The Safe Disposal of Nuclear Waste

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The most significant practical issue in nuclear electricity generation is the issue of nuclear waste. Regardless of the political or economic factors in the debate over nuclear power, the question of waste disposal is a legitimate and timely one. A safe, long-term solution is needed for Australia and the world.

On even the most conservative projections, the use of nuclear power is likely to increase over the next few decades. On top of that, there is also a large stockpile of nuclear waste from power stations and nuclear weapons which needs permanent disposal. Many countries simply do not have the geological, political, economic and administrative capacity to store their waste safely and durably.

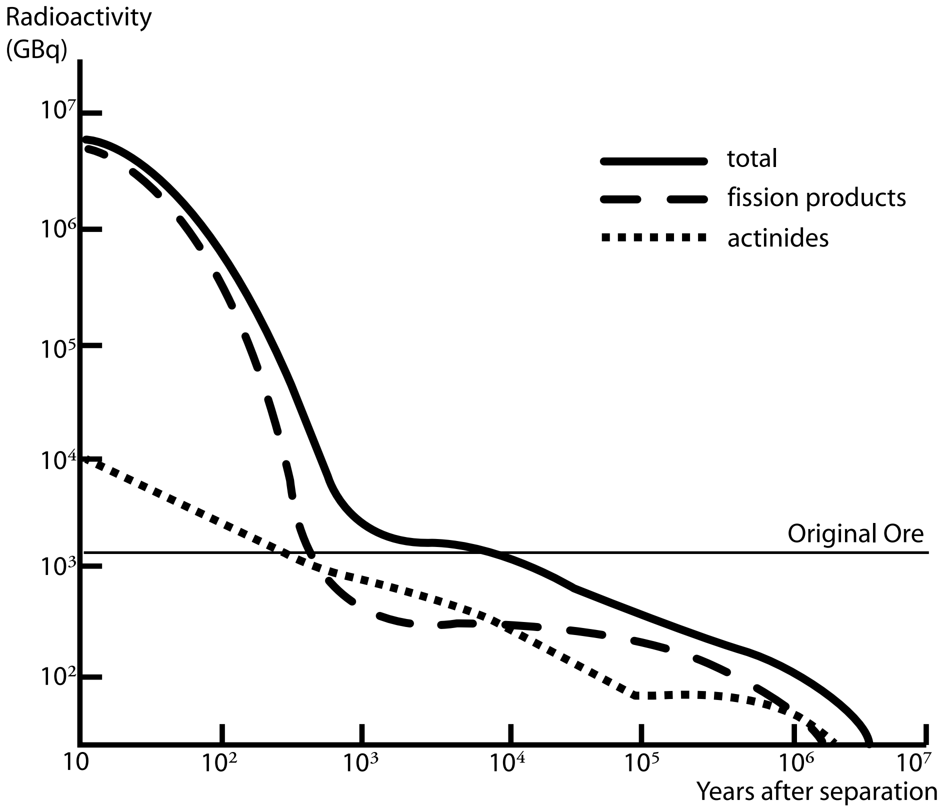
Australia may be in a unique postion to offer safe long-term burial of waste. The key element is the development of an internationally accepted and approved high-isolation disposal site that would be unique. The waste management system would include a disposal site, a railway and the associated seaport docking facilities.

The problem of long-term disposal of radioactive waste affects all developed countries. Even countries without nuclear power or research reactors use radioactive isotopes for medical and industrial purposes, and these isotopes must be safely stored until their levels of radioactivity are no longer dangerous. Countries which produce nuclear energy or have research reactors (such as Australia), face an even greater challenge because nuclear reactors produce waste which has very high initial levels of radioactivity. The time needed for safe disposal is neatly illustrated below. High-level waste takes at least 5,000 years before its activity becomes similar to that of a uranium orebody. Thus, waste needs to be safely isolated for extremely long times, up to a million years, if the highest standards of radiation safety are to be met.

Nuclear power utilities throughout the world have already produced 270,000 tonnes of spent nuclear fuel. During the next 25 years, this inventory will increase by approximately 12,000 tonnes annually, assuming that no new power plants are constructed.

Every country that has reviewed the problem of long-term disposal of its radioactive waste has reached the same conclusion: for the greatest long-term security, their wastes should be placed in a geologically stable un-

Figure 1: Decay in radioactivity of high-level waste from reprocessing one tonne of spent PWR fuel



GBq = 10^9 becquerel
The straight line shows the radioactivity of the corresponding amount of uranium ore.
NB both scales are logarithmic
Source: OECD NEA 1996, *Radioactive Waste Management in Perspective*

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derground repository. Such a repository is typically designed much like an underground mine, with ramps or shafts and elevators to access the underground workings, and waste packages inserted into the walls or floors of excavated tunnels. The repository protects people against direct exposure to radiation from the unwanted nuclear materials and must be sited and designed so that there will be no accidental escape of significant amounts of radioactivity to the point where humans or animals might be exposed.

Since the 1960s, extensive research programmes have been underway to develop the technology required to identify and characterize suitable disposal sites, to encapsulate and store the wastes, and to demonstrate the long-term safety of a disposal facility. With few exceptions, the scientists and engineers involved in these programmes have concluded that the technology exists to dispose of these wastes safely.

Despite these efforts, however, no repositories for disposal of spent nuclear fuel or high-level waste have been constructed. Additionally, the majority of the public believes that the problems of disposing of radioactive waste have not been solved and that radioactive wastes represent a serious threat to the environment. Why is there such a discrepancy between the opinions of informed scientists and those of the public? One reason for this lack of public confidence lies in distrust of the necessarily untried technological solutions that are being proposed for the different disposal programmes. While most scientists have confidence that all of the key questions have been answered, the public is not yet convinced. Given a requirement for engineered components to survive intact for orders of magnitude longer than any existing human works, the public's skepticism may not be unreasonable.

If the public is skeptical about high-technology solutions, why not seek out disposal sites whose geological properties would intrinsically provide reliable long-term containment or better isolation of the wastes? There are several geological formations, worldwide, that have been highly stable for hundreds of millions of years. If such geological formations exist, and they support no processes capable of allowing the escape of buried wastes to the human environment, it would be possible to avoid depending on these engineered barriers.

Essentially, all of the countries currently planning radioactive waste repositories have limited choices in the types of geological system in which they could bury the wastes. Some are geologically active, others have more stable geology, but active groundwater. While such sites can be perfectly safe, they require highly effective underground engineered barriers in order to be safe for all time. Finally, many countries over the time periods that must be considered have regularly experienced periods of glaciation, which can profoundly affect the climate, the flow of surface and subsurface waters, and erosion.

A useful approach, therefore, is to identify the characteristics of 'a high-isolation region', which could contain an intrinsically safe repository site and to then look for its characteristic signatures worldwide. If such regions could be found in countries that are politically stable and which have safe transportation routes, they could be a key to solving the world's radioactive waste disposal problem.

The concept of a natural site means that the repository must be simple and superior in safety ▶

Table 1: Characteristics of a High Isolation Site

Key Issues	Signatures
Minimizing groundwater flow	Very flat topographic surface Low annual precipitation (desert or near desert) High potential evaporation rates Dense sedimentary (clay/shale) formation
Maximizing time to reach biosphere	Dense sedimentary (clay/shale) formation
Minimizing possibility of human exposure	Saline or brackish, undrinkable groundwater No fresh-water aquifers No underlying mineral resources
Long-term stability	Climate stable for a very long time Low erosion rates Flat geologic units, simple stratigraphy Low seismicity
Engineering requirement	At least 200 metre thick disposal unit
Predictability	Disposal units well below groundwater table Flat geologic units, simple stratigraphy

terms to other disposal systems. High-isolation regions can be selected after reviewing geologic formations around the world, and considering the types of natural barriers inherent in the geology and in the present and possible future conditions at or near the surface, called collectively the biosphere.

Table 1 shows the important characteristics needed for a high-isolation site.

A global survey points to several regions that may contain sites matching this high-isolation signature. Many apparently promising areas do not, however, meet all of the criteria. The only extensive areas that appear to have the potential for high-isolation sites are in Australia, Namibia/South Africa, the Terim Basin (in China), and southern Argentina.

There are a number of non-geological criteria that limit the number of possible locations for a repository site. For example, suitable transportation corridors must exist. Also, the host country must be politically stable, must accept the presence of a repository, and must have the necessary institutions and technology to oversee its development and operation safely. After considering all such considerations, truly ideal high-isolation sites are very rare, and in their own way represent a geological resource of great value to humanity.

The political and commercial consequences of a repository in Australia are potentially far-reaching. The public and political hurdles that must be overcome are well known and have been delineated over many years.

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The disposal of commercial fuel in regional or international repositories for environmental and efficiency reasons has been validated by the recent completion of negotiations of a Vienna Convention on the safe management of radioactive wastes and spent fuel (IAEA). This convention, which is supported by Australia, contains provisions for the transfer of radioactive wastes across international boundaries for disposal.

Australia should offer to dispose of the wastes generated from the uranium supplied from our own mines in the first instance and, in addition, consider the disposal of wastes from our region where countries are unlikely to find secure high-isolation sites.

The greenhouse debate has heightened the view that the world should be searching for sources of energy that do not generate greenhouse gases. Australia will be making a substantial contribution to this search by encouraging the nuclear power option to be responsibly considered.

Considering the amount of uranium existing worldwide today, as well as the annual production rates for the foreseeable future, there is a pressing need for a high-isolation site. Simply restricting storage to Australian-sourced uranium would already make for a substantial market of 1,000–2,000 tonnes of spent fuel annually.

An industry price estimate for disposal is \$1million per tonne of spent fuel. This price is comparable to the cost of nuclear fuel reprocessing. The projected price corresponds to a cost of approximately 0.4 cents per kWh for a light-water reactor plant.

The disposal of spent fuel and high-level waste in Australia is a major opportunity. It would not only be a significant business opportunity, but also a major enabling step for the use of nuclear power, an important contribution to nuclear safety, and a major contribution to our region.

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