Man's Fear of Nuclear Technology is Mistaken
Better and Safer than Fire[1]

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The great enemy of the truth is very often not the lie – deliberate, contrived and dishonest – but the myth – persistent, persuasive and unrealistic. Too often we hold fast to the cliches of our forebears. We subject all facts to a prefabricated set of interpretations. We enjoy the comfort of opinion without the discomfort of thought. John Fitzgerald Kennedy

Public acceptance of new technologies

To support a sizeable population, civilisation needs energy and mutual trust as well as food and water. Both of these have been damaged by official and public reactions to what happened at Fukushima Daiichi in 2011, but the basis for these reactions is fundamentally unsound.

The final confrontation with the Environmental Anti Fire Party, perhaps 25,000 BC

Originally man relied for energy on the digestion of food like all animals, but at a historic moment he began to domesticate fire as a source of external energy for lighting, cooking and heating his home. Although this was a dangerous step, it was essential to civilisation. No doubt the environmentalists of those days objected and had a strong case, but they had to accept that the benefits outweighed the dangers, provided education and training in the use of fire was given to everybody including children.

1 The author is a member of the SARI group, Scientists for Accurate Radiation Information http://radiationeffects.org/ This article is based on an invited lecture given at the Second AGORA Conference, Tokyo. and at the British Chamber of Commerce in Japan, 8 and 9 Dec. 2013. A more extended discussion with references may be found in the book *Radiation and Reason* available from http://www.radiationandreason.com together with other recent articles in Kindle, ePub, Japanese and Chinese editions, also available from Amazon.

At the start of the 20th Century a similar decision was made to use mechanised traffic. Nobody denied that there were places of great danger[2] but again the solution was education and training, and from a young age everybody learnt to avoid these dangers. Modern society would have been severely hampered if fire had not been brought into the home or if we were still worrying about further restrictions on road traffic -- or even ruling it out.

Today, in a similar debate about the use of nuclear energy, the risks are far less than those of fire or traffic, as shown by the accident at Fukushima, but the required public education and training has never been given and primitive fear persists.

2. Accident at Fukushima Daiichi

On 11 March 2011 and the days following there was a natural disaster, an unnecessary panic and a self-inflicted social disaster. An exceptional earthquake generated a tsunami responsible for over 18,000 deaths.[3] Neither the tsunami nor the quake damaged any nuclear reactors in Japan, but at the Fukushima Daiichi plant the ancillary diesel generators were destroyed so that the emergency power then failed. As a result the reactors overheated and radioactivity was released from the fuel assemblies into the cooling water and also into the atmosphere when the pressure was vented to avoid a rupture. Outside the reactor the vented hydrogen exploded chemically and this was seen on video around the world. Unlike Piper Alpha and Deep Water Horizon this accident killed no one immediately and, as will be explained, no late casualty from the radiation is expected. Nevertheless, political authorities and media worldwide, with an understanding of nuclear matters informed more by Hollywood than science, panicked. The imagined dangers of *the worst possible* spooked public opinion and caused a serious breakdown of trust in science and, more widely, in authority and society in general. This has had serious economic consequences in Germany, Japan and many other countries. Just at the time when the dangerous effect of fossil fuels on the environment has begun to be appreciated, nuclear energy, the sole reliable solution, is being scaled back. Locally in Japan itself large scale evacuation, both voluntary and compulsory, has destroyed many communities and over 1000 people have died from the extreme stress caused. Food supplies have been condemned and businesses ruined.

3. Questions raised

These official reactions have been damaging and without benefit. They were an attempt to calm the public response that still recoils at the mention of the words *nuclear* or *radiation*. Instilled by the propaganda of the Cold War this reaction can

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2 One may imagine how today's media might have sensationalised the dangers:
Scientific experts now acknowledge that on a busy road with cars still permitted to carry young children and pregnant women, there are places, just a few metres away in the face of oncoming traffic, where death is almost certain within a few seconds!

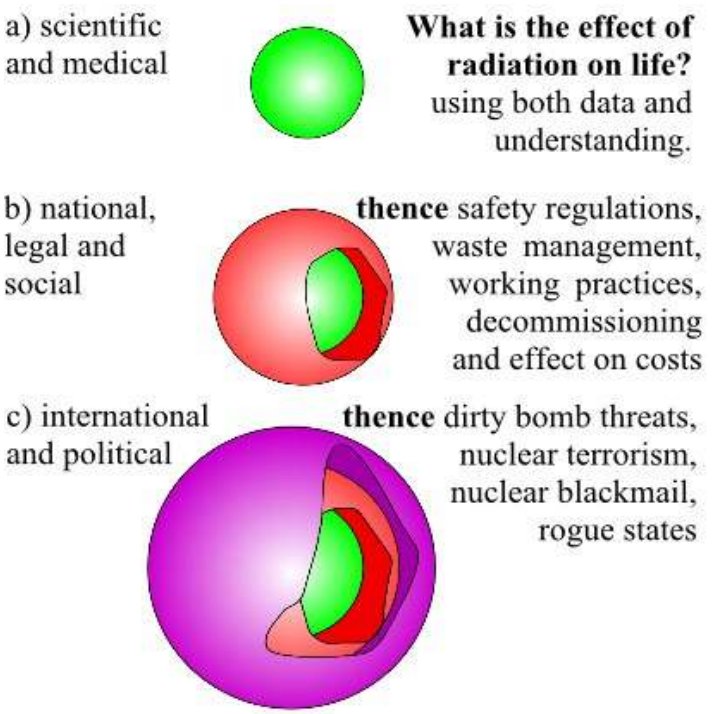
3 The energy source of the quake was the internal heat of the Earth due to its natural radioactivity -- although labelling some energy as *natural* and some other as *artificial* is not a useful distinction.

only be defused through long term re-education. In this article we make a start by asking two questions:

How dangerous to life is nuclear radiation?

How can we build public trust in the answer?

The first is a purely scientific and medical question that can be answered with evidence and also understanding of the how and why. These must fit together to leave no doubt. Actually this is a well trodden path, for research and experience with radiation goes back well over a hundred years. Knowing whether it is dangerous to life (shown symbolically by the green sphere below) we can answer all the consequential questions (shown by the red sphere). For example, worries about nuclear waste should only be important in so far as nuclear radiation is exceptionally dangerous. Concerns at an international level are symbolised by the violet sphere. For instance, nations are only open to black mail by a terrorist group or rogue state if the related threats frighten the public of the nation. In fact today, a dirty bomb would be a far greater threat to public order than to health.



The second question is more difficult. How is it possible to create trust, especially if it has been lost previously? One approach is to think of a similar problem and study how that has been tackled successfully. For example, banks must create trust in the currency need everyone in society to value their grubby pieces of paper, the bank

notes. How do they do it? Some carry pictures of kings, queens or presidents while others use images of famous scientists or literary figures as symbols of trust that everybody respects. Since some of these have a natural connection with radiation and the nuclear story we have a possible way forward.

In the right hand diagram above are four scientists who command public confidence.

> Marie Curie, physicist, chemist, pioneer radiologist, who wrote *Nothing in life is to be feared, it is to be understood.*
>
> Charles Darwin, pioneer naturalist, geologist, student of divinity, who also witnessed and described the major Chilean earthquake and tsunami of 1835.
>
> Florence Nightingale, nursing pioneer and early statistician, who wrote *How very little can be done under the spirit of fear.*
>
> Adam Smith, economics pioneer and philosopher, who wrote *Science is the great antidote to the poison of enthusiasm and superstition.*

Their example shows how study, personal experiences of life, common sense and fearlessness can be used to build trust and confidence. They were all remarkably broad in their skills and would not have seen themselves as narrow *experts* of the kind sought out by today's press for an instantly quotable opinion.

Personal confidence comes slowly with familiarity, education and thinking matters through. In Japan everyone knows what to do in the event of an earthquake and tsunami – they learn it at school from a young age. On 11 March they did not wait for orders from above – they put into action what they had learnt. So that, although there were 500,000 people in the area subsequently inundated, all but 18,800 reached safety. This was a real achievement in contrast to the reaction to the arrival of radioactivity. The public had understood that nothing should go wrong with nuclear – absolute safety was assured. So when it seemed that the impossible had happened, there was panic. Reference to higher authority evoked political reaction rather than scientific guidance. Heightened fear encouraged talk of absolute safety – but that is impossible because nature always has the ability to overpower by *force majeure*. Then after more than two and a half years the disarray continues and the accident is still referred to as a *radiation disaster* although there have been no casualties at all. But you cannot have *Hamlet* without bodies!

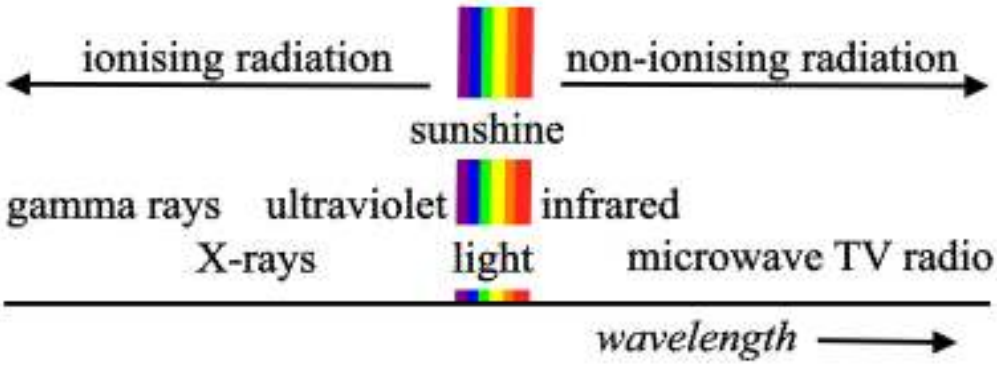
Understanding radioactivity is not difficult and with a little instruction most high school students could calculate the following by multiplying three or four simple numbers:

> Anyone would have to eat more than five tonnes of food described as contaminated [100 Bq per kg, as at April 2012] over a period of three months to get a dose as large as one whole body CT scan – and that is quite harmless. Condemning such food is ridiculous because eating so much is impossible, and so the regulation is a waste of time and money.

> In April 2011 TEPCO announced that it had intentionally discharged into the ocean 11,500 tons of water contaminated by 10,000 Bq per litre and it said that this was both 100 times the regulation level [100 Bq per litre, at that time] and also perfectly safe. This sounds contradictory but both statements are true! Calculation shows that drinking nothing but this water for three months would give the same dose as two CT scans.

In addition the extra CO_2 emission and cost of closing the power plants have had a serious effect on the atmosphere and the economy. These are caused solely by political fear, and that continues, it seems.

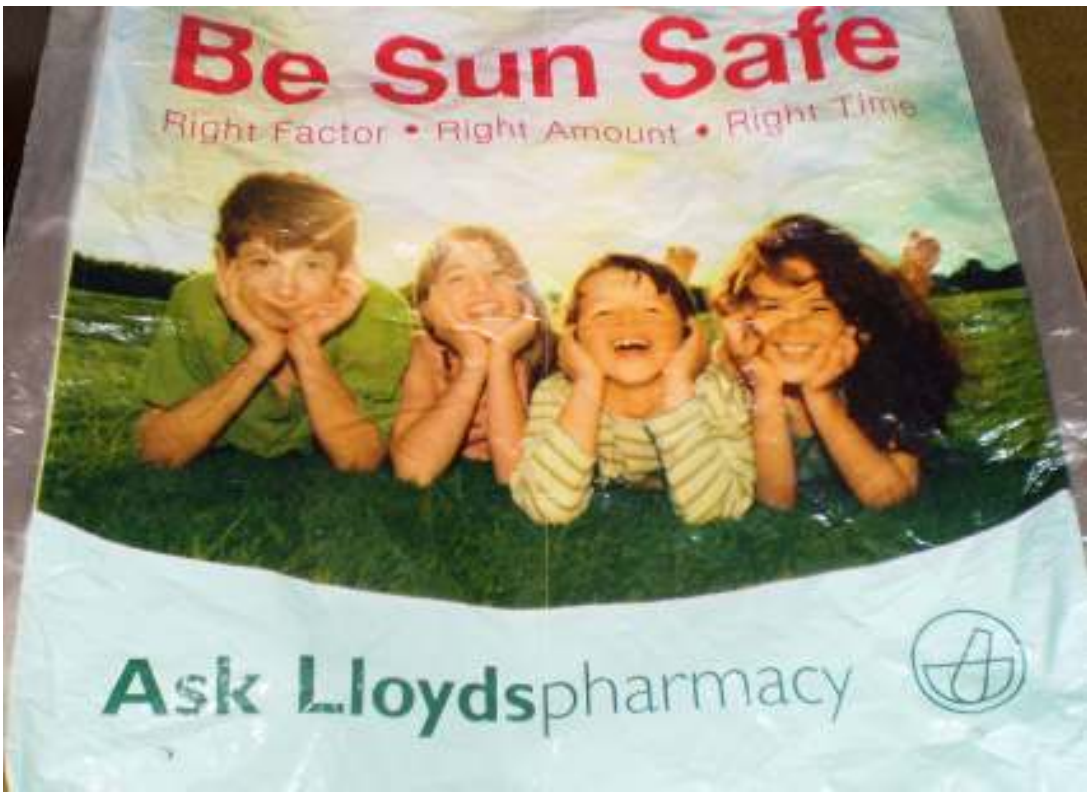
4. Familiar radiation



The radiation spectrum

In fact everyone experiences such radiation – it is found in more familiar contexts than nuclear power. The diagram above shows the spectrum of radiation with the rainbow of light radiation at the centre. To the right there is non-ionising radiation -- the only effect this has on living tissue is to heat it, and you can feel that long before it does any harm. To the left is ionising radiation that can break molecules apart, including the sensitive biological ones like DNA. First there is ultraviolet (UV) and then X-rays and gamma rays. The main difference between them is that X-rays and gamma rays penetrate the skin while UV does not.

Sunshine includes important amounts of UV as well light and heat radiation in the infra red. Like all forms of ionising radiation sunshine can kill living cells in the short term and may result in cancer later in life. We learn to enjoy the benefits of the sun and take care to avoid sunburn and skin cancer – and we teach children about it too. Simple advice to the family may come from a doctor or a neighbourhood pharmacy as shown on the plastic carrier bag illustrated below. It is true that all risk might be avoided by taking summer vacations in a dark hole in the ground, only emerging by starlight, but such vacations are not popular. An international committee on sun bathing set up under the United Nations would be ignored by most people. Gamma rays and X-rays – call it nuclear radiation -- are no different from UV in principle. The burns and cancer that they cause may be deeper in the body but skin cancer is no less dangerous. So the cry *it's nuclear!* is purely cultural, with no scientific basis.



Living, loving and laughing with UV radiation -- a shopping bag with sensible advice about radiation for families

5. Why nuclear radiation is relatively harmless

You might expect nuclear energy to be far more dangerous to life than chemical energy because it can break delicate biological molecules with ease.[4] But that would be too simplistic, for the only business of biology has been to evolve life forms that can cope with such attack and it has had more than 1000 million years of Darwinian selection to perfect its solution.

If, as with a virus or the bellicose behaviour of a neighbouring tribe, a threat can change or evolve, resistance may be problematic. But protection against a threat that never changes is almost always achievable given time. The effect of nuclear radiation is like that and life has found a near perfect set of overlapping protective mechanisms. These act subconsciously and work at the cellular level to protect inanimate as well animate forms of life. The same mechanisms are effective against the common all-garden attack by normal metabolic oxidation because that too results in a broad spectrum of broken molecules and disabled cells. They work in three ways:

> the basic design of life with its self organising reproduction, first at the level of individuals and then of replaceable cells with their own copies of DNA;
>
> the active defence against an attack by means of antioxidants, DNA repair enzymes, planned cell death and the action of the immune system, among

4 Per atom (or per kg) nuclear energy is a million times more powerful than chemical energy. This is a simple consequence of Quantum Mechanics.

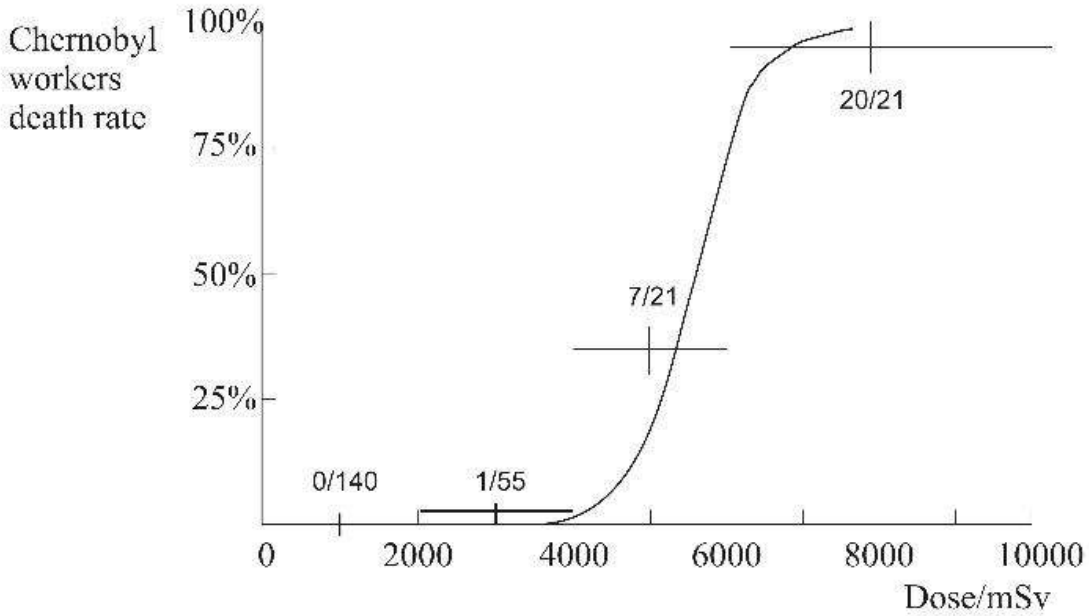
others;

the adaptive reaction, whereby cells are stimulated to build up extra supplies of antioxidants and enzymes and to modify their immune reaction in the light of recent attacks including those due to exercise and mental activity.

The adaptive reaction is called *hormesis* – we get used to moderate levels of sun when on holiday and get fit by taking regular exercise. In the same way moderate levels of nuclear radiation at low rates can improve health by stimulating the immune reaction.[5]

But this stabilised response can be overloaded by a large and sudden radiation dose. This is a familiar feature of any stabilised system, for instance in the engineering of a car suspension or an audio amplifier. If hit by an input above a certain threshold in a short time the stabilisation fails and damage or distortion results. So in the case of radiation, how large is this threshold and what is a short time in this context? These questions are answered by examining evidence.

6. Dangerous doses of nuclear radiation



The mortality of early fire fighters at Chernobyl shown by crosses. The numbers give died/total in each dose range. The curve is for rats.

The diagram shows that most of the initial workers on the scene at Chernobyl who received more than 4000 mSv died, in fact from Acute Radiation Syndrome (ARS) not cancer, within a few weeks. Evidently there is a step, a risk threshold, somewhere between 2000 and 4000 mSv. However, many people are surprised to learn that any normal radiotherapy patient in the course of cancer treatment receives a dose ten times greater to large healthy parts of their body. The type of radiation used is no

5 This was demonstrated with animals as early as 1919 and published in reputable journals.

different and the dose may be 1000 mSv every day for five or six weeks. This tedious protracted treatment allows the healthy tissue to recover each day while the tumour itself, receiving double this dose, just fails to do so. This treatment works and shows that the repair time may be as short as a day -- without repair all patients would die before the end of their treatment, and would do too if 20 mSv per year were a sensible safety limit in the environment.[6] This all shows that the public has access to their own evidence that such a safety limit is far too cautious and not based on sound science.

7. Traditional apprehension of the safety of radiation

The Cold War inculcated a dread of nuclear missile exchange based on the thousands of nuclear weapons deployed at that time. The sheer energy of a nuclear explosion creates a blast wave and a major fire storm effective for many kilometres from the detonation site. That would be relatively local on a world scale but the putative effect of the radiation released would be global and last for decades. Faced with marchers and demonstrations against nuclear war every government attempted to reassure the populace by setting radiation protection levels with extreme caution, in fact As Low As Reasonably Achievable (ALARA). But these were set by reference to naturally occurring doses, quite unrelated to risk, and were approved by the United Nations itself, to add extra gravitas. Although officially advisory it became very difficult for any nation not to implement them although they were about 1000 times more stringent than the safety guidelines of 1934, the year that Marie Curie died.

Although unrelated to any demonstrable risk they were given a semblance of scientific respectability by the so-called *Linear No-Threshold hypothesis* (LNT). In the name of special caution this sets aside all the mechanisms of Darwinian biology just discussed. Although academically discredited, this hypothesis still holds sway today at a regulatory and political level and was responsible for generating the inappropriate panic in Japan, in 2011 and since. Any safety limit established on a basis of established risk would give a figure that is As High As Relatively Safe (AHARS) -- that after all is the way in which we treat other risks, for instance the failure of a bridge or dam. It may be sensible to apply extra caution – the Precautionary Principle -- to the early use of any new technology, but with over a century of experience that hardly applies to nuclear.

6 As suggested by the authorities in Japan with the support of the International Atomic Energy Agency (IAEA).

The natural protection of life provided by slow evolution wins easily against regulation determined by committee, as illustrated by Aesop's Fable of the Race between the Tortoise and the Hare

Popular concern about nuclear radiation focusses in particular on the effect of internal radiation -- that is on radiation emitted over an extended period by radioactivity absorbed into the human body itself. In the Fukushima accident attention has centred on Caesium-137 which spreads throughout the body and has a 30-year radioactive life time, even though at Chernobyl no casualty could be linked to it. Any accident involving internal doses 1000 times greater than any measured at Fukushima would provide a convincing demonstration of any risk -- that is above a few million Bq.[7] Such an accident happened at Goiania, Brazil, in 1987 when a Caesium-137 radiotherapy source of 20 TBq was stolen and broken open.[8] It glowed with an enticing blue light and children painted themselves with it, spreading it around their home and kitchen, and their neighbours were invited in to see and admire. When finally resolved, 249 people had been contaminated, internally or externally. Four died of ARS including a girl with an internal radioactivity of 1000 million Bq. In addition 28 had serious burns requiring surgery. Since the accident two babies were born to women with a high internal dose, one with 0.2 million Bq who was pregnant at the time and another with 300 million Bq who gave birth 3 years 8 months later. No problems with the births has been reported. Now, more than 25 years later the total number of cancers reported with any possible link to the radiation is zero. How can this be? The internal radioactivity that spread throughout their bodies gave a dose protracted over many months which enabled the action of the repair and adaptive responses. Certainly the residents of Fukushima need have no concern whatever on account of Caesium-137 and the work of decontamination is just not necessary.

7 In a survey of 32,811 residents published by Hayano et al in Proc. Japanese Academy (2013) the highest activity measured was 12 thousand Bq.

8 That is 20 million million Bq.

The sight of officials in protective clothing suggests danger and kills confidence

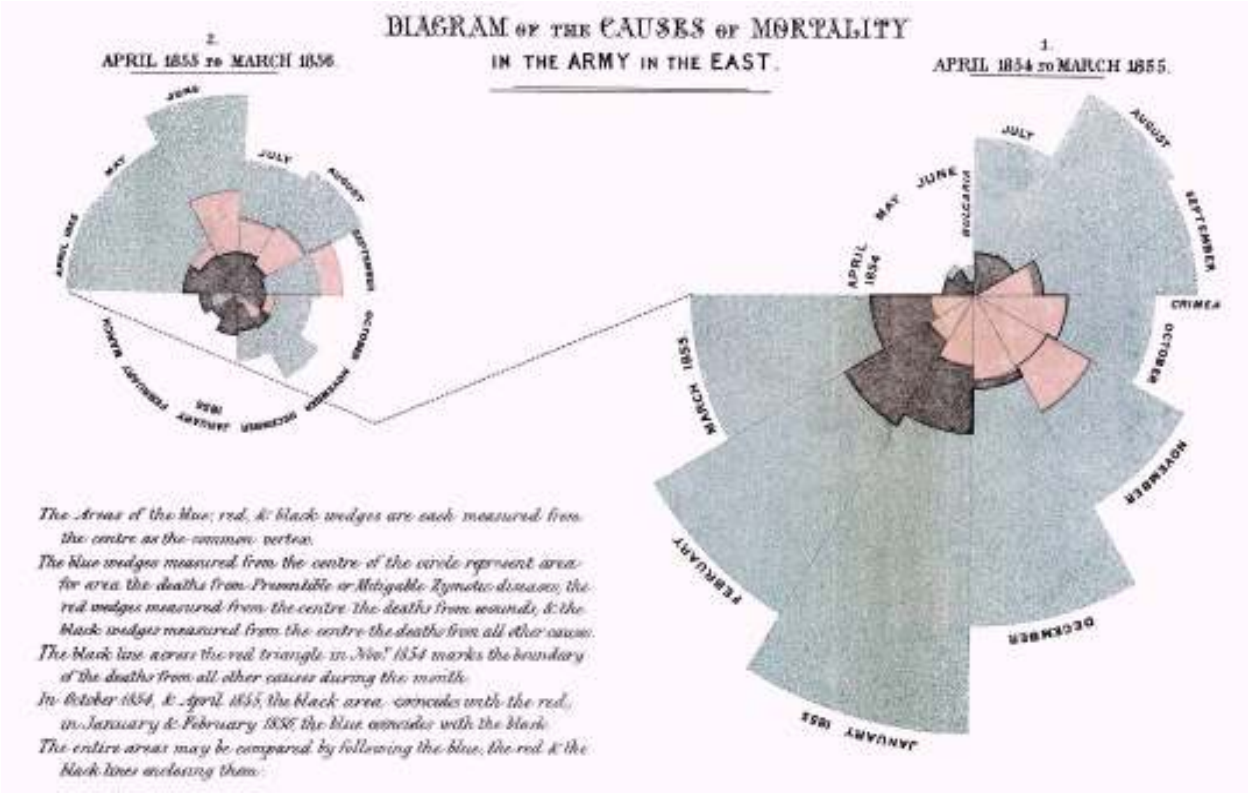
But residents of the contaminated regions of Fukushima have other worries. The sight of officials with meters and protective gear probing a children's playground would be enough to frighten the most hardened parent. Except within the plant itself this gear cannot be necessary. It may be an exercise in authority and "*I am an official doing something important"* but it certainly damages public confidence.

In the story of King Canute the tide ignores the King's command to retreat, for science and the laws of nature are deaf to the authority of governments, the United Nations, courts of law, majority votes and the influence of money

So how should we view the safety of radiation? With respect, experience and our own judgement, I suggest, the same as we do with UV in sunshine or fast traffic on the

highway. It is certainly a mistake to believe that every authority and expert has the answer. The ancient story of King Canute illustrated that – his people thought that he could stop the tide coming in! Such ideas should be discouraged in a democracy.

8. A justifiable safety limit

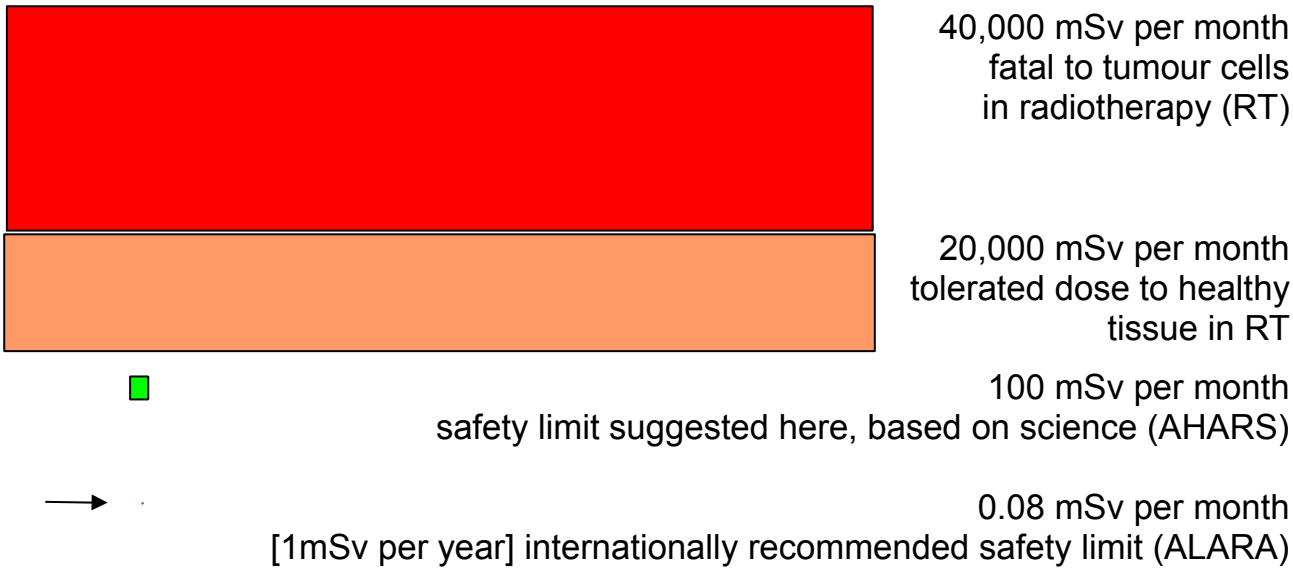


Statistics, graphics and public persuasion as used by Florence Nightingale

To start to build trust we should follow the example of Florence Nightingale. She collected data on how soldiers were dying in the Crimean War and then drew diagrams -- one is shown above -- to explain the need for better care of sick soldiers. She brought this evidence to the attention of the generals and politicians of the day. She succeeded in spite of the fact that those politicians would never have heard the word *data* before -- they were still learning about risk from the recent fate of the Charge of the Light Brigade!

Our objective is not dissimilar. We need to expose blind adherence to narrow judgements formed in another age – in our case the Cold War rather than the Napoleonic War. Faced with our task, how might Florence Nightingale have drawn a diagram to illustrate that current radiation regulations are inept and out of touch with modern medicine and biology? Perhaps with the simple diagram below which depicts doses received in a month as proportionate areas.[9]

9 To be conservative a month is chosen rather than a day. It is common experience that biological reactions are generally complete within a month even when they take longer than a day.



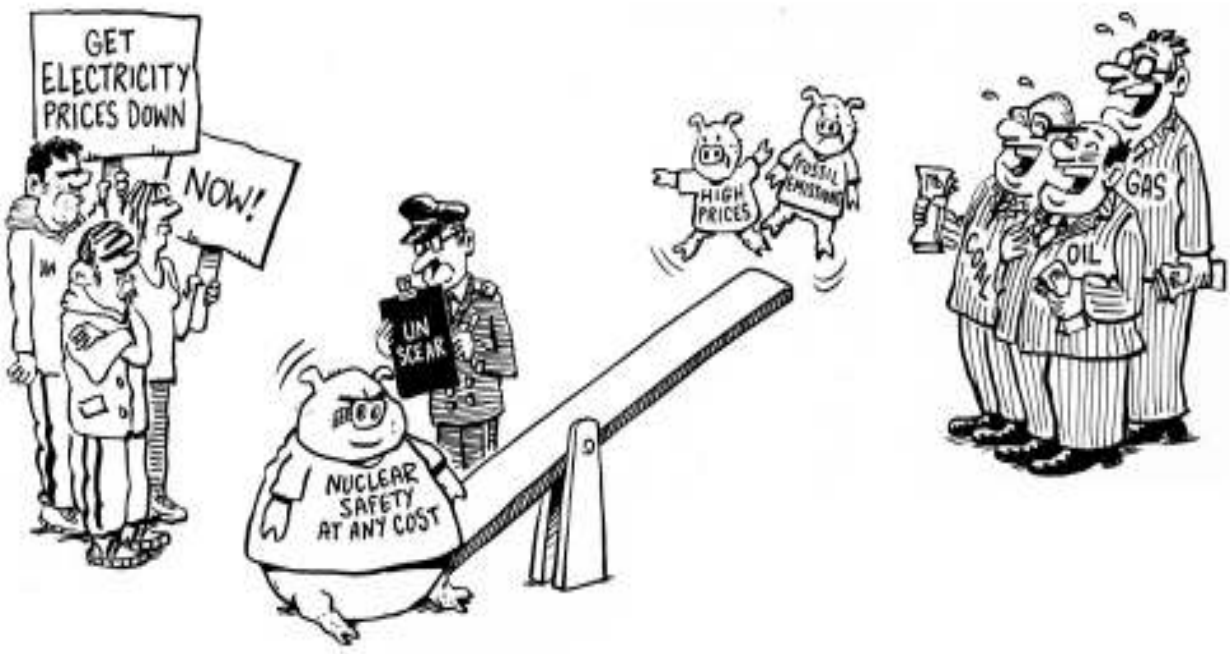
A set of simple areas comparing monthly doses
(the ALARA limit is the small dot at the head of the arrow)

The rather small difference between the monthly dose to the tumour and to healthy tissue (factor 2) contrasts with the difference to the ALARA limit (factor 200,000). A conservative safety limit of 100 mSv per month is suggested.[10] There is no established risk to health from such a dose rate, seen As High As Relatively Safe (AHARS). It is a conservative factor 200 less than the healthy tissue value frequently experienced by the patients in RT treatment and a 1000-fold relaxation of ALARA limit. It would reset safety levels to where they were in 1934 and suggest that up to ten full CT scans should be acceptable per month without concern. Such a new safety limit might be argued up or down by a factor two or three but a value different by a factor of more than ten would be unreasonable.

In Japan the entire scale of the evacuation, the condemnation of food and water, the clean up of the soil, the instruction of the population and the safety of the power plants should be reconsidered. The same paradigm shift should be considered world wide, for the same misunderstanding has occurred everywhere and it caused unnecessary social suffering following the accidents at Chernobyl and Goiania too.

Overcoming the current widespread primitive fear of nuclear ought to be easier than overcoming such a fear of fire in prehistoric times – and it is no less important for the future of civilisation. The environmental effect of the use of fossil fuels continues to escalate and time may be short. If another Fukushima accident should occur, like last time it would be less serious than the frequent disasters that follow the pursuit of fossil fuels with their significant loss of life. It is unlikely that climate change can be limited without a major switch to nuclear energy, and accepting nuclear, in a democracy at least, requires a radically new appreciation of science in society, not only by politicians and the media, but by scientists too.

10 More evidence for such a limit and the failure of the LNT hypothesis are discussed in the book *Radiation and Reason* and in articles on the website www.radiationandreason.com



An image of the unbalanced and narrow perspective currently taken by the United Nations and other authorities – and the consequences which voters in some countries are starting to notice