

### 3 DESCRIPTION OF ALTERNATIVE SYSTEMS

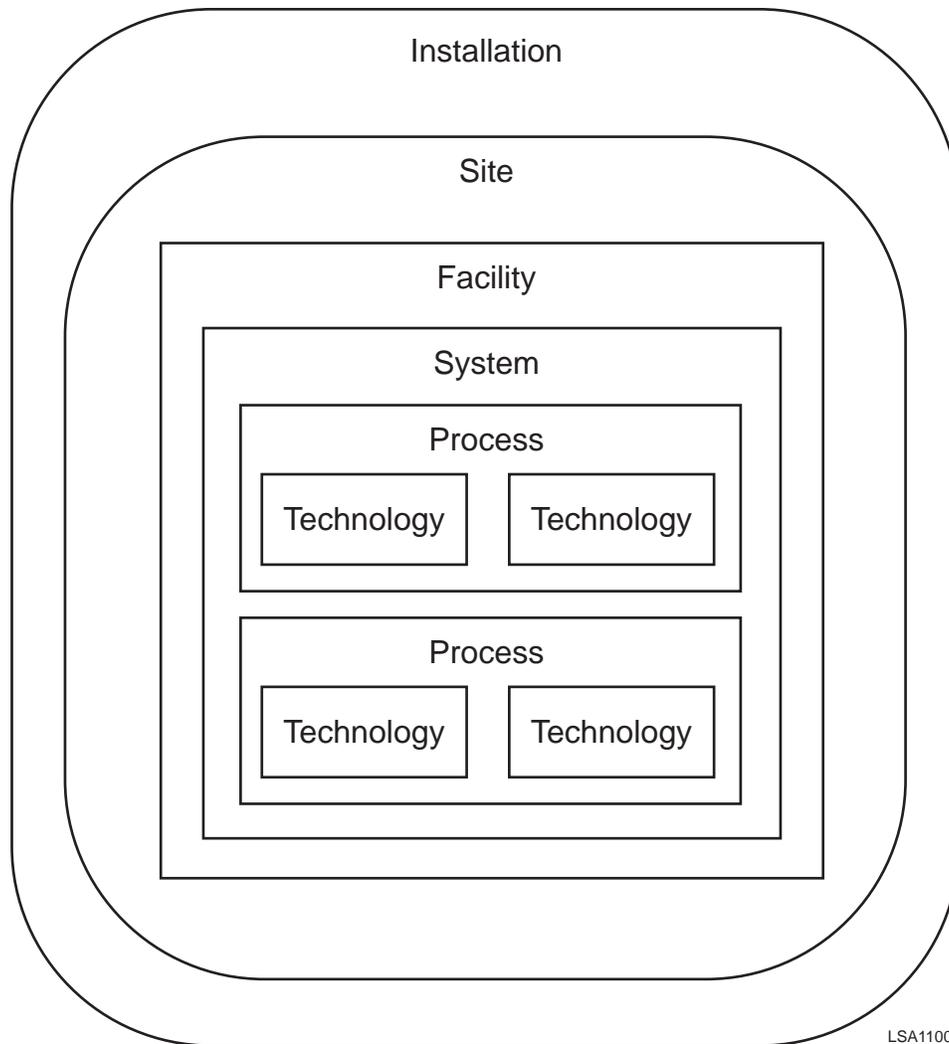
#### 3.1 INTRODUCTION

This chapter describes characteristics of ACWs and the alternative ACWA destruction systems proposed for pilot testing at one or more of the ACW stockpile installations. The alternative technologies included in these destruction systems were demonstrated as part of the ACWA selection process (see Section 2.4) (PMACWA 1999). Pilot testing of these systems is being considered because, even though the component technologies have been demonstrated, the full integration of the processes has not. As a result, significant issues of system reliability and effectiveness remain to be addressed. Systems designs continue to evolve.

This chapter first discusses the elements that are common to the proposed systems. It then describes the technologies that are proposed for each process and discusses their state of development at the stage of demonstration testing. Finally, installation-specific elements of the destruction systems, including infrastructure, work force, and resource requirements, are described in Chapters 4, 5, 6, and 7.

The ACWA program must provide a system that is a total solution for ACW destruction. It needs to cover the following interrelated processes: opening the weapons; treating agents, energetics, metal parts, and dunnage; and controlling pollution. The terms identified below are employed in discussing the alternatives. Figure 3.1-1 presents the relationships among these terms graphically.

- *Installation (i.e., Post):* The Army activity or depot at which ACWs are being stored and at which emplacement of an ACWA system is being evaluated. It includes both the chemical and nonchemical weapons areas. It is the entire parcel of land owned by the Army.
- *Site:* The location on the installation at which ACWs are currently being stored; also, the location at which the structure for ACW destruction would be built.
- *Facility:* The structure that would be built on the site to implement the ACW destruction activity.
- *System:* A complete approach to weapons destruction that includes disassembling a munition, destroying agents and energetics, treating component parts (e.g., metal and dunnage), and managing and disposing of effluents. Each system is considered an alternative action in this ACWA EIS.



**FIGURE 3.1-1 Relationship of Terms Used to Identify Elements of the Proposed Action**

- *Process*: A category of activity that contributes to a total system. The processes are munitions access, agent treatment, energetics treatment, dunnage treatment, metal parts treatment, and effluent management/pollution control.
- *Technology*: The technique or techniques used to accomplish a process. More than one technology may be involved in a process. In addition, the same (or a similar) technology (e.g., heat treatment) may be used in multiple processes.

### 3.1.1 Characteristics of Assembled Chemical Weapons

The ACWs that are to be destroyed exist in a variety of forms, each with different combinations of components. All consist of a metal casing, within which there is some type of chemical agent (Figure 3.1-2). By definition, ACWs also contain some type of explosive (known as a burster, which may be accompanied by a supplemental explosive charge) for chemical agent dispersal. This burster may be accompanied by a fuze (an initiating mechanism) and an additional supplemental charge.

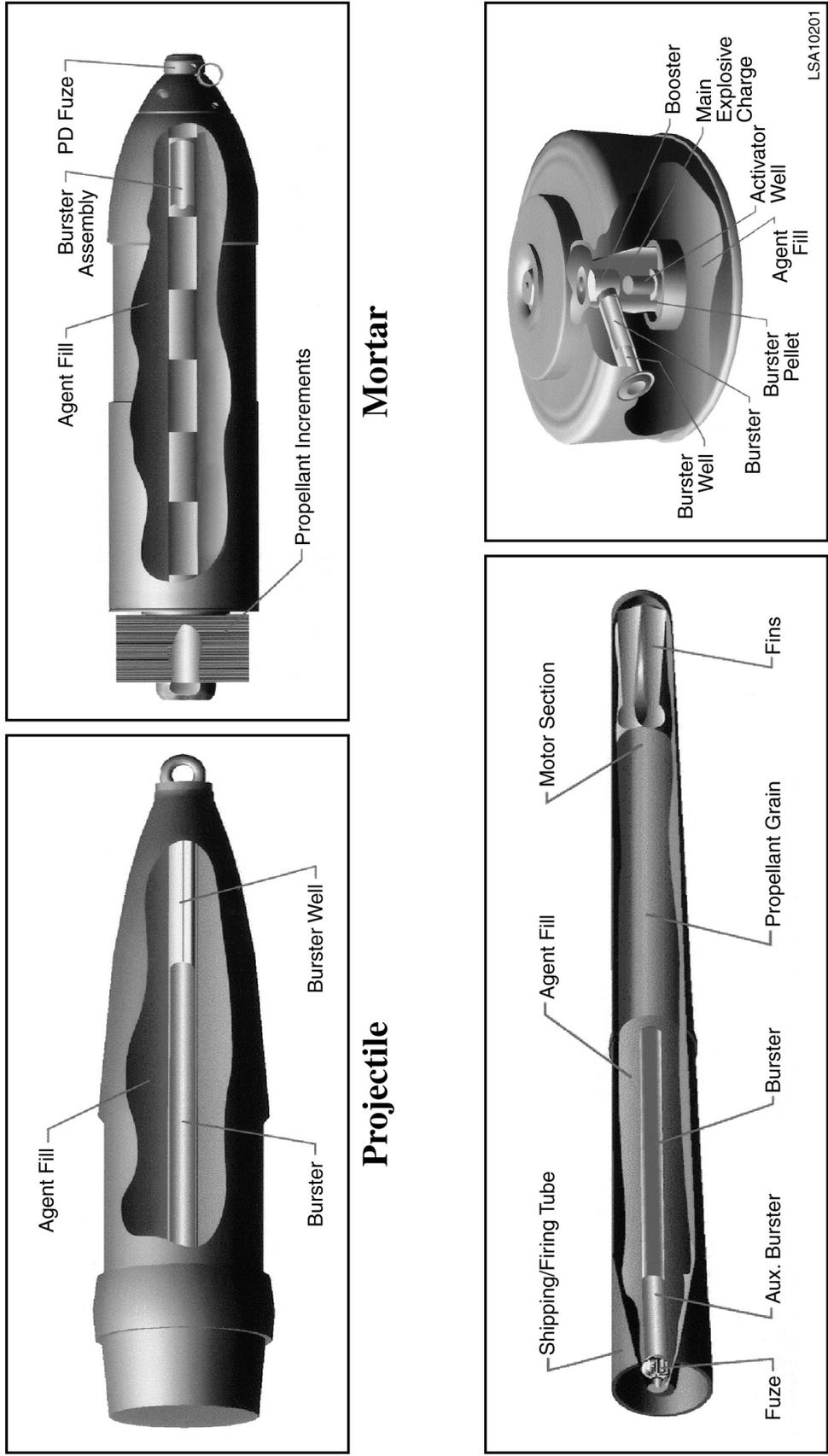
The types of explosives used to disperse the agent contained in ACWs include tetryl, tetrytol, Composition A5, Composition B4, and trinitrotoluene (TNT). Tetrytol is a mixture of tetryl and TNT. Composition A5 is the explosive RDX mixed with stearic acid. Composition B4 is a mixture of TNT and RDX (CBDCOM 1997). All of these explosives also are used in nonchemical munitions. While these explosives are powerful, they are relatively insensitive to heat or shock. A fuze assembly containing a more sensitive explosive compound, such as lead azide, must be used to detonate the explosives listed above. Fuzes are mechanical devices that include a variety of safety mechanisms to protect the explosives from accidental detonation.

Some weapons are also assembled with a propellant designed to fire or launch the weapon. The propellants are designed to generate large quantities of gaseous products through rapid burning rather than through detonation of the materials. The propellants used in the ACWs being considered by ACWA are primarily composed of nitrocellulose and nitroglycerin in varying proportions. Other chemicals are added to this mix to control the rate of burning and other attributes of the propellants. The propellants are relatively insensitive to shock and heat and must be ignited by a small charge of black powder or pyrotechnic material. Together, explosives and propellants make up a category of materials referred to as “energetics.”

Artillery projectiles, mortar projectiles, rockets, and land mines are the major forms of ACWs. The chemical agents contained in these forms fall into two main categories, nerve agents and chemical blister agents.<sup>1</sup> GB (Sarin) and VX are the two types of nerve agents in ACWs. Both are highly toxic and can cause death to a receptor within minutes of exposure to liquid or aerosol forms. GB also creates vapors that are extremely toxic. Both GB and VX interfere with the nervous system and can cause failure of the respiratory system and other bodily functions. Three closely related types of blister agents are used in ACWs: the mustard agents H, HD, and HT. Exposure to liquid, aerosol, or vapor forms of these agents causes severe disruption of skin and membrane functions. Major symptoms of mustard exposure commonly do not appear until

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<sup>1</sup> For more information on chemical agents, see <http://www.sbccom.apgea.army.mil/RDA/msds/index.htm> and [http://www.mitretrek.org/mission/envene/chemica/chem\\_back.html](http://www.mitretrek.org/mission/envene/chemica/chem_back.html).



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FIGURE 3.1-2 General Diagrams of a Projectile, Mortar, Rocket, and Mine

several hours after exposure. Death may occur if the skin and membrane disruption is sufficiently widespread over the body.

Table 3.1-1 lists the types and locations of ACWs presently in the U.S. chemical weapons stockpile that are included in this EIS. The table also identifies the types of components that may be associated with each type of munition. Any single ACW contains one type of agent and one or more types of energetic. (Some munitions may have one or more of their component energetics removed and stored separately.) Each stockpile location has a different combination of ACW types. Explanations of the ACW configurations are as follows:

- *Projectile*: A weapon designed to be fired from a cannon. ACW projectiles contain dispersing explosives. Except for mortars and rockets, stockpiled projectiles are designed to be breech-loaded.
- *Mortar*: A projectile designed to be fired from a muzzle-loaded cannon. ACW mortar projectiles are assembled with fuzes and propellants, in addition to the agent and dispersing explosives.
- *Cartridge*: A projectile assembled with a fuze and packaged with propellants, in addition to the agent and dispersing explosives.
- *Rocket Warhead*: A projectile with agent, fuzes, and dispersing explosives.
- *Rocket*: A rocket warhead with an attached rocket motor containing propellant.
- *Mine*: A weapon designed to be fixed in place. ACW mines contain fuzes, agent, and dispersing explosives.

### **3.1.2 Processes Required for ACW Destruction**

Each of the alternatives for destruction and disposal of ACWs being considered is designed to treat four categories of material: agent, energetics, metal parts, and dunnage (materials such as protective suits, pallets, and packaging are collectively called “dunnage”). The major processes being considered to accomplish this goal are illustrated conceptually in Figure 3.1-3. The first step, munitions disassembly (i.e., opening the munition), is common to each of the technologies for treating the ACW components being considered, although some modifications of the baseline process have been proposed (see Kimmell et al. 2001). Once the

**TABLE 3.1-1 Agent, Burster, and Propellant Types That May Be Associated with Each Munition Type**

ACW Form and Munition Type	Agent Type	Burster and Supplemental Charge Type	Fuze <sup>a</sup>	Propellant <sup>b</sup>	Applicable Location <sup>c</sup>
155-mm projectiles M121, M121A1, M104, M110, M122	GB, VX, H, HD	Composition B4, tetrytol, TNT	No	No	ANAD, PCD, <sup>d</sup> BGAD
105-mm projectiles M60, M360	HD, GB	Tetrytol, Composition B4	Yes	No	ANAD, PCD <sup>d</sup>
105-mm cartridges M60, M360	HD, GB	Tetrytol, Composition B4	Yes	Yes	ANAD, PCD <sup>d</sup>
8-in. projectiles M426	GB, VX	Composition B4, TNT	No	No	ANAD, BGAD
4.2-in. mortars M2, M2A1	HD, HT	Tetryl, tetrytol	Yes	Yes	ANAD, PCD <sup>d</sup>
Rockets M55, M56 <sup>e</sup>	GB, VX	Composition B4, tetrytol	Yes	Yes <sup>e</sup>	ANAD, PBA, BGAD
Land mines M23	VX	Composition A5, Composition B4, tetryl	Yes	No	ANAD, PBA

<sup>a</sup> Fuzes are mechanical devices that trigger the detonation of a small explosive charge (commonly lead azide) that in turn detonates the larger supplemental and burster charges.

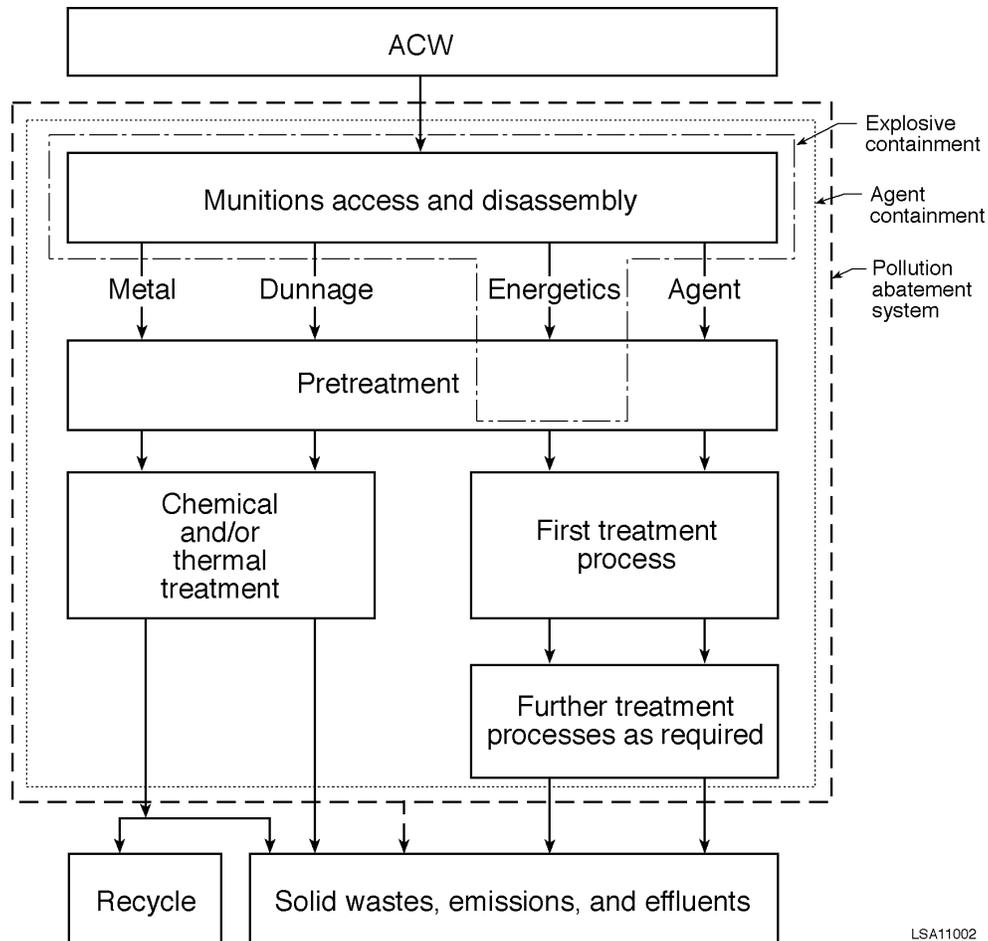
<sup>b</sup> Propelling charges are predominately nitrocellulose compounds with nitroglycerin added.

<sup>c</sup> Only for those locations included in this EIS.

<sup>d</sup> Only the mustard agents HD and HT are contained in munitions at PCD.

<sup>e</sup> The M56 is a rocket warhead without a rocket motor (i.e., propellant) attached.

Source: U.S. Army (1988).



**FIGURE 3.1-3 Conceptual Overview of Proposed Alternatives for ACWA Systems**

munitions are disassembled, the components can be separated into the four material streams for subsequent processing. The proposed technology systems vary in their approach to ACW destruction.

### 3.1.3 Containment Structure and Facility Size

Pilot tests of ACW destruction would take place in structures designed to prevent the release of agents to the environment. Disassembly of ACWs and preparation of energetics for treatment would be carried out in an explosion containment area. The overall structure would use features such as air locks and negative internal air pressure to contain agent. Ventilation systems and process gases would pass through the pollution abatement system (see Section 3.3.7) before being released from the structure.

The current facility designs are based on structures used in the baseline incineration process. The main structure would be a two-story building built of noncombustible materials, with a concrete structural frame and a low-slope, concrete roof. This building would contain equipment and systems for munitions disassembly, processing of contents and components, and pollution abatement. It would also contain a chemical analysis laboratory and areas for support of personnel and maintenance.

The facility footprint for each of the proposed technologies would require approximately 25 acres (10 ha). Additional area might be required for support facilities and construction operations (U.S. Army 1997a) and for storm water management, access roads, and utilities, depending on conditions at each installation.

## **3.2 ACWA SYSTEMS**

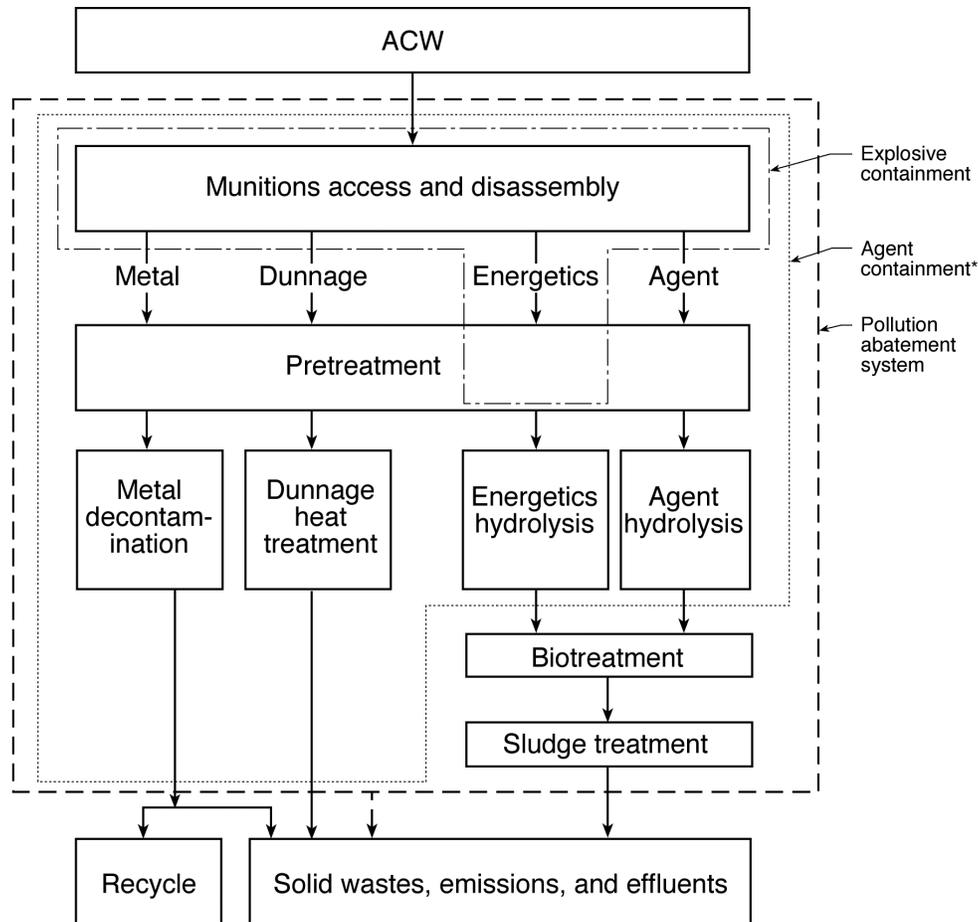
Four systems for ACW destruction are being considered for pilot testing: neutralization/biotreatment, neutralization/supercritical water oxidation, neutralization/gas-phase chemical reduction/transpiring wall supercritical water oxidation, and electrochemical oxidation.

### **3.2.1 Neutralization/Biotreatment System**

A detailed system description of the Neut/Bio alternative is provided in Kimmell et al. (2001). The PMCD selected a variation of this process for pilot testing as a method for destroying mustard agent at Aberdeen Proving Ground, Maryland. Also, Parsons/Allied Signal (now Parsons/Honeywell) successfully demonstrated similar Neut/Bio processes for destroying blister agent for the PMACWA, but the system has not been successfully demonstrated for destroying nerve agent (PMACWA 1999).

The general process flow of the Neut/Bio system is shown in Figure 3.2-1. As envisioned, the system would use the baseline reverse assembly process or a modification of this process for ACW disassembly. The system would employ hydrolysis (i.e., neutralization) using water and then a caustic solution (such as sodium hydroxide) to treat blister agent, and it would also employ hydrolysis using a caustic solution to treat energetics.

To completely eliminate other hazards and chemical compounds of concern, the hydrolysates (i.e., products resulting from the neutralization process) would be subjected to biological treatment. The treatment would result in a sludge, which would be prepared for disposal by using wastewater treatment equipment to flocculate and solidify the biotreatment effluent. The treatment of metal parts and dunnage would involve caustic hydrolysis and/or thermal treatment.



\*Agent containment could be expanded to enclose the entire process, if desired.

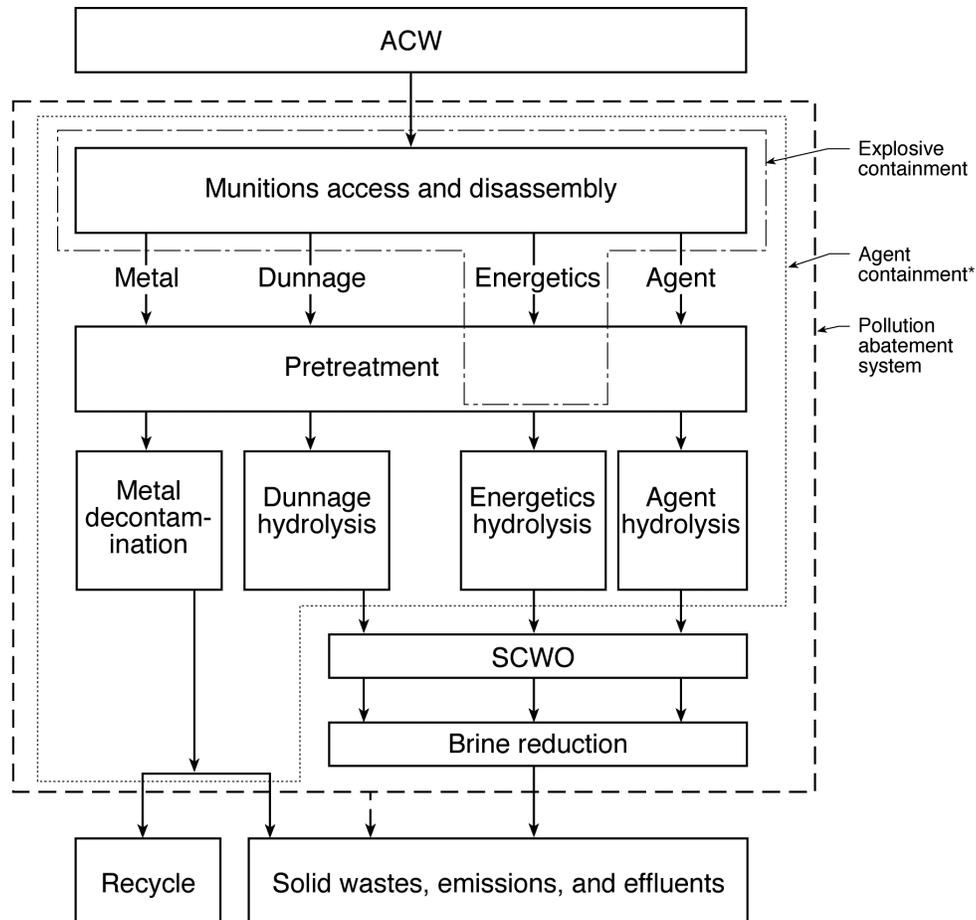
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**FIGURE 3.2-1 Neutralization/Biotreatment System**

### 3.2.2 Neutralization/Supercritical Water Oxidation System

The Neut/SCWO system is characterized in Kimmell et al. (2001). General Atomics demonstrated Neut/SCWO processes for the PMACWA. The PMCD also selected this type of process for pilot testing as a method for destroying bulk quantities of VX agent at a pilot test facility at Newport Chemical Depot, Indiana.

Figure 3.2-2 illustrates the major processes that make up the Neut/SCWO system. As currently envisioned, the system would employ parts of the baseline reverse assembly process for ACW disassembly. After disassembly, materials would be prepared for neutralization. For example, dunnage would be reduced in size. Agents and energetics would be separated and neutralized in separate systems.



\*Agent containment could be expanded to enclose the entire process, if desired.

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**FIGURE 3.2-2 Neutralization/SCWO System**

To completely eliminate other hazards and chemical compounds of concern that might remain after neutralization, the agent and energetic hydrolysates would be placed in separate SCWO units. The proposed design includes reactor vessels constructed of a corrosion-resistant metal such as platinum. Slurry prepared from the hydrolyzed dunnage and from used filter carbon would be treated with the energetics hydrolysate in the SCWO unit. Metal parts would be washed in caustic; the caustic would then be treated in the SCWO unit, and the washed metal parts would be thermally treated to ensure that all agents and energetics were removed.

### 3.2.3 Neutralization/Gas-Phase Chemical Reduction/Transpiring Wall Supercritical Water Oxidation System

The Neut/GPCR/TW-SCWO process would incorporate neutralization of agents and energetics, gas-phase chemical reduction (GPCR) of solids and gases, and treatment of hydrolysate by transpiring wall (TW) supercritical water oxidation (SCWO). Kimmell et al.

(2001) provides a detailed description of the GPCR/TW-SCWO system. Foster Wheeler, Eco Logic, and Kvaerner demonstrated GPCR/TW-SCWO processes for the PMACWA. The general process flow of the system is shown in Figure 3.2-3. As envisioned, the system would use the baseline reverse assembly process or a modification of this process for ACW disassembly. After disassembly, materials would be prepared for neutralization. Agents and energetics would be neutralized in separate hydrolysis systems.

To completely eliminate other hazards and chemical compounds of concern that might remain after neutralization, the agent and energetic hydrolysates would be combined and treated by SCWO. This process would take place in a vessel lined with a transpiring wall through which water would be pumped continuously to prevent corrosion and buildup of solids. Metal parts would be treated by caustic hydrolysis and washed. Then metal parts and dunnage would be thermally treated in a hydrogen and steam atmosphere to ensure that all agents and energetics were removed.

### **3.2.4 Electrochemical Oxidation System**

The electrochemical oxidation system (Elchem Ox) would employ silver nitrate in a concentrated nitric acid bath to oxidize organic substances. Thermal decontamination would be used for metal parts and dunnage. A detailed description of the system is provided in Kimmell et al. (2001). AEA Technology and CH2M HILL demonstrated SILVER II™ for the PMACWA.

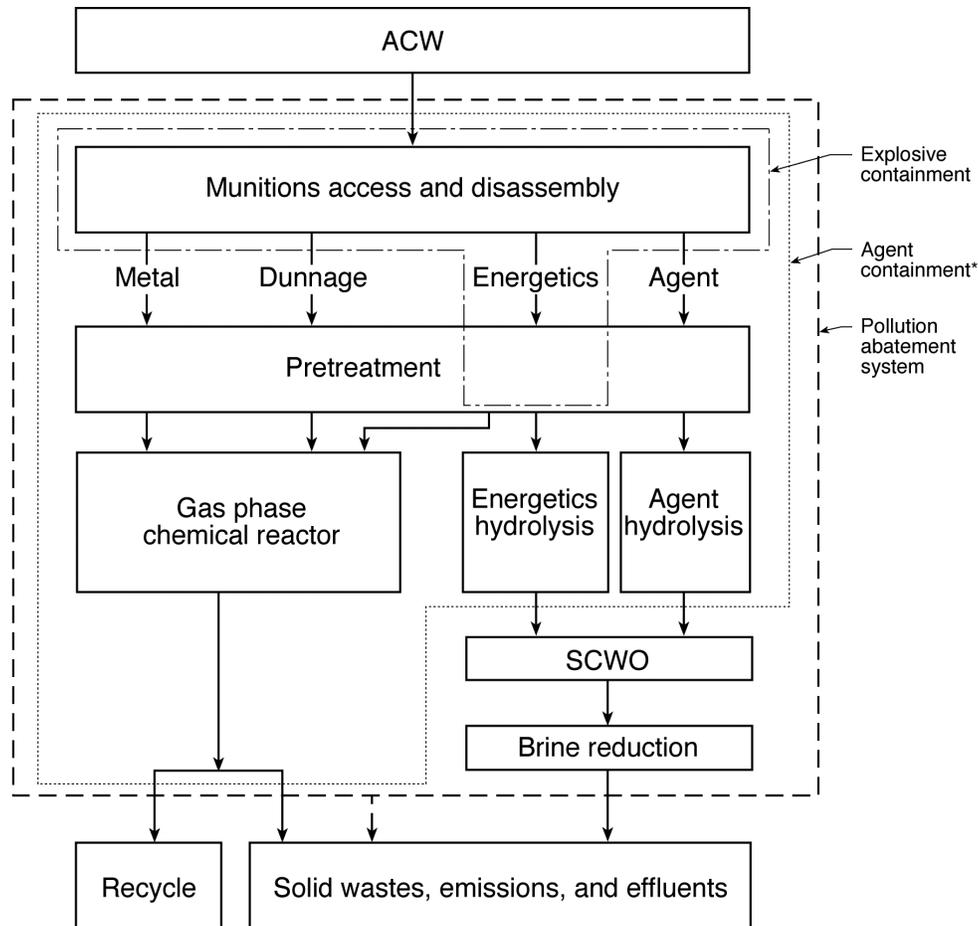
The general process flow of the system is shown in Figure 3.2-4. As currently envisioned, the system would use the baseline reverse assembly process or a modification of this process for ACW disassembly. After disassembly, materials would be prepared for treatment. To completely eliminate other hazards and chemical compounds of concern, agents and energetics would be treated in separate oxidation systems.  $\text{NO}_x$  formed as a result of the oxidation process would be reformed to nitric acid.

Dunnage would be size-reduced and then would be thermally treated. Metal parts also would be thermally treated to ensure that all agents and energetics were removed.

## **3.3 ACWA PROCESSES**

### **3.3.1 Removal and Movement from Storage**

A pilot test of the destruction system would begin by removing pallets that hold ACWs from the storage igloo and moving them to the chemical handling area of the pilot facility for



\*Agent containment could be expanded to enclose the entire process, if desired.

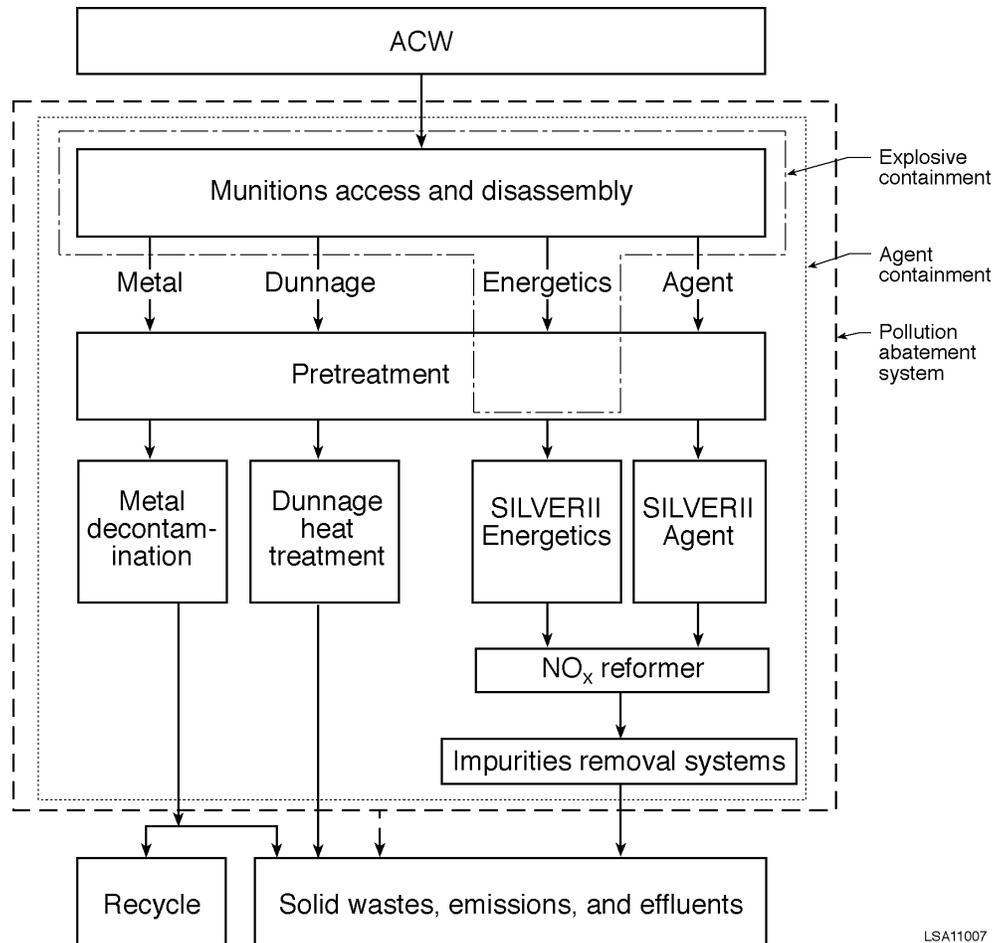
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**FIGURE 3.2-3 Neutralization/GPCR/TW-SCWO System**

disassembly. Before igloos would be opened, the munitions would be monitored to determine if they were safe for transport. If unsafe munitions were identified, they would be overpacked and made safe for transport. All movement of munitions from the storage site to the pilot facility would be within the installation. Monitoring and movement would conform to all applicable safety guidelines and regulations.

### 3.3.2 Disassembly Process

With regard to ACWs, the term “disassembly” refers to the steps employed to separate the agent and energetics from the metal casing and other metal parts. The basic process used to disassemble ACWs is called baseline reverse assembly. Baseline reverse assembly is employed at JACADS and TOCDF and, with some modifications, would be employed by each of the ACWA alternatives considered.



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**FIGURE 3.2-4 Electrochemical Oxidation System**

In conjunction with baseline reverse assembly of the munitions, various technologies could be used to open the metal casing and remove the agents. Details are provided in Kimmell et al. (2001). Demonstrated modifications to reverse assembly could include these:

1. High-pressure fluid jet to cut the munitions,
2. High-pressure wash to remove the agent and energetics, and
3. Cryofracture (a process in which munitions are embrittled by cooling in liquid nitrogen and then fractured) to access the agent after the energetics were removed.

Disassembly would be followed by preparing these streams of materials and the dunnage for further treatment.

### 3.3.3 Pretreatment Process

Pretreatment is the linking step between disassembly of an ACW and the treatment of its component parts. Most pretreatment activities are specific to the treatment process and are described as part of that process, such as reducing the size of dunnage before its treatment within a SCWO process. However, during the design and construction of integrated systems, it might be determined that material handling equipment, mixing tanks, heating components, and similar items not described in the disassembly and treatment processes (such as SCWO) would be needed.

### 3.3.4 Neutralization Process

Neutralization (or hydrolysis) is a process that is common to the Neut/Bio, Neut/SCWO, and Neut/GPCR/TW-SCWO alternatives. However, variations in the technology and equipment that would be used to implement the process have been proposed. Hydrolysis is a chemical process that uses a caustic solution (such as sodium hydroxide in water) or water followed by a caustic solution. It can be applied to energetics as well as to nerve and blister agents. This process breaks up the chemical compounds that form the agents and reduces the flammability and explosive reactivity of energetics, but it does not eliminate all hazards. Neutralization of agents produces residual compounds that are controlled under Schedule 2 of the CWC.<sup>2</sup> Secondary processes, such as biotreatment or SCWO, are required to destroy these compounds.

In the process envisioned, after the munitions would be disassembled to access the agents and energetics (explosives and propellants), the agents and energetics would be neutralized with water and a caustic solution or with a caustic solution alone. (Neutralization is discussed in Kimmell et al. [2001]). The temperature of the solution might be increased above ambient temperatures to speed up the reaction, decrease the time needed to treat the agent and energetics, and reduce the quantity of wastes produced. The product that results from the neutralization process is called hydrolysate.

### 3.3.5 Biotreatment Process

Biotreatment uses microbiological organisms to convert complex organic compounds to simpler materials. The organisms convert organic matter to stable forms (e.g., carbon dioxide, water, nitrates, and phosphates) as well as other organic material. The production of new organic matter is an indirect result of biotreatment. As envisioned, biotreatment would take place at temperatures and pressures near ambient conditions in tanks or similar structures designed to control retention time and hydrolysate contact with the biological organisms. The treatment

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<sup>2</sup> The agents themselves are designated as Schedule 1 compounds. Schedule 2 compounds are mainly agent precursors and are restricted from commercial distribution because they can be used to create toxic agents. Schedule 1 and 2 compounds are identified in Appendix B of Kimmell et al. (2001).

would result in a sludge that would be prepared for disposal by using wastewater treatment equipment to flocculate and solidify the biotreatment effluent. Additional details on the biotreatment process are available in Kimmell et al. (2001).

Biotreatment is a relatively mature technology that has been demonstrated for many types of wastes and is commonly used for municipal sewage and industrial wastes. However, the toxicity of the feed materials (e.g., due to metals content) can be a limiting factor that requires monitoring and control.

### **3.3.6 Supercritical Water Oxidation Process**

SCWO is a thermal oxidation process that takes place at temperatures and pressures above the critical point of water (i.e., at supercritical conditions; for water, this means pressures more than 220 times the atmospheric pressure and temperatures greater than about 705°F [340°C]). In the supercritical phase, water exists in a form that is more like a dense gas than a liquid and has enhanced solvent properties. Organic compounds (such as products of neutralized chemical agents and energetics) tend to break apart and dissolve under these conditions. Two different SCWO reactor technologies are being considered for pilot testing. In the processes envisioned, after chemical reactions would be complete, the effluent would be cooled, depressurized, and separated into gaseous and liquid waste streams. Salts and other materials would be removed from solution by evaporation. See Kimmell et al. (2001) for more detailed descriptions.

SCWO has been used on a pilot scale to treat various types of wastes and is in commercial operation. However, its potential for long-term operability in treating energetics has not yet been fully demonstrated. In addition, the issues associated with salt plugging and corrosion associated with the SCWO reactor and feed line design have not yet been addressed fully (PMACWA 1999). These issues and reactor technology issues associated with thermal stress on the reactor lines are being studied by the PMACWA (2001).

### **3.3.7 Electrochemical Oxidation Process**

Electrochemical oxidation occurs when an electric current is applied across an anode and cathodes in a cell containing acids in compartments separated by a membrane. The organic feed containing the agents or energetics is metered into the cell, which also contains silver nitrate. When the current is applied, the silver ions that are generated oxidize the organic materials, while the nitric acid is reduced to NO<sub>x</sub> and water.

### 3.3.8 Thermal Treatment Processes

Demonstrated methods of thermal treatment for contaminated dunnage and metal parts include the use of steam, hot gas (such as hydrogen), or radiant heat. Temperatures are raised in excess of 1,000°F (538°C) for 15 minutes as prescribed in Army standards (U.S. Army 1997b). Under these conditions, the chemical bonds of the nerve and blister compounds are broken and the chemical hazards are eliminated.

### 3.3.9 Pollution Abatement and Waste Handling Processes

Gases and solids would constitute the major types of wastes from the alternative technologies. Process water streams would be treated and recycled. There would be a nitric acid liquid waste stream from Elchem Ox. Plant ventilation systems would be designed to cascade air flow from the areas least likely to be contaminated to those where there would be a greater possibility of contamination. Catalytic purifiers (similar to automotive catalytic converters), high-efficiency particulate air (HEPA) filters and carbon filters, liquid scrubbers, and combinations of these technologies have been demonstrated and could be used to control air pollution. Ventilation air could be held and tested before its release to pollution control processes.

Solid residues, such as salts, would be considered hazardous waste if they leached heavy metals at levels above those allowed by the *Resource Conservation and Recovery Act* (RCRA) Toxic Characteristic Leaching Procedure (TCLP). Stabilization of these wastes would be required to reduce the leachability of heavy metals to levels below TCLP levels. After stabilization, these wastes could be disposed of in a landfill permitted to receive them. Metal parts would be cleaned sufficiently for release and then recycled. Environmental regulations might create additional requirements at some installations.

## 3.4 INPUTS AND OUTPUTS

### 3.4.1 Resource Requirements

The estimates of resource requirements that follow are not exact but do provide an “envelope” for possible levels of annual throughput. Since the alternatives under consideration would involve pilot testing, their operation is unlikely to be continuous, and resource use might differ from the estimates presented here. As presented in this chapter, the inputs for the technologies are installation-specific, but the outputs are general in nature. The differences in inputs for each installation stem from differences in the munition types and inventories and in the types of agent present in the ACW inventory at each installation. Installation-specific information for outputs is provided in Chapters 4, 5, 6, and 7.

### 3.4.1.1 Neutralization/Biotreatment

Table 3.4-1 lists estimated annual utility and process input requirements for pilot testing the Neut/Bio system for mustard agent. The estimates are based on assumed operations of 12 h/d, 6 d/wk, and 46 wk/yr.<sup>3</sup>

### 3.4.1.2 Neutralization/SCWO

Estimates of annual utility and process input requirements for pilot testing the Neut/SCWO system are provided in Table 3.4-2. These estimates are also based on assumed operations of 12 h/d, 6 d/wk, and 46 wk/yr.<sup>3</sup> Resource requirements are listed for nerve agent, rather than for GB and VX separately, because the demonstration testing did not provide a basis for developing separate estimates.

### 3.4.1.3 Neutralization/GPCR/TW-SCWO

Table 3.4-3 lists estimated annual utility and process input requirements for pilot testing the Neut/GPCR/TW-SCWO system. The estimates are based on assumed operations of 12 h/d, 6 d/wk, and 46 wk/yr.<sup>3</sup>

### 3.4.1.4 Electrochemical Oxidation

Estimated annual utility and process input requirements for pilot testing the Elchem Ox system are provided in Table 3.4-4. The estimates are based on assumed operations of 12 h/d, 6 d/wk, and 46 wk/yr.<sup>3</sup>

## 3.4.2 Routine Emissions and Wastes

Detailed information on the emissions and wastes for each technology at each installation is provided in Sections 4.4, 5.4, 6.4, and 7.4.

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<sup>3</sup> The ACWA pilot plants will be available 24 h/d and 365 d/yr, but the four destruction processes (Neut/Bio, Neut/SCWO, Neut/GPCR/TW-SCWO, and Elchem Ox) will operate about 38% of the available time (12 h/d, 6 d/wk, 46 wk/yr). The other 62% of the time, they will be devoted to maintenance, review of operational data, and other activities not expected to generate significant waste, emissions, or effluents.

**TABLE 3.4-1 Estimates of Annual Operational Input for Neutralization/Biotreatment by Site<sup>a</sup>**

Input	Input per Site		
	ANAD	PCD	BGAD <sup>b</sup>
Electric power <sup>c</sup>	36 GWh	36 GWh	2 GWh
Natural gas <sup>c</sup>	50 × 10 <sup>6</sup> scf	94 × 10 <sup>6</sup> scf	9 × 10 <sup>6</sup> scf
Fuel oil <sup>d</sup>	48,000 gal	48,000 gal	2,800 gal
Potable water <sup>e</sup>	6,400,000 gal	6,400,000 gal	300,000 gal
Process water <sup>c</sup>	7,000,000 gal	13,000,000 gal <sup>f</sup>	1,300,000 gal
Air for biotreater <sup>g</sup>	150,100 tons	280,000 tons	25,600 tons
Water in caustic <sup>g</sup>	510 tons	970 tons	90 tons
Sodium hydroxide (in 50% solution) <sup>g</sup>	510 tons	970 tons	90 tons
Sulfuric acid <sup>g</sup>	10 tons	30 tons	2 tons
Dipotassium phosphate <sup>g</sup>	30 tons	50 tons	4 tons
Magnesium chloride <sup>g</sup>	10 tons	20 tons	2 tons
Calcium chloride <sup>g</sup>	10 tons	20 tons	2 tons
Ammonium phosphate <sup>g</sup>	50 tons	90 tons	8 tons
Ammonia <sup>g</sup>	190 tons	350 tons	30 tons
Ferrous sulfate <sup>g</sup>	3 tons	6 tons	1 ton
Hydrogen peroxide <sup>g</sup>	70 tons	140 tons	10 tons

<sup>a</sup> Unit conversions: 1 ft<sup>3</sup> = 0.028 m<sup>3</sup>. 1 gal = 3.8 L. 1 ton = 0.91 tonne.  
1 scf (standard cubic foot) = 0.028 Nm<sup>3</sup> (normal cubic meter).

<sup>b</sup> At BGAD, values for all commodities other than fuel oil are based on 16 days of operation per year. The value for fuel oil is based on 35 hours of operation per year.

<sup>c</sup> At ANAD and PCD, values for electric power, natural gas, and process water are based on 276 days of operation per year at 6 d/wk and 46 wk/yr.

<sup>d</sup> At ANAD and PCD, values for fuel oil are based on 600 hours of operation per year.

<sup>e</sup> At ANAD and PCD, values for potable water are based on 365 days of operation per year.

<sup>f</sup> The number used for process water for Neut/Bio at PCD was from demonstration testing. Subsequent design studies now indicate 5.7 million gal/yr would be used.

<sup>g</sup> Values are based on 38% availability of operations.

Source: Kimmell et al. (2001).

TABLE 3.4-2 Estimates of Annual Operational Input for Neutralization/SCWO by Site and Agent<sup>a</sup>

Input	Input per Site and Type of Agent							
	ANAD		PBA		PCD		BGAD	
Electric power <sup>b</sup>	60 GWh		60 GWh		60 GWh		60 GWh	
Natural gas <sup>b</sup>	69 × 10 <sup>6</sup> scf		52 × 10 <sup>6</sup> scf		149 × 10 <sup>6</sup> scf		52 × 10 <sup>6</sup> scf	
Fuel oil <sup>c</sup>	48,000 gal		48,000 gal		48,000 gal		48,000 gal	
Potable water <sup>d</sup>	6,400,000 gal		5,500,000 gal		6,400,000 gal		6,400,000 gal	
Process water <sup>b</sup>	8,300,000 gal		6,100,000 gal		18,000,000 gal <sup>e</sup>		6,300,000 gal	
	Mustard	Nerve	Mustard	Nerve	Mustard	Nerve	Mustard	Nerve
Kerosene <sup>f</sup>	1,000 tons	620 tons	830 tons	830 tons	1,500 tons	810 tons	130 tons	810 tons
Compressed air <sup>f</sup>	4 tons	990 tons	2,100 tons	2,100 tons	7 tons	2,000 tons	1 ton	2,000 tons
Liquid oxygen <sup>f</sup>	5,700 tons	4,000 tons	4,400 tons	4,400 tons	7,800 tons	4,400 tons	680 tons	4,400 tons
Liquid nitrogen <sup>f</sup>	2,000 tons	2,900 tons	0	0	7,200 tons	810 tons	640 tons	810 tons
Water in caustic <sup>f</sup>	660 tons	1,200 tons	2,000 tons	2,000 tons	1,300 tons	2,000 tons	140 tons	2,000 tons
Sodium hydroxide (in 50% solution) <sup>f</sup>	540 tons	1,200 tons	1,800 tons	1,800 tons	1,000 tons	1,800 tons	120 tons	1,800 tons
Phosphoric acid <sup>f</sup>	10 tons	630 tons	1,200 tons	1,200 tons	30 tons	1,200 tons	2 tons	1,200 tons

<sup>a</sup> Unit conversions: 1 ft<sup>3</sup> = 0.028 m<sup>3</sup>. 1 gal = 3.8 L. 1 ton = 0.91 tonne. 1 scf (standard cubic foot) = 0.028 Nm<sup>3</sup> (normal cubic meter).

<sup>b</sup> Values for electric power, natural gas, and process water are based on 276 days of operation per year at 6 d/wk and 46 wk/yr.

<sup>c</sup> Values for fuel oil are based on 600 hours of operation per year.

<sup>d</sup> Values for potable water are based on 365 days of operation per year.

<sup>e</sup> The number used for process water for Neut/SCWO at PCD was from demonstration testing. Subsequent design studies now indicate 1.3 million gal/yr would be used.

<sup>f</sup> Based on 38% availability of operations.

Source: Kimmell et al. (2001).



**TABLE 3.4-4 Estimates of Annual Operational Input for Electrochemical Oxidation by Site and Agent<sup>a</sup>**

Input	Input per Site and Type of Agent											
	ANAD			PBA			BGAD					
Electric power <sup>b</sup>	105 GWh			121 GWh			122 GWh					
Natural gas <sup>b</sup>	53 × 10 <sup>6</sup> scf			48 × 10 <sup>6</sup> scf			52 × 10 <sup>6</sup> scf					
Fuel oil <sup>c</sup>	48,000 gal			48,000 gal			48,000 gal					
Potable water <sup>d</sup>	6,400,000 gal			6,400,000 gal			6,400,000 gal					
Process water <sup>b</sup>	1,000,000 gal			900,000 gal			1,000,000 gal					
	Mustard	GB	VX	GB	VX	GB	VX	Mustard	GB	VX		
Silver nitrate <sup>e</sup>	1,170 tons	160 tons	120 tons	150 tons	40 tons	200 tons	130 tons	30 tons				
Nitric acid <sup>e</sup>	0	0	30 tons	0	7 tons	0	0	1.6 tons				
Calcium nitrate <sup>e</sup>	550 tons	220 tons	0	210 tons	0	90 tons	180 tons	0				
Oxygen <sup>e</sup>	1,700 tons	1,500 tons	2,100 tons	1,800 tons	750 tons	170 tons	1,500 tons	700 tons				
Sodium hydroxide <sup>e</sup>	210 tons	210 tons	290 tons	260 tons	110 tons	20 tons	31 tons	170 tons				

<sup>a</sup> Unit conversions: 1 ft<sup>3</sup> = 0.028 m<sup>3</sup>. 1 gal = 3.8 L. 1 ton = 0.91 tonne. 1 scf (standard cubic foot) = 0.083 Nm<sup>3</sup> (normal cubic meter).

<sup>b</sup> Values for electric power, natural gas, and process water are based on 276 days of operation per year at 6 d/wk and 46 wk/yr.

<sup>c</sup> Values for fuel oil are based on 600 hours of operation per year.

<sup>d</sup> Values for potable water are based on 365 days of operation per year.

<sup>e</sup> Values are based on 38% availability of operations.

Source: Kimmell et al. (2001).

### **3.4.2.1 Neutralization/Biotreatment**

Both solid wastes and air emissions would result from the Neut/Bio process. Ventilation air and gases generated by processing ACWs would pass through an air pollution abatement system and be monitored before their release to the atmosphere. Sludge solids (consisting of biosolids and biosalts) from biotreatment would be disposed of in a permitted landfill. Because of their salt and heavy metal content, these solids, as well as the salts from the pollution abatement system, might require polymer solidification and encapsulation before disposal. Any wastes identified as hazardous would be stored and disposed of in accordance with RCRA requirements.

All liquids generated by the process and all liquid laboratory wastes would be reused in the process or disposed of through Neut/Bio. The only liquid effluents expected would be sanitary wastes. It is expected that decontaminated metal would be sold for recycling and that nonhazardous wastes associated with routine operation, such as domestic trash and office wastes, would be disposed of either on site or in a commercial landfill.

### **3.4.2.2 Neutralization/SCWO**

Wastes from the Neut/SCWO process would include both air emissions and solid wastes. Ventilation air and gases would pass through a series of filters and would be monitored before release to the atmosphere. The solid waste stream of dried salts from the SCWO process might not meet RCRA requirements with regard to leaching of heavy metals. As a result, secondary treatment might be required (page 22 of PMACWA 1999), or solidification and encapsulation might be used. Encapsulation would also probably be required for dried salts resulting from the brine evaporation process of the pollution abatement system. These solid wastes would be disposed of in a permitted landfill in accordance with RCRA requirements.

All liquids generated by the process and all liquid laboratory wastes would be reused in the process or disposed of through Neut/SCWO. The only liquid effluents expected would be sanitary wastes. It is expected that decontaminated metal would be sold for recycling and that nonhazardous waste associated with routine operation, such as domestic trash and office waste, would be disposed of either on site or in a commercial landfill.

### **3.4.2.3 Neutralization/GPCR/TW-SCWO**

Wastes from the Neut/GPCR/TW-SCWO process would include both air emissions and solid wastes. Ventilation air and gases would pass through a series of scrubbers and filters and would be monitored before being released to the atmosphere. The solid waste stream of dried salts that would result from the TW-SCWO process might not meet RCRA requirements with regard to leaching of heavy metals. In that case, secondary treatment might be required

(PMACWA 2001), or solidification and encapsulation might be used. Encapsulation would also probably be required for the dried salts that would result from the brine evaporation process used in the pollution abatement system. These solid wastes would be disposed of in a permitted landfill in accordance with RCRA requirements.

All liquids generated by the process and all liquid laboratory wastes would be reused in the process or disposed of through the neutralization or SCWO processes. The only liquid effluents expected would be sanitary wastes. It is expected that decontaminated metal would be sold for recycling and that nonhazardous waste would be disposed of in a commercial landfill. Nonhazardous solid waste associated with routine operations, such as domestic trash and office waste, would be disposed of in a commercial landfill.

#### **3.4.2.4 Electrochemical Oxidation**

Solid wastes, liquid wastes, and air emissions would result from the Elchem Ox process. It is expected that the solid waste stream of dried salts would be containerized and treated to meet RCRA requirements for disposal. Silver chloride precipitate would be thermally treated to destroy contaminants and shipped off site for silver recovery (PMACWA 2001).

NO<sub>x</sub> produced as a result of the SILVER II process would be reformed into nitric acid, and most of it would be reused in the process or recycled. A small waste stream of dilute nitric acid would also require disposal.

Ventilation air and gases would pass through a series of scrubbers and filters and would be monitored before being released to the atmosphere. It is expected that decontaminated metal would be sold for recycling and that nonhazardous solid waste associated with routine operations, such as domestic trash and office waste, would be disposed of in a commercial landfill.

### **3.5 NO ACTION ALTERNATIVE**

The no action alternative is continued storage at the stockpile installations until a destruction system could be implemented (PCD and BGAD) or until the ACW stockpile could be destroyed by the baseline incineration facility already being used for other demilitarization activities (ANAD and PBA).

### 3.5.1 Storage

No action as well as the proposed action would involve continued storage of ACWs at the current storage locations; that is, the ACWs would not be moved or destroyed. It is assumed that current safety procedures for storage would continue to be followed, including monitoring and surveillance.

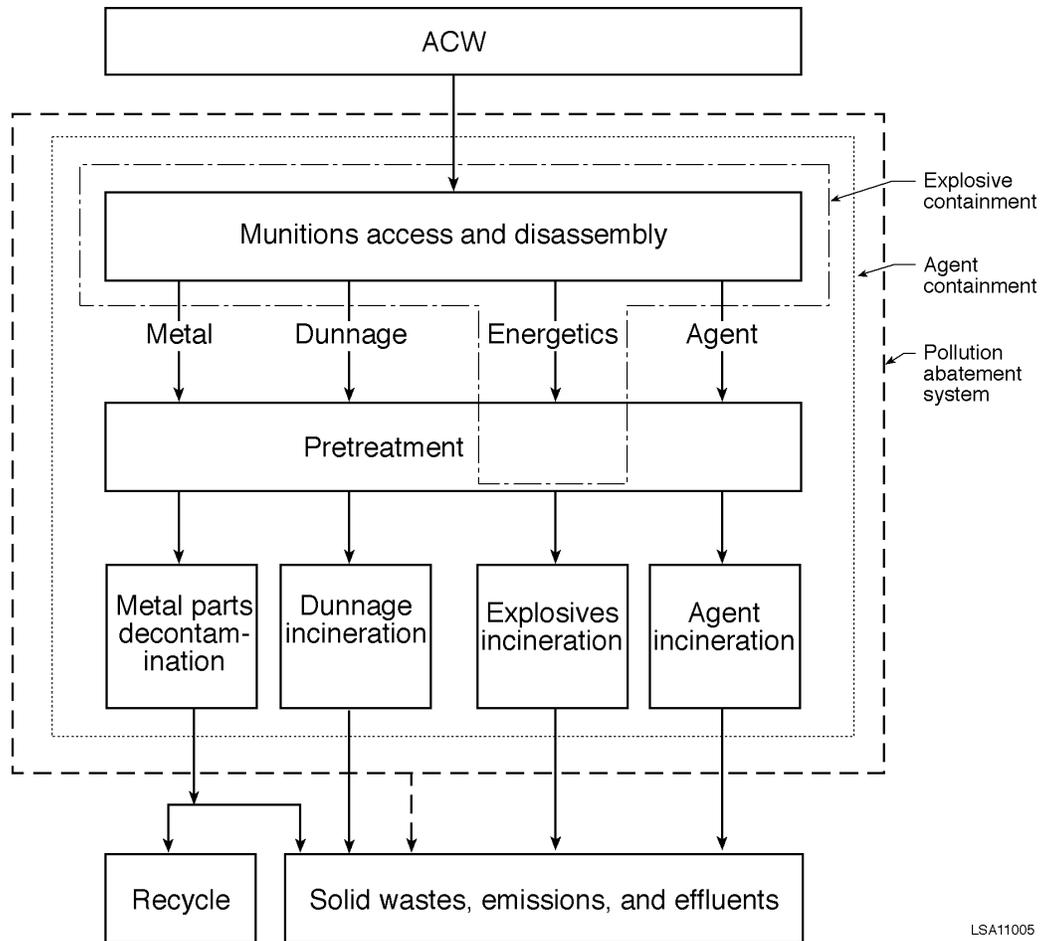
The ACW stockpile is currently stored in a variety of configurations in compliance with Army regulations. ACWs are stored in igloos where they are protected from external hazards and monitored for leakage. Leaking munitions are encased in an overpack to prevent any dispersal of agent.

Hazards associated with this alternative would derive from (1) handling during the course of inspection and maintenance activities, (2) external hazardous events (e.g., earthquake, airplane crash), and (3) continued degradation of the agent containers (U.S. Army 1988).

### 3.5.2 Baseline Incineration

Baseline incineration systems are currently being constructed at ANAD and PBA. At these sites, under both no action and the proposed action, ACWs would be destroyed by incineration. Figure 3.5-1 provides an overview of the baseline incineration process. ACW components would first be disassembled. After disassembly, they would be treated thermally in different types of incinerators. Their destruction would occur inside a structure designed to contain any leakage of chemical agents. Within that structure, agents and energetics would be separated from metal parts, and energetics would be incinerated in a rotary kiln incinerator (deactivation furnace) within a reinforced, explosive-containment structure. Agents would be transferred to the liquid-injection incinerator for destruction. Metal parts, which might contain residual agents and/or energetics, would be treated in a roller hearth incinerator. Contaminated dunnage would be reduced in size before incineration. In addition to the primary chamber, all of the incinerators would have a secondary chamber to destroy any residual agent not incinerated in the primary chamber. See Kimmell et al. (2001) for additional process information.

Scrubbers, HEPA filters, and carbon filters would be used to control emissions to the air. The primary waste materials from the system would consist of scrubber brine salts and incinerator residue (ash and slag). After polymer encapsulation or other treatment that might be required to reduce leaching of heavy metals, the salts, incinerator ash, and slag would be disposed of in a licensed landfill.



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**FIGURE 3.5-1 Baseline Incineration Process**

### 3.5.2.1 Annual Resource Requirements

Estimates of annual utility and process input requirements for all four installations, should an incinerator be constructed, are provided in Table 3.5-1. Estimates are based on full-scale operation, assuming system operation of 24 h/d, 7-d/wk, and 365 d/yr.

### 3.5.2.2 Routine Emissions and Wastes

Air emissions and solid wastes would be the main waste components that would result from the baseline incineration process. Sanitary waste would be the only liquid effluent expected from the facility. All liquids generated by the agent incineration process and liquid laboratory wastes would be disposed of by incineration. The exception is liquid brines, which might be treated, if necessary, and sent to a treatment, storage, and disposal facility (TSDF) for disposition. Solid wastes that are identified as hazardous would be stored and disposed of in accordance with RCRA requirements.

**TABLE 3.5-1 Estimates of Annual Operational Input for Baseline Incineration**

Input	Quantity per Year			
	ANAD <sup>a</sup>	PBA <sup>b</sup>	PCD <sup>c</sup>	BGAD <sup>d</sup>
Electric power (GWh)	33	33	29	36
Natural gas (scf) <sup>e</sup>	$1.3 \times 10^9$	$1.4 \times 10^9$	$4.6 \times 10^8$	$8.4 \times 10^8$
Fuel oil (gas)	1,400,000	1,400,000	1,400,000	1,400,000
Potable water (gal)	6,400,000	5,500,000	6,400,000	6,400,000
Process water (gal)	88,000,000	47,000,000	16,000,000	97,000,000
Dry air, process (tons)	82,000	95,000	87,000	93,000
Sodium hydroxide (tons)	900	600	2,000	700
Hydrochloric acid (tons) <sup>f</sup>	1,000	800	3,000	1,000
Sodium hypochlorite (tons) <sup>f</sup>				

a U.S. Army (1991).

b U.S. Army (1997a).

c COE (1987).

d Carnes (2001).

e scf = standard cubic feet.

f The annual consumption rates for hydrochloric acid (HCl) and sodium hypochlorite (NaOCl) are rough order-of-magnitude estimates based on ratios developed by using a detailed mass balance for incineration at PCD entitled "PUCDF M&E Balances," prepared in October 1995 by Parsons for the U.S. Army Corps of Engineers, Huntsville Division.

### 3.6 REFERENCES FOR CHAPTER 3

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