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What to do with Nuclear Waste

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Progress is being made with the disposal of nuclear waste, but public perception does not necessarily reflect this. The nuclear industry has assumed that the root of the public's continued concern is its inability to comprehend the scientific and technical aspects of the issue. It is true that the majority of the population does not and never will understand all aspects of the technology sufficient for them to be confident of the final outcome. Issues such as geological space and time; radioactivity half-life and half-distance; mathematical expressions of hazard, probability and risk; multiple barriers; and isolation periods of many thousands of years are not topics that engender public understanding, confidence and acceptance.

The nuclear industry has contributed to this dilemma in many ways. In some countries the final disposal of long-lived waste has reached a stalemate and is typified by large expenditures, institutionalised research programmes, and the loss of many prospective disposal sites. While there are exceptions to this general rule, as in Finland and Sweden, this generalisation holds true for most countries. For a closed nuclear fuel cycle the waste disposal step is yet to be validated, but it can be and this paper addresses some of the issues. Continued public education is part of the answer, but by far the biggest advance will come from **a better understanding of the public psyche by industry, and not by a better understanding of the industry by the public**.

Background

In the heady days of the 1970s, the accelerating growth of commercial nuclear power was acknowledged in publications projecting exponential growth, shortages of uranium and enrichment services, the need for spent fuel reprocessing and a breeder reactor programme. As society tried to adjust to this rush to nuclear, it was assumed that the closure of the fuel cycle and the disposal of its wastes was a foregone conclusion. Many options for disposal were proposed, such as geological burial, indefinite storage on or near the surface, placement on or in the ocean bed, continental subduction zones, ejection into space or placement on the ice sheet of Antarctica. Failing these, there was a belief that a society that was technically able to develop safe nuclear power would surely be inventive enough to devise an acceptable disposal regime. It would be but a short time before the safe disposal of all nuclear waste was demonstrated – a prompt technical fix. After all, the volume of waste was small when compared to other industrial waste and the radiotoxicity would decay with time. The waste was specific and better managed than other hazardous wastes and therefore things would turn out all right in the end. There was also a sense that government was standing firmly behind industry to prevent any default and a belief, or hope, that a compliant public would accept such a nationally important issue as they had done with similar essential industrial developments until that time.

However, the period of rapid expansion in nuclear power coincided with deep social change as communities gained sufficient understanding and resources to be able to mount organised resistance to the siting of critical facilities, such as power reactors and waste repositories. Nuclear power was not alone in this, as there is now similar resistance to the siting of gaols, motorways, drug rehabilitation centres and airport extensions. The process of *Decide, Announce and Defend* (DAD) no longer satisfied society and DAD became DADA, *Decide, Announce, Defend and Abandon*.

Classification of waste

Under this heading, the nuclear industry usually enters into a discussion about definitions for, and boundaries between, the various levels of radioactive waste. The recent re-categorisation of radioactive waste to include Exempt, VLLW, LLW, LILW-SL, LILW-LL and HLW[1] has many advantages, one of which is to provide an opportunity to compare nuclear waste to society's other hazardous waste. It becomes clear that not all radioactive waste needs to be regarded as highly hazardous. There is a range of degree of radioactivity from that similar to background radiation (as, for say, VLLW) to the very high levels of HLW. There is, however, a public perception that all nuclear waste is a singular material, discrete from other waste because of its radioactivity. The nuclear industry has promoted this concept in the knowledge that radiotoxicity decays with time whereas chemical toxicity does not necessarily. The isolation of radioactive waste should therefore be less of a problem than, say, the isolation of insecticide residues or heavy metals.

[The British Medical Association (BMA) stated that while radioactive waste is in the remit of hazardous waste it is in many ways singular – it is a discrete area of operation…*Hazardous waste* means 'a material that may present a hazard to human health or the environment through its use, handling or disposal…'. Whether a waste is hazardous depends on its physical, chemical and infectious characteristics and on its quantity and concentration.][2]

In perpetuating the concept that radioactive waste is different from other hazardous wastes, the nuclear industry has been 'hoist on its own petar'[3]. It has wrongly engendered and perpetuated in the minds of the public the idea that *all* radioactive waste is *equally* the most hazardous of all materials. I believe that it would be more logical to discard this adopted distinction. After all, most hazardous wastes are discrete in some physical, chemical or biological aspect, one from another. There are hundreds, if not thousands of hazardous wastes, and we may well ask how each of these is being disposed of. While the nuclear industry has always shied away from criticising competing energy sources or wastes produced from other industries, it is now time to review this. It has become clear that a comparison of all wastes and their disposal is the only way for the public to comprehend the degree of potential hazard. Scientific statements as to the nature and degree of a potential hazard are generally unintelligible.

A comparison between, say, LLW and waste from insecticide production or hospitals would show that the former is more manageable. It is solid, does not require further processing other than compaction, does not require sealed containment and is adequately disposed of in shallow earth burial. Short-lived intermediate level wastes would appear as just one of the moderately hazardous wastes of society, if compared to, say, ex-military chemical wastes. Long-lived intermediate and high level waste would, of course, rank much higher on a list of all of society's hazardous wastes, but these too can be shown to be manageable and safely disposed of.

The dynamics of waste disposal

Wastes do differ from one another, but there is a common theme running through all waste disposals. I believe that this theme, as illustrated in *Figure 1*, is captured in the phrase "**All waste will become part of the Earth**". The Earth I refer to is all of the atmosphere, hydrosphere and lithosphere. Axiomatically, this includes the entire biosphere – that part of the air, water and rock that supports life.

It seems that the public perception of each waste disposal is that it involves a single step, putting it somewhere so that it will no longer be a potential hazard to the environment. Once placed, it is regarded as being static, securely locked away, and usually forgotten. In reality, however, all waste disposal is a dynamic process that accommodates chemical, physical and biological change, and then dilution and dispersion over time. The products of combustion are discharged into the atmosphere and within minutes are diluted and dispersed into that medium – a brief but dynamic process (setting aside the question of whether all gaseous emissions are truly harmless to the environment). Waste legitimately placed into landfill instantly becomes part of the biosphere, but with time it will be neutralised, diluted and possibly dispersed into the soil so as not to be hazardous to the environment.

Waste requiring isolation for a short period, such as surplus radio-pharmaceuticals (e.g. thallium and technetium), are retained for a few days to allow for partial decay before being safely discharged into the environment. The disposal of radioactive LILW-SL waste from the nuclear industry is a further demonstration of dynamic waste disposal. It accommodates physical change over time (radioactive decay) before there is any opportunity for it to connect with the biosphere. Beyond its designed isolation period, and with dilution and dispersal into the surrounding rock, the legacies of that waste should not present a hazard to the biosphere.

The disposal of HLW is a long dynamic process that uses time to allow for radioactive decay, and eventually for its dilution and absorption into its over-pack and surrounding rock. It is the combination of containment and a selected space and time that will ensure that this waste will not be hazardous, should its remnants ever connect with the biosphere.

The modus operandi of all waste disposal is therefore to provide not only the space and medium of disposal, but to provide the time necessary for the change from being potentially hazardous to passive – a truly dynamic process.

The fourth dimension of disposal

The disposal of any waste requires the development of a three dimensional repository. Having also established the common thread of dynamism (change with time) that runs through all waste disposal, we are left with a further problem. I previously published the results of my research[4] in this field in Japan, Switzerland and UK. In summary, when considering the subjects of family and environment, about 60% of the populations tested selected an outer time horizon of 50 years or less and about 85% selected 100 years or less. This response is compared to the isolation periods for a range of nuclear wastes in *Figure 2*. In a subjective way this can be expressed as *a majority of the people have an outer time horizon not greater than the life of their grandchildren*. This is a significantly shorter time period than that necessary for the isolation of longer-lived hazardous wastes and is perhaps the root of the public's lack of confidence. I measured the public's confidence in deep geological disposal and found that more than half the population believe that the isolation could break down and allow a connection of waste to the biosphere in 1000 years or less. This compares unfavourably with the need to provide isolation periods of up to 100 000 years.

The next step is to undertake the research necessary to understand better the thinking of the general public. My research so far has shown that the public does believe that the user of the goods and services should meet the cost of waste disposal. I believe that the public also recognises that the generation of energy and materials does create waste, and they would be happier if those wastes were properly disposed of in their own generation, without risk to the environment. They do not naturally think about, or imagine things that have a lifetime greater than the life of their grandchildren. Issues that could have an effect in periods greater than 100 years forward are unimaginable and are therefore usually rejected. The public seems to want to prevent such long-lived processes being put in place rather than to nonchalantly accept them and assume that any potential impact would be so far off in the future that it could be ignored.

There is a possible solution to the puzzle of the disposal of all long-lived wastes. The wastes should be contained, buffered with suitable materials, put in place with a high probability of being safe, and allowed to change from potentially hazardous to passive with time. The public would probably have a greater confidence in such a disposal regime if that process could be reversed and the waste be recovered, should any future generation decide that it is necessary to do so. The general concept for a dynamic but retrievable scheme is shown in *Figure 3* where 'A' represents the opening of the repository; 'B' the closure of the repository; 'C' the design life of the containment system; 'D' the time by which all waste, if absorbed into the Earth, would no longer be a potential hazard to the biosphere.

The repository would remain open while receiving waste. At any time during that period the process can be reversed if required, and the containers of waste recovered. After the repository is closed, the containers of wastes can be retrieved by mining methods, if society requires it. The technology for such retrieval exists today but the container and repository design may need to be reviewed. The minimum design life for the containment system should be not less than the period necessary for the isolation of the waste, beyond which there could be a gradual dilution and dispersal into the over-pack and surrounding rock, without presenting a hazard to the biosphere. Should future generations find that a repository is imperfect, then it could be repaired, using current geotechnical processes. The next step is to thoroughly test people's inherent values and beliefs about reversible deep geological disposal.

Conclusion

An acceptable regime for the disposal of higher level, and longer-lived nuclear and other hazardous wastes remains to be implemented in most countries. This has once again been brought into focus with the possible resurgence of nuclear power due to a growing power demand and a need to reduce greenhouse gas emissions. More recently, the prospect of the clandestine use of nuclear waste as a weapon has once again focused attention on the security of interim surface storage of these wastes.

I hold that the resolution of this critical issue lies in a better identification and quantification of public attitudes and beliefs. I believe that the public's preferred option is *for*, not *against*, an acceptable final disposal for <u>all</u> existing and future hazardous waste. Of all of the sciences employed so far in the research for an acceptable regime for nuclear waste disposal, sociology seems to have been practically omitted, but this can be put right. We should start by identifying the disposal regimes acceptable to the public, and then develop the technologies and processes to achieve this.

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1. Classifications of nuclear waste: Exempt, VLLW-Very Low Level Waste, LLW-Low Level Waste, LILW-SL Low and Intermediate Level Waste-Short Lived, LILW-LL Low and Intermediate Level Waste-Long Lived, HLW-High Level Waste.
2. British Medical Association, *Hazardous Waste and Human Health*, 1991, Oxford, Oxford University Press.
3. *For 'tis the sport to have the engineer Hoist with his own Petar:* Shakespeare, Hamlet (1601) act 3, sc. 4, l. 206.
4. *Disposal of radioactive waste: a puzzle in four dimensions*, Ian J Duncan, Nuclear Energy, 2002, 41, no.1, Feb., 75-80.

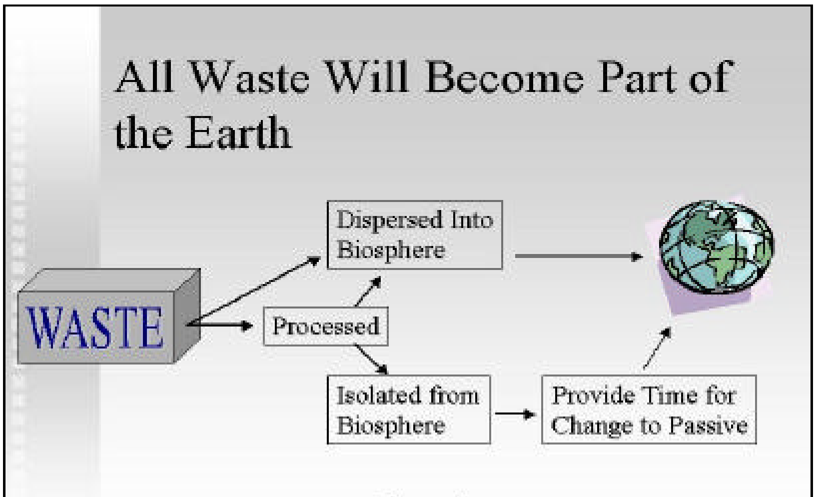

Figure 1.

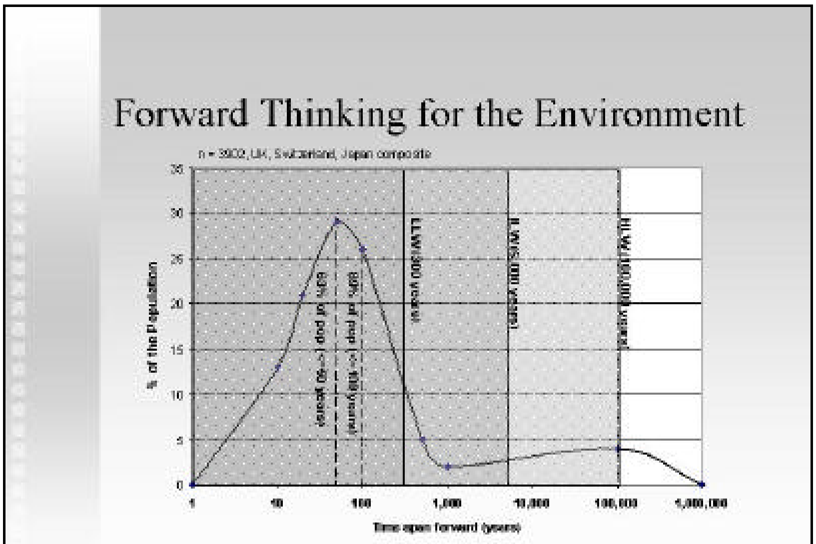

Figure 2.

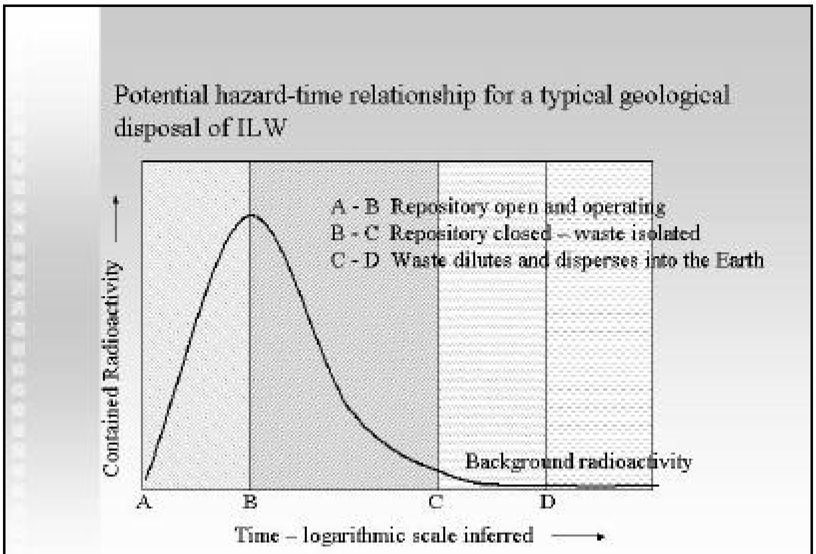

Figure 3.