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MANAGING THE UK PLUTONIUM STOCKPILE

As a result of both civilian and military activities in the UK, a stockpile of plutonium has accumulated, for which there is currently no long term management strategy. Proposed options include treating it as a waste or using it in nuclear fuel to generate electricity. Discussions have recently been initiated by the Committee on Radioactive Waste Management (CoRWM) on the implications of managing plutonium as waste; currently none is classified as waste. This note provides background information on the UK's plutonium stockpile and examines safety and proliferation issues. It outlines why a management strategy is required and summarises commentary on long-term options.

Background

Plutonium is produced as a by-product of the use of uranium fuel in nuclear reactors. It is contained within spent (used) fuel when it is removed from a reactor but can be extracted by reprocessing (see Box 1), after the fuel has been stored for an initial period. The plutonium can then be re-used to make reactor fuel or stored pending other management decisions. In the UK, plutonium exists in four different forms resulting from the different stages of this process:

- plutonium contained in spent fuel
- separated plutonium (in the form of plutonium dioxide powder) from reprocessing of spent fuel
- plutonium contained in un-irradiated (not yet passed through a reactor) 'Mixed Oxide' (MOX) fuel (page 2)
- small concentrations of plutonium in material that has been contaminated during the above processes ('plutonium-contaminated material' or PCM)

This note focuses on management of the UK's civil separated plutonium stockpile, stored at Sellafield. This has arisen largely from commercial reprocessing of spent fuel from UK nuclear power plants and makes up the greatest proportion of the UK's total plutonium stockpile. The remainder is military plutonium and is not discussed in this briefing. There are 70 tonnes of civilian plutonium in stock. Based on anticipated arisings from UK gas cooled reactors, this could rise to 100 tonnes within the next 10 years.[1] Some plutonium stored in the UK belongs to overseas customers.

Box 1: Reprocessing in the UK

Reprocessing involves dissolving spent fuel in nitric acid and separating the re-usable plutonium (0.7%) and uranium (98.9%) from residual waste products (0.4%). In the UK, this technique was originally developed to obtain plutonium for military use but later evolved into a commercial activity. The uranium and plutonium so produced can be re-used in reactor fuel. A detailed discussion of why the UK originally adopted a commercial reprocessing policy, and the contention surrounding the activity, is beyond the scope of this report. There are two operational commercial reprocessing plants in the UK, both at Sellafield in Cumbria: the Magnox plant, which reprocesses spent fuel from the UK's Magnox gas cooled reactors ; and the Thermal Oxide Reprocessing Plant (THORP), which reprocesses fuel from overseas Pressurised Water Reactors (PWRs) and from the UK's Advanced Gas Cooled Reactors (AGRs).

Safety of separated plutonium

Stores are designed to avoid potential hazards associated with plutonium (Box 2) such as criticality, heat generation from radioactive decay, deterioration of packaging and contamination. Safety measures include storing only small amounts of plutonium in each container to avoid criticality. Also, precautions are observed during handling.

Box 2:Potential hazards associated with plutonium

- Plutonium is radioactive and so poses a health hazard: ingestion or inhalation of plutonium can significantly increase the risk of developing cancer. However, the radiation associated with it is very weakly penetrating, so it is much less harmful outside the body.
- Some plutonium isotopes[2] are 'fissile': under specific conditions and in sufficient quantities, they can sustain a nuclear chain reaction. Also known as 'criticality', this can result in the release of large amounts of energy. It is the principle behind both nuclear reactors and nuclear weapons. Thus, plutonium can pose a proliferation risk.

Specific concerns arise with separated plutonium since it is stored as a powder, and may be more easily dispersed in a fire or explosion than materials such as MOX or spent fuel. Compared to these materials, plutonium is also more accessible for weapons production.

Security of separated plutonium

Civil nuclear facilities in the UK are subject to the UK's safeguards agreements with international bodies (the IAEA[3] and EURATOM), and to the safeguards provisions of the EURATOM Treaty. These are designed to detect diversion of material into clandestine weapons programmes, and involve accounting for material and submitting to international inspections. However, concerns remain: a Royal Society report on separated plutonium points out that it is stored in quantities small enough to handle (~10 kg). Moreover, the radiation at the surface of the canisters is low, so they could be handled without exposure to dangerous levels of radiation.[4] However, fabricating a nuclear weapon from civil plutonium would pose major technical challenges.

Plutonium Management Options

Since some isotopes of plutonium have radioactive half-lives[5] of thousands of years, there is widespread consensus that long-term storage of separated plutonium in its current form is not acceptable, and a long term management strategy is required. Options include: using plutonium as fuel; transmutation (changing plutonium into shorter lived or stable elements); or treating it as a waste. The first two options would themselves produce some radioactive waste that would need to be managed.

Plutonium as a fuel

Some commentators argue that plutonium incorporated into reactor fuel would be less dispersible than separated plutonium, and would reduce the proliferation risk, since it would be less accessible for weapons production. There are three key fuel types:

- Mixed Oxide Fuel (MOX): is a mixture of plutonium oxide and uranium, from reprocessing spent uranium fuel. MOX has been used in reactors in several countries outside the UK. It is discussed in more detail in the next section. Plutonium is consumed when MOX fuel is used in a reactor. However, the rate of plutonium consumption is reduced because nuclear reactions occur which produce fresh plutonium. Reactors can be configured so that there is a net consumption of plutonium; hence a gradual reduction in the stockpile can be achieved.
- Thorium/plutonium mix fuels: thorium is a fissile element much more abundant in nature than uranium. Less plutonium is produced during this fuel cycle than with conventional uranium fuel. Drawbacks are that the reaction produces the fissile isotope uranium-233, which poses a proliferation risk. Also, some materials used in fuel fabrication are toxic. This fuel is not yet being used in commercial reactors, but research is occurring in Japan, the US and India as well as within the EU. More research would be required before it could be considered for new or existing UK reactors.
- Inert matrix fuels: this would involve implanting plutonium in an 'inert' matrix, where using the fuel would not breed fresh plutonium. Thus the plutonium stockpile would be reduced more quickly. However, it is yet to be demonstrated on an industrial scale. More research would be required before it could be considered as an option.

Mixed Oxide Fuel (MOX)

Some countries with plutonium stockpiles, such as France, Russia, Japan and the USA, have adopted, or plan to adopt, MOX as an integral part of their plutonium management strategy. MOX accounts for ~5% of the world's reactor fuel usage. In Europe, 37 Pressurised Water Reactors (PWRs) (two in Belgium, 22 in France, 10 in Germany and three in Switzerland) operate with part MOX loading. Four plants produce, or will in future produce, commercial quantities of MOX fuel. Two are in France, one in Belgium, and a fourth, the Sellafield MOX plant or SMP, is in the UK (see Box 3).

MOX fuel is not used in UK reactors. Of the UK's 27 nuclear power reactors, only Sizewell B (the most modern, operated by British Energy) would be capable of using ~30% MOX in its core without major modification. However, there are no plans to use MOX in this reactor. According to the Plutonium Working Group,[6] not all the UK's plutonium stockpile could be managed by this reactor alone, within its lifespan.[7]

If there were new nuclear build in the UK this might be more favourable to MOX use (although the Government has no current plans for new build). British Nuclear Fuels plc (BNFL) recently proposed the introduction of a new generation of reactors, the 'AP1000'. Based on the current PWR design, these would consume 100% MOX (compared with the current 30%). BNFL estimate that two AP1000 reactors could convert the UK's currently envisaged separated plutonium stockpile into spent fuel, within their lifetimes (60 years). However CoRWM recently pointed out that *there are various uncertainties, technical as well as economic, regarding the use of plutonium in both existing and new* (UK) *reactors*.[8]

Proliferation issues associated with spent fuel and MOX

The proliferation risk associated with either un-irradiated MOX fuel, or spent fuel (whether it be spent MOX fuel or another fuel type), is less than that of separated plutonium. This is because the plutonium in spent fuel or MOX would need to be extracted before it could be used in weapons.

Box 3: MOX in the UK and France

MOX production at BNFL's Sellafield MOX plant (SMP)
Government approval for the production of MOX from foreign plutonium was given in 2001 following public consultation. BNFL has contracts with Germany, Switzerland and Sweden, all of which have reprocessing contracts with THORP (see Box 1). Under current plans, the SMP will not convert any of the UK's separated plutonium into fuel. However, BNFL state that if a decision were made to build new reactors in the UK, capable of consuming MOX fuel, then SMP could be used to produce MOX from UK plutonium. This would require a new consultation process. From April 2005, the Nuclear Decommissioning Authority (NDA) will assume ownership of all BNFL's commercial nuclear assets, including SMP and BNFL's civil separated plutonium. NDA will be responsible for implementing government policy on how this plutonium is managed, once a strategy is in place.

There has been controversy over SMP's operation. This has been exacerbated by the fact that several technical and operational difficulties have delayed its opening, and by the data falsification incident at its predecessor plant (the MOX Demonstration Plant) in 1999 (POST note 137).

MOX production and use in France
France is the world's largest producer and user of MOX. It has two MOX-producing facilities and 22 reactors operating with part MOX loading. However, France has not yet achieved a 'neutral plutonium fuel cycle', where there is no net increase in plutonium. Between the end of 1994 and the end of 1997, stocks of separated civilian plutonium rose from 21.9 to 38.7 tonnes.[9] According to the IAEA, this figure had increased to 43.5 tonnes by the end of 1999. There has been a gradual decline in the rate of accumulation of plutonium, but the stockpile is still growing. The accumulation will decline further if plans to use MOX in more reactors, and to construct a European PWR capable of 100% MOX loading, are implemented. These plans are under review. France also has one operational experimental fast breeder reactor, which can use plutonium in its core.

Spent fuel is difficult to handle since it is highly radioactive. However, un-irradiated MOX is significantly less radioactive, and so is easier to handle than spent fuel. Thus, MOX is classified as a 'category 1' (highest risk) material under international security standards. Some NGOs say that the transport of radioactive and nuclear materials arising from the international MOX fuel trade increases the risk of proliferation (see page 4).

Transmutation

This involves bombarding heavier elements, such as plutonium, with neutrons from a nuclear reactor or accelerator, to produce shorter lived or stable elements. Although transmutation could reduce the stock of plutonium, it would create secondary radioactive wastes requiring long-term management. It has not been demonstrated on a commercial scale; the UK's former Radioactive Waste Management Advisory Committee (RWMAC) have stated that *proving the technology will take time and will be costly (probably prohibitively).*[10] Also, this option requires a long term commitment to nuclear power and reprocessing.

Box 4: Immobilisation techniques

Immobilisation in ceramic
Ceramic immobilisation of simulated high level waste[11] in a Synthetic Rock material has been demonstrated at the Australian Nuclear Science and Technology Organisation (ANSTO). Less research has been done on the ceramic immobilisation of plutonium. However, observations of natural analogues indicate that some ceramic immobilisation methods could retain plutonium safely for long timescales. This method would be more proliferation-resistant than other techniques such as immobilisation in glass. However, more research would be required before it could be used on an industrial scale. BNFL and ANSTO are discussing the possibility of conducting further research in the UK in future. Of all the immobilisation options, the Plutonium Working Group concluded that ceramic immobilisation offers the most promising solution.

Low Specification MOX
This is MOX that does not comply with fuel grade specifications, and is intended for eventual disposal. The Plutonium Working Group have discussed the possibility of manufacturing low spec MOX at SMP.[7] However, BNFL must fulfil contracted business for overseas customers before a change of use can be considered for SMP. Low Spec MOX reduces the proliferation risk of the plutonium compared to separated plutonium, but may not provide the same level of security as other forms of immobilisation.

Vitrification (immobilisation in glass)
This involves immobilising plutonium by mixing it with molten glass. It could be done in two ways: One possibility is to simply vitrify the plutonium alone. The other possibility would be to combine the plutonium with high level waste (HLW) before vitrifying and storing it ready for disposal. However there is limited understanding of how chemical differences between plutonium and HLW may affect the stability of the glass. Vitrification of HLW on its own already takes place on an industrial scale, but more research would be needed to adapt the technology to plutonium.

Immobilisation with a high level waste (HLW) barrier
This would involve surrounding immobilised plutonium with a protective barrier of vitrified HLW. A similar technique is the 'can in canister' approach, which involves arranging pucks of plutonium in a can and filling in the gaps with vitrified HLW. This was studied in the US, but ultimately rejected. Both techniques would reduce proliferation risks , by reducing the accessibility of the plutonium. However, carrying out safety and security checks would be difficult.

Plutonium as a waste

At least 5% of the separated plutonium stockpile is unsuitable for use in fuel due to contamination caused by radioactive decay and historic packaging. Therefore at least a small proportion will need to be treated as waste at some point. It would need to be 'immobilised' to reduce the risk of proliferation, and to make it easier to manage in the long term.

Immobilisation
Immobilisation techniques are at various stages of development (see Box 4); none has yet been carried out on an industrial scale. Whether a technique is suitable will depend on the facilities available and the intended waste management method. In the UK, the only immobilisation plant in operation is the Sellafield vitrification plant. This mixes high level liquid waste from

reprocessing with molten glass, to produce vitrified high level waste. However, existing facilities are fully committed until 2015 and there would be many difficulties faced in adapting this plant to immobilise plutonium.

Management of immobilised plutonium

After immobilisation, the plutonium would need to be managed. Opinions vary over the preferred strategy: NGOs such as Greenpeace favour long term above ground storage. Other commentators oppose this on safety and security grounds, and favour 'deep disposal' underground. Disposal of immobilised plutonium poses technical challenges, as safety and proliferation considerations would need to be taken into account. Studies by Nirex, the UK's radioactive waste management organisation, indicate that the deep geological disposal of immobilised plutonium is technically feasible. Some plutonium-contaminated material (PCM) has been included in the 'Nirex Phase Disposal Concept' for intermediate level waste (ILW): 7.9 tonnes of PCM and fragments of spent fuel will be distributed among the ILW.[12] However, more research would be needed to devise a strategy for disposal of larger quantities of plutonium, particularly as it would be the major contributor to the long-term radioactivity of the wasteforms. Criticality and safeguarding measures would be required if plutonium were included in a high level waste management programme. It would therefore be cost effective to decide what proportion will be treated as waste, at an early stage of the design process.

CoRWM

The Committee on Radioactive Waste Management (CoRWM) was established in 2003 to review options for managing solid radioactive waste, and to recommend what should be done with the wastes for which no long-term management strategy exists. CoRWM is considering a wide range of options, including interim and indefinite storage (both above and below ground) as well as final disposal. Although no options have yet been ruled out, CoRWM has published an early indication of its thinking, on which it will seek views.[13] It proposes to keep the options of deep disposal, phased deep disposal and interim storage on its preliminary shortlist. A range of other options, including indefinite storage, near surface disposal, disposal in space and sub-seabed disposal, requires further discussion before a decision is made. CoRWM's preliminary view is that some other options should not be pursued further.

Part of CoRWM's objective is to identify the inventory on which to make its recommendations. This includes consideration of radioactive materials not currently classed as waste, such as separated plutonium and uranium from reprocessing, and spent fuel, that may need long-term management. CoRWM will investigate the impact of different plutonium management strategies on the UK's radioactive waste inventory.

Transport

All of these would give rise to transport of radioactive and nuclear material, by road, rail, and in some cases by sea, in containers designed to withstand a range of accident scenarios. Transport of plutonium is contentious, as shown by protests over the recent shipment of weapons-grade plutonium from the port of Charleston in the US to Cherbourg in France. This plutonium is destined to be transformed into MOX for use in US nuclear power plants. Opponents such as Greenpeace say plutonium should not be reused but should be processed for '*safe disposition through immobilisation*'. They argue that immobilised plutonium is safer and more proliferation resistant than spent fuel or MOX.

Overview

- A stockpile of separated plutonium has accumulated in the UK, for which there is currently no long term management strategy.
- Many commentators argue that storing it indefinitely in its current form cannot be considered as a long-term option, due to safety and proliferation considerations.
- Proposed management options include: using the plutonium in nuclear fuel; immobilising it and then disposing of it as waste, or placing it in long-term storage; or transforming it using transmutation techniques.
- At least some of plutonium stockpile will eventually have to be classified as waste.
- The option of using the remaining plutonium in fuel will be influenced by future decisions concerning new nuclear build in the UK.

Endnotes

1 Source: British Nuclear Fuels plc (BNFL).
2 Atoms of the same element with different numbers of neutrons.
3 International Atomic Energy Agency.
4 *Management of Separated Plutonium*, the Royal Society, Feb.1998.
5 The time taken for the activity of a radioactive isotope to halve.
6 The Plutonium Working Group form part of the BNFL stakeholder dialogues, facilitated by the Environment Council.
7 *Final Report, Plutonium Working Group,* BNFL National Stakeholder Dialogue, produced by the Environment Council, March 2003.
8 *Preliminary Report on the Inventory*, document no. 542, CoRWM.
9 *Materials and Sites, French sources and stocks of plutonium*, Mary Byrd Davis, Nuclear France*,* 1997.
10 *The Radioactive Waste Management Advisory Committee's Advice to Ministers on the Application of Partitioning and Transmutation in the UK*, RWMAC, Dec. 2003.
11 In the UK, radioactive waste is classified by its radioactivity and the heat it generates. In order of decreasing hazard the categories are High Level Waste, Intermediate Level Waste, Low Level Waste, Very Low Level Waste. Classification systems vary in different countries.
12 The Nirex Phased Disposal Concept is one of the options on which Nirex conducts research for the long-term management of intermediate-level radioactive waste.
13 *Nuclear Waste Options Reduced,* CoRWM press release, Nov.2004.

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