miles from the terminus at Paddington. This time, the train that went through the red did not have ATP, but the older system was working. The driver would therefore have received—and had to acknowledge—audible warnings as he passed each of two yellow signals and then the red, where he should have stopped. The signals were in order—and had in fact been examined and approved by the Health and Safety Executive a few months before.

It was a terrible smash. At least 30 people died, some incinerated when diesel fuel ignited. You probably saw the pictures in Australia on television or in the papers. It held the headlines here for days. The main lines to Paddington were closed for a fortnight, causing enormous inconvenience to London commuters.

Meanwhile, John Prescott, the Transport Secretary, announced that automatic train protection would be installed across the network, regardless—you guessed it—of expense.

Hang on a tick. This is the man who is meant to be delivering an integrated transport policy. At today's prices, ATP would cost £1 billion, perhaps more—or something like £17 million for every life it is estimated that it will save (before Ladbroke Grove, no passenger had died in a train crash for nearly two years).

In fact, 'joined-up government' and 'regardless of expense' can't go together. Joined-up government means *not* spending £17 million per life saved on ATP when there are many other investments that would save more lives for less money. In Mr Prescott's own domain, measures to make the roads safer for pedestrians would save more lives (by international comparisons, British roads are safe for drivers and passengers but dangerous for pedestrians)—and get more children walking to school. In the National Health Service, improved cancer services would certainly be much more cost-effective than ATP.

As I write this, people expect that a Transport Bill will be announced in the Queen's Speech opening the new session of Parliament in November. It will be interesting to see how joined-up it is.

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IPA

# Radioactive Waste

ALAN P. MARKS

Whether we like it or not, we've already got it!

## RADIOACTIVITY, THE MEDIA AND POLITICS

There is often media hysteria about radioactivity and radioactive waste. Emotive language implies irresponsible operators have casually abandoned leaking drums—undoubtedly rusty and disintegrating—in pristine natural surroundings in a national park! Naturally, *dumping* takes place upstream of an unpolluted, sparkling river or immediately above an artesian basin!

Late in 1998, the Australian media reported on a concept for an Australian repository for imported high-level radioactive waste (HLW) and spent fuel. The proponent was Pangea, an Australian company with British, Swiss and Canadian shareholders. The concept may be traced to ideas published by the Synroc Study Group which was established in the late 1980s at the behest of Senator John Button, then Minister responsible for the Australian Nuclear Science and Technology Organization (ANSTO) to investigate the commercialization of Synroc.

Synroc, an Australian invention, was developed jointly by ANSTO and the Australian National University (ANU), and funded by the Federal Government. It is a ceramic with strong retention for radioactive elements present in HLW. Reprocessing plants in Britain and France immobilize separated HLW in borosilicate glass. Synroc would perform similarly but with improved characteristics.

The Pangea story gave the public an impression that large volumes of imported radioactive waste would imminently arrive in Australia, leaving a hazardous trail before being *dumped*—note the emphasis on this word!—in an unsuitable location. Politicians of all parties quickly distanced themselves from this distorted proposition and dismissed any serious study of the concept.

Disposal of radioactive waste is an example of the stalemate often arising from the intersection of science, technology and politics. Governments were once expected to analyse, assess and then act responsibly on a potentially controversial proposal. Today there seems to be more emphasis (though unspoken) on whether politicians would thus place their individual careers at risk at the next election.

But Australia already has radioactive waste. How is this so? Before answering this, we should clarify the difference between radioactive and non-radioactive waste.

## WHAT IS WASTE?

Everybody knows what non-radioactive waste is (let's just call it 'waste'), it's that stuff we drop into bins and wheel out to the nature strip every week. The council's contractor collects it and takes it to the municipal *tip*. This domestic waste is literally *tipped* out of the truck, mingled with soil, and then left to decompose over a period of time. Governments have evolved regulations for municipal tips to safeguard the public and encourage the tipping process to be effective and efficient. There are other forms of waste, of both domestic and industrial origin, which cannot be tipped in this way. Some industrial waste can be very hazardous, containing metals and intractable chemicals that must be carefully and permanently isolated from the biosphere.

*Radioactive waste,* however, is beyond the experience of most people, partly because there is so little of it. It is also beyond experience because we usually cannot touch, taste or smell radioactivity, even if we can see the waste. Perhaps the undeserved reputation of radioactive waste is an inevitable consequence of its difference, since it can be detected with simple instruments in even smaller quantities than could be seen through a microscope. These 'simple instruments', however, are much less

common than, say, the ubiquitous mobile phone! Perhaps this implies that if something can't be detected by the human senses, it must automatically be feared and avoided.

Compared to other types of waste, the volume of radioactive waste is small, so that it is feasible to encapsulate it to prevent it from returning to the biosphere. Compare a clean warehouse full of sealed drums with the area and aroma of one municipal tip, or compare a 100 tonne steel and lead transport container on one railcar with a small mountain of fly ash.

## AUSTRALIAN WASTE

Much of the radioactive waste generated in Australia originates at the laboratories of ANSTO at Lucas Heights. ANSTO operates the HIFAR research reactor, which generates radioactive waste—for example, in the fuel in which the chain reaction takes place, the filtration media that help to purify the circulating water and in other equipment used for research and production.

Production of radioisotopes used in medicine and industry requires reactor irradiation of target materials and subsequent processing of extracted isotope products. These operations generate radioactive waste, such as tissues, protective clothing, containers and residual liquids. The solids, containing minimal radioactivity, are compressed into steel drums for storage. Liquid waste may be solidified and mixed with concrete in a steel drum.

The radioactivity in the waste diminishes with time. When the rate of decay is rapid, storing the waste allows residual radioactivity to become so low that disposal is permitted as non-radioactive waste. Governmental guidelines cover this situation.

Some radioactive waste, however, takes many years to reach a non-significant level. This waste must be stored until a permanent method of disposal is available.

In addition to the Lucas Heights waste, radioactive waste is produced in varying quantities and types elsewhere. This includes industrial sources (for example, for industrial radiography) whose radioactivity is exhausted, self-illuminated signs (for example, 'Exit' signs), residues from nuclear medicine activities, and obsolete smoke detectors and alarms. The radioactive content of all of these, and others, even when no longer useful, requires storage and ultimate disposal which meets legal requirements.

Australia possesses radioactive waste by virtue of its place in the modern world and its citizens' preference for modern facilities and services. We have radioactive waste because we use radioactivity. We use it in science and medicine, in engineering and production technology and we use it in research and development. Without it, many diagnostic and measurement processes would become difficult or impossible. Many people have benefited from *nuclear medicine*, that is, the use of radioactive pharmaceuticals in very low concentrations for diagnosis. Some diagnostic tests would not be possible or require risky invasive procedures if nuclear medicine were unavailable. Many people are likely to benefit from nuclear medicine diagnostics over their lifetimes.

Surprisingly, most households in Australia contain radioactive material. The cheapest and most effective form of smoke detector—a required fitting in homes, hotels and offices—contains a small amount of americium, a radioactive element. When the detector becomes obsolete, it must be treated as radioactive waste and disposed of appropriately.

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Australia is a supplier of uranium for nuclear electricity generation overseas. Hence Australia is also linked to the generation of radioactive waste in other countries.

## LOW LEVEL WASTE

Most of the waste described above is called *Low Level Waste* (LLW). International standards for LLW disposal permit it to be buried in defined types of containers in shallow trenches in an appropriate environment. Note that the word *dump* does not describe this type of disposal!

Federal and State governments agreed in the early 1980s to seek a site for a National LLW Repository, but the process of selecting a site and establishing the Repository is yet to be completed. Test drilling in an arid region of mid-north South Australia is proceeding, however, and the Repository should be in operation within the next few years.

Criteria for LLW disposal are based on the low level of radioactivity and the relatively short-lived nature of LLW. Location in an arid region reduces the risk of waste being disturbed by surface water. The risk is further reduced by the integrity of the containers and by use of an impervious lining to the trenches. Once full, trenches will be backfilled and the facility covered with a layer of earth and reinforcing material to maintain its overall integrity. After some years, there would be no further need for surveillance and the site would be fenced off and only occasionally inspected.

## INTERMEDIATE LEVEL WASTE

LLW is not the only waste classification in Australia. At Lucas Heights and elsewhere there is *Intermediate Level Waste* (ILW), longer-lived and more radioactive than LLW. Examples of ILW are ion exchange resins used in water purification for HIFAR, and equipment used in the reactor and in other work with radioactive materials.

There are government regulations for LLW disposal, but there is nothing corresponding for ILW. International standards require underground ILW disposal, generally hundreds of metres below the surface in caverns excavated in solid rock in a region meeting other criteria.

The fundamental requirement for safe disposal of radioactive waste is minimum possibility of the waste moving by natural forces from the emplacement area over a period of time commensurate with the decay period or radioactive half-life. Other than major earthquake movements, the only mechanism is the presence and movement of groundwater. Site selection requires evidence that groundwater is absent or is essentially stationary over the relevant time scale. Hence geological evidence must be fully assessed for a candidate site.

Disposal of Australian ILW suffers from the smallness of the overall quantity and that identification and establishment of an ILW repository would be disproportionately expensive. The Fed- ▶

eral Government's response is only to propose that ILW should be stored, a facility being co-located with the LLW repository.

Another source of Australian ILW could be waste from HIFAR spent fuel. About half of this spent fuel will be processed in France. The small proportion of waste arising would eventually be returned to Australia, possibly as a concreted mass in containers. Many years may elapse before this waste is returned; there is no urgency at present to establish an ILW repository.

## HIGH LEVEL WASTE

The third major classification of radioactive waste is *High Level Waste* (HLW), which is the residue from chemical reprocessing of spent fuel from nuclear power stations. Although unreprocessed spent fuel itself is not strictly HLW, the two are often considered together; both have intense radioactivity requiring heavy radiation shielding and thermal cooling for some time after their removal from the power station.

Although waste from HIFAR spent fuel may be classified as ILW, there is no unanimity on the classification of separated waste from spent fuel, whether from power stations or research reactors. The nature of the waste is broadly similar in both cases. Waste from research reactors, if put in a concentrated form, would be more akin to HLW, and equally, if in a more dilute form, could be classified as ILW since the radioactivity would be long-lived and require radiation shielding but not cooling.

As Australia has no nuclear power stations, it has neither power station spent fuel nor HLW arising from it.

## PANGEA AND SYNROC

The Synroc Study Group's studies, published in 1991, included the idea of a repository for HLW immobilized in Synroc; this repository could be located in Australia or elsewhere.

Commercial use of Synroc is now more likely to involve the immobilization of specialized waste streams into which HLW could be divided in the reprocessing plant; this aspect is being examined in France and Japan. The USA has selected Synroc as a preferred wasteform for the immobilization of plutonium.

Pangea's concept is independent of the immobilization wasteform for HLW and is equally applicable to unreprocessed spent fuel. The proposal is based on the ideal geological conditions for the disposal of radioactive waste that exist in parts of Australia, as well as Australia's perceived political stability and maturity. Pangea also recognized that many overseas countries with nuclear power stations have had difficulty in obtaining scientific verification of chosen disposal sites. Large sums of money have been lost seeking such verification; often problems arose because the site had been chosen on political rather than technical grounds. Since capital costs of repositories are high, some countries are concerned that domestic disposal of relatively small quantities of HLW and/or spent fuel will be disproportionately expensive.

Pangea recognized the economies of scale of a central repository and also assumed there would be interest in Australia for the economic benefits arising from its integrated concept.

***Radioactive waste has a great advantage … the ability to detect its presence, even in minute quantities***

Pangea proposed to build in Australia large numbers of one-hundred-tonne transport containers and specialized double-hulled ships to carry the transport containers from overseas. A rail link from a port to the disposal site would be required. Overall, these proposals could create significant numbers of long-term jobs and a financial benefit to Australia valued annually at some billions of dollars.

Other countries having difficulty in establishing repositories may welcome an international repository. This could provide recognition of Australia as a major contributor to disarmament through permanent disposal of immobilized plutonium from weapons stockpiles.

Pangea's proposals may have been prematurely disclosed, and caught some of its potential political supporters off guard, unable to admit publicly to any willingness to consider the merits of the concept. Whether anything will come of the concept remains to be seen, and may depend on support from a potential beneficiary such as a State Government.

## THE MESSAGE

Australia *has* radioactive waste, stored in temporary locations throughout the country. Eventually arrangements must be made for its disposal rather than leaving it for future generations. One exception: Western Australia recognized the need to manage its own waste and, several years ago, set up a small disposal site for both radioactive and intractable waste at Mount Walton East.

Ultimately the National LLW Repository will exist and will accept LLW. Only small quantities of LLW are generated in Australia. Once the initial backlog is cleared, the Repository may only need to be used infrequently to admit new waste, perhaps annually.

Disposal of existing ILW, and HIFAR fuel element waste when eventually returned, will be more difficult, due to the anticipated cost of an underground repository.

It is disappointing that Pangea's proposals seem to have been dismissed out of hand by nervous politicians, given the potential for the establishment of new industries and significant job creation. Why is there this nervousness? Has any politician declared his or her fear of the unseen radiation? Most of the dismissive statements rely on so-called 'policy' that Australia will not take radioactive waste from elsewhere: no plausible rationale for this policy has been given.

Radioactive waste has a great advantage over other kinds of waste, namely the ability to detect its presence, even in minute quantities and often at a distance. This powerful property in turn enables enclosure and containment of radioactive waste—or any other radioactive material—to be achieved and confirmed to avoid all uncertainty as to its status and safe management.

So what is the problem?

## AUTHOR'S NOTE

This article is as non-technical as the subject permits. Note that the scheme of waste classifications LLW, ILW, HLW used here is only one of several alternative schemes. I used this one in the interests of simplicity and minimal technicality.

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