No2NuclearPower

nuClear news

No.132 May 2021

Special Issue on Plutonium

1. Plutonium Policy Update

Introduction

The Nuclear Decommissioning Authority (NDA) now expects the Magnox Reprocessing Plant at Sellafield to close this year (2021) – one year later than previously planned. The newer Thermal Oxide Reprocessing Plant (THORP) was shut in November 2018. Reprocessing, which has always been unnecessary, is the chemical separation of plutonium and unused uranium from spent nuclear waste fuel.

When reprocessing ends there will be around 140 tonnes of separated civil plutonium stored at Sellafield - the world's largest stockpile of separated civil plutonium. (1) In 2008 the NDA launched a consultation on options (2) for dealing with this embarrassing stockpile – it is highly toxic, poses a permanent risk of proliferation, and will cost taxpayers around £73 million a year to store for the next century. (3) Today, after almost a decade and a half of dithering, the UK Government has failed to make any decisions, but still appears to favour the re-use option, which would probably involve transporting weapons useable plutonium or MoX fuel to reactor sites, such as Hinkley Point C and Sizewell B (and C if it is ever built) with an armed escort.

The NDA itself said in 2008 that deciding soon could save money by removing the need to build further plutonium stores. And the Government's refusal to admit that using the plutonium as fuel for new reactors is not only extremely technically challenging but also probably unaffordable, means funds are being spent developing both re-use and immobilisation options thus maximising the cost of plutonium disposition at the same time maximising the cost of plutonium storage.

The story so far

When reprocessing ends in 2021 there will be around 140 tonnes of separated civil plutonium stored at Sellafield. About 23 tonnes of this is foreign-owned, largely but not exclusively by Japanese utilities, and is managed under long-term contracts. (4) The UK's stockpile of plutonium has been consolidated at Sellafield by transporting material at the former fast reactor site at Dounreay in Caithness down to Cumbria. The NDA says it has been working with the UK government to determine the right approach for putting this nuclear material beyond reach. (5) The options it is considering are all predicated on the development of a Geological Disposal Facility (GDF). Radioactive Waste Management Ltd (RWM) – a subsidiary of the NDA - is assuming that a GDF will be available to receive its first waste in the late 2040s. Then it will take around 90 years to emplace all existing waste before it can begin emplacing other materials such as immobilised plutonium or spent plutonium fuel. And there are no guarantees this timetable will be achieved. In Sweden, for example, which is perhaps one of the countries most advanced in its development of an underground repository, nuclear utilities have warned reactors may have to close early because of delays in the approval of the repository. (6)

The Options

Options considered for dealing with plutonium include using it as a fuel called Mixed Oxide Fuel (MoX) in nuclear reactors (followed by storage as spent fuel pending disposal in a Geological Disposal Facility (GDF)). There was a MoX fuel fabrication plant at Sellafield which closed in 2011. According to a 2012 review (7), "*the actual performance of the plant was very poor*." With the "*projected annual throughput of 120te HM ... SMP actually manufactured 13.8te HM of MOX fuel during its operating life*." The review also noted that "*SMP had very significant gaps both in its design and operating capability. This meant that the plant as built was not fit for purpose and struggled from the start with a wide range of operational problems*."

But it is not just the UK which has problems with MoX Fuel Fabrication. In the US work started on a design in 1999, with construction beginning in 2007. The facility was originally estimated to cost $1 billion and be delivered by 2016. By 2014, the cost estimate had grown to in excess of $7.7 billion, with operations expected by 2019 at the earliest. A 2015 analysis suggested a minimum of $12.6 billion would be required to complete the plant. In response to escalating costs and timescales the Obama Administration announced in 2013 that "*This current plutonium disposition approach may be unaffordable ... due to cost growth and fiscal pressure*". (8)

The NDA has been looking at using plutonium in generic LWR-type fuels rather than specific fuels for reactors in the UK's new build programme – EDF has denied the suggestions it is considering the use of MoX. (9) If MoX fuel were to be used in new UK nuclear reactors like Hinkley Point C, or even the existing PWR reactor at Sizewell B, this would involve transporting a weapons-useable material on the UK road or rail network. Such transports would require an armed escort. (10)

The NDA has also looked at building a CANMOX fuel plant and at least two CANDU EC-6 reactors in the UK to irradiate the fuel as proposed by the Canadian company, SNC Lavalin; and a proposal by GE Hitachi Nuclear Energy (GEH) to build a fuel fabrication plant and two PRISM reactors to irradiate a plutonium alloy fuel. The NDA reports that no discernible evidence was offered that the CANMOX approach would be significantly simpler or more cost-effective than reuse as MOX in LWRs, and the cost, scope and extent of work required to progress Fast Reactor options, such as the GEH PRISM, as well as the timeframe means it is not credible for the NDA to develop this option. (11)

Another option would be immobilisation of the plutonium as a waste. Given the diverse nature of the inventory, a number of different approaches are being investigated so that parts or all of the inventory can be immobilised in a form suitable for ultimate disposal in a Geological Disposal Facility (GDF).

Both the re-use and immobilisation options would require new expensive plants which would be very technically challenging. Any new plant would take one or two decades to plan and build before processing of material could begin, so there is no quick or inexpensive solution. (12)

Some of the plutonium wouldn't be suitable for reuse as MOX in nuclear reactors in any case, due to its physical or chemical properties. It will need to be immobilised and treated as waste, followed by storage pending disposal in a GDF. (13)

In December 2011, the UK government concluded that its preferred policy for managing the vast majority of UK plutonium was to reuse it as MOX in nuclear reactors (14). Any remaining plutonium unsuitable for conversion into MOX would be immobilised and subsequently treated as a waste for disposal. The policy position recognises that not all the inventory could be reused; therefore, any strategy will also require the development of approaches to immobilise plutonium for storage pending disposal. It was emphasised at the time that, while UK government believed it had sufficient information to set a direction, it did not have sufficient confidence to progress into implementation. The government would only proceed when it was confident that its preferred option could be implemented safely and securely, was affordable, deliverable and offered value for money. (15)

The NDA is continuing to investigate how immobilisation and reuse might be implemented. It's latest strategy document says using the material as MOX fuel in light water reactors is the most mature option from a technical and licensing perspective. But the UK government will only take a decision when it can be underpinned with sufficient evidence and should not be made in isolation. This is due to potential interactions with national security and important infrastructure investments including nuclear new build and geological disposal. (16)

Storage Problems

Meanwhile plutonium will have to continue to be stored at Sellafield. The NDA's 2008 report said "*If a decision were taken today on a solution for the inventory, there could still be a requirement to provide storage for around 40 years*." (17)

Continued long-term storage of civil plutonium is not as easy as it sounds nor is it cheap, and there are many technical challenges. In fact, very long-term storage of plutonium is not well understood. Research indicates that there may be a requirement to treat or repackage some plutonium if it were to be stored for significant periods. Heat treatment and repackaging plants are likely to cost significantly more than a new store. All operations with plutonium are dose-intensive for operators, and best practice would be to minimise operation time for plutonium works. Another problem is that the plutonium isotope with the shortest half-life – Pu241 - decays to form Americium (Am-241), which is more radioactive than plutonium making the plutonium more difficult to handle. The half-life of Am-241 is 432 years. The NDA has begun a campaign of repackaging and treatment of packages Due to the size of the plutonium inventory and the complexity of developing and implementing the options, any long-term management solution will take many decades to fully implement.

The NDA considers some of the older plutonium packages and facilities used in early production to be amongst the highest hazards on the Sellafield site. Therefore, it is aiming to gradually transfer all plutonium to a new store, the Sellafield Product and Residue Store (SPRS) which opened in 2010. (18) The SPRS cost several hundred million pounds, but does not have the capacity to store all of the plutonium. The NDA has been transferring plutonium canisters into the store since 2012, and reported to the National Audit Office in 2018 that it was approximately 30% full. Two more stores are likely to be required to house the entire stock. (19) The first store extension is expected to be ready in 2033 and the second in 2040. (20)

In 2008 the NDA reported that "…*if we plan to store [plutonium] for the long term (post 2036) then additional capacity will need to be added to the new store.* ***This is a cost that could be potentially avoided.***" [emphasis added] (21)

To complicate matters, some of the existing canisters are unsuitable for storage in SPRS, and need to be repackaged. The NDA expects to do this through a new project, the Sellafield product and residue store retreatment plant (SRP). In addition, some canisters that have already been transferred into modern storage will, at some point in the future, have to be repackaged in the SRP facility to ensure they do not degrade. Based on current estimates the SRP facility is expected to become operational in less than 10 years and to operate for nearly 40 years. (22)

A proportion of the plutonium canisters at Sellafield are decaying faster than the NDA anticipated. A leak from any package would lead to an 'intolerable' risk as defined by the Office for Nuclear Regulation (ONR). The NDA has therefore decided to place the canisters more at risk in extra layers of packaging until SRP is operational.

In 2018 SRP was reported to be in the design phase. It was originally estimated to cost £470 million and be ready by 2023. But in June 2018 the NDA told the National Audit Office the estimated cost had increased to between £1 billion and £1.5 billion and it wouldn't be ready until 2025 at the earliest. This means the NDA has had to explore contingency arrangements for repackaging some canisters between 2023 and 2025. In 2019 the NDA agreed that the overall programme to manage the indefinite storage of UK held plutonium has increased between £0.5 - £1 billion from the current estimate of £3.5 billion (undiscounted) – taking is to £4 - £4.5 billion. (23)

In 2019 the NDA reported that it had evaluated the need for the new repackaging plant, SRP, in the context of the long-term plutonium disposition options under development and concluded that, irrespective of which option is chosen, this new capability is required to ensure continued safe and secure storage. (24)

In 2014, the House of Commons Public Accounts Committee reported that the Government did not have a strategy in place for the plutonium stored at Sellafield. 7 years later, it has still not decided between the two options available to it: readying the plutonium stockpile for long-term storage in a geological disposal facility (that has yet to be constructed); or reusing it as fuel in new nuclear power stations. (25)

Conclusion

The Government's preferred option for the disposition of plutonium still appears to be to use the majority of the stockpile to fabricate Mixed Oxide Fuel for use in Light Water Reactors. This could mean transporting weapons-useable plutonium on our roads or rail network to Sizewell and Hinkley Point. These transports would need to be accompanied by armed police.

This is despite the fact that a plutonium immobilisation plant would be required in any case to immobilise that portion of the plutonium stockpile which is not suitable for use in MoX fuel.

Meanwhile, the Nuclear Decommissioning Authority needs to continue its programme of modernising Sellafield's plutonium storage facilities, which will involve the construction of two extensions to the Sellafield Product and Residue Store (SPRS) and retreating and repacking some of the existing canisters which are considered unsuitable for storage in a modern store. This will also involve construction the Sellafield (Product and Residue store) Retreatment Plant (SRP).

Had the Government decided soon after the publication of the NDA's options report to immobilise the UK plutonium stockpile, as advised by environmentalists and proliferation specialists, it is likely that savings could have been made by removing the requirement for one or both of the plutonium store extensions. Indeed, if a decision is taken soon, it may still be possible to avoid the cost of building the second store extension.

In short, Government policy appears to be maximising the cost of plutonium disposition by requiring both a MoX fuel fabrication plant AND a plutonium immobilisation plant, and at the same time maximising the cost of plutonium storage. Under this policy MoX fuel containing weapons useable plutonium would have to be transported under armed guard around the country.

---

1. Hyatt, N. Plutonium management policy in the United Kingdom: The need for a dual track strategy, **Energy Policy** Volume 101, February 2017, Pages 303-309 https://www.sciencedirect.com/science/article/pii/S030142151630458X
2. NDA Plutonium Options for Comment August 2008 https://tools.nda.gov.uk/publication/plutonium-options-for-comment-august-2008/
3. Fichtlscherer, C et al Britain has 139 tons of plutonium. That's a real problem, **Bulletin of Atomic Scientists**, 17th April 2020 https://thebulletin.org/2020/04/britain-has-139-tons-of-plutonium-thats-a-real-problem/
4. Progress on Plutonium, NDA, March 2019 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/791046/Progress_on_Plutonium.pdf
5. NDA Strategy Effective March 2021 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/973438/NDA_Strategy_2021_A.pdf
6. KFGO 5th May 2021 https://kfgo.com/2021/05/05/five-swedish-reactors-risk-closure-by-2028-due-to-tardy-nuclear-waste-decision/
7. Sellafield Mox Plant – lessons learned review, DECC, 18th July 2012. http://fissilematerials.org/library/decc12.pdf
8. Hyatt, N. Plutonium management policy in the United Kingdom: The need for a dual track strategy, **Energy Policy** Volume 101, February 2017, Pages 303-309 https://www.sciencedirect.com/science/article/pii/S030142151630458X
9. Fichtlscherer, C et al Britain has 139 tons of plutonium. That's a real problem, **Bulletin of Atomic Scientists**, 17th April 2020 https://thebulletin.org/2020/04/britain-has-139-tons-of-plutonium-thats-a-real-problem/
10. See http://corecumbria.co.uk/mox-transport/

11. Progress on Plutonium, Consolidation, Storage and Disposition, NDA, March 2019 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/791046/Progress_on_Plutonium.pdf
12. NDA Plutonium Options for Comment August 2008 https://tools.nda.gov.uk/publication/plutonium-options-for-comment-august-2008/
13. NDA Strategy Effective March 2021 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/973438/NDA_Strategy_2021_A.pdf page 61
14. Management of the UK's plutonium stocks A consultation response on the long-term management of UK-owned separated civil plutonium DECC December 2011 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/42773/3694-govt-resp-mgmt-of-uk-plutonium-stocks.pdf
15. Progress on Plutonium, Consolidation, Storage and Disposition, NDA, March 2019 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/791046/Progress_on_Plutonium.pdf
16. NDA Strategy Effective March 2021 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/973438/NDA_Strategy_2021_A.pdf
17. NDA Plutonium Options for Comment August 2008 https://tools.nda.gov.uk/publication/plutonium-options-for-comment-august-2008/
18. World Nuclear News 24th May 2010 https://www.world-nuclear-news.org/WR-New_storage_facility_at_Sellafield-2405105.html
19. The Nuclear Decommissioning Authority: progress with reducing risk at Sellafield, National Audit Office 20th June 2018 https://www.nao.org.uk/wp-content/uploads/2018/06/The-Nuclear-Decommissioning-Authority-progress-with-reducing-risk-at-Sellafield.pdf
20. Letter from David Pettie to Meg Hillier, chair of the Public Accounts Committee 22nd July 2019 https://www.parliament.uk/globalassets/documents/commons-committees/public-accounts/Correspondence/2017-19/Letter-from-David-Beattie-to-Chair-in-response-to-the-Committees-report-on-Nuclear-decomissioning-authority.pdf
21. NDA Plutonium Options for Comment August 2008 https://tools.nda.gov.uk/publication/plutonium-options-for-comment-august-2008/ para A.4.1.2
22. Progress on Plutonium, Consolidation, Storage and Disposition, NDA, March 2019 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/791046/Progress_on_Plutonium.pdf
23. Letter from David Pettie to Meg Hillier, chair of the Public Accounts Committee 22nd July 2019 https://www.parliament.uk/globalassets/documents/commons-committees/public-accounts/Correspondence/2017-19/Letter-from-David-Beattie-to-Chair-in-response-to-the-Committees-report-on-Nuclear-decomissioning-authority.pdf
24. Progress on Plutonium, Consolidation, Storage and Disposition, NDA, March 2019 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/791046/Progress_on_Plutonium.pdf
25. Nuclear Decommissioning Authority: risk reduction at Sellafield, Public Accounts Committee, October 2018 https://publications.parliament.uk/pa/cm201719/cmselect/cmpubacc/1375/1375.pdf

2. Plutonium Remobilisation in the Irish Sea

Low-level aqueous radioactive waste has been discharged from the Sellafield site into the Irish Sea for more than 50 years. Originally it was thought that soluble radionuclides discharged from Sellafield (such as caesium and tritium) would be diluted and dispersed whereas long lived, transuranic nuclides such as Plutonium, and Americium would leach out of the liquid phase and become preferentially adsorbed to the surface of sedimentary particles in the water column, sink to the seabed and remain permanently bound and immobilised in seabed deposits and therefore isolated from human populations and the environment.

Unfortunately, it has since emerged that a proportion of such sediment associated radioactivity has, and is being actively transported around the Irish Sea while the remainder is temporarily "sequestered" in the seabed but subject to any future disturbance mechanisms such as storm, wave and seismic activity. In addition, a proportion of dissolved nuclides did not necessarily remain dissolved in liquid form in the water column, but could become incorporated into organic particles and deposited into sedimentary environments where they could be temporarily sequestered, but subsequently recycled back into the environment by dredging, trawling storm and seismic activity.

Plans by West Cumbria Mining (WCM) for an under-seabed coal mine off the coast of Cumbria near Whitehaven and the possibility of a Geological Disposal Facility, also under the seabed off the coast of Cumbria have raised concerns that transuranic radionuclides currently sequestered in Irish Sea sediments could be further remobilised as a result of these activities,

A large proportion of the Sellafield-derived radionuclides disposed to sea have become associated with the sediment at two sites close to the waste disposal pipeline: the Irish Sea Mudpatch and the Esk Estuary. The Mudpatch is a belt of fine-grained sediments located about10 km from the waste pipeline.

In 1999 Kershaw et al showed evidence that sediment-bound radionuclides over the previous decade were being redistributed. There was a decrease in the coastal zone around Sellafield and increases in Liverpool Bay and the western Irish Sea. Levels of dissolved 239/240Pu in the water column decreased only slowly since the peak discharge rates in the 1970s and much more slowly than the drop in Sellafield discharges. This suggests that material is moving from contaminated sediments and becoming dissolved in seawater where it is available for transport. Indeed, in the western Irish Sea, evidence has been found that 239/240Pu is being transported from the eastern Irish Sea. There is also evidence of the direct transport of contaminated sediment. (1)

Daisy Ray et al. highlight the fact that "*once mobilised, the radionuclides can be transported elsewhere in the Irish Sea … Although waste discharges are continuing to decrease from the Sellafield site, the Mudpatch may continue to supply "historic" Sellafield-derived radionuclides to other locations. Indeed, recent data from Welsh and Scottish coastal areas suggest that the Mudpatch still acts as a source of radionuclides to UK coastal areas.*" (2)

The model developed by Aldridge et al. at the Centre for Environment Fisheries and Aquaculture Science (CEFAS) in 2003 strongly suggest that the principal source of 239/240Pu in the Irish Sea was sediments in the eastern Irish Sea contaminated from past discharges, rather than new inputs from Sellafield. (3) Radionuclide re-distribution can occur by two principal mechanisms. Directly, by the transport of contaminated sediment, or indirectly via exchange and transport in dissolved form (dissolution). The latter process operates when tidal, wind or trawling activity re-suspends bed material allowing transfer of radionuclides to the water column. (4)

Ray el al. also suggest that bioturbation - the reworking of soils and sediments by animals or plants - at the Cumbrian Mudpatch will continue to act as a source of "historic" Sellafield-derived radioactivity to the UK Coastal Environment.

If this redistribution of historical discharges of radionuclides is happening by natural processes, it can be assumed that the problem could become much more serious as a result of human mining activities under the seabed,

A recent report by Marine Consultant, Tim Deere-Jones concludes that:

"*It is evident that any subsidence within the WCM designated seabed mining zone will generate some form and degree of seabed morphological distortion. It is equally evident that any such seabed distortion will remobilise previously sequestered seabed sediments, and their associated pollutants, which will subsequently be transported and re-distributed through the regional marine and coastal environments. It is inevitable that such re-mobilisation and re-distribution will expose marine wildlife and human coastal populations and stakeholders to some degree of exposure doses to those pollutants via a number of mechanisms and pathways.*" (5)

1. J.N. Aldridge, P. Kershaw, J. Brown, D. McCubbin, K.S. Leonard, E.F. Young (2003) Transport of plutonium (239/240Pu) and caesium (137Cs) in the Irish Sea: comparison between observations and results from sediment and contaminant transport modelling, **Continental Shelf Research**, 23:9, 869-9 https://www.sciencedirect.com/science/article/abs/pii/S0278434303000475
2. Ray, Daisy and Leary, Peter and Livens, Francis and Gray, Neil and Morris, Katherine and Law, Kathleen A. and Fuller, Adam J. and Abrahamsen-Mills, Liam and Howe, John and Tierney, Kieran and Muir, Graham and Law, Gareth T.W. (2020) Controls on anthropogenic radionuclide distribution in the Sellafield-impacted Eastern Irish Sea. **Science of the Total Environment**, 743 https://strathprints.strath.ac.uk/73556/
3. See (1)
4. Aldridge, John & Kershaw, Peter & Brown, J & Mccubbin, D & Leonard, Kinson & Young, Emma & Denoon, D. (2000). Transport of plutonium (239/240 pu) and caesium (137 cs) in the Irish Sea: comparison between observations and results from sediment and contaminant transport modelling. https://www.researchgate.net/publication/267687634_TRANSPORT_OF_PLUTONIUM_239240_Pu_AND_CAESIUM_137_Cs_IN_THE_IRISH_SEA_COMPARISON_BETWEEN_OBSERVATIONS_AND_RESULTS_FROM_SEDIMENT_AND_CONTAMINANT_TRANSPORT_MODELLING/link/5492c51d0cf225673b3e0a1f/download

5. Briefing Paper: Radiological Implications of Potential Seabed Subsidence Seismicity & "Fault Re-activation" Beneath the Cumbrian Mud Patch: induced by "mass removal", rapid extraction & void space creation, Tim Deere-Jones, Keep Cumbrian Coal in the Hole, June 2020 https://keepcumbriancoalinthehole.wordpress.com/2020/06/11/briefing-paper-radiological-implications-of-potential-seabed-subsidence-seismicity-fault-re-activation-beneath-the-cumbrian-mud-patch-induced-by-mass-removal/