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Risk, Detriment and Hidden Conservatism: How to Price Nuclear out of the Marketplace

Summary

For most people in most of the world, worrying about one-in-a-million risks is a fairly futile occupation; it is also not something which is in the forefront of people's minds as they go through their daily life - though such risks are a daily if not hourly occurrence. But we in the nuclear industry worry for them, and in so doing increase the cost of all things nuclear by billions of pounds to the immense overall detriment of the planet.

This presentation examines the assessment methods used in several nuclear activities and finds a preoccupation with peak risk over likely detriment, multiple layers of conservatism and an almost total failure to communicate. This means that the industry takes no credit from the public or decision makers for levels of precaution which are both extreme and expensive. In the UK, the advent of the Nuclear Decommissioning Authority, which is looking for value for money in nuclear cleanup, the Energy Review (which has kept the nuclear option open) and the recommendations from the Committee on Radioactive Waste Management (CoRWM) regarding the search for a volunteer-based geological disposal site, behoves the nuclear community to reassess previous conservatisms in the light of sustainability on a UK plc basis. Should this opportunity be taken, there may be a chance that lessons learnt in the UK may be applicable to other countries facing the same dilemmas.

Risk and Detriment

The regulation of activities which may cause harm to people is clearly crucial to any democratic and industrial society. Regulation has adopted the concept of welfare of the population (reduce overall detriment or 'harm' to the population) and the welfare of the individual (reduce risk to the most exposed individual). This leads to a 'Plain English' aim of providing 'the greatest good for the greatest number while safeguarding the welfare of the individual'. Thus regulation is addressing two goals at once, and any leaning towards the one may lead to the sub-optimisation of the other.

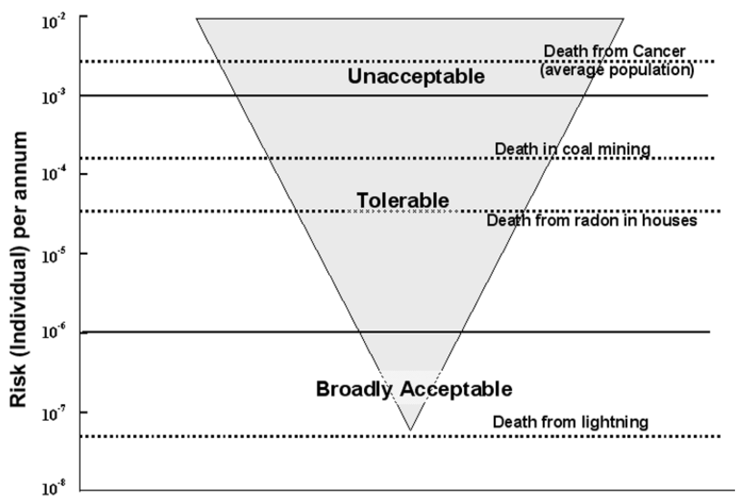

Figure 1

The nuclear industry has always been in the forefront of methodology development in safety assessment and regulatory techniques. Springing from the early weapons programmes, nuclear power was viewed as uniquely dangerous. Most safety codes and regulations had been built up over decades by trial and error, but here was a power source where this was clearly not appropriate. So probabilistic and deterministic techniques were developed, all with the basic aim of restricting very large accidents to very low frequencies. The effects of large accidents are deterministic and can apply to large numbers of people, people are rightly very averse to large incidents, and it was in this context the 'one in a million per annum' standard was arrived at. It was a standard applied to an individual, but against the background of an event causing considerable detriment in terms of numbers of human lives, material and environmental damage.

In the UK, the transfer of the nuclear concepts of risk regulation into the wider sphere of health and safety was done via the concept of Tolerability of Risk (ToR), which held that no worker should be put at an occupational risk of death greater than one in a thousand per annum, with no member of the public greater being put at a risk of death greater than one in ten thousand. Risks above these levels were deemed Intolerable. Risks lower than one in a million were classed as Broadly Acceptable, with an area of tolerability in between. This is illustrated in *Figure 1*.

Now let us put risk into context. The median expectation of life (or 'half life') if you take a one-in-a-hundred risk every year of your life is approximately 61.17 years. For a one-in-a-thousand risk it is 611.7 years, and so on to 611,700 years for one-in-a-million. So later in the paper when we get to risks of one in ten billion per annum, these could be the only barrier between you and a half life considerably longer than that of uranium 238.

ToR concentrated on individual risk, and was free from the 'large event - large detriment' subtext of the original safety regulations. It was therefore logical that the maximum allowable risk to the public individual rose by a factor of 100 from one-in-a-million. The ToR concept was most recently propagated by the 2001 version of the Health and Safety Executive paper 'Reducing Risks, Protecting People'[1]. ToR seeks to regulate almost entirely by limiting the peak risk to individuals.

In contrast, the welfare of the population (limiting the overall detriment to people) is given a relatively lower priority. Overall detriment is measured as the number of fatalities or other effects and improvements in detriment to the many should be balanced against the reduction in risk to the few, but this involves difficult choices in how to value each side of the equation. Such balances are perceived to be ethically challenging, but in the context of UK plc the authors believe that this is the proverbial nettle which could and should be grasped.

In particular, the concept of financially valuing a statistical life is relatively well developed, but while it finds use and acceptance in the spheres of transport and medicines, it has been largely ignored in regulation of radioactive discharges. In practice, the policy and regulatory regime of these discharges has been driven by the use of the ALARA (As Low As Reasonably Achivable) mechanism to reduce peak risk to individuals with scant regard for the societal consequences of these actions. Current Government practice takes the Value of Spend for Saving a Statistical Life (VSSSL) of around £1M, and Treasury guidance [2] discourages 'aversion' increases of over a factor of 2. In contrast, studies [3, 4] on nuclear schemes have shown VSSSLs of tens or even hundreds of millions of pounds.

It is contended that the current policy and regulatory regime, led by the public dread of radiation, political aversion to tackling difficult choices and a response from the nuclear industry now lacking the commercial drivers which underpin proportionality, is pushing UK nuclear activities into a region of seriously disproportionate regulation with excess costs of many millions of pounds per annum.

Radiation risks in context

Reducing Risks, Protecting People provides many examples of accident statistics for people at work or at play: from a one in 17,000 risk of death in a road accident to a one in 19 million from being struck by lightning. In 29 out of 30 statistics quoted, the person concerned ends up dead or injured, with death or injury very demonstrably caused by the event stated. The odd-risk-out is a one in 29,000 risk of death from cancer caused by radon in the home.

This is the clear difference between radiation and other risks considered. If I am the one in 19 million hit by lighting the evidence is unequivocal. If I am the one in 29,000 radon deaths I take my place unheralded among the one in 387 per annum overall cancer mortality risk. This may be compared with the risk from highest dose to a member of the UK public from routine operations of the nuclear industry of less than one in 100,000 per annum.

Conflating radiation risk with accident risk in this way disguises a very important difference between the risks being studied as far as the individual is concerned. Accident risk is unarguable - the victims of the accident are either demonstrably dead or they are not. In the case of radiation, however, the number of statistical deaths is based on a linear-no-threshold (LNT) extrapolation of the effects of high doses of radiation. This may or may not be conservative, but certainly leads to the consideration of all risks, no matter how small. This is particularly relevant, since the number of people exposed to the largest doses of radiation are a tiny proportion of the population. Everyone in the UK is subject to a road accident fatality risk of 1 in 17,000 per annum with an expected detriment of around 3,500 identified lives, but only the few members (say 20) of the Sellafield Critical Group are exposed to the one in 100,000 per annum risk, giving an expected detriment around 0.002 statistical lives based on LNT.

The welfare of the population can be measured using Collective Dose, which models the dose to all affected persons from discharges of radioactivity to air or water. In practice, these doses are predominantly made up from a large number of very small doses to many people over a long time. For example, it has been demonstrated that the bulk of the collective dose from a typical Sellafield discharge programme [5] is delivered between 0.0000015 and 0.000000015 mSv per annum, corresponding to an annual risk between one in ten billion and one in 1000 billion. The exact methodology which has been applied is subject to debate, the fact that the estimates are conservative is not.

This realisation has prompted the view that to set levels of VSSSL without regard to risk level is counter-intuitive, and that a valuation scheme which reduces with reducing risk would seem to better align the treatment of radiation risks with those of other industries and broader societal risks. Such a valuation scheme has been suggested [6], and its effect on ToR is shown in *Figure 2*.

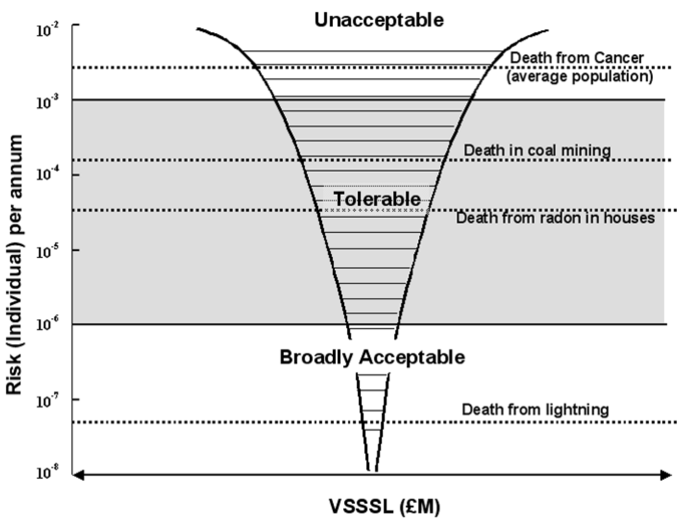

Figure 2

Discharge Regulation in the UK and ALARA

In the UK, the overall philosophy of regulating with reference to the highest risk is carried through by limits of 20mSv per annum to the workforce and 1mSv to the public. These levels roughly correspond to the upper end of the tolerability band under ToR. The limit is then reduced to 0.5 mSv and 0.5 mSv by a site and plant constraints. In practice, the maximum site critical group dose is below 0.15mSv, and it is the stated aim of the UK Discharge Strategy [7] to reduce the doses to the public to below 0.002mSv by 2020, corresponding to a risk of about one-in-a-million per annum. This has effectively removed the 'tolerable' region from ToR and changed the 'Broadly Acceptable' line to an upper risk limit.

This erosion of a factor of 100 in the tolerable risk levels is reinforced by two other policy positions:

- HSE has announced that their 'no danger' criterion [8] for delicensing sites will be interpreted as a one-in-a-million per annum risk to the most exposed individual plus Best Practical Means - which will presumably lead to pressure for levels below the new limit.
- The Environment Agency's requirements for radioactive waste disposal [9] state that '*After control is withdrawn, the assessed radiological risk from the facility to a representative member of the potentially exposed group at greatest risk should be consistent with a risk target of 10^{-6} per year (i.e. one in a million per year)*'

So - the nuclear industry is now regulated at a level where other industries' 'below regulatory concern' is nuclear's upper limit. Apart from industry protests, which, for a variety of reasons were either weak, ineffective or both, the only process to stand in the way of this 'regulatory creep' was Regulatory Impact Assessment (RIA). This process, run from the Cabinet Office, is intended to ensure that a prospective estimate of cost and value for money is carried out at the time that regulatory change is proposed. In practice, the process is barely given lip-service in the nuclear arena, and Reference 10 gives a critique of the RIA of the Sellafield Discharge Authorisation Review of 2000, and concludes that '*In these two examples, the RIA (or equivalent) was not conducted to the RIA Guide prescription. Best estimates of cost and benefit were not generated and hence could not be used in the analysis. It follows that RIA meeting Guide criteria did not inform these regulatory decisions*'.

Compliance and Conservatism

In the situation outlined above, it could at least be expected that the one-in-a-million level itself would be estimated without undue conservatism - but this is actually far from the case, and this may be illustrated with reference to the assessment of risk from disposal and the selection of critical groups.

GEOLOGICAL DISPOSAL

The methodology used for evaluating risk from deep geological disposal is very highly precautionary. Evaluations by UK Nirex [11], calculate doses to a potentially exposed group (PEG). For future doses these people may be assumed to be in a farming group living all their lives in the area where there is the highest concentration of radionuclides discharging to the biosphere from a repository via the groundwater pathway. They are assumed to both use this water for all their drinking and cooking requirements, and also grow all their food in this area. This is in fact a far more severe definition of maximally exposed individuals that is in use to define critical groups today.

The other main source of risk considered in the evaluation of deep geological disposal is human intrusion, and for this the dominant term is often the exposure of a geotechnical engineer from boring or coring through the repository. Here the dose is delivered because the engineers, who are technologically equipped to drill and core to 5-800 metres depth, are not equipped to notice some very unnatural substances in the drill cuttings or to register increased radiation levels.

With these examples in mind it is worthwhile examining what the current practices might be bequeathing to our descendents. As previously noted, the regulation of disposal is indifferent to detriment, but surely it is only by considering detriment that we can gain any perspective on the possible effects of our actions.

Imagine, for example, that our Potentially Exposed Group (PEG) numbers 50, and is subject to a dose of 2 mSv/a, which implies a 100-fold failure to meet the safety objective. An individual living to be 70 years old would then experience a dose of 140mSv which would equate to a 0.8% chance of a fatality. Let the PEG live on in the area, unsuspecting, for 10,000 years. This would attract a collective dose of some 1,000 man Sieverts, equating to 60 statistical fatalities, at a rate of 0.006 per annum.

It may be thought provoking to say that we are very clearly not talking about a 'disaster' on the scale of a Bhopal or a Serveso. We are in fact, talking about an effect which would be at best marginally detectable using all the techniques of modern epidemiology, and which has a far smaller consequence than moving house from London to Cornwall.

CRITICAL GROUPS

If we look at the regulation of current discharges, the critical groups '*can be defined as the individual or group of individuals representative of those most exposed as a result of the practice of disposal of the site concerned' [12] and is added to by 'the Environment Agency should not exclude from consideration any pattern of behaviour that a reasonable person might adopt, whether or not anyone actually engages in such behaviour at a* given time' [13]. In practice, this means that critical groups often indulge in activities and eating patterns which 99% of the population would find unusual or strange. It is surely relevant to protect such people when there is a danger that they may inadvertently exceed public regulatory limits, but it is surely less relevant to use these groups as a major driver of dose and discharge reduction when their doses are well below such limits.

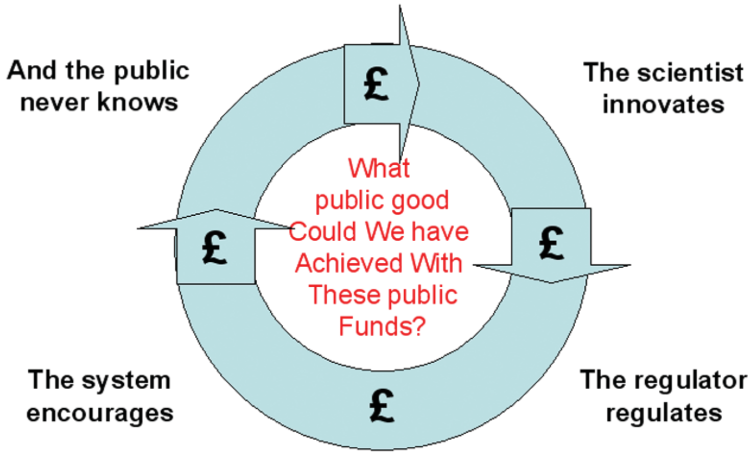

Figure 3

Overall Position - a Great Unknown

The UK industry is now in the position where it is protecting the maximally exposed individual(s) at well below and safe/unsafe boundary and spending many times the Government guidelines for reducing overall public detriment, which is overwhelmingly delivered at miniscule risks. It is planning to dispose of waste to standards which aim to prevent dose differences which occur naturally from one locality to another in many parts of the country. They are applying these standards to groups of people using assumptions and habit surveys appropriate to the safe/unsafe boundary, but surely inappropriate for levels a factor of a hundred below an already conservative limit. The application of these limits is leading to the over-expenditure of millions of pounds - pounds that could have been spent on schemes that could provide demonstrable health or environmental benefits for the people of the UK.

Encouraged by the need for the Nuclear Decommissioning Authority to demonstrate both progress and value for money in nuclear cleanup, a multi stakeholder group developed a measure for Radiological Hazard Potential (RHP) [14] which forms a key element in enabling the NDA to concentrate its efforts on the most significant wastes. A further multi-stakeholder group used the RHP with other measures to devise a prioritisation procedure which has been trialled with the NDA's site contractors [14]. These initiatives are to be applauded, but they are as yet only scratching the surface of the progress needed if a truly balanced and sustainable position is to be reached.

It is accepted that any suggestions for 'better' safety and environmental care inevitably provoke knee-jerk acceptance from the public, which tends to drown out any consideration of proportionality. This position is exacerbated by the very intelligence and inventiveness which has made the nuclear industry a beacon of innovation.

The search for continuous improvements in the safety of waste treatment and disposal by some of the world's best scientific minds seems often to lose sight of the adequate in pursuit of the perfect. The efforts of scientists to bring ever more sophisticated techniques and materials to bear can and does form a feedback loop, with regulatory regimes seeking improvement largely unfettered by considerations of cost and proportionality. The roles and processes of this development are seen in *Figure 3*.

This spiral can only be halted by will, methodology and communication.

- Will: for decision makers to require some assurance that the broader good is being served, and that the nuclear cleanup industry is not just 'spending because it can'.
- Methodology: for the NDA to continue the path of understanding what it is spending its money on and to be ready to challenge and justify its expenditure and progress.
- Communication: to enable decision makers and all other stakeholders to appreciate the difficult choices which have to be made, and to understand and respect the mechanisms which are used to make them.

Of these three, it is probably the communication of the need for, and benefits of, proportionality which is the biggest challenge. Proportionality has only recently become a concept which the nuclear industry has begun to grapple with. In the cosy days of cost-plus commercial contracts, it was only too easy to acquiesce to any request for 'improvement'- and to spend someone else's money. The new game still involves spending somebody else's money, but the somebodies are the UK taxpayers. It is time to tell them what they are getting for their money and how nuclear clean-up is being achieved in a way which promotes the overall good.

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