FUTURE TREATMENT AND DISPOSAL OF AQUEOUS ACTINIDE CONTAMINATED WASTE AT AWE ALDERMASTON

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ABSTRACT

AWE Aldermaston has provided and maintained the warheads for the United Kingdom’s nuclear deterrent for over 50 years. AWE’s activities necessarily involve the use of radioactive materials and low levels of radioactivity are discharged to the environment, some of it in radioactive aqueous waste and the remainder in aerial discharges. A key part of AWE’s Environmental, Safety and Health Policy to ensure “that our actions cause no harm to the environment, public or employees” and there is a commitment to continue to drive down AWE’s discharge of radioactivity to the environment. As part of this policy AWE have made a commitment to cease discharge, by April 2005, of treated radioactive aqueous effluent, via a dedicated pipeline to the River Thames.

This paper sets out how AWE have approached this challenge and how the best practicable environmental option (BPEO) for the management and disposal of AWE’s radioactive aqueous wastes was identified. The BPEO identified that wastes whose radioactivity is predominantly due to the presence of actinides should be treated separately to those containing predominantly tritium. This is because of the very different behaviour of tritium compared to actinides. A separate strategy has been developed for these tritiated wastes, but is not covered within this paper. The proposed treatment process for actinide contaminated aqueous waste is condensing evaporation followed by membrane filtration of the condensate. The evaporator concentrate will be solidified and the permeate will be discharged as non-radioactive trade waste.

The paper highlights the importance in the decision making process of the identification of the sources of actinide contaminated radioactive aqueous waste on the AWE site and an understanding of the waste collection system. It also considers the important roles waste characterisation, waste minimisation, decommissioning, changes in work practices, stakeholder participation and implementation of best practice have played in arriving at a cost effective solution for the management of actinide contaminated aqueous wastes at AWE Aldermaston.
INTRODUCTION

AWE is responsible for providing and maintaining the United Kingdom’s nuclear deterrent and has been central to UK defence for over 50 years. AWE deals with the whole-life cycle of nuclear weapons: current work practices include maintenance of Trident as the current weapon system, dismantling weapons no longer required and decommissioning redundant facilities. The main AWE site at Aldermaston covers 670 acres and is situated about 35 miles west of London.

AWE’s work practices necessarily involve the use of nuclear materials and consequently gaseous, solid and aqueous radioactive wastes are produced. Radioactive waste production is minimised by the continual application of Best Practical Means (BPM). Minimisation of radioactive waste in turn minimises the radioactivity discharged to the environment.

However, it is not possible to eliminate totally radioactivity discharges to the environment. AWE discharges low levels of radioactive aqueous waste via the Pangbourne Pipeline (PPL) to the River Thames and low levels of gaseous radioactive waste are discharged to atmosphere via HEPA (High Efficiency Particulate in Air) filtered stacks. Solid Low Level Waste (LLW) is transferred to the national repository at DRIGG, near Sellafield in Cumbria, whilst solid Intermediate Level Waste (ILW) is stored on site at Aldermaston.

AWE is committed to reducing their discharges to the environment and a priority for AWE is to cease discharge of radioactive aqueous waste to the River Thames via the PPL by April 2005. This priority has been formalised by the issue of a regulatory improvement requirement to AWE from the Environment Agency (EA) in April 2000. To comply with this requirement the EA has stipulated that AWE must identify an alternative route which provides the “Best Practicable Environmental Option” (BPEO) for the management and disposal of radioactive aqueous waste at AWE. BPEO is defined as “the option that provides the most benefits or the least damage to the environment as a whole, at acceptable cost, in the long term as well as in the short term.”

GENERATION AND COLLECTION OF RADIOACTIVE AQUEOUS WASTE AT AWE

Prior to 2000 there were 60 facilities on the Aldermaston site that generated effluent that was treated as radioactive aqueous waste. Around half the facilities were served by the site’s radioactive aqueous waste collection system (a series of bunded tanks, usually situated outside the facilities they serve, and a network of pipes with a total length of approximately 4.3km). This network leads to a central treatment plant (which is exposed to the elements). Over 2km of the collection network is installed below ground level in a series of underground concrete and masonry ducts and pits. In addition there are a number of bunds that are open to atmosphere.

It is important to note that there is a very high water table across the majority of the Aldermaston site. Ground, rain and floodwater leaks, falls or flows into these structures. It is considered that all ingress water becomes contaminated because of the presence of historic contamination. Consequently all water ingressing into the collection system is pumped forward together with waste generated by facilities to the central treatment plant. Figure 1 shows a schematic of the piped network.
The remaining thirty or so facilities had their radioactive aqueous waste transferred to the same treatment plant by purpose built road tanker, which collects the aqueous waste from tanks housed in concrete and masonry pits or bunds. For the same reason as given for the piped network ground, rain and floodwater ingress into these pits and bunds is also considered to be radioactive.

In early 2000 a comprehensive survey of aqueous waste generation at AWE was carried out. A summary of the findings is set out in Table I. The survey estimated that out of the 7000m$^3$ per annum of radioactive aqueous waste treated, only 1000m$^3$ was produced in the facilities. The remainder was from rain, ground and floodwater ingress into the collection systems.

<table>
<thead>
<tr>
<th>Source</th>
<th>Estimated volume (m$^3$/ per annum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste generation in facilities connected by piped network collection system</td>
<td>400</td>
</tr>
<tr>
<td>Ingress into by piped network collection system</td>
<td>4100</td>
</tr>
<tr>
<td>Waste generation in facilities where waste is collected by tanker</td>
<td>550</td>
</tr>
<tr>
<td>Source</td>
<td>Estimated volume (m$^3$/ per annum)</td>
</tr>
<tr>
<td>--------------------------------------------------------------</td>
<td>------------------------------------</td>
</tr>
<tr>
<td>Ingress into collection system associated with tanker collection</td>
<td>1300</td>
</tr>
<tr>
<td>Wash water associated with tankers</td>
<td>200</td>
</tr>
<tr>
<td>Ingress associated with aqueous waste treatment facility</td>
<td>350</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>6900</strong></td>
</tr>
</tbody>
</table>

Figure 2 shows a photograph of a bunded tank that is part of AWE’s radioactive aqueous waste collection system.

Fig. 2. Typical Bunded Tank

**TREATMENT AND DISPOSAL OF RADIOACTIVE AQUEOUS WASTE AT AWE**

At the central “Liquid Effluent Treatment Plant” (LETP) the radioactive aqueous waste is treated by a ferric flocculation process. During this process, over 95% of the actinide activity in the waste is precipitated out in a ferric hydroxide sludge. The ferric hydroxide sludge is subsequently stored on site pending conditioning and ultimate disposal. The clarified and filtered effluent is sampled, analysed and then discharged via the PPL to the
River Thames. This discharge is authorised by the EA under the provisions of the Radioactive Substances Act 1993.

The LETP is an ageing uncovered facility that will need replacement irrespective of the requirement to cease discharges down the PPL. The uncovered nature of the LETP is a source of further rainwater ingress into the large surface area of its bunded tanks. Figure 3 shows a photograph of the facility.

![Liquid Effluent Treatment Plant](image)

**Fig. 3. Liquid Effluent Treatment Plant**

The volumes and activities of treated radioactive aqueous waste disposed to the River Thames via the PPL in 2000 and 2001 are set out in Table II together with the latest authorisations from the EA. It should be noted that AWE also discharges part of its flood water management system volumes down the PPL. This accounts for why the year 2000 discharge is about 1500m³ higher than the volume given in Table I.

<table>
<thead>
<tr>
<th></th>
<th>Revised Authorisation 2000</th>
<th>Discharge 2000</th>
<th>Discharge 2001</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Volume (m³)</strong></td>
<td></td>
<td>8484.6</td>
<td>6498.3</td>
</tr>
<tr>
<td><strong>Alpha (MBq)</strong></td>
<td>60</td>
<td>13.64</td>
<td>5.91</td>
</tr>
<tr>
<td><strong>Beta (MBq)</strong></td>
<td>50</td>
<td>9.76</td>
<td>5.91</td>
</tr>
<tr>
<td><strong>Tritium (GBq)</strong></td>
<td>60</td>
<td>2.16</td>
<td>1.84</td>
</tr>
</tbody>
</table>
BPEO STUDY METHODOLOGY

In accordance with AWE’s procedures on undertaking BPEO assessments (as agreed with the EA) a dedicated options assessment panel (OAP) was formed to undertake the assessment. OAP members were chosen to ensure a representative mix and expertise from across AWE. This was the first BPEO study carried out at AWE. Subsequently the EA commended AWE on their BPEO methodology as best industry practice. AWE has since shared their experiences in this area with other UK nuclear sites.

The BPEO study was based on AWE’s BPM study methodology, which essentially outlines the issues AWE consider and the process they follow to ensure that the generation of radioactive waste is minimised. This was then extended to consider the discharge / disposal of the waste that would be produced and the impact on the environment, thus determining the BPEO. The actual methodology that was used is discussed below.

For convenience, the waste management process was divided into two areas:
- Collection; and
- Treatment and Disposal.

The OAP, in its deliberations, took cognisance of the large ingress of water into the collection system (mainly due to the poor state of repair) and the age and condition of the LETP. In addition, it recommended that waste minimisation, implementation of best practice and waste stream characterisation were of paramount importance irrespective of the outcome of the study.

Only aqueous wastes whose activity is predominantly due to the presence of actinides (plutonium and uranium) were considered, as there are no practical decontamination processes for relatively large volumes of aqueous waste that has low levels of tritium contamination.

The following process was applied to each area:

Stage 1 A wide range of potential options for undertaking the relevant processes were identified.
Collection options such as refurbish the current collection system, replace it, decommission it, local treatment (therefore you do not need a collection system) and the use of tankers and small containers were considered. Processes such as evaporation, ion exchange, flocculation, membrane filtration, phytoremediation, electrodialysis and solidification were considered for treatment and disposal.

Stage 2 The OAP identified a set of minimum requirements for any successful option.
These requirements were, the option:-
- Must address Improvement Requirement;
- Must not prevent AWE from complying with conditions of its Nuclear Site License;
- Must not prevent AWE from complying with other relevant UK legislation;
• Must not generate any waste forms that cannot be managed;
• Must be decommissionable; and
• Must not prevent AWE from continuing its operations.

Any options failing to satisfy these requirements were rejected and excluded from further assessment.

Stage 3 The satisfactory options were developed in more detail.

Stage 4 The OAP then assessed each of the remaining options against the relevant standard company derived BPEO criteria.

Twenty-two assessment criteria were applied. These were:-

• Predicted radioactive discharges to air;
• Predicted radioactive discharges to water;
• Comparison with actual levels of discharge from the site;
• Public critical group dose and public collective dose;
• Worker dose;
• Generation of solid waste;
• Availability of disposal routes for solid wastes;
• Credible accidental releases;
• Safety;
• Generation of Radioactive Aqueous Waste;
• Generation of Trade Waste;
• Water use;
• Energy requirements;
• Stakeholder concerns;
• Monitoring/measurement requirements;
• Storage requirements;
• Implementation costs;
• Practical/availability;
• Plant capacity/flexibility;
• Implications to other operations;
• Project risk; and
• Nuisance.

Stage 5 The above assessment procedure allowed the option most likely to provide the BPEO to be identified.

The BPEO study methodology recognises that the identified BPEO needs to be continually reviewed to take account of any external changes such as new legislation or technological advances.

THE IDENTIFIED BPEO

The identified BPEO for collection of radioactive aqueous waste is to decommission the existing piped network and containerise the aqueous waste. It will either be collected by road tanker from tanks connected to the facility (but disconnected from the piped network system) or via an approved 45 litre container for smaller volumes. When complete this will eliminate rain and groundwater ingress.
Figure 4 shows a flow diagram of the identified BPEO for treatment and disposal of radioactive aqueous wastes. The radioactive waste will be subjected to a condensing evaporation process. This would be followed by advanced filtration (such as reverse osmosis). This is to remove any entrained radioactive material from the condensate. The BPEO identified the following benefits for this approach:

- Very low discharge of radioactivity to the environment; and
- Very low secondary waste production (i.e. number of drums of solidified waste).

![Flow diagram of the identified BPEO for treatment and disposal of radioactive aqueous wastes](image)

**Fig. 4. Identified BPEO for Treatment and Disposal of Radioactive Aqueous Wastes**

The OAP considered these benefits outweighed the requirement for relatively large amounts of energy for this approach. Permeate from advanced filtration will be disposed to the atmosphere as a gaseous discharge via an ambient temperature evaporation process. A gaseous discharge was identified as the BPEO because there was a high level of uncertainty as to the perception of AWE’s stakeholders to the continued use of an aqueous discharge route. It was therefore felt more prudent to pursue a gaseous discharge route, until this uncertainty could be resolved.

The benefits attached to the adoption of the identified BPEO solution includes:

- The elimination of rain, ground and floodwater ingress will result in a significant reduction (up to 80%) in the volume of waste needing to be treated and discharged;
- The high decontamination factors achievable by evaporation followed by high efficiency filtration of the condensate will result in a reduction of more than 99.9% in the amount of radioactivity discharged to the environment compared to current discharges via the PPL;
- An estimated 20% reduction in production of secondary wastes;
- Overall doses to members of the public (already less than 1% of the statutory limit) will reduce further, but it should be noted there will be a minute increase of dose to nearby residents because the aerial discharge of tritium will increase by about 0.1%; and
- Substantial progress towards AWE’s contribution to the commitment made by the UK Government at the OSPAR convention in 1998 in Sintra, Portugal.
BPEO REVIEW (STAKEHOLDER PARTICIPATION)

Subsequently the BPEO was presented to, reviewed and agreed by all stakeholders. During this review the stakeholders expressed a strong preference for an aqueous discharge over a gaseous discharge. Their main reason for this was that it would avoid the possibility of a visible plume, sometimes associated with gaseous discharges. In this interim period AWE had also been in discussions with the Regulators and found that they were more amenable to an aqueous discharge than had previously been thought. Taking this new information into account, along with the energy saving associated with not using a gaseous discharge and the corresponding dose saving to local residents, the BPEO was reassessed and amended accordingly.

Provisional discharge limits have been agreed with the Regulators, which providing the decontaminated waste meets these limits, it can be disposed of as Trade Waste. The contamination levels entering the plant will be in the order of 0.5MBq/m³. A Decontamination Factor (DF) of about 10⁴ is required, to meet these provisional discharge activity levels. AWE is confident that the use of hot condensing evaporation followed by advanced filtration will enable this magnitude of DF to be easily achieved. Pilot plant evaporator trials are underway to confirm this.

Based on the disposal constraints identified above and assuming a maximum throughput of 2500m³ per year, the discharge from the new treatment plant will account for less than 0.5% of the Trade Waste discharge limits for both alpha and beta activity. It will also allow the current limits and discharges associated with the PPL to be eradicated.

STATUS AS OF OCTOBER 2001

Waste Minimisation and Application of Best Practice

There is continuing effort to ensure generation of aqueous waste is minimised by application of best practice. This approach has included:-

- The elimination or minimisation of radioactive facility floor washing and/or the use of detergents.
- Ensuring contaminated emulsifiers and penetrants are conditioned and disposed as solid waste (and not discharged as radioactive aqueous waste).
- Recycle of organic solvents such as acetone and alcohol.
- Waste non-radioactive chemical reagents are not disposed to radioactive aqueous waste.
- Blocking off of surplus sinks and drains in radioactive facilities.
- Condensate from radioactive facility air conditioning units is minimised.
- Minimisation of rain, ground and flood water ingress into the radioactive aqueous waste collection system, e.g. covering bunds to eliminate rainwater ingress and in one case (where a natural aquifer was cut during construction of a facility) extensive land drainage engineering works.

Decommissioning of Piped Collection System

To date five facilities have been decommissioned. Further facilities will be decommissioned as they become available.
Waste Sentencing and Application of Best Practice
Non-radioactive streams that were historically discharged to the radioactive aqueous waste collection system have been identified and diverted, via a “hold-and-monitor” procedure to the Trade Waste Treatment Plant. These streams accounted for the majority of the facilities that were historically connected to the radioactive aqueous waste collection system.

The result of these diversions, coupled with the progress on tankering & containerisation of effluent and decommissioning, means that only four facilities remain connected to the radioactive aqueous waste collection system.

The Radioactive Aqueous Waste Treatment Plant – Sizing and Materials of Construction
As a result of the above waste minimisation, waste sentencing and decommissioning initiatives, the volume of radioactive aqueous waste currently treated in the LETP this year (extrapolated from the first 10 months of 2002) is approximately 4200m$^3$. In addition these initiatives have allowed the volumes of radioactive waste in 2004 (when the new treatment is planned to be operational) to be estimated realistically. This has allowed the evaporator to be sized at 1500m$^3$ per annum, with a maximum throughput of 2500m$^3$.

It is vitally important that the radioactive aqueous influent to any new treatment process is as fully characterised as is possible. This will allow the right decisions to be made regarding the new plant, including issues such as equipment choice, materials of construction, plant capacity and plant life assessments. A knowledge of waste stream sources, together with chemical analysis of samples taken at various stages in the waste collection system, has been and will continue to be used to characterise the waste and produce a feedstock envelope for the aqueous waste streams to be treated in RAWTP. This waste characterisation exercise will be continually reviewed as waste minimisation, decommissioning and improved sentencing progress.

The Radioactive Aqueous Waste Treatment Plant – Design
Contractors have carried out 2 feasibility studies and both confirmed the BPEO, i.e. condensing evaporation followed by a high efficiency filtration step. The only significant difference in terms of design was that one contractor proposed to use one evaporator and the other proposed to use a series of two evaporators to achieve the specified decontamination factor. The same contractors have carried out two concept design studies and preliminary safety reports. The concept designs have been independently reviewed. Current situation is that AWE are involved in a competitive tender exercise against performance based specification. An environmental statement has been produced for the new plant and this has been submitted to the Local Planning Authorities and planning permission has been granted.

SUMMARY AND CONCLUSIONS
The paper has briefly set out why AWE has needed to reconsider its management of radioactive aqueous wastes and how AWE has approached this challenge using a methodology based on identifying the best practicable environmental option. The identified option to decommission the existing collection systems and implement a waste treatment process based on evaporation and filtration (and separation of any low volume high activity streams) is challenging but achievable. In discussions with AWE’s stakeholders and
Regulators the requirement for a gaseous discharge was changed and a disposal route of the treated waste via Trade Waste was agreed (provided the radioactivity content of the treated effluent meets stringent targets). The paper has also shown how waste minimisation initiatives and changes in work practice (i.e. implementation of best practice) have increased the chances of successfully meeting this challenge.

ACKNOWLEDGEMENTS

The authors of this paper would like to thank:-

- All the AWE personnel that were involved in the production of the BPEO study.
- AWE Reprographics department for providing the figures for this paper and accompanying presentation.

\[a\] In determining whether particular means are the “best practicable”… the Operator shall not be required to incur expenditure whether in money, time or trouble which is, or is likely to be, grossly disproportionate to the benefits to be derived from, or likely to be derived from, or the efficacy of, or likely efficacy of, employing them, the benefits or results produced being, or likely to be, insignificant in relation to the expenditure….. the means to be employed shall include i) the provision, maintenance and manner of operation of any plant, machinery or equipment used in connection with or giving rise to radioactive waste and ii) the supervision of any operation involving radioactive waste. – This is taken from AWE’s discharge authorisation issued by the EA under provisions of the Radioactive Substances Act 1993.

\[b\] In broad terms LLW is defined as waste where the activity of alpha emitting radionuclides is below 4GBq ($\approx 0.1$ Curies) per tonne or the activity of all other radionuclides is below 12GBq ($\approx 0.3$ Curies) per tonne. Generally ILW is waste in which the activity exceeds these limits.

\[c\] This definition is taken from the 12th Report of the Royal Commission on Environmental Pollution and applies to non-radioactive wastes. There is no definition available specifically for radioactive wastes, so in the absence of a specific definition, AWE use this definition.

\[d\] Bunds are generally concrete and masonry structures that are either at ground level or slightly below ground level. Their purpose is to act as secondary containment in the event that the primary containment (i.e. the tank) fails. An example of a bunded tank can be found in Figure 2.

\[e\] All aspects of use and disposal of tritium have been considered in a separate corporate strategy.

\[f\] Trade Waste is equivalent to trade effluent as defined under the Water Resources Act 1991. “trade effluent” includes any effluent which is discharged from premises used for carrying on any trade or industry, other than surface water and domestic sewage, and for the purposes of this definition any premises wholly or mainly used (whether for profit or not) for agricultural purposes or for the purposes of fish farming or for scientific research or experiment shall be deemed to be premises used for carrying on a trade.