U.S. Army
Chemical Materials Agency
Program Manager for the Elimination of Chemical Weapons

Cost-Benefit Analysis of Off-Site Versus On-Site Treatment and Disposal of Newport Caustic Hydrolysate

Prepared by:
Project Manager for
Alternative Technologies and Approaches

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1. INTRODUCTION

Caustic hydrolysis is the treatment process for the destruction of the nerve agent *O*-ethyl *S*-[2-(diisopropylamino)ethyl] methylphosphonothioate (VX) at the Newport Chemical Agent Disposal Facility (NECDF). The byproduct from the VX destruction is a caustic wastewater called hydrolysate. The Project Manager for Alternative Technologies and Approaches (PMATA) has identified shipment off-site for treatment of the caustic hydrolysate produced at the NECDF as a safe and efficient means for disposal. PMATA proposes to utilize the DuPont Secure Environmental Treatment (SET) facility in Deepwater, New Jersey for post treatment.

The DuPont SET is the world's largest commercial and industrial wastewater treatment plant and can treat up to 40 million gallons of wastewater every day. The facility has sufficient capacity to complete the treatment of Newport caustic hydrolysate (NCH) in a short timeframe, minimizing processing duration and reducing storage risks. Based on extensive technical and programmatic review, including waste treatability and ecotoxicity studies conducted by DuPont since July 2003, the PMATA has determined that this approach is cost-effective as well as protective of human health and the environment. This document provides the results of the cost-benefit analysis of off-site treatment of NCH at DuPont versus on-site treatment and disposal.

Language was included in Committee Report 109-89 of the National Defense Authorization Act for Fiscal Year 2006, Report of the Committee on Armed Services, House of Representatives on H.R. 1815, directing the Secretary of the Army not to proceed with any action to transport or relocate NCH from NECDF until:

1) The health and environmental concerns raised by the Environmental Protection Agency (EPA) and the Centers for Disease Control and Prevention (CDC) in their April 2005 report "Review of the U.S. Army Proposal for Off-Site Treatment and Disposal of Caustic VX Hydrolysate from the Newport Chemical Agent Disposal Facility" have been addressed in a manner so that both the CDC and the EPA conclude that the process would not result in substantial ecological risk or risk to human health; and

2) The Secretary certifies to the congressional defense committees that sending the VX hydrolysate off-site for treatment would result in significant cost and schedule savings compared to on-site disposal of the hydrolysate.

> In addressing the issue of cost and schedule savings, the Secretary shall conduct and provide to the congressional defense committees a detailed cost-benefit analysis of both off-site treatment of the hydrolysate and on-site treatment methods, including chemical oxidation, wet-air oxidation, electrochemical oxidation, supercritical-water oxidation, solvated-electron technology, gas-phase chemical reduction, plasma arc technology, and biodegradation.

In response to the House Armed Services Committee (HASC) report, the eight technologies referenced were evaluated for technical feasibility and cost benefit. Shipment of the NCH to the DuPont SET for off-site treatment was compared to the identified on-site NCH treatment options (Shaw 2006). A schedule analysis was conducted to apply the impact of programmatic risks. The cost implications of maintaining the NECDF agent neutralization plant until an on-site treatment plant is available and the impact of delayed NECDF closure were also estimated. The final data demonstrate that in addition to numerous technical advantages, off-site treatment has significant cost savings over any on-site option and reinforces the decision to ship NCH to the DuPont SET for final treatment.

2. PLANNED NCH TREATMENT APPROACH

2.1 NCH Transportation Safety

NECDF operations have been underway since May 2005; as of 31 March 2006, over 12 percent of the VX stockpile at the Newport Chemical Depot has been neutralized. Pending ultimate disposition, the resultant NCH is in temporary storage in intermodal shipping containers located at the NECDF site. This approach allows for the isolation of transportable quantities of NCH that can be safely moved via truck to the DuPont SET. The U.S. Army has made a commitment that NCH will not be shipped off site unless it has been demonstrated to meet stringent criteria, including non-detect for VX, non-detect for EA2192 and be nonflammable.

Extensive studies of the process of treatment and the means of transport were conducted. The *Transportation Safety Assessment and Risk Management Plan,* issued in final form by DuPont on March 3, 2004 (DuPont Company 2004a), evaluated transportation route options. The safety assessment followed standard methods utilized by a number of government agencies and determined that the NCH can be safely shipped based on the following factors:

- The NCH was characterized as a medium-hazard corrosive – something regularly transported on the highways.
- Concentrations of reaction byproducts were well below toxic levels.
- Transportation equipment consists of specialized tanks that contain less than 5,000 gallons of liquid, each permanently mounted in a protective steel support frame.
- Tank design meets or exceeds DOT specifications.
- There are four optional highway transportation routes, allowing flexibility to accommodate weather or other considerations.
- Transportation routes were selected to minimize risks to populations, employees, emergency response personnel, and the environment.

2.2 DuPont Treatment Process

Once at DuPont the NCH will be treated in a two-step process, referred to as the Phosphonate Removal Technology. The first step is a combined chemical oxidation process using hydrogen peroxide and sodium persulfate followed by chemical precipitation using ferric chloride and lime. The reaction mix is then filtered to remove the solids. The resulting solids are sent to DuPont's on-site Resource Conservation and Recovery Act (RCRA)-licensed landfill. The remaining liquid is pumped to the Wastewater Treatment Plant (WWTP) and mixed with other on-site and off-site industrial wastes for biological treatment prior to discharge to the Delaware River. The DuPont process requires low temperature and pressure and is based on simple components and materials routinely used in the chemical industry.

In addition to the transportation risk assessment described above, DuPont conducted technical studies to demonstrate efficacy for NCH treatment and to address public concerns regarding effluent discharge.

- A series of treatability studies were conducted to evaluate both pretreatment through chemical oxidation as well as biotreatment (DuPont Company 2004b, 2005a). The studies evaluated the chemistry of the process, operational capacities, and ability to comply with environmental permit requirements. Findings proved that DuPont can effectively treat the NCH using the demonstrated combined pretreatment technology. The treated NCH can be disposed of in a manner compliant with current limits imposed by all of DuPont's relevant New Jersey Department of Environmental Protection (NJDEP) landfill RCRA permits. DuPont will require a major permit modification to include processing of NCH.

- A screening-level environmental risk assessment was conducted to evaluate the environmental exposure pathways and screening level risk to ecological receptor species in the Delaware River and Estuary (DuPont Company 2004c). The study demonstrated that the anticipated discharge concentrations are not toxic to aquatic organisms in the receiving water. Based on the low concentrations and limited bioavailability of the phosphorus content, the assessment indicated that discharge of the effluent would have no adverse effect on the estuary.

- Toxicity testing conducted by DuPont, exposure information, literature searches, and technical predictive modeling all support the conclusion that NCH, when subjected to the combined pretreatment process and two-stage PACT® biotreatment, will exhibit no toxicity levels of concern to the Delaware River (DuPont Company 2004d, 2005b, 2005c).

DuPont scientific assessments have determined the proposed project can be accomplished in a safe and environmentally sound manner and poses no unique hazards. DuPont has made these comprehensive studies available for public review on their website at http://set.dupont.com/dod.html.

2.3 Independent Support of Off-Site Treatment Approach

Oversight of the Army's approach by outside agencies has also concluded that off-site shipment is an effective and safe means of treating NCH for ultimate disposal.

National Research Council. A common theme throughout the history of National Research Council (NRC) assessments of hydrolysate treatment technologies has been that, wherever possible, commercially available technologies should be employed. The NRC has consistently supported the concept of shipping hydrolysate off site for post treatment and disposal. For example, in support of the Alternative Technologies and Approaches Program (ATAP), the NRC recommended that the Army should pilot test VX neutralization followed by off-site treatment of the hydrolysate at a permitted treatment, storage, and disposal facility (TSDF) (NRC 1996). In a subsequent review, the NRC indicated that the off-site treatment of hydrolysates may have significant cost and schedule benefits (NRC 2000).

Centers for Disease Control and Prevention (CDC)/Environmental Protection Agency (EPA). New Jersey and Delaware officials requested that the CDC perform a formal review of PMATA's proposed plan to ship NCH off site for treatment. Following this congressional request, the CDC issued a report in final form in April 2005 in which they stated that they found the Army/DuPont plans sufficient for addressing human toxicity, transportation and treatment of NCH (CDC 2005). However, the CDC did not recommend proceeding with the proposed plan for treatment and disposal at DuPont until the EPA concerns regarding river discharge were addressed. DuPont has since performed additional acute and chronic toxicity testing that demonstrated there would be no adverse impact on the Delaware River (DuPont Company 2005b). In a letter dated February 2006, the EPA has reported that all the ecological concerns have been resolved (EPA 2006). This letter addresses the first requirement of the HASC report 109-089.

3. TECHNICAL ASSESSMENT OF OPTIONS

Shaw Environmental, Inc. (Shaw) was tasked by the PMATA to develop technical cost and schedule information comparing eight on-site technologies on an equivalent basis to the planned shipment and off-site treatment of NCH. The evaluation was conducted by professional engineers and cost and schedule engineers with extensive experience in design and estimation of large industrial facilities. The cost and schedule to implement each of the technologies considered technically acceptable for NECDF were developed based on previous Army evaluations and updated with current information regarding the nature of the NCH and expected throughput requirements. The candidate processes were not tested and only existing data was used. The results of this evaluation are provided in the following paragraphs.

Some specific boundaries were established by the PMATA at the outset for this effort. Only on-site technologies referenced in the HASC Report 109-89 were evaluated and compared to the off-site DuPont Phosphonate Removal Technology (DuPont). These include: Chemical Oxidation (CO), Wet-air Oxidation (WAO), Supercritical Water Oxidation (SCWO), Electrochemical Oxidation (ECO), Solvated-Electron Technology (S-ET), Gas-Phase Chemical Reduction (GPCR), Plasma Arc Technology (PA), and Biodegradation (BIO). The reference to the eight technologies in the HASC Report 109-89 appeared to have been derived from an NRC assessment performed for the office of the Project Manager for Non-Stockpile Chemical Materiel (PMNSCM), whose mission includes the disposal of chemical munitions that have been recovered from burial sites. The PMNSCM waste is typically small quantities of organic materials resulting from neutralization of multiple types of agents. Since the nature of aqueous NCH waste is significantly different, each technology was investigated for applicability to the Newport effort by including the known properties and volumes of the NCH waste stream. Although eight technologies were referenced by the HASC, not all were found to be technically appropriate to meet NCH treatment requirements. In this evaluation, five technologies were found to be not viable. Specifically, ECO, S-ET, GPCR, PA, and stand-alone BIO were eliminated from further evaluation. Table 1 provides the primary factors leading to the decision to eliminate them from further cost-benefit evaluation.

Table 1. Rationale for the Elimination of Five Technologies from the Cost-Benefit Analysis for NCH Treatment

Technology	Factors Leading to Elimination
Electrochemical Oxidation	• Not appropriate for aqueous wastes • Concern about scale-up issues and risks • Generates large volumes of waste streams needing additional treatment
Solvated-Electron Technology	• Not appropriate for aqueous wastes • Generates hydrogen • Uses difficult to handle reagents
Gas-Phase Chemical Reduction	• Company no longer exists • Generates high volumes of gaseous waste • Hydrogen reagent considered a safety risk
Plasma Arc Technology	• Not appropriate for large quantities of aqueous wastes • Considered similar to incineration • Limited experience with both hazardous and aqueous solutions
Stand-alone Biodegradation	• Primary reaction products in NCH are not amenable to direct treatment by biodegradation • Not efficient for on-site waste volumes; cannot obtain economies of scale available at large scale treatment, storage, and disposal facilities

Three technologies were considered to be potentially applicable for the on-site treatment of NCH, including CO, WAO, and SCWO. For each technology, costs and schedules associated with engineering, capital costs, systemization, optimization, operations and decommissioning were estimated. These total costs were compared with the cost established for off-site shipment for NCH treatment. Brief descriptions of each of the selected on-site treatment technologies are provided in the following paragraphs.

Chemical Oxidation. CO is a process where specific chemicals are employed to cause partial or complete destruction of organic wastewater contaminants. In general, chemical oxidation reactions are carried out in liquid reactors operated at or near atmospheric pressures and at operating temperatures less than 212°F for aqueous systems. CO converts organic contaminants to benign chemicals that are amenable to biodegradation. This process has been demonstrated for the treatment of NCH and utilizes standard chemical processing equipment and instrumentation.

Wet-Air Oxidation. WAO is a liquid phase reaction in water using dissolved oxygen to cause air to react with wastewater contaminants. The treatment reactions normally occur at moderate temperatures of 300 to 610°F and at pressures from 150 to 3,000 pounds per square inch (psi). The process converts organic contaminants to benign chemicals that are amenable to biodegradation. WAO has been demonstrated to be effective at commercial scale and used for the treatment of wastes similar to NCH. However, this technology has not been tested on NCH, has not been demonstrated to operate consistently or with equivalent throughput to that needed for the NCH volume.

Supercritical Water Oxidation. SCWO refers to the high temperature, high pressure hydrothermal process that causes specific reactions to take place beyond the critical point of water. These reactions occur rapidly above 1,200°F and 3,400 pounds per square inch gauge. This technology has been tested on similar caustic hydrolysate produced from VX, but has not been demonstrated at production scale. Furthermore, it has not been demonstrated to have the availability and reliability necessary to meet the required throughput.

4. COST-BENEFIT ANALYSIS

4.1 Technical Assumptions

A conceptual design was developed for each potential on-site technology, with facility design and operating assumptions for each technology delineated by generating the following:

- Project scope and process, including material and product handling, facilities requirements and project schedule

- Process flowsheets

- Site preparation, including location and description of site and facilities

- Utilities (steam, water, power, sanitary, electrical, etc.)

- Buildings and structures, including preliminary sizes and types of construction, design, sketches, architectural criteria, and general arrangements and elevations

- Piping and instrumentation diagrams

- Equipment (lists and sizes)

- Man-hours

- Procurement.

The best available process information for all technologies was used to develop cost and schedule data consistent with the conceptual designs. To develop an "apples-to-apples" comparison, all three on-site technologies were sized for equivalent operations throughput of 1,100 pounds per hour (2,950 gallons per day), which is consistent with the Assembled Chemical Weapons Alternatives (ACWA) design for the Blue Grass SCWO reactors. The throughput of any on-site alternative if selected for implementation would have to be optimized as part of the design process. In addition, key assumptions included that all liquids will be disposed of on-site using the existing sewage treatment facility and solids will be shipped offsite for disposal at an appropriate commercial disposal facility.

The technical basis, costs and schedules for the off-site treatment option were based on previous estimates developed by DuPont. The 10,000 gallons per day throughput assumed for DuPont exceeds the NECDF production rate, is within the capabilities of the facility, and was the basis of treatability studies conducted by DuPont. This, coupled with the ability to implement nearly two years earlier than the on-site technologies, allows treatment of the NCH to occur almost simultaneously with NECDF operations. Since all on-site treatment operations would start well after the completion of NCH production, it is not necessary to match the NECDF production rate. The resultant DuPont estimate includes fixed disposal equipment, transportation costs, and treatment cost on a per-gallon basis.

4.2 Schedule and Cost Development

Using the conceptual designs, a project plan was developed for each treatment alternative. The plans integrate the execution strategy, cost, and schedule for each alternative and show the sequence of activities and activity interdependencies for the engineering and design, permitting, construction, operation, and decommissioning efforts. Durations of specific activities vary among technologies due to differences in the level of technical maturity, permitting history, and process complexity. The operations period was the same for all on-site treatment technologies because the NCH processing rate was assumed to be the same.

Shaw used the combination of the conceptual design and schedules to provide the basis for estimating the cost associated with implementing each technology. A series of additional risk factors were applied to the overall cost and projected schedule. These scenarios can be thought of as contingencies for technical and commercial uncertainties associated with specific processes and are based on standard methods used by professional engineers in cost estimation for construction of industrial facilities.

4.3 Programmatic Schedule and Cost Estimate

Using the costs generated by Shaw, programmatic risks were then applied to present cost and schedule estimates consistent with the method commonly used by the Department of Defense (DoD). The software package Automated Cost Estimating and Integration Tool (ACEIT) is the primary tool required by DoD acquisition programs for creating cost estimates that account for schedule risk. Programmatic risk is applied to estimates within ACEIT using a standard statistical method. Examples of programmatic risks that could cause a delay in schedule and associated increase in cost include the unavailability of qualified personnel or the threat of a labor strike. The resulting figures provided the cost estimate that includes both technical cost elements and associated risk for the implementation of each option.

In addition, cost impacts of keeping a portion of the NECDF operational after completion of agent operations were also determined to be necessary to support on-site treatment. This additional cost is not necessary for the DuPont option because the post-treatment of NCH will occur simultaneously with the agent neutralization operation. The total programmatic cost estimate for each option includes the technical cost, programmatic risk and NECDF operations cost to support hydrolysate treatment (on-site options).

For this cost-benefit analysis, the base cost was the estimate for the currently proposed off-site treatment of NCH at the DuPont SET. To protect proprietary information generated by DuPont for the potential treatment of NCH, the costs for implementation of each on-site option are reported relative to the DuPont base cost without disclosing the actual value of the DuPont option.

When evaluating the implementation of each technology from design through operations, the off-site treatment option was demonstrated to have significant technical, cost and schedule advantages over the three on-site options. As shown in table 2, with programmatic risks and NECDF impacts considered, on-site treatment was estimated to cost up to $347 million more than the proposed off-site treatment at DuPont. This cost savings is illustrated in figure 1.

Similarly, figure 2 shows that after applying programmatic risk, the overall time required from start of neutralization operations to finish of hydrolysate treatment is longer for all on-site technologies by up to 57 months.

Table 2. Additional Costs of On-Site Treatment Technologies Relative to the DuPont Base Cost Before and After Applying Programmatic Risk

Cost Element	DuPont	CO ($M)	WAO ($M)	SCWO ($M)
Technical Estimate	BC	BC + $146	BC + $149	BC + $201
Total Programmatic Cost Estimate	PBC	PBC + $230	PBC + $259	PBC + $347

Note:

BC = Base Cost for implementation of the option to ship NCH off site for treatment at the DuPont SET.
CO = Chemical Oxidation
PBC = Programmatic Base Cost includes the cost for implementation of the option to ship NCH off site for treatment at the DuPont SET plus programmatic risk
SCWO = Supercritical Water Oxidation
WAO = Wet-air Oxidation

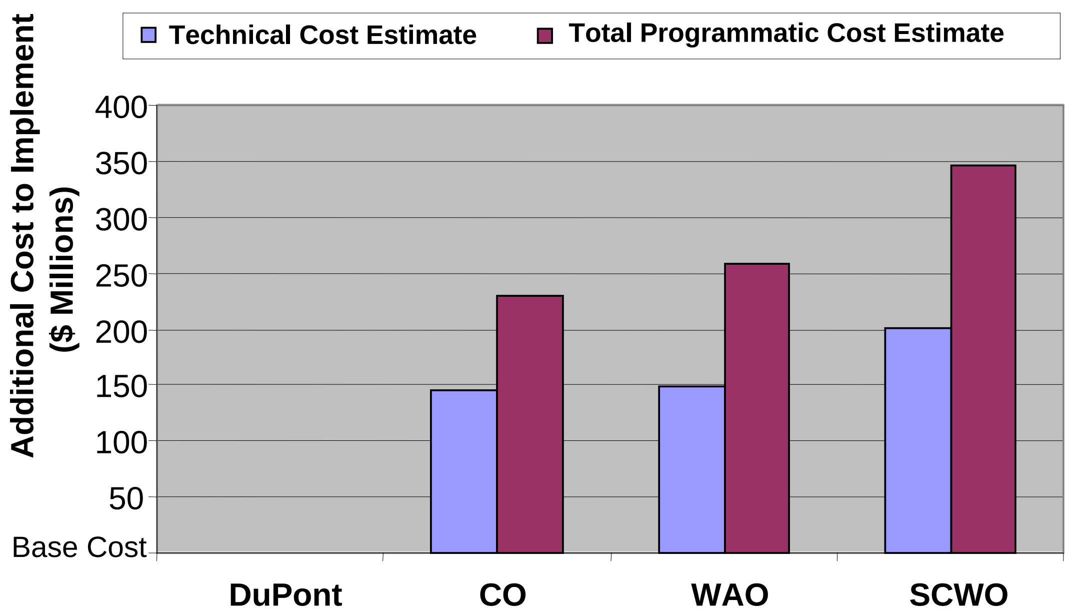

Figure 1. Additional Costs of On-Site Treatment Technologies Relative to the Off-Site Base Cost (DuPont)

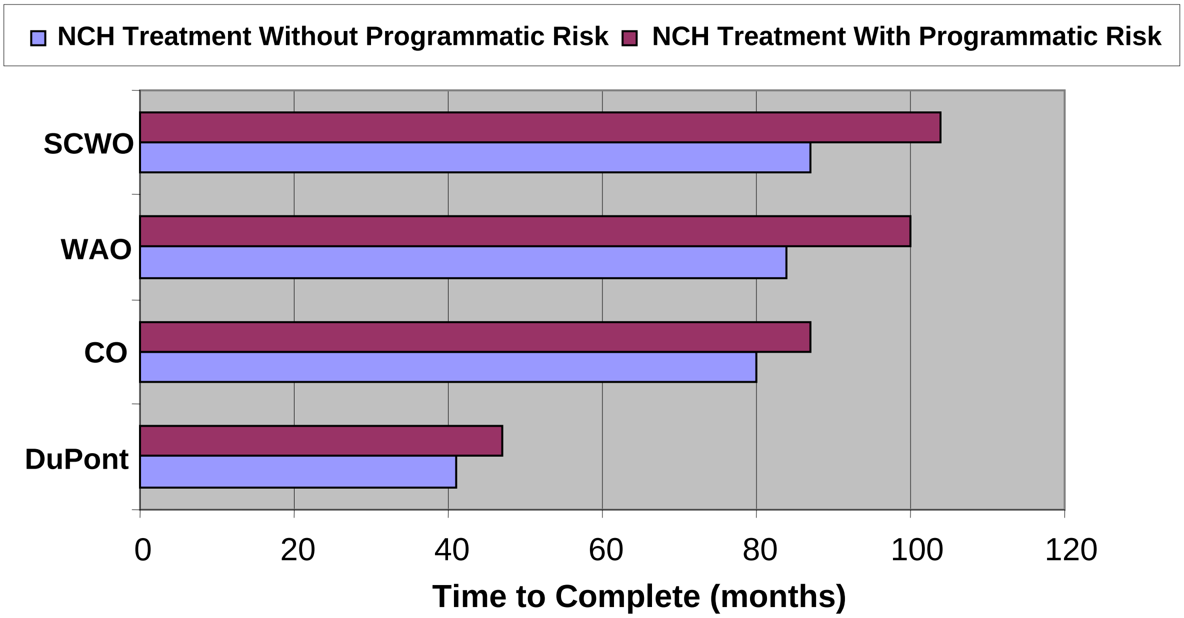

Figure 2. Schedule Durations Comparing Treatment Options With and Without Programmatic Risk

5. CONCLUSION

Off-site shipment of NCH to DuPont is the most cost-effective option for post treatment of NCH. Some of the primary contributors to the DuPont option having significant advantages over the on-site alternatives are:

- The DuPont process is relatively simple due to low pressure, low temperature, and common components. It is based on well-understood chemical and biological processes. On-site CO, WAO and SCWO are either significantly more complex processes or would require additional processing steps before the effluent could be discharged to the federally-owned treatment works (FOTW).

- The DuPont pre-treatment process followed by biotreatment has been demonstrated through a series of treatability studies to produce a product that can be disposed of in compliance with existing regulatory requirements. Of the three on-site alternatives, only CO has been tested with NCH. SCWO has been demonstrated with similar caustic hydrolysate at pilot scale, while WAO has not been tested with NCH.

- Treatment of NCH at DuPont has the fewest technical risks of the alternatives considered.

- Whole Effluent Toxicity testing on both the combined pretreatment step as well as the PACT® biotreatment on species in the Delaware River (DuPont's outfall location) has demonstrated that there would be no adverse impact on the Delaware River. With the exception of SCWO, it is anticipated that toxicity studies would be required for the WAO and CO effluent to support the permitting process.

- The EPA has reported that all of the ecological concerns have been resolved.

- It is available in the shortest period of time and minimizes the amount of time that NCH must be stored at NECDF.

- It is the least costly alternative.

The proposed plan to transport NCH off-site to the DuPont SET for post treatment has been demonstrated to be safe, environmentally sound and more cost effective when compared to on-site treatment options. The combined DuPont process has been demonstrated to produce a product that can be safely disposed of in compliance with existing regulatory requirements. Through the detailed cost-benefit analysis, this proposed plan has also been shown to have significant cost and schedule advantages.

6. REFERENCES

Centers for Disease Control and Prevention, Department of Health and Human Services, *A Report to Congress: Review of the U.S. Army Proposal for Off-Site Treatment and Disposal of Caustic VX Hydrolysate from the Newport Chemical Agent Disposal Facility,* April 2005.

DuPont Company (2004a), *Transportation Safety Assessment and Risk Management Plan: Shipments of Newport (Indiana) Caustic Hydrolysate (NCH), Newport IN to Deepwater NJ,* March 2004.

DuPont Company (2004b) *Treatability of Newport (Indiana) Caustic Hydrolysate*; March 2004.

DuPont Company (2004c) *Screening Level Ecological Risk Assessment for Discharge of Effluent from the Treatment of Newport (Indiana) Caustic Hydrolysate*; March 2004.

DuPont Company (2004d) *Toxicology Assessment of Health Hazard Considerations for Safe Management of Newport (Indiana) Caustic Hydrolysate (NCH),* March 2004.

DuPont Company (2005a), *Treatability Study Summary for Phosphonate Removal Technology*, February 2005.

DuPont Company (2005b), *Chronic Whole Effluent Toxicity Study for Pretreated and Biotreated 8% Newport (Indiana) Caustic Hydrolysate,* June 2005.

DuPont Company (2005c), Treatability Study Summary for Phosphonate Removal Technology on 16% Newport Caustic Hydrolysate (NCH), August 2005.

Environmental Protection Agency, *Letter from Walter Mugdan, Director Division of Environmental Planning and Protection to Dr. Howard Frumkin, Director NCEH/ATSDR*, February 2006.

National Research Council, Panel on Review and Evaluation of Alternative Disposal Technologies *Review and Evaluation of Alternative Chemical Disposal Technologies,* 1996.

National Research Council, *Integrated Design of Alternative Technologies for Bulk-Only Chemical Agent Disposal Facilities*, 2000.

Shaw Environmental, Inc., *NECDF On-Site Hydrolysate Post Treatment Estimate*, April 2006.