as low level radioactive waste at significant and perhaps unnecessary cost.

Low Level Waste

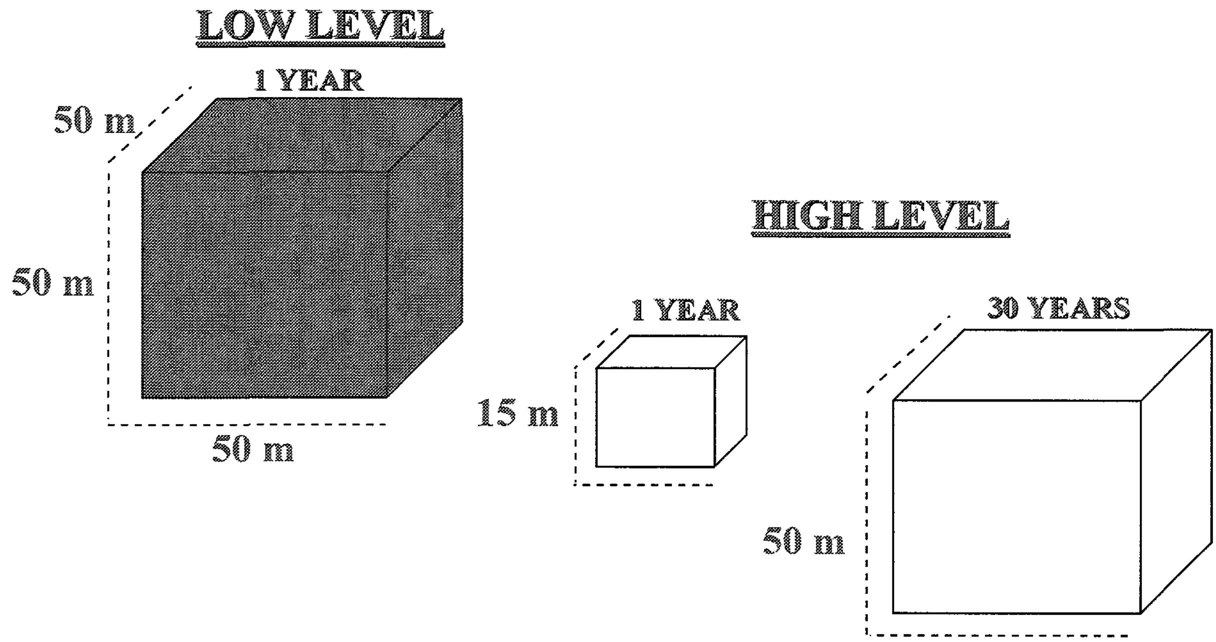
Contrary to public perception, **"the hazard from low level waste is exceedingly small as its radiation intensity is low. Relatively rapid decay limits the long term hazard potential to only some hundred years, with safe containment unquestionably feasible for this time period".**

The radiation levels of low level waste is sufficiently low so that simple protective measures — even for highly compacted waste — are adequate during handling. The levels are low enough that if fertiliser, Brazil nuts and coffee beans were produced at a nuclear site they would be treated as low level waste since they contain natural radioactive substances, such as radioactive potassium and radium.

Low level waste can be disposed of in simple near surface trenches. Although not dictated by radiation protection purposes, it is routinely isolated in engineered structures such as concrete lined trenches and vaults.

Most low level waste consists almost solely of short lived substances with less than 30 year half-lives. Thus, the radioactivity level decreases rapidly, about tenfold in 100 years and an additional tenfold in another 100 years.

Worldwide Waste Volumes



Before turning to some final remarks covering high level waste, a look at the total volumes of both low and high level waste from nuclear power plants is useful.

A typical nuclear power plant produces some 200 cubic meters annually, under 100 000 cubic meters from all operating plants worldwide — equivalent to a cube somewhat less than 50 meters on each side. The worldwide total of high level waste annually is some 4000 cubic meters, equivalent to a cube 15 meters on each side.

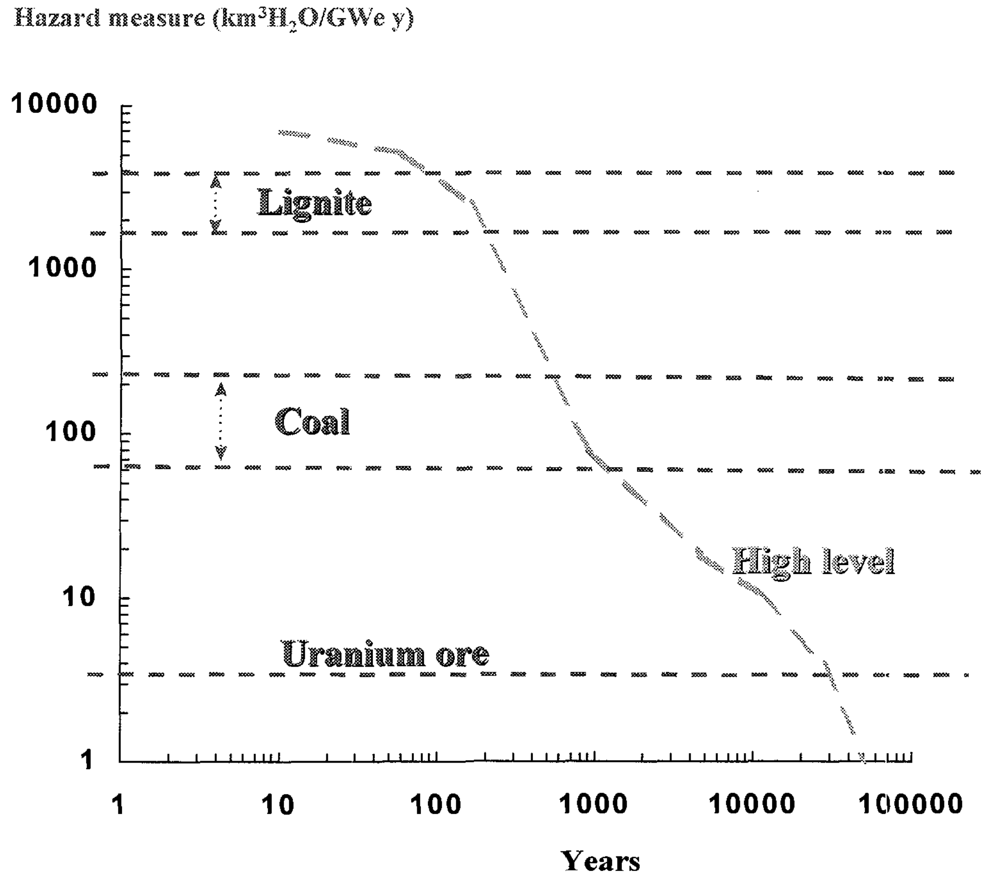
The total volume of high level waste produced over the next 30 years from today's operating power plants would be somewhat more than 120 000 cubic meters, equivalent to a cube some 50 meters on each side. Indeed, the quantities involved are remarkably small.

High Level Waste

"The hazard from deep underground repository disposal of high level radioactive waste is exceedingly small since many transport barriers and dilution by underground water would lead only to radiation exposures well below natural background levels". Contrary to this statement, the public believes it is extremely difficult or not possible to assure safe management of high level waste. But, high level waste contains only residual heat energy and a chain reaction or chemical explosion is physically not possible. Radiation from hundreds of meters below ground cannot reach the surface as it is absorbed in the engineered and natural barriers that isolate the radioactive waste. The only credible human radiation exposures would be in the distant future involving incidents caused by long term corrosion or mechanical forces. It would result in a limited and slow movement of radioactive substances to the surface, greatly diluted by underground water, potentially leading to only minimal individual exposures well below natural background levels.

Safety assessment models, along with natural analogues such as uranium deposits, confirm that the current multiple barrier concept would limit the quantity of radioactive substances reaching the surface. Nevertheless, the current regulatory approach calls for calculated exposures to be similar to those for normal releases from today's operating power plants, on the order of 0.1 mSv annually. Not only is the calculation process which considers time periods up to 1 million years unscientific, but also to limit exposures from an incident that may never occur to exceedingly low levels is not sensible. If limits are required, it would be more reasonable to use the intervention levels for accident situations which can be some 1000 times greater.

Radioactive and Fossil Fuel Waste Hazards



This final figure is concerned with the long lived nature of high level radioactive waste where time works in its favour as radioactive decay continuously decreases the hazard potential. But time is only one factor influencing the hazard potential, the quantity of waste being another. Hazard indicators that consider both factors have been developed. One such indicator compares the amount of water necessary to dilute the radioactive substances in nuclear power waste and the toxic substances in fossil fuel waste to admissible drinking water standards — the less water needed, the lower the hazard potential.

In some 100 years, high level waste from reprocessing would require less water than lignite waste, and in some 500 years less water than coal waste. It would be similar to uranium ore in under ten thousand years. The principle reasons are the small amount of radioactive waste and the relatively rapid decay of reprocessing waste as much of the long lived elements, such as plutonium, have been removed. Without reprocessing, the time periods increase, with radioactive waste approaching coal in several thousand years and uranium ore in some tens of thousand years, but not the many millions of years commonly perceived.

A balanced treatment of radioactive waste requires abetter understanding of the issues and an appreciation of the inconsistent approaches to radioactive and other hazardous waste. Ihope this paper has contributed to a better understanding .