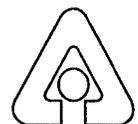

**Technology Resource Document for the
Assembled Chemical Weapons Assessment
Environmental Impact Statement
Volume 4: Assembled Systems for
Weapons Destruction at Pueblo Chemical Depot**

**Environmental Assessment Division
Argonne National Laboratory**



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ANL/EAD/TM-101
Volume 4

**Technology Resource Document for the
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Environmental Impact Statement
Volume 4: Assembled Systems for
Weapons Destruction at Pueblo Chemical Depot**

by T. Kimmell, S. Folga, G. Frey, J. Molberg, P. Kier, B. Templin, and M. Goldberg

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May 2001

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NOTATION

The following is a list of the acronyms, initialisms, and abbreviations (including units of measure) used in this document. Some acronyms used in tables or figures only are defined in the respective tables and figures.

ACRONYMS, INITIALISMS, AND ABBREVIATIONS

ACW	assembled chemical weapons
ACWA	Assembled Chemical Weapons Assessment
ANAD	Anniston Army Depot
APG	Aberdeen Proving Ground
ASG	Army Surgeon General
ATP	Alternative Technology Program (development of chemical agent neutralization process)
BGAD	Blue Grass Army Depot
BRA	brine reduction area (baseline post-treatment drum drier equipment)
BSR	burster size reduction
BSRM	burster size reduction machine
CAA	Clean Air Act
CAMDS	Chemical Agent Munitions Disposal System
CatOx	catalytic oxidation
CBDCOM	Chemical and Biological Defense Command
CFR	Code of Federal Regulations
Composition B	high explosive composed of 60% RDX, 39.5% TNT, and 0.5% calcium silicate (referred to as Comp B)
CRS	condensate recovery system
CST	continuous steam treater
CSTR	continuously stirred tank reactor
CTF	chemical transfer facility
CWA	Clean Water Act
CWC	Chemical Weapons Convention
DCD	Deseret Chemical Depot
DFS	deactivation furnace system (baseline furnace consisting of a rotary retort and a heated discharge conveyor [HDC])
DOD	U.S. Department of Defense
DOT	U.S. Department of Transportation
DPE	demilitarization protective ensemble (highest level of chemical agent personal protective equipment)
DPG	Dugway Proving Ground
DRE	destruction removal efficiency
DSHS	dunnage shredder/hydropulper system

ECBC	Edgewood Chemical Biological Center
ECR	explosion-containment room
EDS	engineering design study
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
ERDEC	U.S. Army Edgewood Research, Development, and Engineering Center
ERH	energetics rotary hydrolyzer
FIRE	Factor Information Retrieval
FTE	full-time equivalent
HAP	hazardous air pollutant
HDC	heated discharge conveyor (baseline electric radiation tunnel furnace)
HEPA	high-efficiency particulate air (type of air filtration system)
HMA	hot mix asphalt
ICB	Immobilized Cell Bioreactor™
JACADS	Johnston Atoll Chemical Agent Disposal System
LIC	liquid incinerator
LLNL	Lawrence Livermore National Laboratory
LPG	liquefied petroleum gas
M104	projectile, 155 mm, chemical agent (H or HD)
M110	projectile, 155 mm, chemical agent (H or HD)
M2	cartridge, 4.2 in., chemical agent (HD or HT)
M28	propellant grain (M55 rocket)
M2A1	cartridge, 4.2 in., chemical agent (HD or HT)
M426	projectile, 8 in., chemical agent (GB or VX)
M55	rocket, 115 mm, chemical agent (GB or VX)
M56	warhead, 115-mm rocket, chemical agent (GB or VX)
M60	cartridge, 105 mm, chemical agent (H or HD)
M60	rocket, 115 mm, inert
M61	rocket, practice 115 mm, simulant (EG)
MDB	Munitions Demilitarization Building
MMDM	modified multipurpose demilitarization machine
MPF	metal parts furnace (baseline tunnel furnace for drained munitions bodies)
MPT	metal parts treater
NCD	Newport Chemical Depot
NEPA	National Environmental Policy Act
NRC	National Research Council
PBA	Pine Bluff Arsenal
PCD	Pueblo Chemical Depot

PM ₁₀	particulate matter with a diameter less than or equal to 10 micrometers
PMACWA	U.S. Department of Defense, Program Manager for Assembled Chemical Weapons Assessment
PMCD	U.S. Army, Program Manager for Chemical Demilitarization
PMD	projectile/mortar disassembly (baseline reverse assembly equipment)
PRH	projectile rotary hydrolyzer
RCRA	Resource Conservation and Recovery Act
RDX	cyclotrimethylenetrinitramine (a high explosive)
RFP	request for proposal
ROD	record of decision
Schedule 2	chemical agent precursors listed in Schedule 2 of the Chemical Weapons Convention (CWC)
SCWO	supercritical water oxidation
SDS	spent decontamination system
TAP	toxic air pollutant
TC	ton container
TNT	2,4,6-trinitrotoluene (a high explosive)
TOCDF	Tooele Chemical Agent Disposal Facility
TOX	toxic cubicle
TRD	technical resource document
TW	transpiring wall
UMDA	Umatilla Depot Activity
1X, 3X, 5X	U.S. Army system for material safety hazard classification (X, XXX, and XXXXX, respectively)

CHEMICAL FORMULAS

Al(OH) ₃	aluminum hydroxide
CaCl ₂	calcium chloride
CO	carbon monoxide
CO ₂	carbon dioxide
FeSO ₄	ferrous sulfate
GA	tabun (nerve agent), O-ethyl N,N-dimethyl phosphoramidocyanidate
GB	sarin (nerve agent), O-isopropyl methylphosphonofluoridate
H	undistilled sulfur mustard, bis(2-chloroethyl)sulfide
HD	distilled sulfur mustard, bis(2-chloroethyl)sulfide
HT	blistering agent, mustard agent (H) with T
H ₂ O	water
H ₂ O ₂	hydrogen peroxide
H ₂ SO ₄	sulfuric acid
H ₃ PO ₄	phosphoric acid

K ₂ HPO ₄	dipotassium phosphate
KOH	potassium hydroxide
LN ₂	liquid nitrogen
LOX	liquid oxygen
MgCl ₂	magnesium chloride
N or N ₂	nitrogen
Na ₂ CO ₃	sodium carbonate
NaOCl	sodium hypochlorite
NaOH	sodium hydroxide
NH ₃	ammonia
(NH ₄) ₂ HPO ₄	ammonium phosphate
NH ₄ OH	ammonium hydroxide
NO _x	nitrogen oxides
O or O ₂	oxygen
PCB	polychlorinated biphenyl
PCP	pentachlorophenol
SO ₂	sulfur dioxide
SO _x	sulfur oxides
T	bis(2-chloroethylthioethyl) (combined with HD to make HT)
VOC	volatile organic compound
VX	methylphosphonothioic acid (nerve agent), O-ethyl S-(2-diisopropylaminoethyl)

UNITS OF MEASURE

acfm	actual cubic foot (feet) per minute
atm	atmosphere(s)
°C	degree(s) Celsius
°F	degree(s) Fahrenheit
cm	centimeter(s)
d	day(s)
ft	foot (feet)
ft ³	cubic foot (feet)
g	gram(s)
gal	gallon(s)
GW	gigawatt(s)
GWh	gigawatt hour(s)
h	hour(s)
ha	hectare(s)
in.	inch(es)
kg	kilogram(s)
km	kilometer(s)
L	liter(s)
lb	pound(s)
m	meter(s)
m ³	cubic meter(s)

M	molar
mi	mile(s)
mg	milligram(s)
min	minute(s)
mm	millimeter(s)
MMBtu	million British thermal units
MPa	megapascal(s)
MW	megawatt(s)
MWh	megawatt hour(s)
ppb	part(s) per billion
psia	pound(s) per square inch, absolute
rpm	revolution(s) per minute
s	second(s)
scf	standard cubic foot (feet)
t	metric ton(s)
wt%	weight percent
yd ³	cubic yard(s)
yr	year(s)

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**TECHNOLOGY RESOURCE DOCUMENT
FOR THE
ASSEMBLED CHEMICAL WEAPONS ASSESSMENT
ENVIRONMENTAL IMPACT STATEMENT**

**VOLUME 4:
ASSEMBLED SYSTEMS FOR WEAPONS DESTRUCTION
AT PUEBLO CHEMICAL DEPOT**

by

T. Kimmell, S. Folga, G. Frey, J. Molberg, P. Kier,
B. Templin, and M. Goldberg

4.1 INTRODUCTION

4.1.1 DOCUMENT PURPOSE

This volume of the Technical Resource Document (TRD) for the *Environmental Impact Statement (EIS) for the Design, Construction and Operation of One or More Pilot Test Facilities for Assembled Chemical Weapons Destruction Technologies at One or More Sites* (PMACWA 2001c) pertains to the destruction of assembled chemical weapons (ACW) stored at Pueblo Chemical Depot (PCD), located outside Pueblo, Colorado. This volume presents technical and process information on each of the destruction technologies applicable to treatment of the specific ACW stored at PCD. The destruction technologies described are those that have been demonstrated during Phase I of the Assembled Chemical Weapons Assessment (ACWA) demonstration process (see Volume 1).

It should be noted that some options for establishing ACWA pilot-scale facilities at specific installations are highly unlikely. However, no judgment regarding the feasibility or practicality of establishing a pilot-scale facility at a specific installation is expressed in this TRD.

4.1.2 THE ASSEMBLED CHEMICAL WEAPONS ASSESSMENT PROGRAM AT PUEBLO CHEMICAL DEPOT

The U.S. Department of Defense (DOD) Program Manager for Assembled Chemical Weapons Assessment (PMACWA) defines ACW as munitions containing both chemical agents and energetic materials (e.g., propellants, explosives) that are stored in the U.S. unitary¹

¹ The term “unitary” refers to the use of a single hazardous compound (i.e., chemical agent) in the munitions. In contrast, “binary” chemical weapons use two relatively nonhazardous compounds that are mixed together to form a hazardous or lethal compound after the weapon is fired or released.

chemical weapons stockpile. Such devices include rockets, projectiles and mortars, and land mines.² Unitary agents include chemical blister agents (i.e., the mustard agents H, HD, and HT) and chemical nerve agents (i.e., GB [sarin] and VX) (CBDCOM 1997). Because H, HD, and HT are listed as hazardous wastes in Colorado, applicable permits under federal and state hazardous waste laws will need to be obtained for the destruction facility. Volume 1 of this TRD provides background information on the agent and energetic components of ACW.

Each of the stockpile installations stores a different combination of individual types or configurations of ACW. Different or modified component treatment technologies are often required for the diverse ACW types or configurations maintained at the various stockpile locations. Thus, a technology or unit that can be applied to one type or configuration of ACW may not be applicable to another type or configuration. This volume of the TRD provides specific information for destruction of ACW at PCD.

The original ACW unitary stockpile contained approximately 31,500 tons (28,576 t) of unitary agents (Pacoraro 1999, as cited in NRC 1999) stored in a variety of ACW and bulk containers (e.g., ton containers [TCs]). In addition to PCD, stockpile locations in the continental United States include Aberdeen Proving Ground (APG), Maryland; Anniston Army Depot (ANAD), Alabama; Blue Grass Army Depot (BGAD), Kentucky; Newport Chemical Depot (NCD), Indiana; Pine Bluff Arsenal (PBA), Arkansas; Deseret Chemical Depot (DCD), Utah; and Umatilla Depot Activity (UMDA), Oregon.³ ACW were also stored at Johnston Atoll in the Pacific Ocean, at the Johnston Atoll Chemical Agent Disposal System (JACADS) facility; however, ACW destruction at JACADS has been completed. The ACW at the Tooele Chemical Agent Disposal Facility (TOCDF) at DCD are currently being destroyed through the baseline incineration process; this process, as defined in PMCD (1988), has undergone a number of improvements since its initial implementation. Baseline incinerator systems are currently being constructed at other stockpile locations, specifically, at PBA, ANAD, and UMDA. Only bulk agent containers are stored at APG and NCD; nonincineration-based destruction facilities are planned for these installations.

Figure 4.1 identifies all the unitary stockpile locations. Table 4.1 provides an inventory (as of November 1999) of the various types of chemical munitions in storage at these installations, including PCD.

² Mortars are often defined as a type of cartridge or projectile.

³ These installations, except for BGAD, store both ACW and chemical agents in bulk (e.g., TCs). Chemical agents stored in bulk are not considered ACW and are not addressed under the ACWA program.

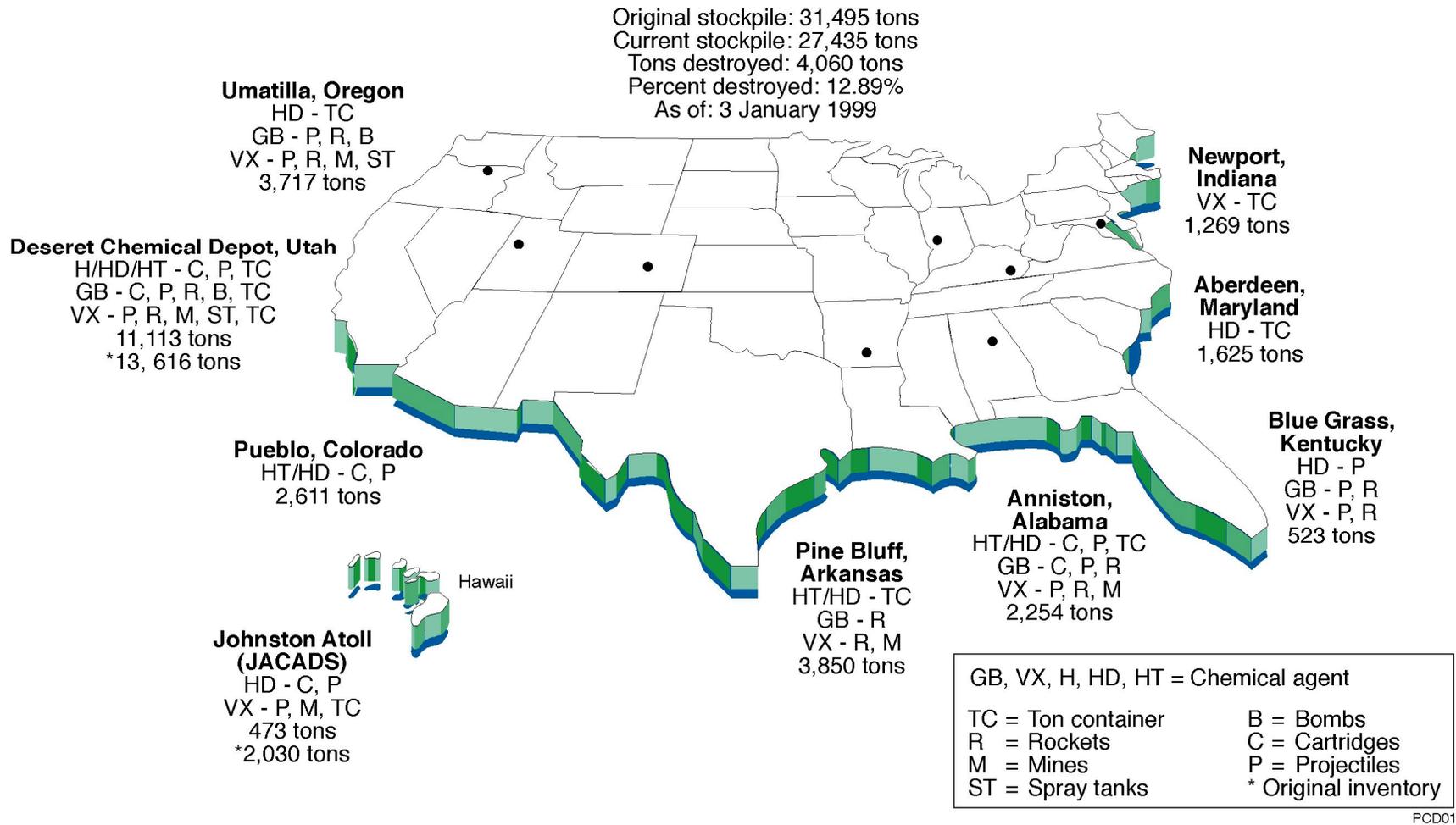


FIGURE 4.1 Types of Agent, Quantities of Agent, Types of Munitions, and Percentage of Total Agent Stockpiled at Each Storage Site (Source: Pacoraro 1999, as cited in NRC 1999) (Note: The information presented in this figure represents the stockpile as of January 3, 1999. Since that time, destruction of the inventory at JACADS has been completed, and much of the inventory at Deseret Chemical Depot has been destroyed.)

TABLE 4.1 Chemical Munitions Inventory by Stockpile Location^{a,b}

Agent	Item	Anniston Army Depot		Deseret Chemical Depot	
		No. of Munitions	Agent (lb)	No. of Munitions	Agent (lb)
H	155-mm projectiles	c		54,663	639,540
HT	4.2-in. cartridges	183,552	1,064,600	62,590	363,020
HD	4.2-in. cartridges	75,360	452,160	976	5,860
HD	105-mm cartridges	23,064	68,500		
HD	155-mm projectiles	17,643	206,420		
GB	105-mm cartridges	74,014	120,640	119,400	194,620
GB	105-mm cartridges	26	40	679,303	1,107,260
GB	155-mm projectiles	9,600	62,400	89,141	579,420
GB	4.2 in. cartridges	16,026	232,380		
GB	M55 rockets	42,738	457,300	28,945	309,720
GB	M56 rocket warheads	24	260	1,056	11,300
VX	155-mm projectiles	139,581	837,480	53,216	319,300
VX	4.2 in. cartridges			1	20
VX	M55 rockets	35,636	356,360	3,966	39,660
VX	M56 rocket warheads	26	260	3,560	35,600
VX	Mines	44,131	463,380	22,690	238,240
L	Ton containers			10	25,920
HD	Ton containers	108	185,080	6,398	11,383,420
HT	Ton container				
GA	Ton containers			2	2,820
TGA ^d	Ton containers			2	1,280
TGB ^d	Ton containers			7	6,960
GB	WETEYE bombs			888	308,140
GB	500-lb bombs				
GB	750-lb bombs			4,463	981,860
GB	Ton containers			5,709	8,598,200
VX	Spray tanks			862	1,168,880
VX	Ton containers			640	910,960

TABLE 4.1 (Cont.)

Agent	Item	Blue Grass Army Depot		Pine Bluff Arsenal	
		No. of Munitions	Agent (lb)	No. of Munitions	Agent (lb)
H	155-mm projectiles				
HT	4.2-in. cartridges				
HD	4.2-in. cartridges				
HD	105-mm cartridges				
HD	155-mm projectiles	15,492	181,260		
GB	105-mm cartridges				
GB	105-mm cartridges				
GB	155-mm projectiles				
GB	4.2 in. cartridges	3,977	57,660		
GB	M55 rockets	51,716	553,360	90,231	965,480
GB	M56 rocket warheads	24	260	178	1,900
VX	155-mm projectiles	12,816	76,900		
VX	4.2 in. cartridges				
VX	M55 rockets	17,733	177,340	19,582	195,820
VX	M56 rocket warheads	6	60	26	260
VX	Mines			9,378	98,460
L	Ton containers				
HD	Ton containers			107	188,400
HT	Ton container			3,591	6,249,100
GA	Ton containers				
TGA	Ton containers				
TGB	Ton containers				
GB	WETEYE bombs				
GB	500-lb bombs				
GB	750-lb bombs				
GB	Ton containers				
VX	Spray tanks				
VX	Ton containers				

TABLE 4.1 (Cont.)

Agent	Item	Pueblo Chemical Depot		Umatilla Chemical Depot	
		No. of Munitions	Agent (lb)	No. of Munitions	Agent (lb)
H	155-mm projectiles				
HT	4.2-in. cartridges	20,384	118,220		
HD	4.2-in. cartridges	76,722	460,340		
HD	105-mm cartridges	383,418	1,138,760		
HD	155-mm projectiles	299,554	3,504,780		
GB	105-mm cartridges				
GB	105-mm cartridges				
GB	155-mm projectiles			47,406	308,140
GB	4.2 in. cartridges			14,246	206,560
GB	M55 rockets			91,375	977,720
GB	M56 rocket warheads			67	720
VX	155-mm projectiles			32,313	193,880
VX	4.2 in. cartridges			3,752	54,400
VX	M55 rockets			14,513	145,140
VX	M56 rocket warheads			6	60
VX	Mines			11,685	122,700
L	Ton containers				
HD	Ton containers			2,635	4,679,040
HT	Ton container				
GA	Ton containers				
TGA	Ton containers				
TGB	Ton containers				
GB	WETEYE bombs				
GB	500-lb bombs			27	2,960
GB	750-lb bombs			2,418	531,960
GB	Ton containers				
VX	Spray tanks			156	211,540
VX	Ton containers				

- ^a Information on items appearing below the dashed line (including ton containers, bombs, and spray tanks) is provided for information purposes only. Although considered part of the unitary stockpile, these items are not ACW.
- ^b The chemical munitions inventory at JACADS is not included in this table because destruction of this inventory has been completed.
- ^c A blank indicates that the item is not included in the inventory at that location.
- ^d The “T” before GA and GB stands for “thickened.”

As can be seen from Figure 4.1 and Table 4.1, PCD differs from the other stockpile sites in that it stores only mortars and projectiles; further, PCD only stores mortars and projectiles containing HD and HT. Therefore, not only are the chemical agents stored at PCD limited to HD and HT, the energetic materials are limited to those present in the mortars and projectiles. Overall, the quantity of chemical agent stored at PCD accounts for 10% by weight of the total U.S. stockpile. This is the fourth largest inventory among the U.S. Army's eight continental U.S. storage sites.

Several ACW types are stored at PCD, including two types of 155-mm projectiles (M104, M110), one type of 105-mm cartridge (M60), and two types of 4.2-in. cartridge rounds (M2, M2A1). Table 4.2 identifies the types of mortars and projectiles stored at PCD and their agent and energetic components. Volume 1 of this TRD contains more detailed descriptions of the ACW types and their components.

4.1.3 ORGANIZATION OF TECHNICAL RESOURCE DOCUMENT

This document provides primary support for preparation of an EIS that evaluates alternative weapons destruction technologies for pilot-scale testing at ANAD, PBA, PCD, and BGAD, in compliance with the National Environmental Policy Act (NEPA) (U.S. Army 2000). This TRD consists of 5 volumes (see Figure 4.2). Volume 1 provides general information on the ACWA program; a description of the ACW, including chemical and energetic components; an overview of the ACWA technology selection process; and a summary of each of the ACWA system treatment technologies. Volume 1 also includes five supporting appendixes. Volume 2 pertains to ANAD; Volumes 3 and 5 pertain to PBA and BGAD, respectively, and this volume, Volume 4, pertains to PCD.

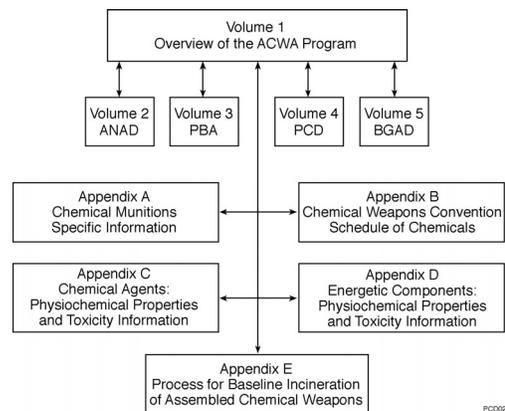


FIGURE 4.2 Organization of Technical Resource Document

Section 4.2 of this volume identifies and describes each of the technologies that could be used to treat the ACW stored at PCD for each of the six process categories (munitions access, agent treatment, energetics treatment, dunnage treatment, metal parts treatment, and effluent management/pollution controls). Following a brief introduction, the history of the technology system is reviewed. Then, a general process overview is provided, the results of demonstration testing and engineering design studies are discussed, and a detailed process description is

TABLE 4.2 Chemical Munitions Inventory at PCD

Munition	Number in Storage ^a	Length ^b	Diameter ^b	Weight ^b	Agent Amount ^b	Burster Type	Burster Amount ^b	Propellant Type	Propellant Amount	Fuze Type	Fuze Amount ^b
155-mm projectile M104 HD-filled	33,062	26.8 in.	1,355 mm	43.1 kg	5.3kg	Tetrytol	0.19 kg	None	None	c	c
155-mm projectile M110 HD-filled	266,492	26.8 in.	155 mm	42.9 kg	5.3 kg	Tetrytol	0.19 kg	None	None	c	c
105-mm cartridge M60 HD-filled	383,418	16 in.	105 mm	17.6 kg	1.4 kg	Tetrytol	0.12 kg	None	None	M57 or M51A5	d
4.2-in. cartridge M2 HD or HT-filled	20,384	21.0 in.	4.2 in.	11.3 kg	2.7 kg HD 2.6 kg HT	Tetryl	0.064 kg	M6 ^e	0.2 kg	M8 ^d	1,300 g tetryl
4.2-in. cartridge M2A1 HD-filled	76,722	21.0 in.	4.2 in.	11.3 kg	2.7 kg HD	Tetryl	0.064 kg	M6 ^e	0.2 kg	M8 ^e	1,300 g tetryl

^a Number in storage represents data as of July 11, 1997.

^b Conversions: 1 in. = 2.54 cm/25.4 mm; 1 lb = 0.454 kg.

^c 155-mm projectiles are stored with lifting rings in place of fuzes.

^d 4.2-in. cartridges are stored with fuzes in place. See Appendix A of Volume 1 of this TRD for a description of the fuze.

^e M6 propellant consists of 52.15% nitrocellulose, 43% nitroglycerine, 3% dibutylphthalate, 1.25% potassium nitrate, 0.6% ethylcentralite, and silk thread.

Source: Compilation of information presented in Appendix A of Volume 1 of this TRD and Appendix A of NRC (1999).

presented.⁴ For all the described systems, technologies common to other systems are also identified, as are possible technology combinations that can be employed to create different, but viable, systems.

Section 4.3 of this volume provides supplemental information for pilot testing assembled systems. Included are facility descriptions, system inputs and resource requirements, routine emissions and wastes, and activities and schedules. This section also addresses both construction and operation of the facility.

Section 4.4 of this volume contains a list of references that were used in preparing this volume. The technology provider reports included in this list (General Atomics 1999, Parsons/Allied Signal 1999) contain more detailed information on the ACWA technologies.

⁴ The descriptions are based on the equipment used by the technology providers during the ACWA demonstrations (PMACWA 1999a, General Atomics 1999, Parsons/Allied Signal 1999). The equipment that may eventually be used in a pilot-scale facility may vary based on the system that is actually employed and system refinements. However, conceptually, the equipment used in a pilot-scale facility would be similar to that demonstrated during the demonstration test phase of the ACWA program.

4.2 ASSEMBLED SYSTEMS FOR WEAPONS DESTRUCTION AT PUEBLO CHEMICAL DEPOT

Two ACWA technology systems are presently under consideration for pilot-scale testing at PCD.⁵ These systems and their corresponding processes are as follows:

- Primary destruction: agent and energetics neutralization; secondary destruction: supercritical water oxidation (SCWO) (demonstrated by General Atomics⁶). This system is referred to herein as neutralization/SCWO.
- Primary destruction: agent and energetics neutralization; secondary destruction: biological treatment (demonstrated by Parsons/Honeywell⁷). This system is referred to herein as neutralization/biotreatment.

The neutralization/SCWO system is a viable technology system for treating ACW containing mustard agent or nerve agent. The neutralization/biotreatment system is viable only for ACW containing mustard agent. Only the ACWA Demonstration I (Demo I) technologies are discussed for PCD. The National Defense Authorization Act for Fiscal Year 2001 (Public Law 106-398) specifically indicates that only ACWA technologies that were demonstrated on or before May 1, 2000, may be considered for PCD. This limitation effectively precludes consideration of the Demonstration II (Demo II) technologies for PCD. The Demo II technologies may be reviewed, however, in the other installation-specific volumes of this TRD.

As indicated in Volume 1 of this TRD, incineration is not a candidate technology in the EIS that this resource document supports. Incineration, including the baseline process as well as a “single-story process,” is being considered as a potential destruction technology at PCD under a separate EIS (U.S. Army 2000b). Although incineration is not a candidate ACWA technology, the two ACWA technologies discussed above employ one or more components of the baseline incineration process (e.g., reverse assembly, pollution abatement system). Elements of the baseline incineration process are therefore included in the overview of baseline and ACWA system technologies provided in Volume 1 of this TRD (Section 1.4). In addition, the baseline incineration process is described in more detail in Appendix E of Volume 1.

⁵ The technology system descriptions presented in this TRD were derived from data and information developed by technology providers during the Phase I PMACWA demonstration test phase for the ACWA program (PMACWA 1999a). The use of technology provider names and nomenclature from demonstration documentation (General Atomics 1999, Parsons/Allied Signal 1999) does not imply endorsement of a specific technology provider.

⁶ General Atomics refers to its ACWA system as the General Atomics Total Solution (GATS).

⁷ Honeywell purchased Allied Signal in early 2000; General Electric purchased Honeywell in 2000. Parsons/Honeywell refers to its ACWA system as the Water Hydrolysis of Explosives and Agent Technology (WHEAT) process.

The single-story process referred to above pertains to a simpler design than the baseline process. The single-story process is housed primarily in a one-story building. In comparison, the baseline incinerator design is housed primarily in a two-story building. Because PCD stores only munitions containing mustard agent, it is amenable to the simpler single-story design. This version of the TRD addresses ACWA technologies that are designed to fit into the baseline two-story building.

Table 4.3 provides an overview of the baseline incineration process and the ACWA technology systems. A more detailed description of each of the ACWA technology systems

TABLE 4.3 Technology Overview for Baseline Incineration and ACWA Technology Systems for PCD^a

Technology	Munitions Access	Agent Treatment	Energetics Treatment	Metal Parts Treatment	Dunnage Treatment
Baseline Incineration	Baseline reverse assembly	Liquid incinerator (LIC) (a stationary LIC)	Deactivation furnace system (DFS) (a rotary kiln incinerator), with heated discharge conveyor (HDC)	Metal parts furnace (MPF) (a roller hearth incinerator)	Size reduction and stationary bed incinerator
Neutralization/ SCWO	Parts of baseline reverse assembly, cryofracture	Hydrolysis ^b followed by SCWO	Caustic hydrolysis followed by SCWO	Caustic hydrolysis followed by thermal treatment with steam	Size reduction/ pulping followed by SCWO
Neutralization/ Biotreatment ^c	Modified baseline reverse assembly (fluid-abrasive cutting and fluid-mining)	Hydrolysis ^b followed by biotreatment	Caustic hydrolysis followed by biotreatment	Thermal treatment with steam	Size reduction/ thermal treatment with steam

^a Combinations of these technologies may also be considered.

^b Nerve agents are treated using caustic hydrolysis; mustard agents are treated using water hydrolysis followed by a caustic wash.

^c Biotreatment is viable for mustard agents only.

Source: Adapted from PMACWA (1999a; 2001a,b).

follows.⁸ This document is based on a conceptual “full-scale” facility as described in the PMACWA Request for Proposal (RFP) for the ACWA program (CBDCOM 1997). Exact specifications of units and processes, including operating temperatures and pressures, may vary.

4.2.1 NEUTRALIZATION/SCWO

The neutralization/SCWO technology system consists of neutralization of agents and energetics and secondary treatment of neutralization residuals using SCWO. This technology system, proposed by General Atomics,⁹ is applicable to all ACW stored at PCD. It uses a solid-wall SCWO process. Operation of a transpiring-wall (TW)-SCWO unit is discussed in Volumes 2, 3, and 5 of this TRD. The following subsections provide a more detailed discussion of the technologies and processes involved in this system. The technology provider’s technology demonstration report (General Atomics 1999) may be viewed for additional detail.

4.2.1.1 Process Overview

The neutralization/SCWO process, as applied to projectiles and mortars stored at PCD, is summarized in Figure 4.3. As Figure 4.3 shows, munitions would be disassembled using a modified baseline reverse assembly process. Once the energetic materials have been removed, agent would be accessed. In the system proposed by General Atomics, this would be accomplished by cryofracturing the munition.¹⁰ However, the agent could be accessed by using other methods. HD and HT would be neutralized/hydrolyzed using water in systems operated at 194°F (90°C) and atmospheric pressure;¹¹ energetics would be neutralized/hydrolyzed using a sodium hydroxide (NaOH) solution, in systems also operated at 194°F (90°C) and atmospheric pressure. Neutralization of HD and HT using water would be followed by a caustic wash using NaOH. Dunnage would be shredded, micronized, hydropulped, and neutralized/hydrolyzed. Resulting hydrolysates would then be treated in separate SCWO units. Dunnage hydrolysate would be added to energetics hydrolysate and would be treated in the same SCWO unit. Thermal treatment would be used to treat metal parts to a 5X condition.¹²

⁸ Monitoring of emissions is part of any environmental waste management scenario. Monitoring of ACW treatment processes will be prescribed in environmental permits issued under the Resource Conservation and Recovery Act (RCRA). Monitoring technologies are not specifically described in this TRD.

⁹ Neutralization is a common element of the other technology systems discussed in this volume of the TRD.

¹⁰ Cryofracture is a system whereby materials are cooled rapidly, usually by immersion in liquid nitrogen. This process embrittles the materials so that they may be easily fractured in a subsequent process.

¹¹ The unit is not operated under pressure.

¹² The definition of 5X is provided in Volume 1 of this TRD (Section 1.2.2.4). While materials treated to a 5X condition may be released for unrestricted use (e.g., recycling), materials that are determined to be in 3X condition must remain under government control. For example, hazardous waste disposal facilities may receive wastes treated to a 3X condition.

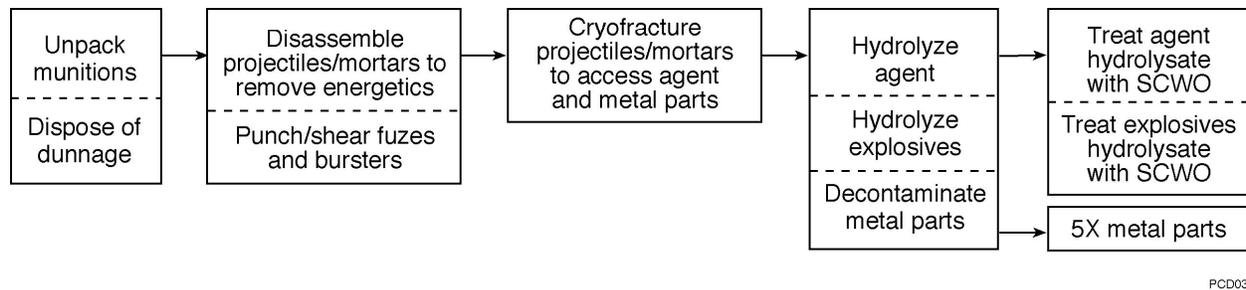


FIGURE 4.3 Overview of the Neutralization/SCWO Process (General Atomics System) for the Treatment of Projectiles and Mortars at PCD (Source: Adapted from NRC 1999)

4.2.1.2 History of Destructive Processes

Neutralization and SCWO are the primary destructive processes employed in this technology. The history of these processes is summarized in the following subsections.

4.2.1.2.1 Neutralization of Agent and Energetics

Agent neutralization and energetics neutralization by hydrolysis are discussed in detail in a 1999 National Research Council (NRC) report (Appendixes D and E, respectively) (NRC 1999). The literature on neutralization of HD is extensive (NRC 1999). Technically, neutralization is a chemical reaction between an acid and a base to form a salt and water (NRC 1999). In this application, neutralization refers to a hydrolysis reaction in which a target compound is reacted with water, an acid, or a base to break chemical bonds in the target compound (NRC 1999). Chemical demilitarization literature, therefore, often uses neutralization and hydrolysis as interchangeable terms for the same process (NRC 1999).

Neutralization using hot water (194°F, 90°C), followed by the addition of a caustic (NaOH) is the process that will be pilot tested at APG for destruction of the bulk HD stored there (APG 1997). The NRC references work performed at the U.S. Army Edgewood Research, Development, and Engineering Center (ERDEC)¹³ and indicates that neutralization has been shown to reduce HD concentrations in hydrolysate to less than 20 ppb (the analytical detection limit); 99% of the HD is converted to thiodiglycol (NRC 1999, ERDEC 1996). Thiodiglycol is a Schedule 2 compound (see Appendix B of Volume 1 of this TRD), and the hydrolysate requires further treatment to meet the requirements of the Chemical Weapons Convention (CWC) (NRC 1999). The neutralization reaction with water requires vigorous stirring because HD is relatively insoluble in water (NRC 1999, see also Appendix C of Volume 1 of this TRD). In addition, a semisolid or gelatinous “heel” of mustard agent can form in stored munitions. The heel, which can amount to up to 10% of the stored agent, can be washed out (NRC 1999). HD hydrolysates

¹³ Now known as the Edgewood Chemical Biological Center (ECBC).

contain high levels of thiodiglycol, as explained above, and may also contain a high salt content, various metals, and chlorinated hydrocarbons (NRC 1999).

For energetics, this technology involves caustic neutralization using solutions of NaOH. The NRC reports that there is less experience with base neutralization of energetic materials relative to experience with chemical agents (NRC 1999). However, neutralization of energetics has been substituted for open burning/open detonation, a treatment that has historically been applied to these materials (NRC 1999). The open literature contains many references to caustic hydrolysis of energetics, dating back to the mid-1800s (NRC 1999). The Navy recently published a review of alkaline hydrolysis of energetic materials pertinent to ACW (Newman 1999, as cited in NRC 1999).

Base hydrolysis decomposes energetic materials to organic and inorganic salts, organic degradation products, and various gases (NRC 1999). The base used — typically NaOH, potassium hydroxide (KOH), ammonium hydroxide (NH₄OH), or sodium carbonate (Na₂CO₃) — usually attacks all the functional groups of the energetic material (NRC 1999). While previous work with base hydrolysis involved studying reactions under ambient conditions, recent work has been conducted at elevated temperatures and pressures, which increases the solubility of the energetics in solution, increases the reaction rate, and reduces clogging of the reactor vessel (NRC 1999). The reactions, however, are exothermic and must be carefully controlled and monitored to prevent an explosion (NRC 1999).

The NRC indicates that caustic neutralization of energetics is not a mature technology; nevertheless, it concludes that “the current level of understanding is, perhaps, sufficient to indicate that engineering practices can probably restrict the domain of possible reaction products” (NRC 1999). Products from the neutralization reaction may include nitrates, nitrites, ammonia, nitrogen, hydrogen, organic acids, and formaldehyde, as well as various salts (NRC 1999).

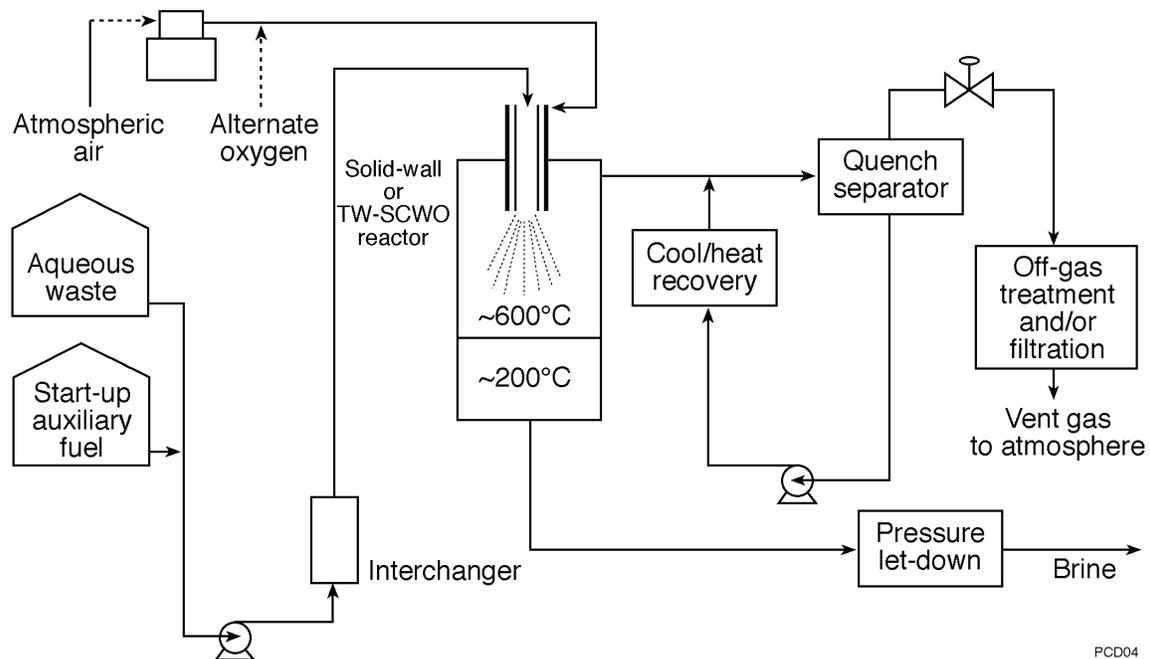
4.2.1.2.2 Supercritical Water Oxidation

The NRC reviews the SCWO process in Appendix F of its 1999 report. Much of the material in that appendix is based on a review of the SCWO technology for application to VX hydrolysates that the NRC performed in 1998 (NRC 1998). That work was conducted primarily in response to the proposed use of the SCWO technology for treating the VX hydrolysates resulting from neutralization of the U.S. Army's bulk stockpile of VX at NCD, Newport, Indiana. Hydrolysis followed by application of SCWO is nearing the pilot-scale testing phase at NCD (PMCD 1998b, NRC 1999). The U.S. Army prepared an EIS of the hydrolysis/SCWO process proposed for NCD for treatment of bulk VX (PMCD 1998b) and concluded that the proposed facility would meet stringent permitting requirements of the Clean Water Act (CWA), the Resource Conservation and Recovery Act (RCRA), and the Clean Air Act (CAA). The U.S. Army further concluded that the site and environs of the facility would be affected by

construction and pilot testing of the proposed facility, but that appreciable adverse human health and environmental impacts would not be unexpected, and those that may occur would be well within regulatory limits (PMCD 1998a).

When SCWO is used, the temperature and water pressure are raised to above supercritical conditions (705°F [374°C] and 3,204 psia [22 MPa]). Under these conditions, salts precipitate out of solution, and organic compounds are oxidized to carbon dioxide (CO₂) and water (H₂O) (NRC 1999). Figure 4.4 is a simplified process flow diagram for a typical solid-wall SCWO process.

SCWO is not widely used within the United States. The NRC reports that SCWO has been used on a pilot scale to treat other types of wastes, but that it is used commercially at only one location within the United States (NRC 1998, as cited in NRC 1999). Although SCWO has been under development for over 20 years, both in the United States and overseas, only recently have problems with the reactor vessel been overcome sufficiently to permit consideration of full-scale operations.



PCD04

FIGURE 4.4 Typical Flow Diagram for SCWO (Source: NRC 1998, as cited in NRC 1999)

4.2.1.3 Demonstration Testing¹⁴

The neutralization/SCWO technology was demonstrated during Demo I of the PMACWA demonstration test program. Demo I testing was conducted in spring 1999. This section provides a summary of demonstration testing for neutralization/SCWO. Demo I testing results are provided in PMACWA (1999a).

Baseline reverse assembly, carbon filtration, the brine reduction area (BRA) operation, and other technologies employed in neutralization/SCWO were not demonstrated during demonstration testing. The PMACWA elected not to demonstrate certain unit operations proposed for neutralization/SCWO for the reasons given below.

Cryofracture System (bath, robotic transport, and press). This is a well-developed system that has been demonstrated at full scale at Dugway Proving Ground (DPG). For the ACWA program, the only required changes to the demonstrated equipment were scaling down the press and instituting conveyor transport of individual munitions through the liquid nitrogen (LN₂) bath. Demonstration of this unit was therefore not required.

Projectile Rotary Hydrolyzer (PRH). Drum dryers, the basis of the PRH, are well developed and have been demonstrated commercially. The PRH is essentially a batch process with a slow tumbling action (identical in principle to the energetics rotary hydrolyzer [ERH]). Therefore, demonstration of this unit was not considered critical.

Heated Discharge Conveyor (HDC). The proposed unit is essentially identical in design to the baseline HDC (used at TOCDF) but would operate in a nitrogen atmosphere. Heated bucket conveyors are well developed and demonstrated commercially. While demonstration of the HDC was originally planned, the discontinuation of testing of polychlorinated biphenyls (PCBs) made an HDC demonstration less essential at this stage in the program.¹⁵

Metal Parts Furnace (MPF). This batch furnace is similar to the baseline MPF structure, except that induction heaters rather than gas-fired heaters are used. Operationally, the MPF differs from the baseline version because an inert atmosphere is used to process solid wastes. Demonstration of this unit was not required, because the MPF has been proposed to treat only surface-washed metal hardware with a low organic loading.

¹⁴ This material was derived from PMACWA (1999a) and refers to demonstration testing during Phase I of the ACWA demonstration process. Because demonstration testing was intended to apply to all ACW from all storage sites, this section does not discriminate with regard to munition type and storage installation.

¹⁵ PCBs were originally identified as a constituent of concern for the M55 rockets because the rockets are stored in shipping/firing tubes made of an epoxy resin that can contain PCBs. PCBs were not evaluated during demonstration testing because regulatory approvals could not be obtained within the allotted time frame. PCBs will be evaluated during pilot-scale testing.

The reasons for selecting the neutralization/SCWO demonstration unit operations, the testing objectives, and the significant deviations from the planned demonstration testing are discussed in the following subsection.

4.2.1.3.1 Agent Hydrolysis

The U.S. Army previously demonstrated agent hydrolysis extensively as part of its Alternative Technology Program (ATP).¹⁶ The PMACWA ran agent hydrolysis units primarily to provide representative feedstock for SCWO and to characterize the intermediate product stream for residual agent, Schedule 2 compounds, and other substances required to verify the mass balance. The specific test objectives of these demonstration units included the following:

- Design, fabricate, and deliver GB and VX hydrolysate production systems with the production capacity of 100 gal (379 L) of hydrolysate per run;
- Use the hydrolysate recipes developed and tested by the Edgewood Chemical and Biological Center (ECBC);
- Demonstrate that the agent concentration in the hydrolysate solution is less than the waste control limit by using the analytical methods developed and approved by the ECBC;
- Characterize solid, liquid, and gas process streams; and
- Provide agent hydrolysate in support of demonstration testing.

GB and VX hydrolysates were produced in a newly constructed 100-gal (379-L) stirred tank reactor system at the U.S. Army's Chemical Agent Munitions Disposal System (CAMDS) located at DCD in Utah. The design and manufacture of a hydrolysis system provided information on equipment and operational parameters that can be used for scale-up to a full-scale facility. Hydrolysate was shipped to DPG for use in the SCWO demonstration.

HD hydrolysate was produced at the chemical transfer facility (CTF) at APG. The equipment used was not intended to be a model for scale-up to a full-scale facility, but was an

¹⁶ Water was tested during the ATP for HD, and caustic was tested for VX.

expedient design suitable for use in the contained environment of the CTF. HD hydrolysate was shipped to DPG for use in the SCWO demonstration.¹⁷

There were no significant deviations from the planned demonstration testing.

4.2.1.3.2 Energetics Hydrolysis

Other government agencies have previously evaluated energetics hydrolysis; however, further knowledge of the process was needed for evaluation, feedstock for SCWO was required, and characterization of the intermediate product streams for residual energetics and other substances was required to verify a mass balance. The specific test objectives of these demonstration units included the following:

- Produce energetics hydrolysate for use as feed material in subsequent demonstration testing;
- Characterize solid, liquid, and gas process streams; and
- Gather process operation information to support the ACWA program and future scale-up.

M28 propellant was hydrolyzed with 12% NaOH to produce hydrolysate in two production runs at the Radford Army Ammunition Plant, Radford, Virginia. Composition B and tetrytol were hydrolyzed by using 12% NaOH in a single production run at the Pantex Plant, Amarillo, Texas. All of the hydrolysates were transported to DPG, Utah, and used as feedstock for the SCWO.

There were no significant deviations from the planned demonstration testing.

4.2.1.3.3 Dunnage Shredder/Hydropulper System

The dunnage shredder/hydropulper system (DSHS) was demonstrated to show that solid wastes (wooden dunnage, demilitarization protective ensemble [DPE]¹⁸ suits, and butyl rubber) could be adequately size-reduced and pulped to a pumpable mixture. Shredded material was used

¹⁷ HT or T-mustard agent was not tested because the PMACWA determined that HT is similar enough to HD that demonstration results for HD can be applied to HT.

¹⁸ DPE suits are made of a plastic material containing chlorinated hydrocarbons.

for SCWO pulped dunnage testing. The objectives of the demonstration testing included the following:

- Validate the ability of the shredders and the hydropulper to adequately prepare the dunnage for downstream processing in the SCWO;
- Qualitatively evaluate the operability of the shredder/hydropulper unit operations with particular focus on material handling; and
- Validate the ability of the shredders to process pallets and, separately, plastics (DPE suits) and butyl rubber.

Several commercial shredders were used to size-reduce the solid materials of interest. A low-speed shredder was used to break up wooden pallets. The rough-shredded wood was size-reduced to small chunks in a hammer mill and then further reduced in a micronizer to the consistency of flour. Belt conveyors were used to transport feeds between the units. A baghouse was used to collect dust generated by the shredding equipment. DPE suits with metal parts removed and butyl rubber (the material of boots and gloves) were rough-shredded in the low-speed shredder, cryocooled in a bath of LN₂, and size-reduced in a granulator. The size-reduced wood, plastic, and rubber, along with activated carbon (air filter material) and energetics hydrolysate, were combined to produce a pumpable slurry to feed to the SCWO. The demonstration shredding equipment is identical in size to the units proposed for the full-scale system.

Significant deviations from the planned demonstration testing included the following:

- Metal pieces were removed from DPE suits prior to shredding because removal by magnets after shredding was ineffective, resulting in damaged granulator blades.
- DPE suit plastic was successfully shredded to less than 0.12 in. (3 mm), a test objective, but this size proved to be too large to be fed to the demonstration SCWO unit without plugging the feed system. Alternatives for further size reduction were explored, but ultimately the plastic was sieved to 0.04 in. (1 mm) or less for use as feed for the SCWO dunnage validation runs.
- The hydropulper operation was not validated. Systemization and the single work-up run indicated that the unit provided no size-reduction benefit. The hydropulper may not be used in the final system design.

4.2.1.3.4 Energetics Rotary Hydrolyzer

The ERH was demonstrated to determine its effects on the physical and chemical properties of the munitions and liquid effluent. The objectives of the demonstration testing included the following:

- Demonstrate effective dissolution of aluminum and energetics in fuzes and bursters and propellant in rocket motors to allow downstream processing in the continuously stirred tank reactor (CSTR), SCWO, and HDC;
- Determine the deactivation of the energetics in fuzes and bursters and the propellant in rocket motors;
- Validate the retention times for aluminum and energetics in fuzes and bursters and propellant in rocket motors; and
- Characterize the gas, liquid, and solid process streams from the ERH.

Fuzes, bursters, and rocket motor propellant were tested with the ERH, thereby demonstrating aluminum and energetics dissolution and energetics hydrolysis for a full-scale ERH. The ERH demonstration unit was a custom-designed cylindrical drum, 4 ft (1.2 m) in diameter ($\frac{1}{2}$ of full scale) and 2 ft (0.61 m) wide filled with 8 to 12-molar NaOH, which rotated at the very slow rate of 0.1 rpm. The drum was heated with condensing steam at 212 to 230°F (100 to 110°C) to melt out the energetics and to increase the hydrolysis reaction rate. In the ERH tests, munition pieces were placed into the caustic-filled drum, and rotation was initiated for periods up to 10 hours. Lifting flights in the drum were tilted at an angle to ensure that the energetics rolled off the flight as the flight rotated out of the NaOH solution, thus minimizing the time the energetics were out of solution. Aluminum metal dissolved to form aluminum salts and hydrogen, and the energetics dissolved and reacted with the NaOH to form an energetics hydrolysate.

There were no significant deviations from the planned demonstration testing.

4.2.1.3.5 SCWO – Agent Hydrolysate

SCWO was demonstrated to validate destruction of Schedule 2 and other organic compounds from agent hydrolysis products. Destruction of Schedule 2 compounds is a CWC requirement, and thus demonstration of the SCWO technology was essential. Testing had previously been performed with VX/NaOH hydrolysate during the ATP but had not been

performed with HD or GB/NaOH hydrolysates. The objectives of the demonstration testing included the following:

- Validate the ability of the solid-wall SCWO to eliminate the Schedule 2 compounds present in the agent hydrolysate feeds;
- Validate the ability of the agent hydrolysis process and the SCWO to achieve a destruction removal efficiency (DRE) of 99.9999% for HD, GB, and VX (not applicable to PCD);
- Demonstrate the long-term operability of the SCWO reactor with respect to salt plugging and corrosion; and
- Characterize the gas, liquid, and solid process streams from the SCWO.

For the SCWO agent hydrolysate tests, mixtures of agent hydrolysate, water, and/or auxiliary fuel, along with air, were fed to the SCWO reactor — a tubular continuous flow reactor operated at approximately 3,400 psia [23 MPa] and 705°F (374°C). In solid-wall SCWO, the injected feed mixture is rapidly heated to supercritical conditions and oxidized to CO₂, water, and inorganic salts. Quench water is injected at the bottom of the reactor to cool the effluent and to dissolve the salts that are insoluble above the critical point of water. The effluent is further cooled in water-cooled heat exchangers and passed through a liquid/gas separator and pressure letdown system. Gaseous effluents are scrubbed in carbon filters and released to the atmosphere. During the demonstration testing, liquid effluents containing soluble and insoluble salts and metal oxides were collected and analyzed. The demonstrated SCWO system operated with a hydrolysate feed rate of approximately 0.1 gal/min (0.38 L/min), which is 1/10 to 1/20 the throughput cited for the full-scale unit.

Significant deviations from the planned demonstration testing included the following:

- SCWO treatment of VX hydrolysate was not demonstrated because of schedule constraints, and
- The proposed platinum-lined reactor was not used because of difficulties in fabrication.

4.2.1.3.6 SCWO – Energetics/Dunnage Hydrolysate

SCWO was demonstrated to validate destruction of organic compounds from energetic hydrolysis products and to show the feasibility of destroying shredded solids. Characterization of gaseous, liquid, and solid effluents and verification of operating parameters were required.

The objectives of the demonstration testing included the following:

- Validate the ability of the ERH, CSTR, and SCWO to achieve a DRE of 99.999% for tetrytol, Composition B, and M28 propellant;
- Determine the impact of the aluminum from the ERH process on SCWO operation;
- Determine the extent to which the organics in the shredded dunnage are oxidized in the SCWO; and
- Characterize the gas, liquid, and solid process streams from the SCWO.

Energetics hydrolysate and shredded/slurried dunnage (wood, DPE material, butyl rubber, and fresh granulated carbon) were blended and processed through SCWO. In this test, organic products, water, and/or auxiliary fuel, along with air, were fed to a solid-wall SCWO reactor operated at approximately 3,400 psia (23 MPa) and 1,200°F (649°C). Because of the low heating value of the slurry, electric preheaters were used to heat the slurry prior to injection. In SCWO, the injected feed mixture is rapidly heated under supercritical conditions and oxidized to CO₂, water, and inorganic salts. Quench water is injected at the bottom of the reactor to cool the effluent and to dissolve the salts that are insoluble above the critical point of water. The effluent is further cooled in water-cooled heat exchangers and passed through a liquid/gas separator and pressure letdown system. Gaseous effluents are scrubbed and passed through carbon filters and released to the atmosphere. During demonstration testing, liquid effluents containing soluble and insoluble salts and metal oxides were collected and analyzed. The demonstrated SCWO system operated with a feed rate of up to 0.1 gal/min (0.38 L/min), which is 1/10 to 1/20 the throughput cited for the full-scale unit.

Significant deviations from the planned demonstration testing included the following:

- The proposed platinum-lined reactor was not used because of difficulties in fabrication.
- During some of the SCWO testing, energetics hydrolysates and slurried dunnage were treated in separate runs because of differing effects of feed preheating. During the last week of demonstration testing, however, three validation runs were conducted using a mixed feed of tetrytol hydrolysate and slurried dunnage.
- Aluminum hydroxide [Al(OH)₃] was either removed from, or not added to, energetics hydrolysates prior to solid-wall SCWO treatment. Reactor plugging occurred while processing energetics hydrolysate feeds containing Al(OH)₃.

4.2.1.3.7 Summary of Demonstration Testing

In summary, cryofracture and baseline reverse assembly are well-developed technologies and, therefore, were not demonstrated. During demonstration testing, the government validated that caustic hydrolysis is effective for destroying agents and energetics. The agent hydrolysis process does, however, produce Schedule 2 compounds; the solid-wall SCWO effectively destroyed all Schedule 2 compounds. The SCWO process effectively treats agent hydrolysates, energetic hydrolysates, and dunnage, thus producing an effluent of low concern and impact to human health and the environment. Three hydrolysis/SCWO critical unit operations were demonstrated. Salt-plugging and corrosion of the SCWO unit are problems that require further examination. These problems were addressed during the engineering design studies (see Section 4.2.1.4). The PMACWA reviews the quality of the data generated during demonstration testing in PMACWA (1999c).

On the basis of demonstration testing, a number of process revisions were proposed that are applicable to PCD and the munitions stored there. Most of these revisions relate to the munitions access processes or dunnage treatment and are minor. These changes include the following (General Atomics 1999):

- Mortar bursters could not be sheared in the burster size reduction machine (BSRM). However, the tetryl fill in the bursters was found to melt out in the ERH during the demonstration tests. Thus, it appeared that size reduction would not be necessary.
- A live-bottom hopper would be used to collect shredded wood discharged from the low-speed shredder. The hopper would have a screw feeder at the bottom to meter the wood into the hammer mill. This change would prevent overfeeding of the hammer mill and micronizer.
- A separate low-speed shredder and collection hopper would be used to shred and store DPE suits and butyl rubber material before feeding to the cryocooler and granulator. This change would allow wood and plastic/rubber materials to be processed independently.
- DPE metal parts would be manually removed in a glove box before feeding the DPE material to the DSHS. The metal parts would be treated to a 5X condition in the induction-heated batch MPF.
- A colloid mill would be used to wet-grind spent activated carbon to ensure adequate size reduction. The carbon slurry would then be added to the slurried dunnage and hydrolyzed energetics for processing through the SCWO system.

- Hydrolyzed aluminum, as $\text{Al}(\text{OH})_3$, would be filtered from energetics hydrolysate before feeding to the solid-wall SCWO system. This filtering would prevent hard aluminum salt deposits from plugging the SCWO reactor. The filtered $\text{Al}(\text{OH})_3$ would be dried and decontaminated to a 5X condition in the MPF.

4.2.1.4 Engineering Design Studies¹⁹

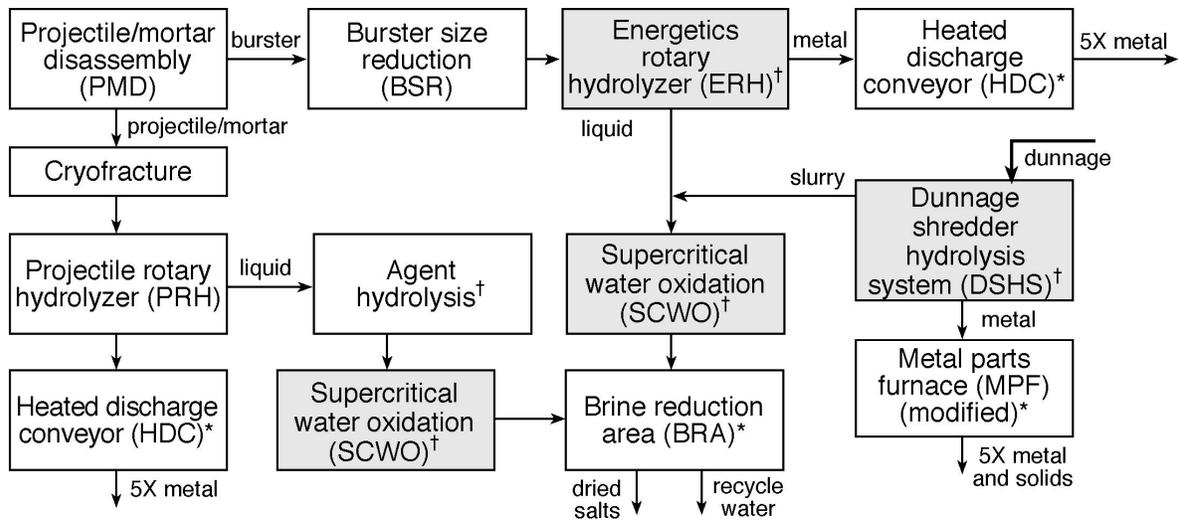
Although demonstration testing for the Demo I and Demo II technologies has been completed, Engineering Design Studies (EDSs) are being implemented. The PMACWA determined that these studies were necessary in preparation for full-scale pilot design and permitting. While EDSs have been completed for the Demo I technologies, EDSs for the Demo II technologies have not been completed. This TRD presents information on what was planned for EDSs only. EDS objectives were as follows:

- Provide information for the full-scale facility with respect to total life-cycle cost, schedule, and safety;
- Support the EIS and permit application preparation under the RCRA; and
- Support preparation of a RFP for a full-scale pilot plant facility.

PMACWA (2000a) gives an overview of the planned EDSs for neutralization/SCWO. Figures 4.5 and 4.6 provide overviews of the neutralization/SCWO process and show unit operations that were evaluated during EDSs for projectiles and mortars (Figure 4.5) and for the M55 rockets (Figure 4.6).

The following subsections summarize planned EDS activities.

¹⁹ Because EDSs were intended to apply to a variety of ACW from all storage sites, this section does not discriminate with regard to munition type and storage installation.

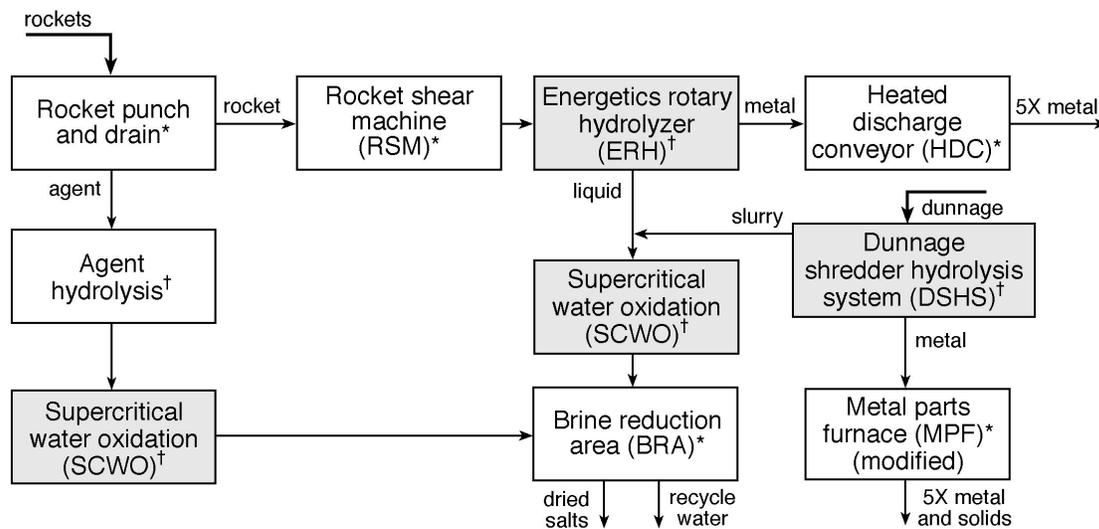


* Baseline incineration process
 † Unit or operation evaluated during demonstration testing

Unit operations undergoing engineering design

PCD05

FIGURE 4.5 Flow Diagram of Neutralization/SCWO (General Atomics System) Showing Units or Operations Undergoing Engineering Design — Projectiles and Mortars (Source: PMACWA 2000a)



* Baseline incineration process
 † Unit or operation evaluated during demonstration testing

Unit operations undergoing engineering design

PCD06

FIGURE 4.6 Flow Diagram of Neutralization/SCWO (General Atomics System) Showing Units or Operations Undergoing Engineering Design — M55 Rockets (Source: PMACWA 2000a)

4.2.1.4.1 Energetics Hydrolysis²⁰

Planned EDS activities for energetics hydrolysis consisted of the following:

- Addressing PMACWA and NRC (NRC 2000) concerns regarding particle size, solubility, by-products that would be produced as a function of time, control strategies, mixtures of energetics, and caustic concentrations; and
- Acquiring information for scale-up.

4.2.1.4.2 Agent Hydrolysis²¹

Planned EDS activities for agent hydrolysis consisted of the following:

- Determining the potential to use 15% by weight mustard agent hydrolysate for feed to the SCWO unit for increased throughput.

4.2.1.4.3 Energetics Rotary Hydrolyzer

Planned EDS activities for the ERH consisted of the following:

- Observing the effects of M28 propellant hydrolysis for rocket motor lengths less than 12 in. [30 cm] (4 and 8 in. [10 and 20 cm]) and multiple pieces of rocket motor lengths (4 in. [10 cm]), and comparing them with results during demonstration (12 in. [20 cm]);
- Observing containment of fugitive emissions; and
- Observing the effect of a higher caustic concentration and bath temperature (19 M [50 wt%] NaOH, 277°F [136°C] or highest allowable) on the rate of M28 propellant hydrolysis.

²⁰ This is the same testing planned for neutralization/biotreatment.

²¹ This is the same testing planned for neutralization/biotreatment.

4.2.1.4.4 Dunnage Shredder Hydropulper System (DSHS)

Planned EDS activities for the DSHS consisted of the following:

- Demonstrating changes to the dunnage shredding equipment for the full-scale design and verifying improved efficiency and uninterrupted operation (e.g., avoiding nesting and unit overloads), while still meeting original particle size requirements; and
- Generating information required for designing the duct emission control system.

4.2.1.4.5 Solid-Wall Supercritical Water Oxidation (HD and GB Hydrolysate Feed, Composition B/M28 Hydrolysate Feed, and Tetrytol Hydrolysate/Al[OH]₃/Dunnage Feed)

Planned EDS activities for the solid-wall SCWO consisted of the following:

- Demonstrating long-term operability without plugging,
- Demonstrating an acceptable corrosion rate,
- Demonstrating that any feed additives for salt transport control do not interact with feed and/or equipment to generate salt plugs or accelerate corrosion,
- Determining a maintenance schedule and shutdown frequency on the basis of the long-term testing results, and
- Generating data for use in validating the SCWO model development work sponsored by the U.S. Army Research Office.

As indicated above, the results of EDSs for neutralization/SCWO were not included in this document.

4.2.1.5 Detailed Process Description

This section presents a detailed process description for neutralization/SCWO as applied to PCD and the ACW stored there, on the basis of demonstration testing results. The equipment used in a pilot-scale facility may vary in nomenclature and design from that described here, on the basis of the system selected and system requirements.

Figure 4.7 illustrates the entire process flow for the neutralization/SCWO process. As the figure shows, munitions access would involve use of a modified baseline reverse assembly and cryofracture. Water hydrolysis followed by a caustic wash would be used for mustard agents, while caustic hydrolysis (employing NaOH) would be used to neutralize the energetics. Munition hardware would be treated with caustic in rotary hydrolyzers (i.e., rotating vessels with a helical transport flight²²): the PRH would be used for agent-contaminated, cryofractured projectiles, and the ERH would be used for all other munition components.²³ Drained agents would be neutralized in CSTRs.²⁴ ERH effluent liquids would be treated in similar CSTRs. Dunnage and other organic solid wastes would be shredded, pulverized, and water/caustic pulped (with solids removal) into a slurry hydrolysate. Thermal treatment would be used to decontaminate solids that are not pulped. Solid effluents from the PRH and ERH would pass to modified (inert atmosphere) baseline HDCs for thermal decontamination to a 5X condition. Nonshreddable solid wastes (metals, glass, etc.) would receive thermal decontamination to a 5X condition in an induction-heated, inert-atmosphere MPF. Munition bodies that have been decontaminated to a 5X condition can be commercially recycled (subject to regulatory agency concurrence). Nonmetal solid waste, if defined as hazardous waste, would be disposed of in a hazardous waste landfill.²⁵ If defined as nonhazardous wastes, these solid wastes may be disposed of in a nonhazardous waste landfill.

Agent hydrolysate (independent of agent type), energetics hydrolysate from the ERH, and dunnage slurry hydrolysate would undergo secondary treatment in solid-wall SCWO units. The energetics hydrolysate and dunnage hydrolysate would be treated in a separate SCWO processing train. Brine from the SCWO units would be evaporated, the water would be condensed and recycled to the hydrolysis units, and the salts would be sent to a hazardous waste landfill.²⁶ The salts may require treatment prior to disposal in a landfill to meet RCRA land disposal requirements. Off-gases from the HDCs would vent to their respective rotary hydrolyzers. Off-gases from the hydrolyzers and the MPF would pass through condensers, scrubbers, and carbon filters before being released to the atmosphere. Liquid from condensers and scrubbers would return to the rotary hydrolyzers for reuse and eventual treatment by SCWO. SCWO off-gas would pass through carbon filters and would be released to the atmosphere.

²² A continuous, flat plate (or “flight”) attached to the inner wall of the vessel, forming a corkscrew or auger-like apparatus from one end to the other. Material is moved along the bottom of the vessel by the helical transport as the vessel rotates.

²³ The terms PRH and ERH are specific to General Atomics. Conceptually, other processes that use a caustic washout design can be substituted for this process.

²⁴ CSTRs were developed pursuant to the Army’s ATP.

²⁵ Solids treated to a 5X condition to remove residual agent may be defined as hazardous waste if they exhibit any of the characteristics of hazardous waste, as defined in Title 40, Parts 260.21 – 260.24 of the *Code of Federal Regulations* (40 CFR 260.21–260.24).

²⁶ These salts may be defined as hazardous waste if they exhibit any of the characteristics of hazardous waste as defined in 40 CFR 260.21–260.24. Typically, these salts contain heavy metals and exhibit the RCRA toxicity characteristic (40 CFR 261.24). In Colorado, the salts may be regulated as listed hazardous wastes because of their association with chemical agent. If the salts are listed as hazardous wastes, a RCRA delisting petition may be pursued to reclassify the wastes as nonhazardous.

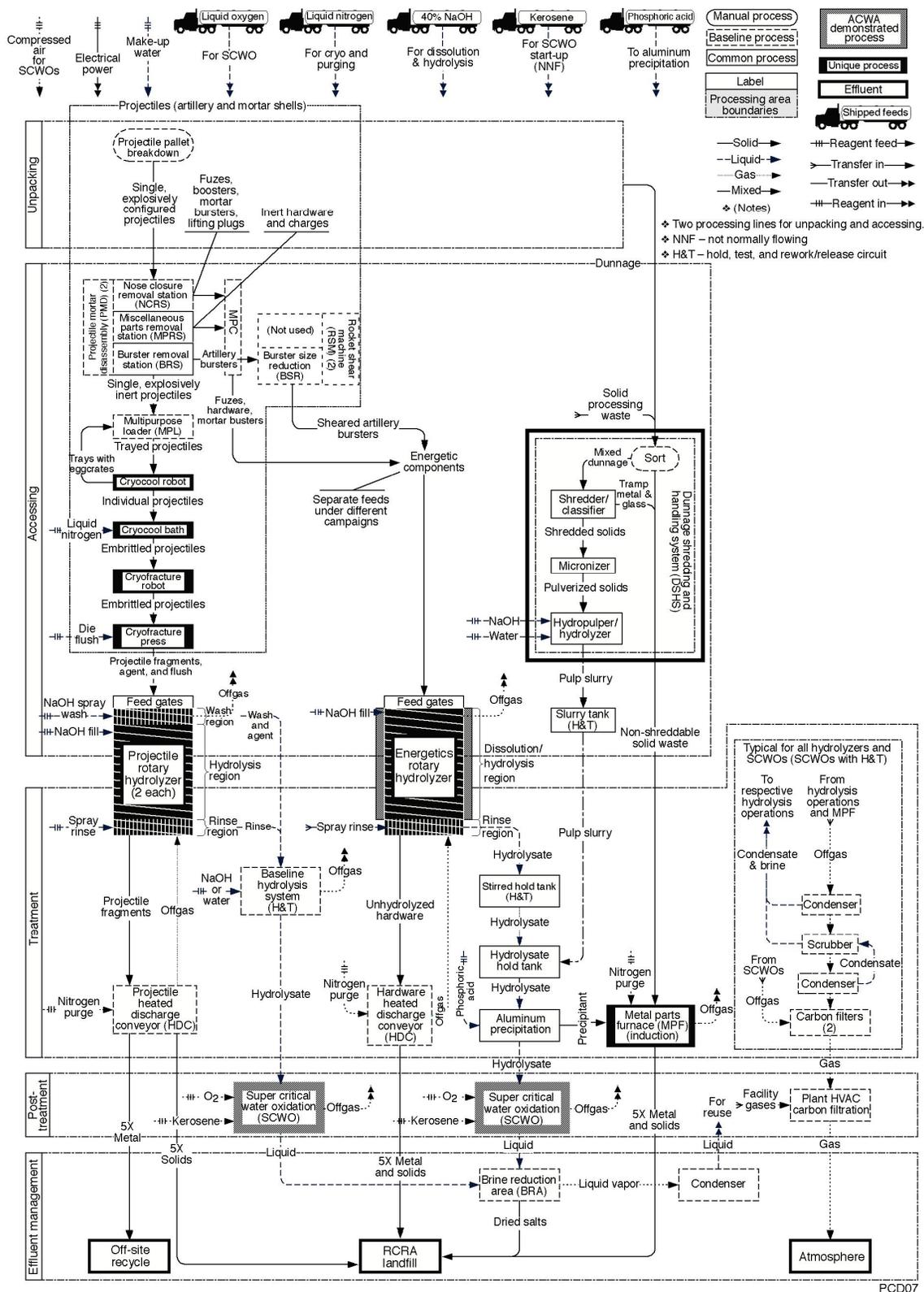


FIGURE 4.7 Flow Diagram of Entire Neutralization/Solid-Wall SCWO Process at PCD (Source: Adapted from PMACWA 1999a,b)

Short descriptions of each of the unit processes included in the neutralization/SCWO process are provided in the following subsections.

4.2.1.5.1 Munitions Access – Projectiles and Mortars

The proposed design for munitions access for projectiles and mortars incorporates many of the units and processes used in the baseline reverse assembly processes (see Appendix E of Volume 1 for details). Units and processes include reverse assembly machines, material handling conveyors, robotic loaders and handlers, HDCs, elements of the MPF thermal treatment system, auxiliary systems, and facilities and support systems. Some of these units have been slightly modified from the baseline process, but the basic unit and operations have been retained. The major units are summarized below.

The projectile/mortar disassembly (PMD) machine and supporting equipment have been adopted without modification. The PMD is a custom-designed, automated machine that uses a turntable to position munitions at the various workstations arranged around the perimeter of the machine. Munitions are processed in a horizontal position. Fuzes or lifting plugs, nose closures, supplementary charges, bursters, and other energetics are removed. Bursters from projectiles are conveyed to the BSRM. For mortars, the nose closure removal station removes the fuze burster assembly, punches the burster, and unscrews it from the fuze. As determined during demonstration testing, however, the BSRM would not be used to shear the mortar bursters. All removed hardware would be discharged through a chute to the floor of the explosion-containment room (ECR).

The BSRM and supporting equipment are part of the baseline process. The BSRM is a modified rocket shear machine used to shear the mortar bursters and includes tooling kits for each burster size.

In the General Atomics system, the projectile/mortar cryofracture process is used to access agent contained in the body of the projectiles and mortars. The process includes LN₂ baths and a hydraulic press capable of exerting a pressure of 500 tons (454 t). Two separate cryofracture treatment trains are used. The press has a relatively small bed area and stroke, thereby reducing its size and weight. It fractures one munition body at a time. All of the tooling used in the baseline process has been adapted to the small press, including the same methods for mounting and fragment discharge. A tilt-table is used to discharge fragments into a chute, which delivers the fragments to the PRH. Decontamination/flush solution is also supplied to the press tooling and discharge chute.

The cryocool bath is modeled after commercial food-freezing tunnels. A belt conveyor, configured to handle a wide variety of munition types, transports munitions from the loading station into the bath. The cryobath length is sized to provide the residence time needed to ensure sufficient cryocooling of the munition and to support the required throughput rate for the

production-scale system. The design of the conveyor and support fixtures minimizes ice and frost buildup. The unit uses baseline bridge robots to transport the munitions from the cryobath to the hydraulic press. Ventilation air is vented through the ducts in the cryocool and press area, where it goes to the PRH.

4.2.1.5.2 Agent Treatment

Two PRHs would be used for agent treatment. The units would be smaller than the ERH described below but would be similar in design. The PRHs would receive cryofractured projectiles and mortars from the two cryofracture systems. The PRHs would operate in parallel; each would process about half of the projectile/mortar throughput. The PRHs consist of large rotary drums with an internal helical flight as well as lifting flights. The helical flight transports material along the axis of the drum and maintains batch separation. The lifting flights ensure agitation and mixing of the hydrolyzing solution with the agent and metal parts. The drum is steam-traced on the outside surface to maintain an internal operating temperature of about 212°F (100°C). At this temperature, agents are readily hydrolyzed. A stationary shell of thermal insulation encloses the drum and minimizes heat loss. The materials move through the hydrolyzer, where water or NaOH solution is continually added at the feed end as agent and metal parts would be discharged by gravity into the drum along with flush solution. The helical flight moves a batch of hydrolyzing solution, agent, and metal parts along the axis of the drum; each batch contains several feeds of agent and metal parts. The drum rotates slowly on drive rollers, and the batch moves such that residence time in the drum is sufficient to ensure complete hydrolysis.

The drum is supported at the discharge end by a spindle through which the coaxial steam supply and return lines pass. Axial loads are also taken by the support trunion of the spindle. High-pressure sprays at the feed end of the drum are used to melt and separate agent and agent heels from the metal parts. Most of the flushed agent and agent heel would flush through a perforated section of the drum at the feed end of the PRH into a tank, where agent hydrolysis continues. Hydrolyzing solution would be added to the metal parts that travel through the drum beyond the perforated section. This hydrolyzing solution would travel through the drum and decontaminate the metal parts; the solution would be discharged through a second perforated section at the discharge end of the drum. The hydrolysate would be transferred to a tank, where hydrolysis would be completed and verified.

Air would be pulled through the PRH to remove volatile organic compounds (VOCs) and other vapors. The air would then discharge to an air treatment system consisting of a scrubber, condenser, and carbon filters, and would eventually be vented through the plant ventilation system.

The neutralization/SCWO system incorporates the ATP neutralization system design being used at APG, with minor modifications to interface with other equipment. The neutralization system includes six CSTRs and associated support systems. The hydrolysis

process used for neutralization/SCWO is chemically identical to that used for neutralization/biotreatment (see Section 4.2.2); however, the physical processes and equipment used are different.

Secondary treatment of the agent hydrolysate to remove Schedule 2 compounds would be accomplished with a solid-wall SCWO unit. The SCWO system for PCD would be sized to process the hydrolyzed mustard agent from the projectiles and mortars. The hydrolysate would first be collected in tanks that are sufficiently large to handle 10 hours of continuous operation. The SCWO system employs a gas-fired preheater and auxiliary fuel system to heat the reactor to the desired operating temperature (705°F [374°C]), and the unit is maintained at an operating pressure of 3,400 psia (23 MPa). Hydrolysate flow is initiated, and auxiliary heat is discontinued. Auxiliary fuel and preheat power are not required under steady-state conditions.

The SCWO system for PCD would be similar to that planned for NCD; however, the two SCWO units installed at PCD would be slightly larger. The SCWO system contains components needed to (1) accept and process hydrolysate piped from the hydrolysate holding tanks, (2) release brines to the BRA, and (3) release gaseous effluents to the plant ventilation system.

4.2.1.5.3 Energetics Treatment

The ERH would be the main element for primary treatment of energetics. The ERH would replace the baseline deactivation furnace system (DFS); however, it has been adapted to the same interfaces with other equipment as the DFS. The ERH would be similar in design and operation to the PRH and would receive energetics and metal parts containing energetics from the ECR. The ERH consists of a large rotary drum with an internal helical flight as well as lifting flights. The helical flight transports material along the axis of the drum and maintains batch separation. The lifting flights ensure agitation and mixing of the hydrolyzing solution with the energetics and metal parts. The drum is steam-traced on the outside surface to maintain an internal operating temperature of 212 to 230°F (100 to 110°C). At this temperature, energetics are melted, and the hydrolysis reaction is enhanced. The materials move through the hydrolyzer, where NaOH solution is continually added at the feed end as energetics and metal parts are discharged by gravity into the drum along with flush solution. The helical flight moves a batch of hydrolyzing solution, energetics, and metal parts along the axis of the drum; each batch contains several feeds of energetics and metal parts. At the discharge end of the hydrolyzer, a perforated section of the drum permits the hydrolysate to discharge into a CSTR to complete hydrolysis of any remaining small particles of energetics. The hydrolysate is subsequently pumped to continuously stirred holding tanks. The hydrolysate then discharges to the energetics hydrolysate/dunnage hydrolysate SCWO treatment system.

Air would be pulled through the ERH to remove hydrolysis vapors and fumes, including hydrogen produced from the hydrolysis of aluminum burster wells that make up some projectiles. Sufficient air flow would ensure that the hydrogen concentration remains well below the lower explosive limit for hydrogen. The air would then discharge to an air treatment system

consisting of a scrubber, condenser, and carbon filters and would eventually be vented through the plant ventilation and carbon filter system.

Secondary treatment of the energetics hydrolysate and added dunnage slurry (see Section 4.2.1.5.5) would be accomplished with a solid-wall SCWO unit identical in design and capacity to the agent hydrolysate SCWO system described above. The SCWO units employed at PCD would be similar in design to the SCWO units planned for pilot testing at NCD. The major difference would be in the slurry feed and the high-pressure pump system.

4.2.1.5.4 Metal Parts Treatment

The munition bodies would discharge from the PRH to modified baseline HDCs. The metal parts from energetics treatment would continue along the axis of the perforated section of the ERH drum and discharge through a chute to a separate HDC. In both HDCs, metal parts would be heated to a minimum 1,000°F (538°C) for a minimum of 15 minutes. The metal parts would be treated to meet a 5X condition, thus destroying residual agent and energetics. Metal from the DSHS would be decontaminated to a 5X condition in the MPF.

4.2.1.5.5 Dunnage Treatment

Dunnage would be treated during the campaign to the extent possible. Material would be processed by shredding and slurring. The slurried dunnage would then be treated in the energetics hydrolysate/SCWO system. Although not all dunnage is agent-contaminated, all dunnage would be treated on-site in this manner.

Nonmetallic dunnage materials — wood, paper, plastic, DPE suits, and spent carbon — would be size-reduced in a series of steps and fed to a commercial hydropulper and grinding pump that slurries the material to a particle size of less than 0.04 in. (1 mm). Wood dunnage would be size-reduced in a dedicated low-speed shredder, hammer mill, and micronizer to achieve a fine particle size suitable for slurring. DPE suits and butyl rubber would be shredded in a dedicated low-speed shredder and then cryocooled and granulated to achieve adequate size reduction. Spent activated carbon would be wet-ground in a dedicated colloid mill. A dilute solution of NaOH would be added to decontaminate the size-reduced solids in the slurry. The resulting slurry is expected to have a particle content of about 10% by weight. This slurry would then be blended with the energetics hydrolysate. At this point, additives would be used to ensure that the solids remain in suspension and that the slurry can be readily pumped and processed in the energetics SCWO system.

4.2.1.5.6 Effluent Management and Pollution Controls

The effluent management and pollution control systems used in neutralization/SCWO would be similar to systems used in the baseline incineration plant. Elements of the system are described below.

The plant ventilation system is designed with cascading air flow from areas of less contamination potential to areas with more contamination potential. The ventilation system would permit room air-change frequencies consistent with area-level designations²⁷ for normal as well as anticipated maintenance activities. Plant ventilation flow would be collected in the main plenum and directed to a bank of carbon filters. From here, the air would be filtered and monitored, passed through induction draft fans, and exhausted to the stack and the atmosphere. This system would be nearly identical to the baseline system.

The decontamination fluid supply system and spent decontamination fluid collection system would be the same as those of the baseline system. Decontamination fluid would be supplied to most rooms in the main plant area, and spent decontamination fluid would be collected in sumps that would be monitored and controlled. That fluid would then be transferred to the spent decontamination system (SDS) treatment area, where it may be mixed with additional decontamination solution to ensure complete destruction of agent.

The DPE-supplied air and personnel support system would include maintenance air locks and donning/doffing support equipment and facilities identical to the baseline.

The BRA would be identical to that used in the baseline system except that it would be modified to handle brine salts from the SCWO process and water recovery by condensation for reuse in the plant. The BRA includes equipment for effluent drying in heated drums. Dried salts would be disposed of in a hazardous waste landfill.

The plant instrument air supply and steam supply systems would be identical to those employed in the baseline system.

Control rooms would be the same as those used in the baseline system, with changes as needed to accommodate the new systems and equipment.

The process for handling munitions from storage to the unpack area would be similar to that used for the baseline system.

²⁷ Level A, B, C, D, or E indicates the potential for contamination; Level A is the highest and E is the lowest.

Personnel support, monitoring systems, and analytical laboratories would be identical to those used in the baseline system.

As indicated previously, elements of the baseline incineration process were included in the overview of baseline and ACWA system technologies provided in Volume 1 of this TRD (see Section 1.4). The baseline incineration process also is described in Appendix E of Volume 1.

4.2.1.6 Common Elements – Other Systems

The neutralization/SCWO process has several elements that are identical or nearly identical to other systems. Commonalities with other applicable technology systems include the following:

- The munitions access system used for neutralization/SCWO would employ much of the baseline reverse assembly system, as do the other ACWA systems, and
- Both neutralization/SCWO and neutralization/biotreatment would employ neutralization as a primary treatment for chemical agents and energetics.

Facility structure; ventilation; decontamination fluid supply; personnel support; pollution abatement; water, air, and steam supply systems; control rooms; monitoring systems; and laboratory support would be identical or nearly identical to those of the baseline system.

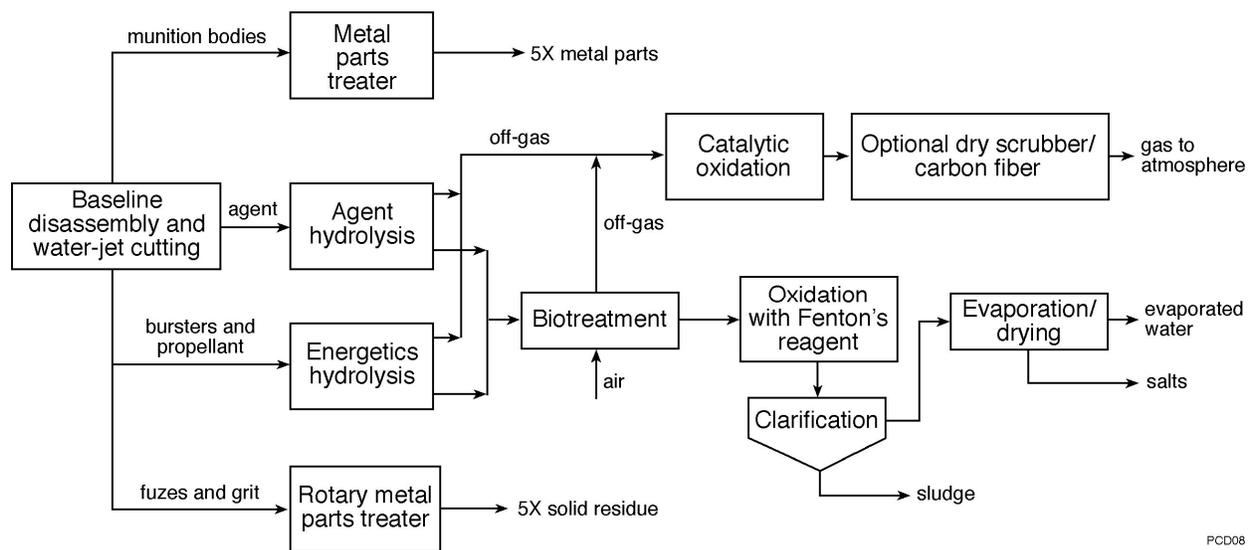
4.2.2 NEUTRALIZATION/BIOTREATMENT

The neutralization/biotreatment technology system consists of neutralization of agents and energetics, and secondary treatment of neutralization residuals using biotreatment. This technology system was proposed by Parsons/Honeywell. During demonstration testing, biotreatment of nerve agent residuals (i.e., hydrolysates) was unsuccessful. Because only ACW containing mustard agent are stored at PCD, the neutralization/biotreatment technology system is fully applicable to all ACW at PCD. The following subsections provide a more detailed discussion of the technologies and processes involved in this system. The technology provider's technology demonstration report (Parsons/Allied Signal 1999) may be viewed for additional detail.²⁸

²⁸ Honeywell purchased Allied Signal in early 2000; General Electric purchased Honeywell in 2000. Parsons/Honeywell refers to its ACWA system as the Water Hydrolysis of Explosives and Agent Technology (WHEAT) process.

4.2.2.1 Process Overview

The neutralization/biotreatment process as applied to projectiles and mortars at PCD is summarized in Figure 4.8. A modified baseline reverse assembly process would be used to disassemble munitions. In the proposed Parsons/Honeywell system, modifications would include fluid-abrasive cutting of mortar bursters followed by fluid-mining of burster charges. Other processes could be employed for this purpose, however, including portions of the baseline reverse assembly process. The HD and HT would be neutralized/hydrolyzed using water solutions in units operated at 194°F (90°C) and atmospheric pressure; energetics would be neutralized/hydrolyzed using a NaOH solution in units also operated at 194°F (90°C) and atmospheric pressure. Neutralization of HD and HT using water would be followed by a caustic wash using NaOH. Agent and energetic hydrolysates would be biotreated together in aerobic reactors called Immobilized Cell Bioreactors (ICBsTM) and would be supplementally treated with hydrogen peroxide/ferrous sulfate ($H_2O_2/FeSO_4$ [Fenton's reagent]). Metal parts and dunnage would be decontaminated to a 5X condition in an electrically heated steam furnace. Gaseous discharges would be catalytically converted by a catalytic oxidation (CatOx) system to remove trace organics, oxidizable nitrogen, and chlorine compounds (NRC 1999) before being discharged to the atmosphere. Emissions from the CatOx system would not require high-efficiency particulate air (HEPA) or carbon filtration (Parsons/Allied Signal 1999).²⁹



PCD08

FIGURE 4.8 Overview of the Neutralization/Biotreatment Process (Parsons/Honeywell System) for the Treatment of Projectiles and Mortars at PCD (Source: Adapted from NRC 1999)

²⁹ The terms ICB and CatOx are specific to Parsons/Honeywell. Conceptually, other processes using similar techniques could be substituted for these processes.

4.2.2.2 History of Destructive Processes

Neutralization and biotreatment are the primary destructive processes employed in this technology. The histories of these processes are summarized below.

4.2.2.2.1 Neutralization of Agent and Energetics

Agent and energetics neutralization by hydrolysis were reviewed in Section 4.2.1.2. Since the history of neutralization of agent and energetics for neutralization/SCWO does not differ from the history of neutralization of agent and energetics for neutralization/biotreatment, this information is not repeated.

4.2.2.2.2 Biological Treatment

Different forms of biotreatment have been employed for many years to treat various types of domestic and industrial wastes. Most notable are sewage treatment plants, which are used to reduce the organic, nutrient, and pathogen content of domestic sewage. Biotreatment is a well-developed, mature, and accepted technology for the treatment of a wide variety of waste types.

Theoretically, microorganisms can degrade almost any organic compound to basic elements (NRC 1999). The use of a biotreatment system is dependent on maintaining a proper environment in which microbes can readily degrade organic contaminants to desired levels. A proper balance of organic food sources and nutrients must be available to the microorganisms (NRC 1999). Other conditions, such as pH, temperature, and oxygen levels, must be carefully maintained. In practice, however, the toxicity of organic and inorganic components in the feed to a biotreatment process can be a limiting factor and requires careful monitoring and control (NRC 1999).

Biotreatment of HD hydrolysates will be pilot tested at APG for the bulk HD stored there. The U.S. Army prepared an EIS for the hydrolysis/biotreatment process proposed for APG (PMCD 1998a). The process involves hydrolysis using a water/caustic solution, followed by biotreatment, and a final polishing step in the facility wastewater treatment plant. The U.S. Army concluded in its EIS that the proposed APG facility would meet stringent permitting requirements of the CWA, RCRA, CAA, and associated State of Maryland regulations. The U.S. Army further concluded that the site and environs of the facility would be impacted by construction and pilot testing of the proposed facility, but that appreciable adverse human health and environmental impacts would be within regulatory limits (PMCD 1998a).

4.2.2.3 Demonstration Testing³⁰

The neutralization/biotreatment technology was demonstrated during Demo I of the PMACWA demonstration test program. Demo I testing was conducted in spring 1999. This section provides a summary of demonstration testing for neutralization/biotreatment. Demo I testing results are provided in PMACWA (1999a).

Baseline reverse assembly, carbon filtration, the BRA operations, and other technologies common to baseline operations were not demonstrated during ACWA demonstration testing of neutralization/biotreatment. In addition, the following unit operations proposed for neutralization/biotreatment were not selected by the PMACWA for demonstration for the reasons given below.

Continuous Steam Treater (CST). This is a new addition to the proposed full-scale process that was incorporated after demonstration was conducted. It is described as a rotary version of the metal parts treater (MPT).

Dunnage Processing (noncontaminated). The originally proposed noncontaminated dunnage processes (shredding, neutralization, and biotreatment) were not considered pertinent to ACWA mixed munitions demilitarization.

The reasons for selecting the neutralization/biotreatment demonstration unit operations, testing objectives, and significant deviations from the planned testing are discussed in the following subsections.

4.2.2.3.1 Agent Hydrolysis

The U.S. Army previously demonstrated agent hydrolysis extensively in its ATP. The PMACWA ran agent hydrolysis units primarily to provide representative feedstock for biotreatment and to characterize the intermediate product stream for residual agent, Schedule 2 compounds, and other substances required to verify the mass balance. The specific test objectives of these demonstration units were identical to those for neutralization/SCWO and included the following:

- Design, fabricate, and deliver GB and VX hydrolysate production systems with the production capacity of 100 gal (379 L) of hydrolysate per run;

³⁰ This material was derived from PMACWA (1999a) and refers to demonstration testing during Phase I of the ACWA demonstration process. Because demonstration testing was intended to apply to a variety of ACW from all storage sites, this section does not discriminate with regard to munition type and storage installation.

- Use the hydrolysate recipes developed and tested by the ECBC;
- Demonstrate that the agent concentration in the hydrolysate solution is less than the waste control limit by using the analytical methods developed and approved by the ECBC;
- Characterize solid, liquid, and gas process streams; and
- Provide agent hydrolysate in support of demonstration testing.

GB and VX hydrolysate were produced in a newly constructed 100-gal (379-L) stirred tank reactor at CAMDS. The design and manufacture of a hydrolysis system provided information on equipment and operational parameters that can be used for scale-up to a full-scale facility. VX hydrolysate and GB hydrolysate were produced for use in the ICB units at CAMDS.

HD hydrolysate was produced at the CTF at APG. The equipment used was not intended to be a model for scale-up to a full-scale facility, but was an expedient design suitable for use in the contained environment of the CTF. HD hydrolysate was produced for use in the ICB unit at the ECBC.

There were no significant deviations from the planned demonstration testing.

4.2.2.3.2 Energetics Hydrolysis

Other government agencies have previously evaluated energetics hydrolysis; however, further knowledge of the process was needed for evaluation, feedstock for biotreatment was required, and characterization of the intermediate product streams for residual energetics and other substances was required to verify the mass balance. The specific test objectives of these demonstration units were identical to those for neutralization/SCWO and included the following:

- Produce energetics hydrolysate for use as feed in subsequent demonstration testing;
- Characterize solid, liquid, and gas process streams; and
- Gather process operation information to support the ACWA program and future scale-up.

M28 propellant was hydrolyzed with 6% NaOH to produce hydrolysate in one production run at the Radford Army Ammunition Plant, Radford, Virginia. Composition B and tetrytol were

hydrolyzed using 6% NaOH at the Pantex Plant, Amarillo, Texas, and were used as feedstock for the ICBs.

There were no significant deviations from the planned demonstration testing.

4.2.2.3.3 Rocket-Cutting and Fluid-Mining

Fluid-abrasive cutting and fluid-mining are reasonably well-established industrial operations; however, the ability to cut through the materials in an M55 rocket was not the major reason for demonstrating the operations. Rather, one reason for demonstrating these operations was to verify their application to accessing energetics in the ACW components. Another reason concerned adaptation of fluid-abrasive cutting to the baseline reverse assembly equipment. Fabrication of robotics for automating fluid-abrasive cutting was not viewed as a requirement; demonstrating the effectiveness of the system to access, extract, and wash out energetics, however, was required. In addition, characterization of the quantity and type of grit required, fluids produced, energetics remaining in the rocket, and the size distribution of energetic particles from rocket access and washout was considered important.

The rocket-cutting and fluid-mining unit operation was designed to demonstrate the fluid-abrasive cutting and fluid-mining of M55 rocket energetic components. The objectives of this demonstration unit included the following:³¹

- Demonstrate the ability to perform circumferential cuts of a rocket at required locations along the rocket length,
- Demonstrate effective fluid-mining and separate collection of rocket bursters, motor propellants, and residual agent simulant,
- Demonstrate the ability to maintain control of rocket metal and plastic parts from cutting and fluid-mining operations,
- Determine energetic particle size of fluid-mined rocket bursters and propellant, and
- Determine the requirements for separating used grit from the residual cutting solution.

³¹ These objectives are potentially applicable to projectiles and mortars at PCD.

The demonstration tests were conducted with ten 115-mm inert M60 rockets, which were filled with concrete and plaster of paris, and ten M61 rockets, which are identical to the M55 rockets but filled with ethylene glycol rather than agent. The demonstration unit applied fluid-abrasive cutting to remove the fuzes and cut the rocket casing, fluid-mining to wash out the burster energetics, and fluid-mining to remove the propellant. However, fluid-mining to remove the propellant was terminated prior to the start of testing.

Several aspects of the proposed fluid-abrasive, mining, or washout operations that the PMACWA had considered demonstrating were not included in the final demonstration testing matrix: fuze washout, fluid-abrasive cutting of mortars, and use of the process effluents for subsequent unit feeds. These items were determined to be unnecessary for a successful demonstration. Energetics in these items are expected to melt out in the MPT or CST.

4.2.2.3.4 Immobilized Cell Bioreactor and Catalytic Oxidation

Allied Signal established the ICB as a commercial treatment for industrial wastewater. Thus, a primary reason for demonstrating the ICB was to validate it with the hydrolysates generated from ACW treatment of agent in the proposed configurations.

The PMACWA determined that it was necessary to conduct separate ICB demonstrations because the HD/tetrytol hydrolysate ICB uses a different design from that of the ICBs used for VX/Composition B/M28 propellant hydrolysate and GB/Composition B hydrolysate, and because the products of each of these hydrolysates represented unique challenges to biotreatment technology. Furthermore, the ICB requires several weeks to acclimate, and validation testing requires approximately 40 days. As a result, it was effectively impossible to run two separate validation tests with a single ICB within the period available for the ACWA demonstration.

In addition to the primary operation of the ICB, the demonstration also included water recycling to verify the effectiveness of the Fenton's reagent ($\text{H}_2\text{O}_2/\text{FeSO}_4$) on each specific feed, both for destruction of the compounds of concern and for its impact on water recycle. This also allowed the demonstration unit to obtain a detailed characterization of what remains in solid biomass (which is required for disposal) and what constituents return with the recycled water. In addition, three CatOx units were included as part of the ICB unit operation (one for each ICB). The CatOx units were included to validate their performance with the ICB gaseous effluent and to allow a detailed characterization of product gases for final treatment.

The ICBs were designed to demonstrate the ability to biotreat the agent and energetic hydrolysates. The objectives of these demonstration units included the following:

- Validate the ability of the unit operations to eliminate Schedule 2 compounds present in the hydrolysate feeds;

- Confirm the absence of agent in the unit operation effluents;
- Validate the ability of the agent hydrolysis processes, the ICB, flocculation reactor, and clarifier unit operations to achieve a DRE of 99.9999% for agent;
- Validate the ability of the energetic hydrolysis processes, the ICB, flocculation reactor, and clarifier unit operations to achieve a DRE of 99.999% for energetics;
- Develop mass loading and kinetic data that can be used for scale-up of the ICB, flocculation reactor, and clarifier unit operations;
- Validate the ability of the CatOx to eliminate the organic compounds and Schedule 2 compounds specified in the Demonstration Study Plan from the ICB process gas streams;
- Determine the potential impact of operating conditions on the fouling and plugging of the CatOx; and
- Characterize the gas, liquid, and solid waste streams from the unit operations for the constituents specified in the Demonstration Study Plan.

The PMACWA conducted three separate ICB demonstrations, one for each of the following combinations of agent and energetic hydrolysates (PMACWA 1999a):

- HD hydrolysate and tetrytol hydrolysate to simulate the material contained in the M60 105-mm cartridge;
- VX hydrolysate, Composition B hydrolysate, and M28 propellant hydrolysate to simulate the material contained in the M55 rocket (not applicable to PCD);
- GB hydrolysate and Composition B hydrolysate to simulate the material contained in the M426 4.2-in. cartridge (not applicable to PCD).

Each ICB demonstration unit consisted of the ICB plus an associated flocculation reactor, clarifier, and CatOx unit.

Certain aspects of the ICB operations were considered for demonstration but were not included in the final demonstration test matrix. These included determining the sensitivity of the ICB to expected impurities, such as MPT liquid effluents, and demonstrating sludge dewatering

and brine reduction for detailed characterizations for disposal requirements. These items were determined not to be necessary for a successful demonstration.

4.2.2.3.5 Metal Parts Treater and Catalytic Oxidation

The MPT is a thermal treatment unit that decontaminates metal parts and dunnage to a 5X condition by maintaining the temperature above 1,000°F (539°C) for the required time (minimum of 15 minutes). The ability of the MPT to effectively treat metal parts to a 5X condition was not a primary reason for demonstrating the unit; it was demonstrated because of several issues raised during the initial evaluation. These issues included the ability to treat dunnage, the ability to control agent driven from metal parts, and the need for characterization of products for all process streams.

Because of the lack of information on the effluents from the MPT, it was considered important to test the unit with as many varied feeds as possible. Therefore, the MPT was demonstrated using mortar bodies containing a quantity of agent representing a 10% heel of GB, VX, and HD. This was considered a worst-case scenario on the basis of the original approach of washing out the projectiles. The MPT was also tested with carbon, pentachlorophenol (PCP)-contaminated wood, fiberglass from rocket shipping and firing tubes, and DPE suit material.

Part of the gaseous effluent treatment for the MPT includes another CatOx unit followed by carbon filters. The most important reason for conducting this demonstration was to characterize the effluents from the MPT. The CatOx demonstration was also considered important because this unit has the potential to extend the life of carbon filters in a variety of demilitarization applications. If the MPT were to produce agent or Schedule 2 compounds in the gas phase, the CatOx could treat them; validation of this capability was a reason for the demonstration. A direct challenge of undiluted agent was considered the ultimate test of this unit, so HD, VX, and GB were all directly fed into the unit to determine the ability of the CatOx unit to destroy any agent volatilized in the MPT.

The MPT unit operation was designed to demonstrate the MPT, its associated condensate recovery system (CRS), and the attached CatOx. The objectives of these demonstration units included the following:

- Validate the ability of the MPT process to treat dunnage;
- Determine what pyrolysis products are produced in the MPT during processing of dunnage and evaluate their impact on the downstream condenser;

- Characterize the liquid effluent from the MPT condenser to determine its suitability for processing in the agent hydrolysis reactor;
- Validate the ability of the MPT condenser and the CatOx to eliminate chemical agents and Schedule 2 compounds from the process gas stream;
- Determine the potential impact of operating conditions on the fouling and plugging of the CatOx; and
- Characterize the gas, liquid, and solid waste streams from the MPT for the constituents and properties specified in the Demonstration Study Plan.

The MPT unit operation was tested with the following:

- M2A1 mortar body with a 10% liquid agent heel,
- Wood pallet material spiked with 0.4% PCP,
- Carbon,
- Fiberglass shipping and firing containers, and
- Double-bagged DPE suits with boots and gloves.

In addition, the CatOx portion of the unit was tested with direct GB, VX, and HD vapor feedstocks.

There were no significant deviations from the planned demonstration testing.

4.2.2.3.6 Summary of Demonstration Testing

In summary, the neutralization/biotreatment system for fluid-abrasive cutting and fluid-mining was for the most part demonstrated during the demonstration test phase. M28 propellant, however, which is present only in M55 rockets, could not be adequately removed from munition items using fluid-mining. An alternative proposal is to push the M28 propellant grain out of the rocket motor casing. The grain would then be sheared and shredded to produce a slurry. The destruction of agents and energetics using hydrolysis was validated in government testing. Use of hydrolysis, along with the thermal treatment of metal parts and other solid wastes, has been validated to effectively treat mustard and nerve agents and the energetic components of ACW. The agent hydrolysis process does, however, produce CWC Schedule 2 compounds. For mustard agent type munitions, these Schedule 2 compounds were effectively treated in the ICB unit. The

process of neutralization followed by biotreatment for the demilitarization of ACW with mustard agent was validated during the demonstration. Therefore, this process was considered a viable total solution for the demilitarization of ACW with mustard agent. The process of neutralization followed by biotreatment for the demilitarization of ACW with nerve agents was not validated during the demonstration. Therefore, this process was not considered a viable total solution for the demilitarization of ACW with nerve agent without further development. The PMACWA reviews the quality of the data generated during demonstration testing in PMACWA (1999d).

On the basis of demonstration testing, Parsons/Honeywell indicated that a number of subsequent studies would be needed to optimize system components and to integrate them with baseline components that are included in the total system (Parsons/Allied Signal 1999). However, no significant changes were proposed to the neutralization/biotreatment system as a result of demonstration testing.

4.2.2.4 Engineering Design Studies³²

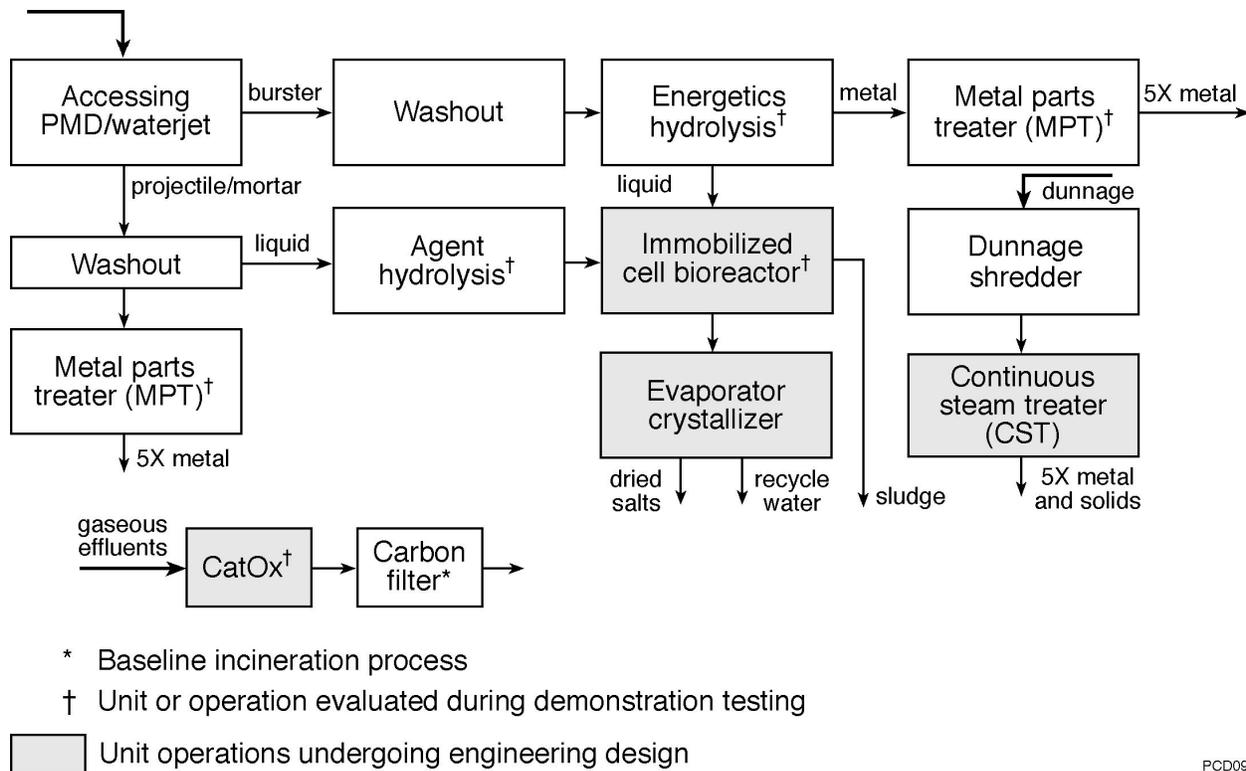
Although demonstration testing for the Demo I and Demo II technologies has been completed, EDSs are being implemented. The PMACWA determined that these studies were necessary in preparation for full-scale pilot design and permitting. While EDSs have been completed for the Demo I technologies, EDSs for the Demo II technologies have not been completed. This TRD presents information on what was planned for EDSs only. EDS objectives were as follows:

- Provide information for the full-scale facility with respect to total life-cycle cost, schedule, and safety;
- Support the EIS and RCRA permit application preparation; and
- Support preparation of a RFP for a full-scale pilot plant facility.

PMACWA (2000a) gives an overview of the planned EDSs for neutralization/SCWO. Figure 4.9 provides an overview of the neutralization/biotreatment process and shows unit operations that were evaluated during the EDSs for projectiles and mortars. It is unclear whether carbon filtration would be employed in the final pilot-scale design (Figure 4.9). For demonstration and EDS testing, the carbon filter was employed as a safeguard because of uncertainty regarding performance of the CatOx system.

The following subsections summarize planned EDS activities.

³² Because EDSs were intended to apply to a variety of ACW from all storage sites, this section does not discriminate with regard to munition type and storage installation.



PCD09

FIGURE 4.9 Flow Diagram of Neutralization/Biotreatment (Parsons/Honeywell System) Showing Units or Operations Undergoing Engineering Design — Projectiles and Mortars (Source: PMACWA 2000a)

4.2.2.4.1 Energetics Hydrolysis³³

Planned EDS activities for energetics hydrolysis consisted of the following:

- Addressing PMACWA and NRC (NRC 2000) concerns regarding particle size, solubility, by-products that would be produced as a function of time, control strategies, mixtures of energetics, and caustic concentrations; and
- Acquiring information for scale-up.

³³ This is the same testing planned for neutralization/SCWO.

4.2.2.4.2 Agent Hydrolysis³⁴

Planned EDS activities for agent hydrolysis consisted of the following:

- Determining the potential to use 15% by weight mustard agent hydrolysate for feed to the ICB unit for increased throughput.

4.2.2.4.3 Immobilized Cell Bioreactor and Catalytic Oxidation

Planned EDS activities for the ICB and CatOx consisted of the following:

- Observing long-term (4 months and 4 biomass retention times) continuous operation of the ICB unit, exclusive of unanticipated extended downtime, under proposed full-scale operating conditions (e.g., aeration, effluent recycling, and original planned HD hydrolysate feed rate);
- Observing the ability of secondary unit operations (e.g., clarifier, filter press, and evaporator/crystallizer/filter press) to perform as proposed;
- Confirming critical design parameters (e.g., aeration rate, CatOx loading) developed during demonstration testing;
- Observing effective control of the biomass throughout the ICB process, including growth within the ICB unit, separation within the clarifier, and filtration;
- Observing the effectiveness of the proposed full-scale control strategy for the ICB, clarifier, CatOx, and evaporator/crystallizer/filter press;
- Characterizing the CatOx outlet, crystallizer off-gas, biomass, and brine salts from the ICB process for selected chemical constituents and physical parameters, and for the presence or absence of hazardous, toxic, agent, and Schedule 2 compounds; and
- Observing the ability of the ICB unit to treat the neutralized CST condensate as part of the feed stream to the ICB.

³⁴ This is the same testing planned for neutralization/SCWO.

4.2.2.4.4 Continuous Steam Treater and Catalytic Oxidation

Planned EDS activities for the CST and CatOx consisted of the following:

- Observing the long-term operability, reliability, and ease of material handling of the CST with wood (pallets), DPE suits, and carbon (filter trays);
- Observing the effectiveness of the proposed full-scale control strategy for the CST;
- Observing the ability of the CST to reach a 5X condition throughout the feed material;
- Verifying critical design parameters (e.g., temperature, steam flow rate, CatOx loading, feed throughput rate) developed during demonstration testing;
- Observing the ability of the CatOx unit to effectively treat the uncondensed gases over long-term operation;
- Determining the expected CatOx catalyst life under continuous CST operation; and
- Characterizing neutralized CST condensate for selected chemical constituents and physical parameters, and for the presence or absence of hazardous and toxic chemicals, including Schedule 2 compounds.

4.2.2.4.5 Catalytic Oxidation Unit

Planned EDS activities for the CatOx unit consisted of the following:

- Observing long-term (500 hours) operation of the CatOx unit with HD,
- Determining whether the CatOx unit catalyst loses efficiency (due to poisoning, fouling, and/or plugging),
- Determining the expected CatOx catalyst life under continuous HD operation, and

- Determining (via characterization) the ability of the CatOx effluent to be treated by a downstream carbon bed.

Additional testing of the neutralization/biotreatment system was conducted during the EDSs, and included the following:

- Water washout of mustard agent projectiles,
- Biotreatment of propelling charge hydrolysate, and
- MPT treatment of inert hardware.

As indicated above, the results of the EDSs for neutralization/biotreatment were not included in this TRD.

4.2.2.5 Detailed Process Description

This section presents a detailed process description for neutralization/biotreatment as applied to PCD and the ACW stored there, on the basis of the results of demonstration testing.

Figure 4.10 illustrates the entire process flow for neutralization/biotreatment. As the figure shows, neutralization/biotreatment starts with munition pretreatment, which uses baseline reverse assembly, fluid-abrasive cutting, and fluid-mining. Projectiles and mortars would be accessed by baseline reverse assembly. A modified multipurpose demilitarization machine (MMDM) would be used to access and drain the agent cavity. Projectile fuzes and bursters would be removed with the propellant macerator device. The fuzes would be fed to the CST, and the bursters would be fluid-mined using water.

Projectiles and mortars, basketed munition hardware, dunnage, and other solid wastes would be thermally decontaminated to a 5X condition in either the MPT, an inductively heated vessel with a superheated steam reactive environment, or the CST, a rotary version of the MPT with a similar structure to that of the baseline DFS. Steam would be condensed from the MPT or CST off-gas and sent to the CRS. Water with a caustic wash would be used to neutralize mustard agent, and NaOH would be used for energetics in CSTRs, similar to the Army's ATP process. Drained agents and CRS effluents would be treated in the agent hydrolyzer, while slurried energetics (from cutting, mining/washing) and spent abrasive wash would be treated in the energetics hydrolyzer.

Agent and energetic hydrolysates would be adjusted for pH, combined, and mixed with reagents and premixed nutrients for aerobic digestion (biotreatment) in the ICB. For all agents, the clarifier side stream would then be sent to water recovery, where it would be evaporated to

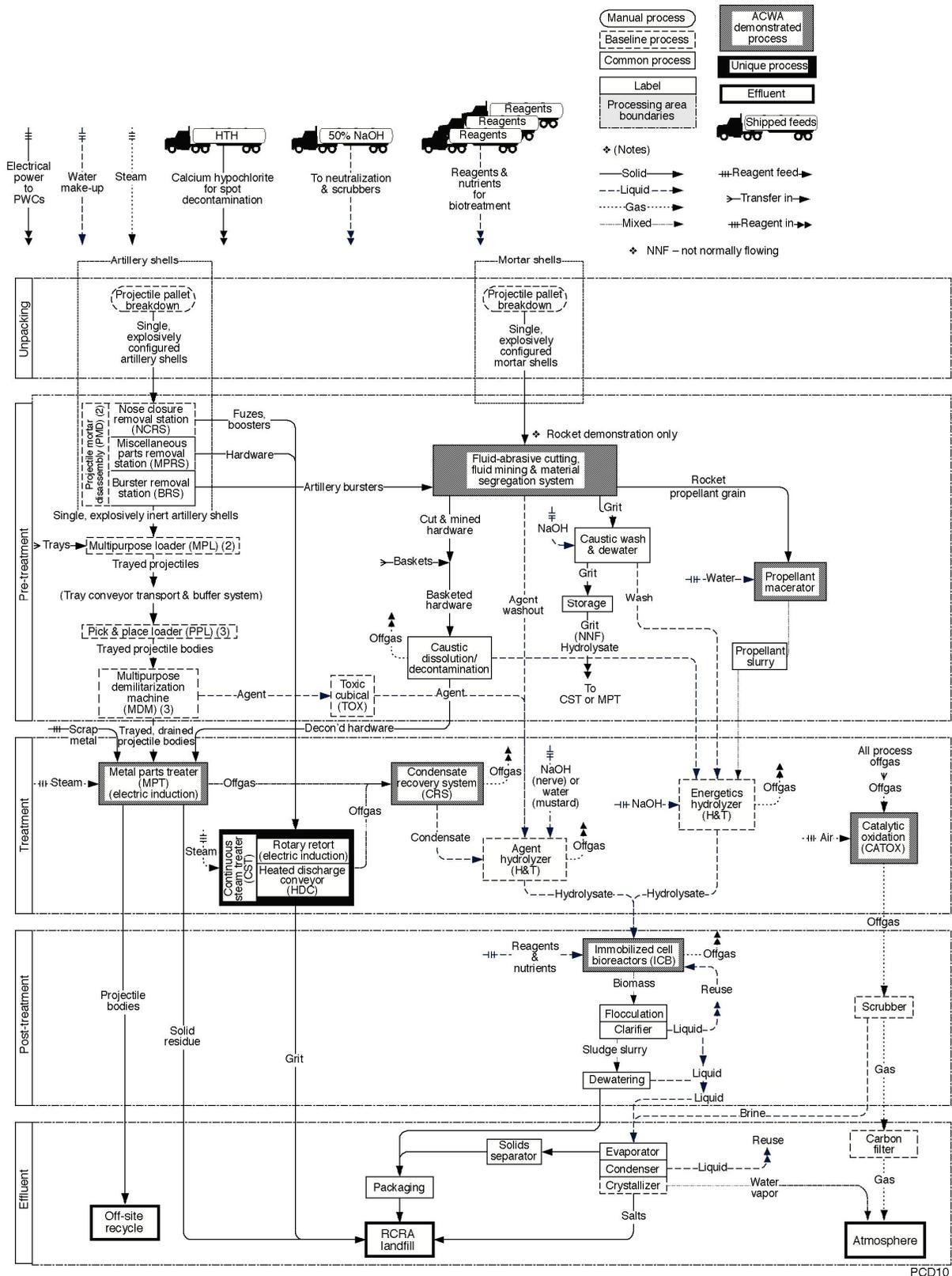


FIGURE 4.10 Flow Diagram of Entire Neutralization/Biotreatment Process at PCD (Adapted from PMACWA 1999b)

concentrate the salt content. Sludge from the ICB would be dewatered, packaged, and disposed of as hazardous waste in a RCRA-permitted landfill. This sludge may be defined as hazardous waste if it exhibits any of the characteristics of hazardous waste as defined in 40 CFR 260.21 – 260.24. This sludge may contain heavy metals and may exhibit the RCRA toxicity characteristic (40 CFR 261.24). In Colorado, the sludge may be regulated as listed hazardous waste because of its association with chemical agent.³⁵ Liquid from sludge dewatering would be sent to the recovered water storage tank for reuse. All process off-gas would be mixed with air and catalytically converted by the CatOx technology, followed by release to the atmosphere. Oxidized liquid and scrubber brine would be dried — first concentrated by evaporation, with water condensed and reused, followed by crystallizing, with water vapor released to the atmosphere and dry salts sent to a RCRA-permitted facility for further treatment, if necessary, and disposal. Treated munition bodies (5X condition) may be commercially recycled, and treated solid wastes (3X or 5X condition) may be disposed of as either hazardous or nonhazardous waste, depending on regulatory requirements.

Short descriptions of each of the unit processes included in the neutralization/biotreatment process are provided in the following subsections.

4.2.2.5.1 Munitions Access

The proposed design for munitions access incorporates many of the units used in baseline reverse assembly (see Appendix E of Volume 1 for details). Units include reverse assembly machines, material handling conveyors, robotic loaders and handlers, HDCs, elements of the MPF thermal treatment system, auxiliary systems, and facilities and support systems. Some of these units have been slightly modified from the baseline process, but the basic unit and operations have been retained. The major units are summarized below.

The PMD machine and supporting equipment have been adopted without modification. The PMD is a custom-designed, automated machine that uses a turntable to position munitions at the various workstations that are arranged around the perimeter of the machine. Munitions would be processed in a horizontal position, and fuzes, nose closures, supplementary charges, bursters, and other energetics would be removed.

Bursters would be conveyed to the multistation fluid-accessing machine, where energetics would be removed through the fuze end of the item by a high-pressure multijet fluid nozzle using water. The multistation fluid-accessing machine replaces the BSRM.

Empty burster casings would be sheared in the burster shear station. The munitions would then be transported to the MMDM, where the burster well would be pulled from the item,

³⁵ If the sludge is listed as hazardous waste, a RCRA delisting petition may be pursued to reclassify the waste as nonhazardous.

thereby exposing the agent. The agent would then be drained using aspiration. The burster well would be crimped, placed back into the munition body, and conveyed to the MPT. The fuzes and burster casings would be sent to the rotary version of the MPT, the CST. Agent would be conveyed to holding tanks in the toxic cubicle (TOX), where it would be stored prior to introduction to the agent hydrolyzer. Energetics washout would be conveyed to the energetics hydrolyzer.

4.2.2.5.2 Agent Treatment

An agent hydrolyzer would be used for agent treatment. Hydrolysis would be conducted in a CSTR, which is similar to the unit used for energetics treatment. The feed would be added to the CSTR, which contains water at the required reaction temperature. Batches would be adjusted as necessary and then released to storage prior to biotreatment. The neutralization technology would incorporate the ATP neutralization system design that will be used at APG, with minor modifications to interface with other equipment. It is chemically identical to that used in neutralization/SCWO (see Section 4.3.2).

Secondary treatment of the agent hydrolysate to remove Schedule 2 compounds would be accomplished using biotreatment. Both the agent hydrolysate and energetics hydrolysate would be treated in the same bioreactor. Concentrated hydrolysates from these operations would be stored until they are fed to the bioreactors. Recovered water would be added, as well as nutrients needed by the microbes used to biotreat the hydrolysates. The bioreactors would process the hydrolysates and pass a clean effluent on to the water recovery operation.

The ICBs used for biotreatment are proprietary reactors. However, other biotreatment processes may be substituted for the proposed biotreatment system. Agent and energetic hydrolysates would be combined in the ICB feed tank with a premixed nutrient solution. This feed would be continuously metered to the bioreactor. Outside air would be forced through the reactor beds. Bioreactor effluent would be taken to a flocculation unit, where sludge would be precipitated out and prepared for removal. The reagent used (Fenton's reagent) would also remove color and odor from the bioreactor effluent. A clarifier would be used to remove the sludge as a slurry that would be pumped to a water recovery unit. Clarifier overflow would be pumped to a recycled water storage tank for subsequent reuse in the system. Biosolids and biosalts would be solidified and disposed of as hazardous waste in a hazardous waste landfill. Noncondensable gases from this system would be passed through the CatOx unit prior to release to the atmosphere.

4.2.2.5.3 Energetics Treatment

The main element for primary treatment of energetics would be the energetics hydrolyzer. The energetics hydrolyzer replaces the baseline DFS but has been adapted to the

same interfaces with other equipment as the DFS. The energetics hydrolyzer is similar in design and operation to the agent hydrolyzer and receives washed-out energetics from the multistation fluid-accessing machine.

The feed would be added to the hydrolyzer, which contains NaOH solution at the required reaction temperature. After the required reaction time, a sample of the hydrolysate would be analyzed for agent and energetics. Batches would be additionally treated as necessary and then released to storage prior to biotreatment. Biotreatment would follow the same process as discussed above for agent hydrolysates.

4.2.2.5.4 Metal Parts Treatment

The metal parts from munitions access would be processed by the MPT, which would either be a tube-type or rotary device that is induction heated. In the MPT, projectile and mortar bodies would be decontaminated to a 5X condition in a superheated steam atmosphere. Induction coils would be used to ramp up the temperature through a prescribed cycle. Volatile liquids would be vaporized and removed by the steam, which would be condensed downstream in the CRS.

The liquid condensate from the CRS would be taken to the SDS, where it would be diluted with the low-concentration alkaline solution of the spent decontamination fluid and subsequently added as makeup water to the agent hydrolyzer. Noncondensable gases would be processed through catalytic converters (the CatOx system).

Energetic hardware — specifically fuzes, nose closure plugs, projectile burster casings, and fuze booster cups — would be processed through a similar device, the CST. As indicated previously, this unit would be a modified version of the MPT and can operate in continuous feed mode.

4.2.2.5.5 Dunnage Treatment

Dunnage would be treated during the campaign to the extent possible. It would be steam-treated in the MPT. Although not all dunnage is agent-contaminated, all dunnage would be treated on-site in this manner.

4.2.2.5.6 Effluent Management and Pollution Controls

The effluent management and pollution control systems used in neutralization/biotreatment would be similar to systems used in the baseline incineration plant (see Appendix E

of Volume 1). Included are scrubbers, condensers, and carbon filters, which are used to remove residual organics from contaminated areas before discharge to the atmosphere. The neutralization/biotreatment system would also include a CatOx system, which would be used to treat organic constituents within the air stream. Two different CatOx units would be employed. One would be used for the bioreactors, and the other would be used for all other systems. Both CatOx units would operate in an identical manner.

The CatOx units that would be used for the bioreactors are not intended to treat agent. They would be provided solely to treat organic compounds that would emanate from the ICB feed or that would be generated during the biodegradation process. Incoming air streams would be heated electrically to reduce moisture and to condition the gas to the CatOx operating temperature. The catalytic matrix within the device is designed to reduce organic materials to basic elements. The bioreactor CatOx units would discharge directly to the atmosphere (no scrubbers or carbon filtration) since it is unlikely that they would receive any agent (Parsons/Allied Signal 1999). The CatOx unit that would be used for the other systems in the neutralization/biotreatment process may vent to the scrubber/carbon filter system as a precaution.

All other systems would be identical to the baseline system, including the personnel support system, the plant instrument air supply and steam supply systems, control rooms, the process for handling munitions from storage to the facility, personnel support, monitoring systems, and analytical laboratories.

4.2.2.6 Common Elements – Other Systems

The neutralization/biotreatment process has several elements that are identical or nearly identical to other systems. Commonalities with other applicable technology systems include the following:

- The munitions access system used for neutralization/biotreatment would employ much of the baseline reverse assembly system, as do the other ACWA systems; and
- Both neutralization/biotreatment and neutralization/SCWO (see Section 4.3.2) systems would employ neutralization of chemical agents and energetics.

Facility structure, ventilation; decontamination fluid supply; personnel support; pollution abatement; water, air, and steam supply systems; control rooms; monitoring systems; and laboratory support would be identical or nearly identical to those of the baseline system.

4.2.3 COMBINATION TREATMENT TECHNOLOGIES

Given the commonalities of the neutralization/SCWO and neutralization/biotreatment processes, the elements of the various unit operations could be combined into different but viable ACW treatment alternatives. A number of different combination technologies may be considered. The following are examples of several combinations that could be employed:

- The cryofracture technology of neutralization/SCWO can be used with any system;³⁶
- The fluid-abrasive cutting and fluid-mining technologies of neutralization/biotreatment can be used with any system;
- The specific units proposed for agent and energetic hydrolysis in either of the neutralization/SCWO or neutralization/biotreatment systems are interchangeable;
- The metal parts treatment technologies proposed for either neutralization/SCWO or neutralization/biotreatment are interchangeable;
- The CatOx unit, as used in neutralization/biotreatment, can be employed with any technology system; and
- Carbon filtration, as used in the baseline process and in most of the ACWA technologies, may be used with any technology system.

³⁶ This process, however, may not perform well with aluminum-bodied munitions such as M55 rockets.

4.3 SUPPLEMENTAL INFORMATION FOR ASSEMBLED SYSTEMS AT PUEBLO CHEMICAL DEPOT

This section provides supplemental information for pilot testing ACWA technology systems at PCD. Included are facility descriptions, system inputs and resource requirements, routine emissions and wastes, and activities and schedules. This section addresses construction and operation of the facility. As the pilot-scale facility design matures, deviations are expected. However, it is anticipated that the final design would result in estimates similar to those provided in the tables in this section.

4.3.1 GENERAL FACILITY LOCATION AND FOOTPRINT

For the purposes of NEPA assessment, it has been assumed that all ACWA program facilities would be constructed within the chemical demilitarization reuse area located in the northeastern corner of the PCD. Figure 4.11 shows the three proposed sites (Sites A, B, and C) for the demilitarization facility within this area. All three sites are adjacent to the existing ACW storage area; one is to the east, one is to the south, and one is to the west. The location of the actual destruction facility within these three areas has yet to be determined. It is possible that multiple ACWA technologies could be tested at PCD.

In general, the physical size of the destruction facility for ACW at PCD is expected to be comparable to that required for baseline incineration. The facility size may differ slightly as a function of technology system alternative. For each technology system, the facility is expected to cover an area of approximately 20 to 30 acres (8 to 12 ha), with additional land area of up to 20 acres (8 ha) needed for construction support facilities. Additional acreage may be required for access roads and utilities; the area required will be determined on a site-specific basis. Table 4.4 provides distance information for each of the three sites. Table 4.5 provides land area requirements during operations.

The land area required during construction may be greater than that required during operations because of the need for the following:

- A construction laydown area for temporary storage of construction materials such as structural steel, pipe, lumber for concrete forms, and electrical conduit;
- Temporary construction offices for housing on-site engineering personnel and construction supervision and management personnel;
- Temporary parking for construction workers and support personnel;

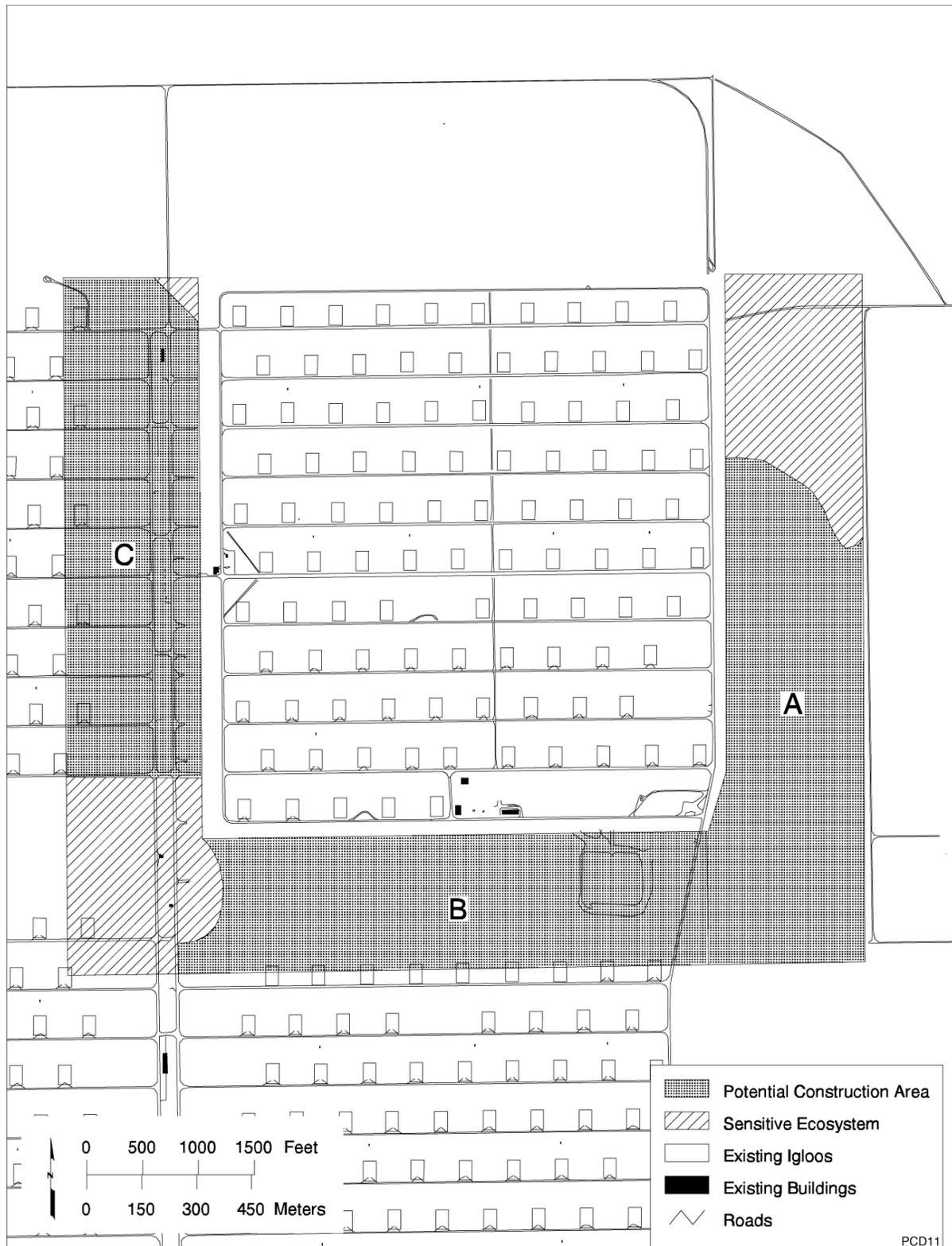


FIGURE 4.11 Map Showing Three Potential Locations for the Demilitarization Facility at PCD

TABLE 4.4 Approximate Distances from Potential Demilitarization Facility Locations A, B, and C to PCD Installation Boundaries (mi)^a

Location	Distance to North PCD Boundary	Distance to South PCD Boundary	Distance to East PCD Boundary	Distance to West PCD Boundary
A	1.5	7.3	1.7	6.0
B	2.1	6.8	3.0	5.2
C	1.3	7.7	3.8	4.4

^a Distance determined from the approximate midpoint of Areas A, B, and C, respectively, as shown in Figure 4.11.

TABLE 4.5 Land Area Requirements during Technology System Operations

Technology	Land Area for Operations (acres)
Baseline incineration	20
Neutralization/SCWO ^a	20–30
Neutralization/biotreatment ^b	20

^a Based on Figure 4.3-8 from General Atomics (1999).

^b Based on Figure 4.3.1-1 from Parsons/Allied Signal (1999) and stated similarity to incineration facility layout.

- Temporary holding basins for control of surface water runoff during construction; and
- Areas for installing required temporary utilities and services, including construction service water, sanitary facilities, electrical power, and vehicle fuels.

The additional land area for construction-related activities would, in general, be on the order of 10 to 20 acres (8 to 12 ha). This analysis conservatively assumes that a total of 50 acres (20 ha) would be required for construction purposes. Examination of the available land area at sites A, B, and C indicates that the above construction-related areas would be readily available at each of these locations.

Existing security fencing along the perimeter of the current chemical storage area would be extended to include the proposed ACWA destruction site, thereby creating a contiguous fenced area around the storage area and the destruction site. The storage area and destruction site would be separated by security fencing to control access. A buffer area around the proposed destruction site would be established as defined by the U.S. Army's Public Access Exclusion Distance — the greater of the fragmentation hazard distance or the 1% lethality distance (U.S. Army 1997). Site personnel not directly associated with the demilitarization operation would be excluded from the buffer area defined by this distance, or provision would be made for their protection or evacuation.

All three areas (A, B, and C) consist of relatively flat terrain with minimal slope. Area C has existing structures, and some demolition or removal of those structures might be necessary. However, the extent of these activities depends on the exact location of the facility within the area bounded by Area C.

Construction of the demilitarization facility would involve small amounts of excavation and fill work. Construction debris would be transported off-site to a commercial disposal facility. A drainage system would be established for the facility to divert surface runoff from the plant site and to prevent erosion and accumulation of surface water on the facility. Minimal clearing and earthwork would be required in the three areas because they are sparsely vegetated.

4.3.2 NEUTRALIZATION/SCWO

This description of the neutralization/SCWO facility is based on preliminary design information provided in General Atomics (1999). As indicated in that report, many of the estimates provided for facility design refer comparatively to the U.S. Army baseline incineration process, which indicates, in general, that estimates are comparable to those for the baseline incineration process (General Atomics 1999). Thus, one of the primary sources of information for this section is the EIS for disposal of chemical agents and munitions stored at Pine Bluff Arsenal, Arkansas (PMCD 1997). That is the most recent EIS that the U.S. Army has prepared for baseline incineration of chemical munitions.

In addition to the above, mass balance estimates, air emission estimates, and solid waste estimates for application of the neutralization/SCWO technology at PCD have been developed (Mitretek 2001b). Air emissions and solid waste estimates for neutralization/SCWO, as discussed below, are based on Mitretek inputs, along with appropriate assumptions on filtration systems, plant operations, and schedule. Figure 4.12 provides an input/output material balance for the major streams for neutralization/SCWO of ACW at PCD containing mustard agent.

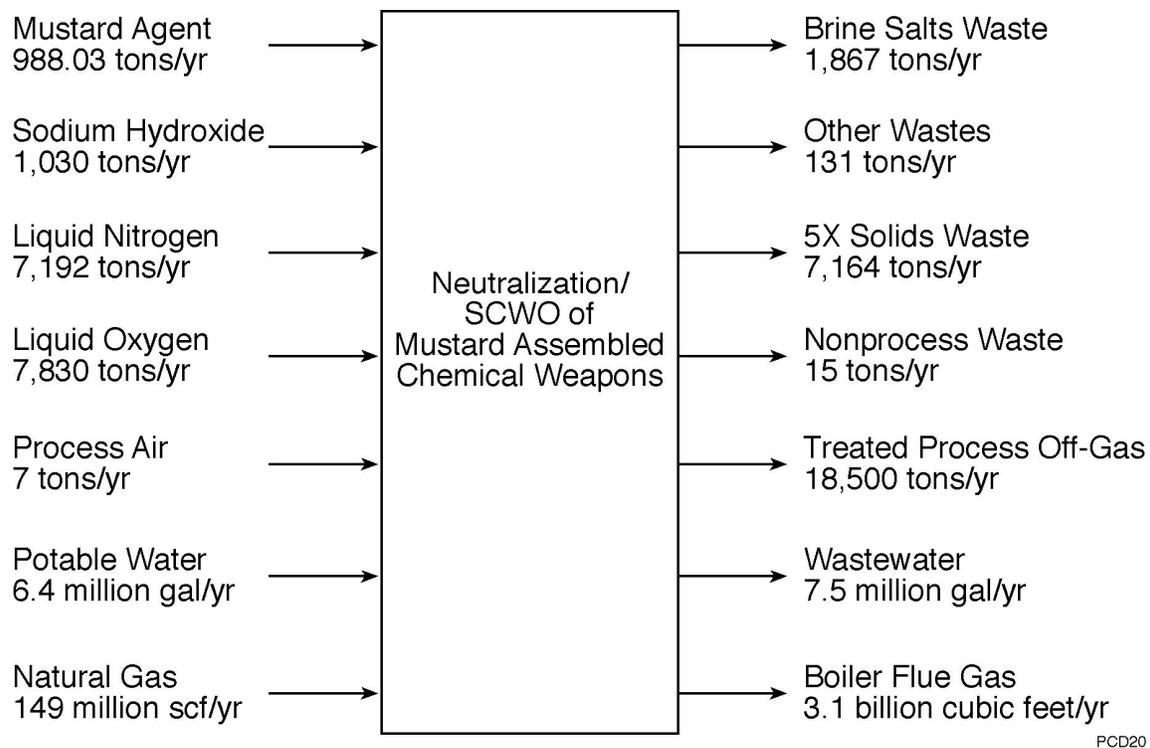


FIGURE 4.12 Input/Output Material Balance for Neutralization/SCWO of ACW Containing Mustard Agent at PCD

Many of the figures and tables referred to in the facility description for this technology system contain estimates (e.g., emissions, resources consumed) associated with processing ACW with a specified agent; these estimates are given on an annual basis (e.g., tons/yr). In some cases, the estimates have been converted from other units (e.g., lb/d) by accounting for the number of days of operation required for processing a specific type of ACW. This time period is referred to as a campaign; a campaign is agent-specific. The values in many of the following figures and tables are based on the number of days in the campaign required to process ACW containing a specific agent. It was assumed that there are 276 operating days in a year. If the campaign is less than or equal to 276 days, annual quantities equal total quantities. If the campaign is greater than 276 days, quantities in the figures and tables are for 276 days of processing. In the latter case, the estimates provided are less than total quantities. Daily (or other) quantities may be obtained by adjusting for the number of days in the campaign.

4.3.2.1 General Facility Description

The proposed neutralization/SCWO facility is designed to fit approximately into the same space and general configuration as the baseline incineration process. Munitions access and disassembly, base hydrolysis, and SCWO operations have been substituted for baseline

incineration operations. The physical plant consists of a two-story building constructed of noncombustible materials, with a concrete structural frame and a low-slope concrete roof.

The site layout for the neutralization/SCWO facility is shown in Figures 4.13 through 4.15. Figure 4.13 shows the general facility layout, Figure 4.14 shows the layout of the first floor, and Figure 4.15 shows the layout of the second floor.

4.3.2.2 Construction Phase

The schedule for destruction of the stockpile at PCD, although tentative, calls for construction of the selected alternative to begin following issuance of the EIS Record of Decision (ROD) and receipt of the RCRA and other required environmental permits, as necessary. It is anticipated that construction of the neutralization/SCWO facility would not differ significantly from that required for baseline incineration. Construction of the neutralization/SCWO facility would take approximately 32 months (PMCD 1997), including a 2-month design

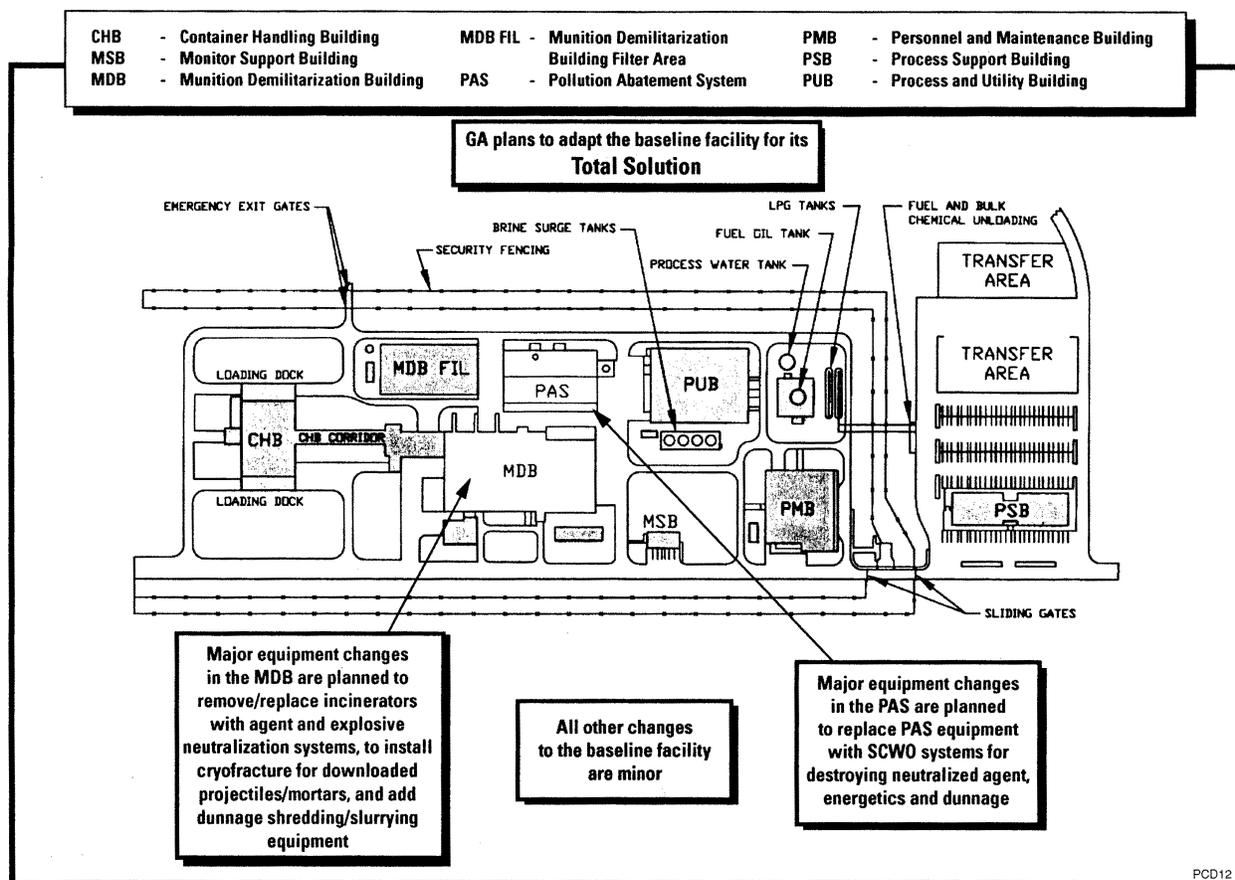
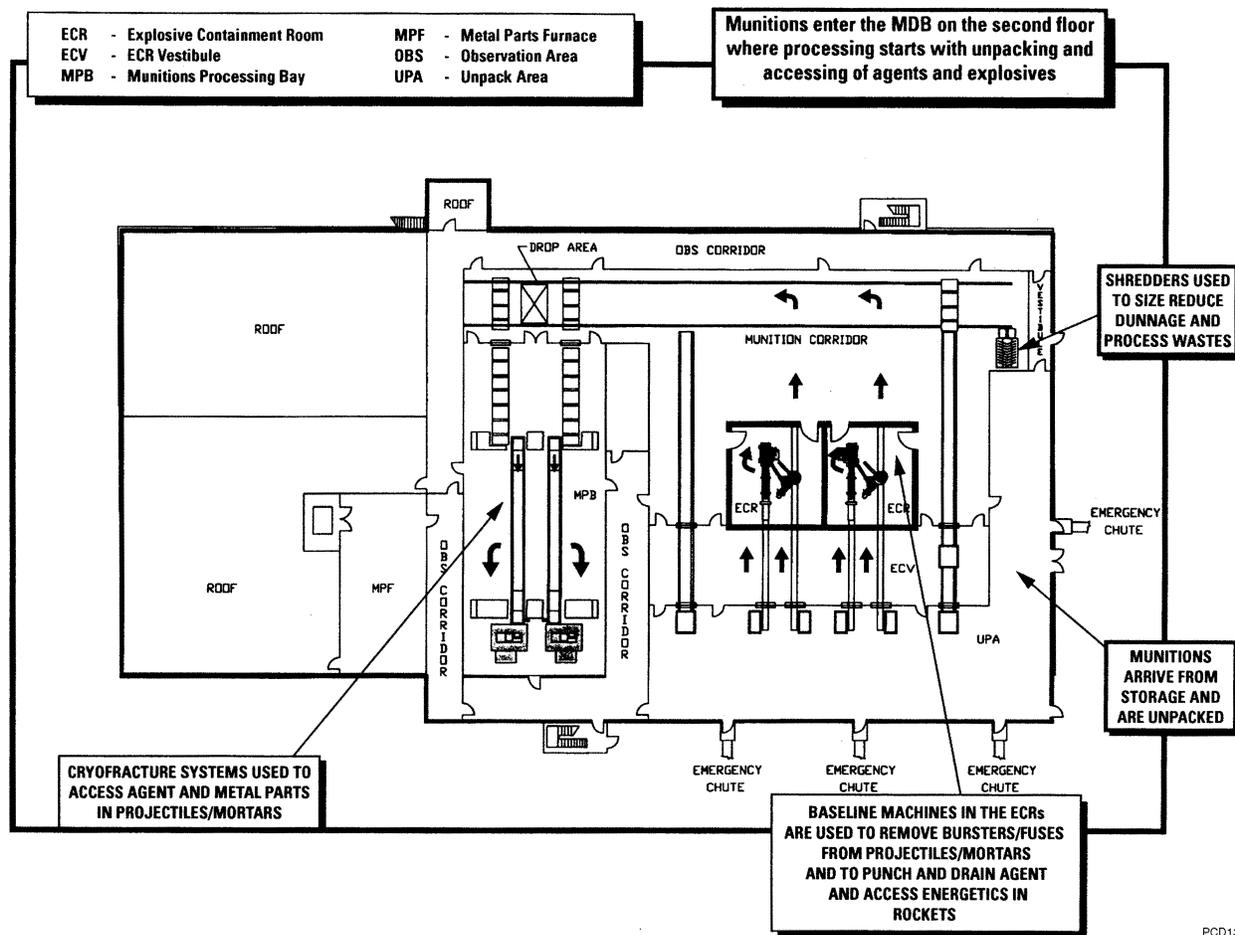


FIGURE 4.13 Neutralization/SCWO Facility Layout at PCD (Source: General Atomics 1999)



PCD13

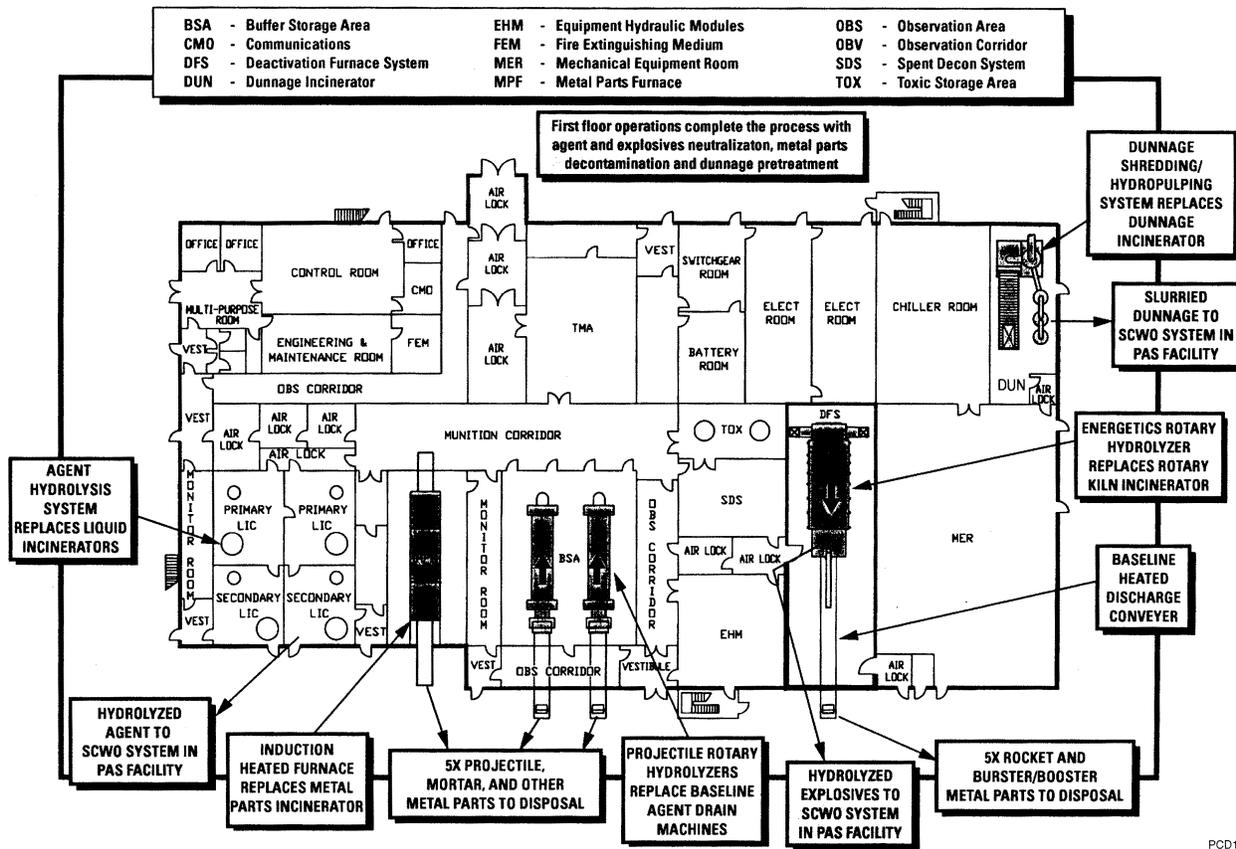
FIGURE 4.14 Layout of First Floor of the Munitions Demilitarization Building for the Neutralization/SCWO Facility at PCD (Source: General Atomics 1999)

and verification period. However, the PMACWA is investigating various means of shortening the construction phase.

Construction of the ACW destruction facility on the PCD installation would result in vehicle exhaust emissions, fugitive dust, noise, destruction of wildlife habitat and native vegetation, increased employment, increased demand for public services, and occupational health hazards.

4.3.2.2.1 Construction Inputs and Resource Requirements

The PMACWA has estimated that the capital cost for the neutralization/SCWO process at PCD would be approximately 10% less than that required for construction of the baseline incineration system (PMACWA 1999b). Resources needed for facility construction include water, electricity, concrete, steel, liquid fuels, lumber, and industrial gases (e.g., propane).



PCD14

FIGURE 4.15 Layout of Second Floor of the Munitions Demilitarization Building for the Neutralization/SCWO Facility at PCD (Source: General Atomics 1999)

Table 4.6 provides estimates of the primary materials that would be consumed during construction.

The total quantities of commonly used construction materials (e.g., steel) for equipment would be minor compared to the quantities given in Table 4.6. The process equipment would be purchased from commercial equipment vendors. Specialty materials, such as Inconel or Monel, do not appear to be required. However, the SCWO reactors may require platinum or an alternative specialty material as an anticorrosive liner in the final design (PMACWA 1999a).

An order-of-magnitude estimate of the number of shipments of construction materials to the site is provided in Table 4.7. The estimate does not include process equipment and related items; the number of shipments associated with these resources is expected to be small in comparison with the estimate of 5,000 total shipments.

An order-of magnitude estimate of the emissions from construction delivery vehicles to the site is provided in Table 4.8, assuming a one-way trip distance of 20 mi (32 km) and delivery by heavy-duty diesel trucks. The actual trip distances would depend on several factors, including

TABLE 4.6 Estimated Materials/Resources Consumed during Construction of a Neutralization/SCWO Facility at PCD^a

Construction Material/Resource	Total Consumption	Peak Demand
Utilities		
Water ^b (gal)	8,000,000	NA ^c
Electricity (MWh)	53,000	2.65 MW
Solids		
Concrete (yd ³)	30,400	NA
Steel (structural and reinforcing) (tons)	7,100	NA
Piping (all) (linear ft)	123,000	NA
Liquids		
Fuel (gal)	2.3E+06 ^d	NA
Gases		
Industrial gases (propane) (gal)	6,200	NA

^a All values can be considered order-of-magnitude approximations of the actual values; more accurate values would require a detailed consideration of construction activities.

^b The water requirement was estimated on the basis of DOE (1997), in which each full-time equivalent (FTE) required 20 gal/d, and solidification required 26 lb per 100 lb of cement.

^c NA = not applicable.

^d This system of exponential notation is equivalent to $N \times 10^x$; for example, 2.3E+06 equals 2.3×10^6 .

the availability of construction materials from local distributors and the distance of the site from the local distributors.

4.3.2.2.2 Construction Workforce

The construction workforce is expected to steadily increase to a peak of about 950 full-time equivalent (FTE) employees near the midpoint of the construction period, and then to decrease steadily until construction is completed. The average number of construction workers is estimated to be approximately 480 FTEs. Assuming a 32-month construction period, approximately 1,300-FTE-years of effort would be expended during construction. Table 4.9 provides an estimate of the employment buildup by year during construction.

TABLE 4.7 Order-of-Magnitude Estimate of the Number of Truck Shipments of Construction Materials for a Neutralization/SCWO Facility at PCD^a

Resource	Total Consumption	Truck Capacity	No. Truck Shipments
Portland cement ^b	3,344 yd ³	10 yd ³	335
Gravel ^b	12,464 yd ³	10 yd ³	1,247
Sand ^b	7,904 yd ³	10 yd ³	791
Steel ^c	7,100 tons	21 tons	340
Asphalt paving ^d	1,100 tons	20 tons	55
Backfill ^e	11,200 yd ³	10 yd ³	1,120
Fuel ^f	2.3E+06 gal	9,000 gal	260
Total			4,148
Total (rounded-up)			5,000

^a The calculation did not include truck deliveries of process equipment and related items.

^b Assumes that concrete is composed of 11% portland cement, 41% gravel, and 26% sand and is shipped to the site in a standard 10-yd³ end-dump truck.

^c Assumes that the net payload for steel transport to site is 42,000 lb.

^d Assumes that hot mix asphalt (HMA) is loaded into 20-ton-capacity triaxle trucks for transport to the paving site.

^e Assumes shipment in standard 10-yd³ end-dump trucks.

^f Assumes shipment using a U.S. Department of Transportation (DOT) 406/MC-306 atmospheric pressure tank truck with a 9,000-gal capacity.

4.3.2.2.3 Construction Emissions and Waste Estimates

During the construction phase, fugitive emissions would consist primarily of dust and vehicle exhaust. Temporary, regional increases in atmospheric concentrations of carbon monoxide (CO), nitrogen oxides (NO_x), hydrocarbons, particulate matter, and sulfur oxide (SO_x) would result from the exhaust emissions of commuter vehicles, heavy construction vehicles, diesel generators, and other machinery and tools. Annual emissions of these pollutants would be small in comparison to de minimis levels typically used by regulators to determine whether an air quality permit or impact analysis is necessary. Emissions from construction vehicles are exempt from permit requirements. Nevertheless, vehicles and machinery would be equipped with standard pollution control devices to minimize air quality impacts.

Estimated emissions from construction activities (not including emissions from delivery vehicles) are shown in Table 4.10. The emissions listed are based on the anticipated construction

TABLE 4.8 Estimated Emissions from Delivery Vehicles during Construction of a Neutralization/SCWO Facility at PCD

Criteria Pollutant ^a	No. of Auto Round Trips ^b	Emission Factor (g/km) ^c	One-Way Trip Distance (mi) ^d	Construction Period (yr)	Emission Rate (tons/yr)
HC	5,000	2.12	20	2.7	0.3
CO	5,000	11.28	20	2.7	1.5
NO _x	5,000	1.25	20	2.7	0.2
SO _x	5,000	0.23	20	2.7	0.03
PM ₁₀	5,000	0.617	20	2.7	0.1

- ^a Abbreviations: CO = carbon monoxide, HC = hydrocarbons, NO_x = nitrogen oxides, PM₁₀ = particulate matter with a diameter equal to or less than 10 micrometers, SO_x = sulfur oxides.
- ^b Number of auto round trips to the construction site was estimated on the basis of the total number of deliveries.
- ^c Emission factors were determined using U.S. Environmental Protection Agency (EPA) modeling software MOBILE5b (EPA 2000c) for HCs, CO, and NO_x, and PART5 (EPA 2000b) for PM₁₀.
- ^d One-way trip distance based on DOE (1997).

TABLE 4.9 Estimated Number of Employees Needed by Year for Construction of a Neutralization/SCWO Facility at PCD

Employees	Year 1	Year 2	Year 3
Total craft workers	290	590	140
Construction management and support staff	70	150	30
Total	360	740	170

TABLE 4.10 Estimated Emissions during Construction of a Neutralization/SCWO Facility at PCD

Criteria Pollutants	Total (tons)	Annual (tons/yr)
CO	116	44
HC	49	18
NO _x	173	65
SO _x	12	4
PM ₁₀ ^a	377	142

- ^a Estimated assuming that 50 acres would be disturbed during construction.

land disturbance and vehicle traffic (for dust particulate pollutants) and fuel and gas consumption. The column marked “total” indicates the total amount of emissions that is estimated to occur over the entire construction period.

Emissions from construction worker commuter vehicles were estimated on the basis of the assumption that an average of 475 automobiles (1 car per construction worker) would be added to the area. Table 4.11 gives annual emission estimates due to the increased traffic.

Additional emissions would be caused by the use of paints and thinners, aerosols, and other area source emissions. These emissions are expected to be minor pollutant contributors and were not included in the current estimates.

Construction would generate solid wastes primarily in the form of excavation spoils and building material debris. These latter wastes would include concrete forms, equipment and hardware containers and packaging, paint cans, waste metal sheeting, pipe and wire, and landscaping debris. Small amounts of liquid wastes, such as solvents, cleaning solutions, and paint wastes, also would be generated. Wastes would be collected and disposed of in accordance with U.S. Army, federal, state, and local requirements. All construction debris would be removed from the site for disposal. Any batteries, used motor oils, and empty containers would be separated from the waste stream and recycled. Any wastes identified as hazardous would be stored and disposed of in accordance with RCRA requirements. Sanitary wastes would be the only significant liquid effluents generated during construction and would be managed on-site.

TABLE 4.11 Estimated Emissions from Construction Worker Commuter Vehicles during Construction of a Neutralization/SCWO Facility at PCD

Criteria Pollutant	No. of Auto Round Trips ^a	Emission Factor (g/km) ^b	One-Way Trip Distance (mi) ^c	Emission Rate (tons/yr)
HC	114,000	1.16	20	9.4
CO	114,000	11.38	20	92.0
NO _x	114,000	0.73	20	5.9
SO _x	114,000	0.12	20	1.0
PM ₁₀	114,000	0.055	20	0.4

^a Number of auto round trips to the construction site was estimated on the basis of the average construction workforce and 240 workdays per year.

^b Emission factors determined using EPA modeling software MOBILE5b (EPA 2000c) for HC, CO, and NO_x, and PART5 (EPA 2000b) for PM₁₀.

^c One-way trip distance based on DOE (1997).

The estimated total quantities of solid and liquid wastes generated from activities associated with facility construction are shown in Table 4.12. The waste generation quantities are based on historic data on land area size and the construction labor force.

4.3.2.3 Operations Phase

Information on the facility operations phase is presented in this section. Preoperational testing is discussed first, followed by facility inputs and resource requirements, workforce requirements, and emissions and waste estimates.

4.3.2.3.1 Preoperational Testing

A preoperational testing period assumed to last 8 months would begin after facility construction (PMACWA 1999b). Often referred to as systemization, this period would be used to ensure that systems are operating as designed prior to full-scale operations. On the basis of similarity with baseline operations, it is projected that 315 FTEs would be needed at the peak of preoperational testing.

4.3.2.3.2 Operations Inputs and Resource Requirements

At full-scale operation, destruction of the mustard agent inventory at PCD is projected to require 731 days for processing (Mitretek 2001b). It is estimated that operations would require approximately 32 months at full-scale operation (see Table 4.13). This duration is based on a 12-hours-per-shift, 6-days-per-week operation, 46 weeks per year, with three 2-week munition changeout periods (General Atomics 1999).³⁷

TABLE 4.12 Estimated Total Wastes Generated during Construction of a Neutralization/SCWO Facility at PCD

Waste Category	Quantity
Hazardous solids	90 yd ³
Hazardous liquids	35,000 gal
Nonhazardous solids	
Concrete ^a	200 yd ³
Steel ^b	36 tons
Other ^c	1,600 yd ³
Nonhazardous liquids	
Sanitary ^d	5.1E+06 gal
Other	2.3E+06 gal

^a Amount of concrete (nonhazardous solid) waste estimated by assuming that 0.65% of concrete usage is spoilage.

^b Amount of steel waste stream was estimated as 0.5% of the steel requirement on the basis of LLNL et al. (1997).

^c Amount of other waste stream was estimated as eight times the concrete stream on the basis of LLNL et al. (1997).

^d Amount of sanitary waste was estimated on the basis of the total construction workforce.

³⁷ The full-scale scenario has been selected as the bounding case for this analysis.

TABLE 4.13 Inventory and Estimated Processing Time for Neutralization/SCWO of ACW Stored at PCD

Munition	Quantity	Agent	Processing Rate (no. of munitions/h)	Processing Time		Changeover (weeks)	Total (weeks)
				Hours	Weeks ^a		
105-mm cartridge	383,418	HD	100	3,834	53.3	0.0	53.3
155-mm projectile	299,554	HD	100	2,996	41.6	2.0	43.6
4.2-in. cartridge	76,722	HD	50	1,534	21.3	2.0	23.3
4.2 in. cartridge	20,384	HT	50	408	5.7	2.0	7.7
Total	780,078			8,772	121.8	6.0	127.8
Total no. of months					30.5	1.5	32.0

^a Estimated by assuming operations of 6 days per week and 12 hours per day.

Annual utility consumption for facility operation, including electricity, fuel, and potable water usage, is presented in Table 4.14. Table 4.15 shows annual usage of consumable chemicals and process material during mustard agent processing. These estimates were based on an assumed average or normal throughput.

Table 4.16 gives transportation data for annual shipment of input material streams into PCD for mustard agent processing. Hazardous materials shipped to the site include corrosives such as sodium hydroxide (NaOH) and phosphoric acid (H₃PO₄), combustibles (kerosene), and a nonflammable gas-oxidizer (oxygen). Oxygen would be transported to the site as a liquid.

4.3.2.3.3 Operations Workforce

The neutralization/SCWO facility would be a government-owned, contractor-operated facility. The expected operating and maintenance labor for the neutralization/SCWO facility has been stated to be similar to that required for incineration (General Atomics 1999; PMACWA 1999b). This analysis assumed that the estimated operations workforce needs are approximately 465 contractor employees for plant operations (Parsons 1995) and 170 government employees for munition handling, security, oversight, and other support activities (PMCD 1997).

4.3.2.3.4 Operations Emissions and Waste Estimates

Wastes from the neutralization/SCWO process would include air emissions and solid wastes. According to the technology provider, the only liquid effluent expected from the destruction facility would be sanitary waste, which would be managed on-site. All liquids

TABLE 4.14 Estimated Utilities Consumed during Destruction of ACW at the Neutralization/SCWO Facility at PCD

Utility	Average Daily Consumption	Peak-Day Consumption	Annual Consumption
Process water ^a	64,000 gal/d	1,800 gal/min	18,000,000 gal/yr
Potable water ^b	17,500 gal/d	180 gal/min	6,400,000 gal/yr ^c
Fire water ^b	NA ^d	3,000 gal/min	NA
Sanitary sewer ^b	20,650 gal/d	395 gal/min	7,540,000 gal/yr ^c
Natural gas ^a	540,000 scf/d	43,000 scf/h	149,000,000 scf/yr ^e
Fuel oil	962 gal/d	406 gal/h	48,000 gal/yr ^f
Electricity	163 MWh	18 MW	59.6 GWh ^{c,g}

^a Estimated on the basis of the ratio of the mustard agent processing rate at PCD to that of the NCD destruction facility.

^b Assumed to be similar to incineration because the number of operations and maintenance personnel and land area are unchanged from incineration (PMCD 1988).

^c Based on 365 days of operations per year.

^d NA = not applicable.

^e Based on 276 days of operations per year.

^f Estimated on the basis of 600 hours of emergency diesel generator operation per year.

^g Based on an annual power rating of 80%.

Source: COE (1987).

generated by the process and all liquid laboratory wastes would be reused in the process or disposed of internally by neutralization/SCWO. Destruction facility operations, including waste management, would comply with U.S. Army, federal, state, and local requirements. Any wastes that are identified as hazardous would be stored and disposed of in compliance with RCRA requirements. Summary descriptions of the types of emissions and solid wastes are provided in the following paragraphs.

Atmospheric Emissions. The major process gaseous residuals expected from the neutralization/SCWO operation include the following:

- Nitrogen gas from the cryofracture operation;
- Ventilation gases from the ERHs, PRHs, and MPF;
- Ventilation gases from the agent hydrolysis system; and

TABLE 4.15 Estimated Raw Materials Consumed Annually during Normal Neutralization/SCWO Operations at PCD, Mustard Agent Processing

Material	Average Daily Consumption (lb/d)	Annual Consumption (tons/yr) ^a
LN ₂	52,000	7,200
Liquid oxygen (LOX)	57,000	7,800
Water in caustic solution	9,100	1,300
NaOH	7,500	1,000
Phosphoric acid (H ₂ PO ₄)	209	29
Kerosene for SCWO	11,000	1,500
Air for SCWO and HDC	49	7

^a Estimated assuming 276 days of operation per year, 12 hours per day (a campaign length of 731 days).

Source: Mitretek (2001b).

TABLE 4.16 Transportation Data for Raw Materials for Neutralization/SCWO of ACW Containing Mustard Agent at PCD

Type of Data	Input Material No. 1	Input Material No. 2	Input Material No. 3	Input Material No. 4	Input Material No. 5
Transported materials					
Type/chemical	NaOH	LN ₂	LOX	H ₃ PO ₄	Kerosene
Physical form	Liquid	Liquid	Liquid	Liquid	Liquid
Chemical composition/temperature, pressure	NaOH/ambient	N ₂ /-321 °F, 1 atm	O ₂ /-297 °F, 1 atm	H ₃ PO ₄ /ambient	Kerosene/ambient
Packaging					
Type	55-gal drum	5,400-gal tanker truck	4,000-gal tanker truck	55-gal drum	5,500-gal tank truck
Container volume (ft ³)	7.35	721.87	534.72	7.35	735.24
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	Varies	Varies	Varies	Varies	Varies
Container weight (lb)	50	NA ^a	NA	50	NA
Material weight (lb) ^b	700	43,720	38,080	774	39,020
Chemical content (wt%)	50% NaOH	100% N ₂	100% O ₂	100% H ₃ PO ₄	N/A
Shipments					
Average weight (tons/yr) ^c	1,030	7,192	7,830	28.8	1,466.9
Average volume (ft ³ /yr)	21,892	237,531	219,893	548	55,288
Packages/yr	2,978	330	412	75	76
Packages/shipment	48	1	1	48	1
Shipments/yr	63	330	412	2	76
Form of transport/routing					
Form of transportation	Truck	Truck	Truck	Truck	Truck

^a NA = not applicable.

^b Based on Mitretek (2001b).

^c Based on 276 days of operation per year.

- Gases from the agent hydrolysate and energetics/dunnage hydrolysate SCWO systems.

These gases would be vented through scrubbers to the facility ventilation system, where they would pass through carbon filters prior to release to the atmosphere. Handling and disposal of process residue in accordance with the provisions of RCRA are expected to result in little potential for significant adverse impacts on air quality. Emissions from vehicles and combustion of natural gas and liquefied petroleum gas (LPG) are regulated by the U.S. Environmental Protection Agency (EPA) and the State of Colorado and are expected to result in little potential for significant adverse impacts on air quality. Dust emissions would also be controlled during operations.

The neutralization/SCWO process would be required to meet RCRA requirements and to operate under permit. The process would be required to destroy agent to a DRE of 99.9999% and to meet agent emission limits as established by the U.S. Army Surgeon General (ASG). Other emissions, including metals and HCl, would be regulated in accordance with the RCRA permit. The operation would also be required to meet air pollution control requirements for conventional pollutants, such as CO, SO₂, and opacity.

All ventilation air would be processed through carbon filtration units before release to the atmosphere. Facility effluent release points would include gaseous releases to the environment. Table 4.17 summarizes the characteristics of facility effluent air release points.

Table 4.18 summarizes the emission rates of criteria pollutants during operations, as estimated on the basis of the annual fuel consumption rates given in Table 4.14 and normal SCWO operations. Daily emissions can be estimated from the hourly rates, assuming 12 operating hours per day.

Small amounts of organic and metallic compounds would be emitted from the combustion of natural gas during normal boiler operations and from the combustion of fuel oil during normal boiler operations. Table 4.19 summarizes the emission rates of toxic air pollutants (TAPs), many of which are also hazardous air pollutants (HAPs), as defined in Section 112 of the CAA. The term TAP is broader in that it includes some pollutants that are not HAPs. These rates were estimated on the basis of the annual fuel consumption rates shown in Table 4.14 and with Factor Information Retrieval (FIRE) 6.22 emission factors for large wall-fired boilers with greater than 100 MMBtu/h of heat input (EPA 2000a). Daily emissions can be estimated from the hourly rates, assuming 12 operating hours per day.

Table 4.20 summarizes the TAP emission rates that were estimated based on the annual consumption rates of fuel oil shown in Table 4.14 and using FIRE 6.22 emission factors for reciprocating diesel engines (EPA 2000a). Daily emissions can be estimated from the hourly emissions, assuming 12 operating hours per day.

TABLE 4.17 Stack Parameters for Neutralization/SCWO at PCD^a

Installation or Emission Point	Physical		Stack Exit			Stack Location ^b
	Stack Height (ft)	Stack Exit Diameter (ft)	Stack Exit Gas Flow (acfm)	Gas Velocity (ft/s)	Stack Exit Gas Temp (°F)	
Process steam boiler I ^{c,d}	70	1.4	5,254	60	325	Near southwest corner of PUB
Process steam boiler II ^{c,d}	70	1.4	5,254	60	325	Near southwest corner of PUB
Process steam boiler III ^{c,d}	70	1.4	5,254	60	325	Near southwest corner of PUB
Diesel generator exhaust I ^c	47	0.67	6,765	323.00	925	Near northwest corner of PMB
Diesel generator exhaust II ^c	47	0.67	6,765	323.00	925	Near northwest corner of PMB
Filter farm stack ^b	120	6	96,000	56.59	77	Center of structure
SCWO stack ^b	80	2.5	12,000	40.74	77	NA, center of structure assumed

^a Abbreviations: NA = not available, PMB = Personnel and Maintenance Building, PUB = Process Utilities Building.

^b Stack characteristics similar to those at Newport, Indiana, assumed (PMCD 1999).

^c Information unavailable concerning the stack characteristics for neutralization/SCWO; characteristics similar to neutralization/biotreatment assumed (Parsons/Allied Signal 1999).

^d Stack exit gas flow for the process steam boiler taken from the neutralization/biotreatment facility (Parsons/Allied Signal 1999) was modified to take into account the annual average natural gas consumption rate of 540,000 scf/d for neutralization/SCWO.

The neutralization/SCWO facility at the PCD would be equipped with building ventilation systems that would discharge, to the atmosphere, indoor air from the Munitions Demilitarization Building (MDB) process area, the Laboratory Building, and the Personnel and Maintenance Building through the filter farm stack. Of the three ventilation systems, only the indoor air from the MDB process area would be potentially exposed to chemical agents during operations.

To estimate the maximum potential emissions of chemical agents, only the MDB process area was considered to be a significant potential source. The filter systems would be designed to remove chemical agents from the ventilation air streams to levels below the allowable stack concentrations that have been recommended by the U.S. Department of Health and Human Services, Centers for Disease Control (53 *Federal Register* 8504–8507, March 15, 1988). Table 4.21 gives the potential chemical agent emission rates on the basis of the assumption that the chemical agent concentrations in the air discharged from the filter farm stack would be at 20% of the recommended allowable stack concentrations (i.e., the level of quantification of the ventilation exhaust chemical agent monitors).

TABLE 4.18 Estimated Hourly and Annual Emission Rates of Criteria Pollutants during Normal Neutralization/SCWO Operations at PCD

Criteria Pollutant	Process Steam Boiler ^a		Diesel Generator Exhaust ^{b,c}		SCWO Stack	
	lb/h	tons/yr	lb/h	tons/yr	lb/h	tons/yr
CO	3.8	6.26	10.4	3.12	0	0
NO _x	6.3	10.43	48.4	14.50	0	0
SO _x	0.03	0.04	3.2	0.95	0	0
PM ₁₀	0.34	0.57	3.4	1.02	0	0
HC	0.25	0.41	4.0	1.18	0	0
N ₂ O ^d	0.0	0.00	0.0	0	15.0	15.5
H ₂ ^d	0.0	0.00	0.0	0	2.4	2.2

^a Estimated on the basis of the utility requirements listed in Table 4.14.

^b Based on 600 hours of operations per year.

^c Operation similar to neutralization/biotreatment assumed.

^d Based on Tables 4.5-1 and 4.5-2 in General Atomics (1999).

TABLE 4.19 Estimated Hourly and Annual TAP Emission Rates during Normal Boiler Operations for Neutralization/SCWO at PCD^a

Compound	Hourly Emission (lb/h)	Annual Emission (lb/yr)	Compound	Hourly Emission (lb/h)	Annual Emission (lb/yr)
2-Methylnaphthalene	1.1E-06	3.6E-03	Dimethylbenz(a)anthracene	7.2E-07	2.4E-03
3-Methylchloranthrene	8.1E-08	2.7E-04	Ethane	1.4E-01	4.6E+02
Acenaphthene	8.1E-08	2.7E-04	Fluoranthene	1.4E-07	4.5E-04
Acenaphthylene	8.1E-08	2.7E-04	Fluorene	1.3E-07	4.2E-04
Anthracene	1.1E-07	3.6E-04	Formaldehyde	3.4E-03	1.1E+01
Arsenic	9.0E-06	3.0E-02	Hexane(n)	8.1E-02	2.7E+02
Barium	2.0E-04	6.6E-01	Indeno(1,2,3-cd)pyrene	8.1E-08	2.7E-04
Benz(a)anthracene	8.1E-08	2.7E-04	Lead	2.3E-05	7.5E-02
Benzene	9.5E-05	3.1E-01	Manganese	1.7E-05	5.7E-02
Benzo(a)pyrene	5.4E-08	1.8E-04	Mercury	1.2E-05	3.9E-02
Benzo(b)fluoranthene	8.1E-08	2.7E-04	Molybdenum	5.0E-05	1.6E-01
Benzo(g,h,i)perylene	5.4E-08	1.8E-04	Naphthalene	2.7E-05	9.1E-02
Benzo(k)fluoranthene	8.1E-08	2.7E-04	Nickel	9.5E-05	3.1E-01
Beryllium	5.4E-07	1.8E-03	Pentane(n)	1.2E-01	3.9E+02
Butane	9.5E-02	3.1E+02	Phenanthrene	7.7E-07	2.5E-03
Cadmium	5.0E-05	1.6E-01	Propane	7.2E-02	2.4E+02
Chromium	6.3E-05	2.1E-01	Pyrene	2.3E-07	7.5E-04
Chrysene	8.1E-08	2.7E-04	Selenium	1.1E-06	3.6E-03
Cobalt	3.8E-06	1.3E-02	Toluene	1.5E-04	5.1E-01
Copper	3.8E-05	1.3E-01	Vanadium	1.0E-04	3.4E-01
Dibenzo(a,h)anthracene	5.4E-08	1.8E-04			
Dichlorobenzene	5.4E-05	1.8E-01			

^a Emission factors from EPA (2000a).

TABLE 4.20 Estimated Hourly and Annual TAP Emission Rates during Emergency Diesel Generator Operations for Neutralization/SCWO at PCD^a

Compound	Hourly Emission (lb/h)	Annual Emission (lb/yr)
Acenaphthene	3.1E-07	1.9E-04
Acenaphthylene	1.1E-06	6.7E-04
Acetaldehyde	1.7E-04	1.0E-01
Acrolein	2.0E-05	1.2E-02
Aldehydes	1.5E-02	9.2E+00
Anthracene	4.1E-07	2.5E-04
Benzene	2.0E-04	1.2E-01
Benzo (a) anthracene	3.7E-07	2.2E-04
Benzo (a) pyrene	4.1E-08	2.5E-05
Benzo (b) fluoranthene	2.2E-08	1.3E-05
Benzo (g,h,i) perylene	1.1E-07	6.4E-05
Benzo (k) fluoranthene	3.4E-08	2.0E-05
1,3-Butadiene	8.6E-06	5.1E-03
Chrysene	7.8E-08	4.6E-05
Dibenzo(a,h) anthracene	1.3E-07	7.7E-05
Fluoranthene	1.7E-06	1.0E-03
Fluorene	6.4E-06	3.8E-03
Formaldehyde	2.6E-04	1.6E-01
Indeno(1,2,3-cd)pyrene	8.2E-08	4.9E-05
Isomers of xylene	6.3E-05	3.7E-02
Mercury	6.6E-08	4.0E-05
Naphthalene	1.9E-05	1.1E-02
Phenanthrene	6.5E-06	3.9E-03
Polycyclic aromatic hydrocarbons (PAHs)	3.7E-05	2.2E-02
Propylene	5.7E-04	3.4E-01
Pyrene	1.0E-06	6.3E-04
Toluene	9.0E-05	5.4E-02

^a Emission factors from EPA (2000a).

Table 4.22 gives the estimated TAP emission rates during operations from the SCWO stack for mustard agent processing. Annual emission rates can be estimated from the daily values, assuming 276 days of actual operations per year.

Emissions from operations worker commuter vehicles were estimated on the basis of the assumption that an average of 635 automobiles (1 car per operations worker) would be added to the area of the site and that each worker would drive an average of 20 mi (32 km) to the site. Annual emission estimates due to the increased traffic are presented in Table 4.23.

TABLE 4.21 Estimated Maximum Hourly and Annual Agent Emission Rates from the Filter Farm Stack for Neutralization/SCWO at PCD

Chemical Agent	Emission Factor (mg/m ³) ^a	Stack Exit Gas Flow (acfm) ^b	Hours of Operation per Year ^c	Stack Emission Rate	
				lb/h	tons/yr ^d
HD, HT	0.006	96,000	3,312	2.2E-03	3.6E-03

- ^a Based on the monitor level of quantification, which is 20% of the allowable stack concentration recommended for each chemical agent in 53 CFR 8504-8507.
- ^b Filter farm stack exit flow based on building ventilation for the MDB.
- ^c Hours of operations based on the assumption that each pilot plant operates at the design throughputs specified in CBDCOM (1997).
- ^d Estimate based on the number of hours of operation per year.

TABLE 4.22 Estimated TAP Emission Rates from the SCWO Stack during Neutralization/SCWO of ACW Containing Mustard Agent at PCD^a

Compound ^b	Emission Rate (lb/d)	Compound	Emission Rate (lb/d)
Acetaldehyde	1E-12	Methyl ethyl ketone/butyraldehydes	5E-13
Antimony	2E-12	Nickel	1E-11
Arsenic	7E-13	Particulates	7E-10
Beryllium	1E-13	Phosphorus	2E-10
Cadmium	1E-13	Selenium	7E-13
Chromium	4E-12	Total HpCDF	2E-21
Cobalt	1E-12	Ethyl benzene	1E-11
Formaldehyde	2E-12	p-cresol (4-Methylphenol)	1E-12
Lead	2E-12	Total TCDD	1E-17
Manganese	4E-12		

- ^a Annual emissions can be estimated on the basis of the assumption that there are 276 days of operations per year.
- ^b Abbreviations: HpCDF = heptachlorodibenzo-p-furan; TCDD = 2,3,7,8-tetrachlorodibenzo-p-dioxin.

TABLE 4.23 Estimated Emissions from Worker Commuter Vehicles for Neutralization/SCWO Operations at PCD

Criteria Pollutant	No. of Auto Round Trips ^a	Emission Factor (g/km) ^b	One-Way Trip Distance (mi) ^c	Emission Rate (tons/yr)
HC	175,000	1.16	20	14.4
CO	175,000	11.38	20	141.5
NO _x	175,000	0.73	20	9.1
SO _x	175,000	0.12	20	1.5
PM ₁₀	175,000	0.055	20	0.68

^a Number of auto round trips to the operation site was estimated on the basis of the annual operating workforce and 276 days of operation per year.

^b Emission factors were determined by using EPA modeling software MOBILE5b (EPA 2000c for HC, CO, and NO_x, and PART5 (EPA 2000b) for PM₁₀.

^c One-way trip distance based on DOE (1997).

Liquid Wastes. As indicated previously, brine liquids from the SCWO units would be sent to the BRA, where they would be dried to form brine salts. Other liquids, such as spent decontamination solutions and laboratory wastes, would be fed to the SCWO units. Domestic sewage is the only liquid effluent expected to be generated at the facility. Small amounts of hazardous liquids could be generated from chemical makeup and reagents for support activities; the quantities may be minor compared to those for domestic sewage (sanitary waste). Sanitary wastes would be managed on-site.

Solid Wastes. The major process solid residuals expected from the neutralization/SCWO operation include the following:

- Brine salts from treatment of the SCWO effluent,
- Decontaminated (5X condition) scrap metal from the HDCs and the inductively heated MPF, and
- Decontaminated (5X condition) Al(OH)₃ salts removed from the energetics hydrolysates and thermally treated in the inductively heated MPF.

The effluent from the SCWO unit would be sent to an evaporator that produces a filter cake with about 70% solids. The water content is bound as water of hydration; free-standing liquid is not expected (NCD 1998b). The filter cake would be transported to an approved off-site hazardous waste treatment, storage, and disposal facility for additional treatment and/or ultimate disposal. Table 4.24 provides information on the chemical composition of the brine salts (filter cake).

TABLE 4.24 Estimated Generation Rates of Brine Salts from Neutralization/SCWO at PCD To Be Sent Off-Site for Land Disposal

Compound ^a	Generation Rate (lb/d)	Compound ^a	Generation Rate (lb/d)
1,2,3,4,6,7,8-HpCDD	9.2E-10	Mercury	8.0E-05
1,2,3,4,6,7,8-HpCDF	8.0E-11	Molybdenum	1.1E+00
2-Butanone	4.8E-04	Naphthalene	1.2E-04
Acetaldehyde	9.5E-03	Nickel	2.6E+00
Aluminum	2.6E-01	Nitrate	1.0E+00
Antimony	3.9E-02	Nitrite	1.2E+00
Barium	4.3E-03	OCDD	3.9E-09
Bis(2-Ethylhexyl)phthalate	7.3E-04	Phenol	7.3E-05
Cadmium	1.8E-02	Potassium	1.6E-01
Calcium	1.0E-01	Selenium	1.9E-03
Chloride	9.4E+01	Siloxane	4.8E-03
Chloromethane	3.6E-04	Silver	3.2E-03
Chromium	7.5E-01	Sodium chloride	5.2E+03
Cobalt	1.0E-02	Sodium phosphate	3.5E+02
Copper	4.8E-01	Sodium sulfate	6.5E+03
Cyclohexanone	3.0E-02	Sulfide, reactive	5.1E-01
Di-n-butylphthalate	1.3E-04	TCDD	6.5E-10
Formaldehyde	3.6E-03	Vanadium	2.5E-03
Iron	1.4E+00	Water in salt cake	1.8E+03
Lead	6.0E-01	Zinc	6.2E-01
Magnesium	1.3E-01	Total	1.4E+04
Manganese	4.9E-02		

^a Abbreviations: OCDD = octachlorodibenzo-p-dioxin, TCDD = 2,3,7,8-tetrachlorodibenzo-p-dioxin.

Nonhazardous scrap metal (5X condition) from the munition bodies would be sold to a scrap dealer or smelter for reuse, if approved by the regulatory authority (see Table 4.25). However, if necessary, these metals could be disposed of off-site in a nonhazardous waste landfill, or in a RCRA-permitted hazardous waste landfill. Brine salts would be disposed of off-site in a permitted hazardous waste landfill. Currently, the U.S. Army does not intend to dispose of any waste materials from the destruction process on-site. Table 4.26 gives the amounts of other process-related wastes.

Nonprocess waste streams would include decon solution, DPE suits, spent carbon, waste oils, trash, debris, and spent hydraulic fluid, which are assumed to be potentially agent-contaminated and would be processed in the dunnage/waste processing system. After this processing, the only streams with a significant solid residue would be the decontamination

TABLE 4.25 Estimated Generation Rates of 5X Solids from Neutralization/SCWO at PCD To Be Sent Off-Site for Land Disposal or Recycling

Compound	Generation Rate (lb/d)
Steel/iron	5.0E+04
Aluminum	1.9E+02
Copper	1.1E+03
Zinc	1.9E+02
Total	5.2E+04

TABLE 4.26 Estimated Generation Rates of Other Solid Wastes from Neutralization/SCWO at PCD To Be Sent Off-Site for Land Disposal or Recycling

Compound	Generation Rate (lb/day)
Metal from dunnage	9.5E+02
Al(OH) ₃ ^a	0.0E+00

^a A zero effluent rate was estimated because the ACW inventory at PCD does not include aluminum oxides (glass).

solution (containing NaOH and sodium hypochlorite [NaOCl]) and miscellaneous metal parts from equipment operation. Table 4.27 provides information on the daily and annual generation rates of treated nonprocess wastes for ACW containing mustard agent. Annual waste generation rates can be estimated from the daily values, assuming 276 days of actual operations per year for agent processing (total campaign length of 731 days for mustard agent processing).

The above waste streams may be shipped from the on-site facility to off-site locations. Table 4.28 provides transportation data for annual shipment of these waste streams during processing of ACW containing mustard agent. It was assumed that all wastes would be packaged in 55-gal (208-L) drums prior to off-site shipment.

Table 4.29 lists the types and quantities of nonhazardous (nonprocess) solid and liquid wastes that could be generated from operation of the facility. Waste generation rates are based on historic data on building size, utility requirements, and facility workforce.

TABLE 4.27 Calculated Quantities of Solid Residues from Nonprocess Wastes from Neutralization/SCWO of ACW Containing Mustard Agent at PCD

Waste Type	Inlet Waste Composition	Treatment Process	Product	Daily Quantity (lb/d)	Annual Quantity (tons/yr)
Decon solution	18 wt% NaOH, NaOCl ^a	SCWO	Brine, 15% water	1,400	11.3
Miscellaneous metal parts	Nonmunition scrap metal	MPF	100% metal	430	3.5
Total				1,800	15

^a Source: APG (1997).

TABLE 4.28 Transportation Data for Solid Wastes from Neutralization/SCWO at PCD during Processing of ACW Containing Mustard Agent

Type of Data	Output Material No. 1	Output Material No. 2	Output Material No. 3	Output Material No. 4
Transported materials				
Type/chemical	Brine salts - waste	5X solids - waste	Other wastes	Nonprocess waste
Physical form	Solid	Solid	Solid	Solid
Chemical composition/ temperature, pressure	See Table 4.24	See Table 4.25	See Table 4.26	See Table 4.27
Packaging				
Type	55-gal drum	55-gal drum	55-gal drum	55-gal drum
Container volume (ft ³) ^a	7.35	7.35	7.35	7.35
Certified by	DOT	DOT	DOT	DOT
Identifier	Varies	Varies	Varies	Varies
Container weight (lb)	50	50	50	50
Material weight (lb)	1,060	450	450	494
Chemical content (wt%)	See Table 4.24	See Table 4.25	See Table 4.26	See Table 4.27
Shipments				
Average weight (tons/yr) ^b	1,867	7,164	131	248
Average Volume (ft ³ /yr)	26,110	238,270	4,340	7,411
Packages/yr	3,552	32,407	591	1,008
Packages/shipment	36	48	48	48
Shipments/yr	99	676	13	21
Form of transport/routing				
Form of transportation	Truck	Truck	Truck	Truck
Destination – facility type	Land disposal ^c	Land disposal ^c	Land disposal ^c	Land disposal ^b

^a Review of the disassembly process indicates that the dimensions of the 5X solids would allow disposal in standard 55-gal drums. Further validation with the technology provider may be required.

^b Estimated based on 276 days of operations per year.

^c Depending on the test for hazardous constituents, off-site disposal at a RCRA-permitted facility may be required.

TABLE 4.29 Estimated Annual Nonhazardous (Nonprocess) Waste Generated during Neutralization/SCWO Operations at PCD

Category	Solid (yd ³)	Liquid (gal)
Nonhazardous (sanitary) wastes	NA ^a	4.1E+06
Nonhazardous (other) wastes ^b	1,600	NA
Recyclable wastes ^c	640	NA

^a NA = not applicable.

^b Nonhazardous (other) wastes include domestic trash and office waste.

^c Recyclable wastes include paper, aluminum, etc., generated by the facility.

Source: Mitretek (2001b).

4.3.2.4 Activities

The PMACWA described activities for installation of the neutralization/SCWO system (PMACWA 1999a). The major phases of the project are shown in Table 4.30.

4.3.2.5 Uncertainties

Each of the individual technologies that forms the neutralization/SCWO system has either previously proven to be successful or has been demonstrated by the PMACWA to be an acceptable technology for application at PCD. However, demonstration testing focused on individual technologies and sometimes employed less than full-scale units. In addition, although EDSs were conducted to evaluate the long-term adequacy of individual technologies, it was not possible to evaluate the long-term viability and performance of the entire, integrated treatment system. The primary uncertainty associated with neutralization/SCWO is that the entire, integrated treatment system with all its component units has not been assembled and tested. The pilot program, if implemented for this technology system, would be designed to evaluate overall operability and long-term performance.

TABLE 4.30 Activities for Neutralization/SCWO at PCD

Key Milestones
EIS Start
EDS testing start
Final EIS/ROD
Final design (65% completion)
RCRA Part B issued
MDB construction start
MDB construction finish
Systemization start (pilot train)
Systemization start (all trains)
Operations start
Operations finish

Source: PMACWA (1999a).

4.3.3 NEUTRALIZATION/BIOTREATMENT

This description of the neutralization/biotreatment facility is based on the preliminary design information provided in Parsons/Allied Signal (1999). As indicated in that report, many of the estimates provided for facility design refer comparatively to the U.S. Army baseline incineration process, which indicates, in general, that the estimates are comparable to those for the baseline incineration process (Parsons/Allied Signal 1999). Thus, one of the primary sources of information for this section is the EIS for disposal of chemical agents and munitions stored at Pine Bluff Arsenal, Arkansas (PMCD 1997). That is the most recent EIS that the Army has completed for baseline incineration of chemical munitions.

In addition, mass balance estimates, air emission estimates, and solid waste estimates have been developed for application of the neutralization/biotreatment technology at PCD (Mitretek 2001a). Air emissions and solid waste estimates for neutralization/biotreatment, as discussed below, are based on Mitretek inputs (Mitretek 2001a), along with appropriate assumptions on filtration systems and plant operations and schedule. Figure 4.16 provides an input/material balance for the major streams for neutralization/biotreatment of ACW containing mustard agent.

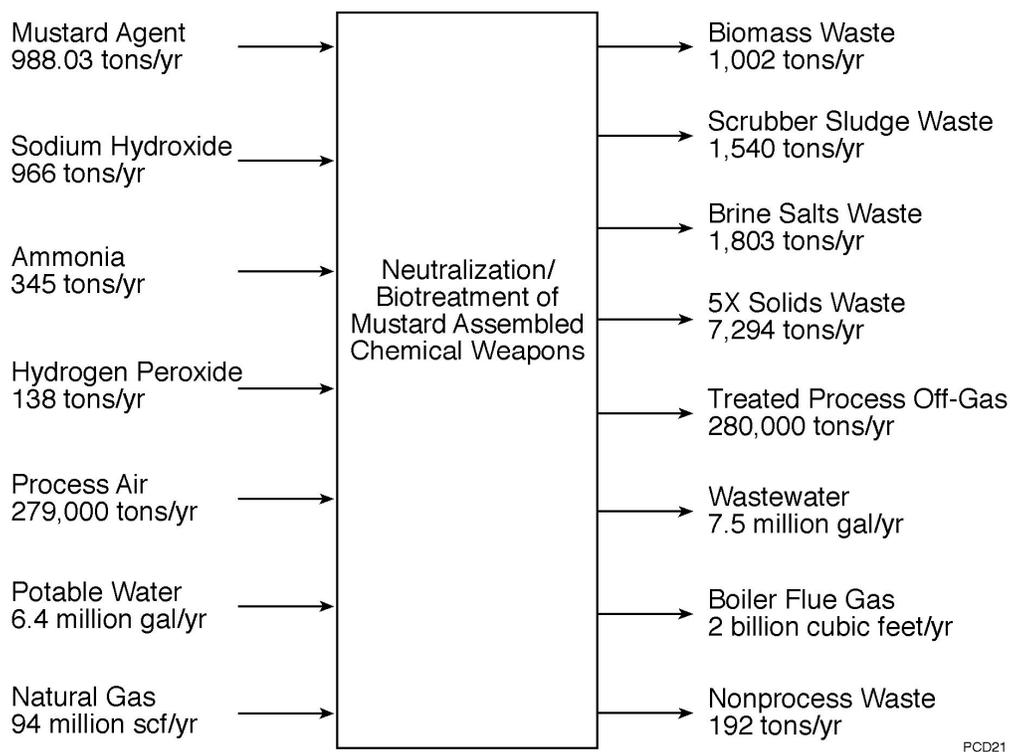


FIGURE 4.16 Input/Output Material Balance for Neutralization/Biotreatment of ACW Containing Mustard Agent at PCD

Many of the figures and tables referred to in the facility description for this technology system contain estimates (e.g., emissions, resources consumed) associated with processing ACW with a specified agent; these estimates are given on an annual basis (e.g., tons/yr). In some cases, the estimates have been converted from other units (e.g., lb/d) by accounting for the number of days of operation required for processing a specific type of ACW. This time period is referred to as a campaign; a campaign is agent-specific. The values in many of the following figures and tables are based on the number of days in the campaign required to process ACW containing a specific agent. It was assumed that there are 276 operating days in a year. If the campaign is less than or equal to 276 days, annual quantities equal total quantities. If the campaign is greater than 276 days, quantities in the figures and tables are for 276 days of processing. In the latter case, the estimates provided are less than total quantities. Daily (or other) quantities may be obtained by adjusting for the number of days in the campaign.

4.3.3.1 General Facility Description

The proposed neutralization/biotreatment facility is designed to fit into approximately the same space and general configuration as the baseline incineration process. Munitions access and disassembly, base hydrolysis, and biotreatment operations have been substituted for baseline incineration operations. The physical plant consists of a two-story building constructed of noncombustible materials, with a concrete structural frame and a low-slope concrete roof.

The site layout for the neutralization/biotreatment facility at PCD is shown in Figures 4.17 through 4.19. Figure 4.17 shows the layout of the first floor, Figure 4.18 shows the layout of the second floor, and Figure 4.19 shows the layout for the biotreatment operation. The biotreatment units would be physically located outside the two-story building.

4.3.3.2 Construction Phase

The schedule for demilitarization of the stockpile at PCD, although tentative, calls for construction of the selected alternative to begin following issuance of the EIS ROD and receipt of the RCRA and other required environmental permits, as necessary. It is anticipated that construction of the neutralization/biotreatment facility would not differ significantly from that required for baseline incineration. Construction would take approximately 32 months (PMCD 1997), including a 2-month design and procurement verification period. However, the PMACWA is investigating various means of shortening the construction phase.

Construction of the destruction facility on the PCD installation would result in vehicle exhaust emissions, fugitive dust, noise, destruction of wildlife habitat and native vegetation, increased employment, increased demand for public services, and occupational health hazards.

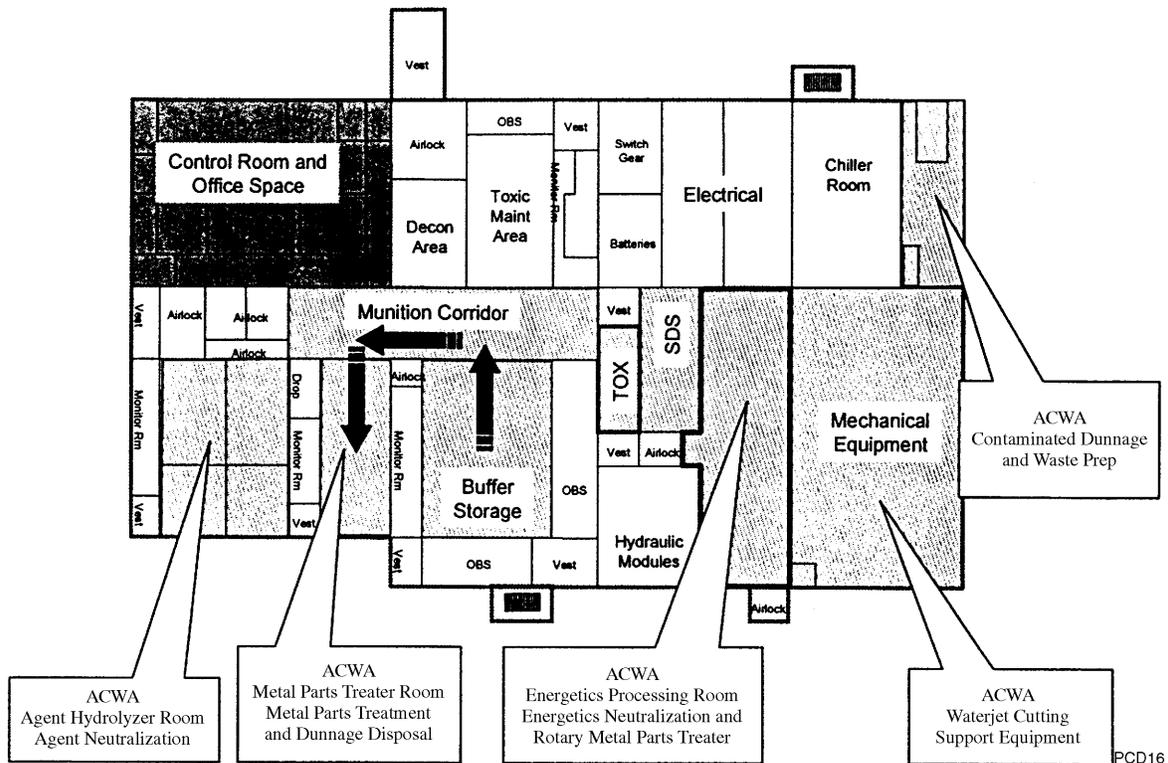


FIGURE 4.17 Layout of First Floor of Neutralization/Biotreatment Facility at PCD
(Source: Parsons/Allied Signal 1999)

4.3.3.2.1 Construction Inputs and Resource Requirements

The PMACWA has estimated that the capital cost for the neutralization/biotreatment process would be approximately 10% less than that required for construction of the baseline incineration system (PMACWA 1999b). Resources needed for facility construction include water, electricity, concrete, steel, liquid fuels, lumber, and industrial gases (e.g., propane). Table 4.31 gives estimates of the construction materials that could be consumed during construction.

The process equipment would be purchased from equipment vendors. The total quantities of commonly used construction material (e.g., steel) would be minor compared to the quantities given in Table 4.31. Specialty materials, such as Inconel or Monel, do not appear to be required. However, the bioreactors may require specialty materials in the final design (PMACWA 1999a).

Table 4.32 provides an order-of-magnitude estimate of the number of shipments of construction materials to the site. The estimate does not include shipments of process equipment and related items; the number of shipments associated with those resources is expected to be small in comparison with the estimate of 5,000 total shipments for construction materials.

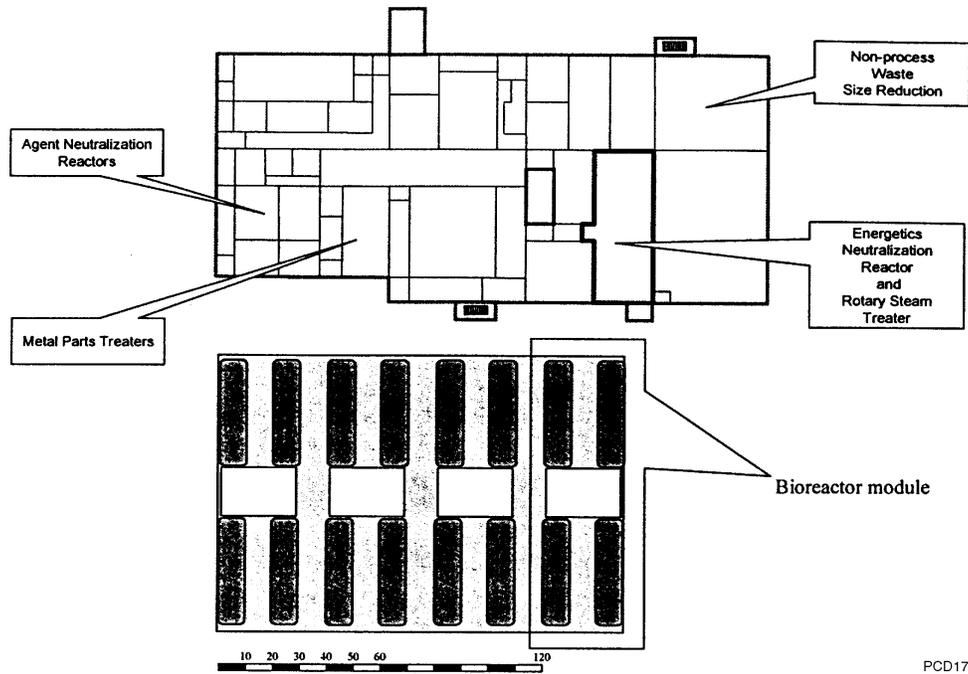


FIGURE 4.18 Layout of Second Floor of Neutralization/Biotreatment Facility at PCD (Source: Parsons/Allied Signal 1999)

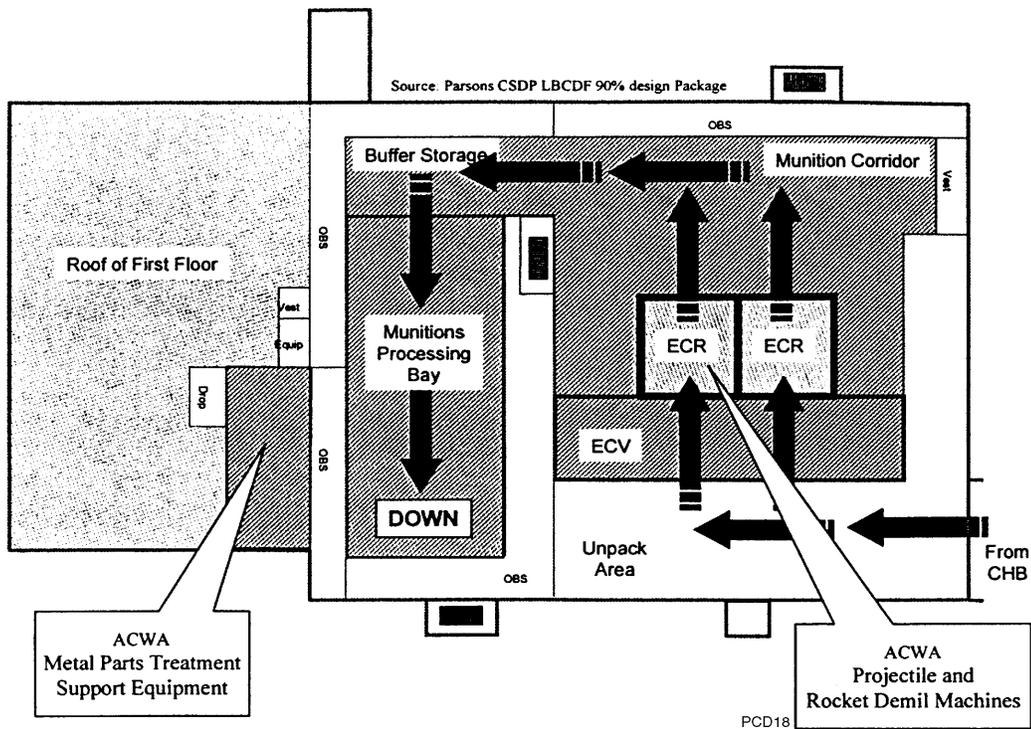


FIGURE 4.19 Layout of Biotreatment Operation of Neutralization/Biotreatment Facility at PCD (Source: Parsons/Allied Signal 1999)

TABLE 4.31 Estimated Materials/Resources Consumed during Construction of a Neutralization/Biotreatment Facility at PCD^a

Construction Material/Resource	Total Consumption	Peak Demand
Utilities		
Water ^b	7,000,000 gal	NA ^c
Electricity	46,000 MWh	2.3 MW
Solids		
Concrete	30,100 yd ³	NA
Steel (structural and reinforcing)	6,400 tons	NA
Piping (all)	116,000 linear ft	
Liquids		
Fuel	2.3E+06 gal	NA
Gases		
Industrial gases (propane)	6,100 gal	NA

a All values are order-of-magnitude approximations of the actual values; more accurate values would require a detailed consideration of construction activities.

b The water requirement was estimated on the basis of DOE (1997), in which each FTE required 20 gal/d, and solidification required 26 lb per 100 lb of cement.

c NA = not applicable.

An order-of-magnitude estimate of the emissions from construction delivery vehicles to the site is provided in Table 4.33, assuming a one-way trip distance of 20 mi (32 km) and delivery by heavy-duty diesel trucks. The actual trip distances would depend on a number of factors, including the availability of construction materials from local distributors and the distance of the site from the local distributors.

4.3.3.2.2 Construction Workforce

The construction workforce is expected to steadily increase to a peak of about 830 FTEs near the midpoint of the construction period, and then to decrease steadily until construction is completed. The average number of construction workers is estimated to be approximately 390 FTEs. Assuming a 32-month construction period, approximately 1,100-FTE-years of effort would be expended during construction. Table 4.34 provides an estimate of the employment buildup by year during construction.

TABLE 4.32 Order-of-Magnitude Estimate of the Number of Truck Shipments of Construction Materials for Construction of a Neutralization/Biotreatment Facility at PCD^a

Resource	Total Consumption	Truck Capacity	No. Truck Shipments
Portland cement ^b	3,311 yd ³	10 yd ³	332
Gravel ^b	12,341 yd ³	10 yd ³	1,235
Sand ^b	7,826 yd ³	10 yd ³	783
Steel ^c	6,400 tons	21 tons	310
Asphalt paving ^d	1,100 tons	20 tons	55
Backfill ^e	10,800 yd ³	10 yd ³	1,080
Fuel ^f	2.3E+06 gal	9,000 gal	260
Total			4,055
Total (rounded up)			5,000

^a The calculation did not include truck deliveries of process equipment and related items.

^b Assumes that concrete is composed of 11% portland cement, 41% gravel, and 26% sand and is shipped to the site in a standard 10-yd³ end-dump truck.

^c Assumes that the net payload for steel transport to the site is 42,000 lb.

^d Assumes HMA is loaded into 20-ton-capacity triaxle trucks for transport to the paving site.

^e Assumes shipment using standard 10-yd³ end-dump trucks.

^f Assumes shipment in a DOT 406/MC-306 atmospheric pressure tank truck with a 9,000-gal capacity.

TABLE 4.33 Estimated Emissions from Delivery Vehicles during Construction of a Neutralization/Biotreatment Facility at PCD

Criteria Pollutant	No. of Auto Round Trips ^a	Emission Factor (g/km) ^b	One-Way Trip Distance (mi) ^c	Construction Period (yr)	Emission Rate (tons/yr)
HC	5,000	2.12	20	2.7	0.3
CO	5,000	11.28	20	2.7	1.5
NO _x	5,000	1.25	20	2.7	0.2
SO _x	5,000	0.23	20	2.7	0.03
PM ₁₀	5,000	0.617	20	2.7	0.1

^a Number of auto round trips to the construction site was estimated on the basis of the total number of deliveries.

^b Emission factors were determined by using EPA modeling software MOBILE5b (EPA 2000c) for HC, CO, and NO_x, and PART5 (EPA 2000b) for PM₁₀.

^c One-way trip distance based on DOE (1997).

TABLE 4.34 Estimated Number of Employees Needed by Year for Construction of a Neutralization/Biotreatment Facility at PCD

Employees	Year 1	Year 2	Year 3
Total craft workers	260	510	110
Construction management and support staff	60	130	30
Total	320	640	140

4.3.2.2.3 Construction Emissions and Waste Estimates

During the construction phase, fugitive emissions would consist primarily of dust and vehicle emissions. Temporary, regional increases in atmospheric concentrations of CO, NO_x, hydrocarbons, particulate matter, and SO₂ would result from the exhaust emissions of commuter vehicles, heavy construction vehicles, diesel generators, and other machinery and tools. Annual emissions of these pollutants would be small in comparison to de minimis levels typically used by regulators to determine whether an air quality permit or impact analysis is necessary. Emissions from construction vehicles are exempt from permit requirements. Nevertheless, vehicles and machinery would be equipped with standard pollution control devices to minimize air quality impacts.

Table 4.35 gives the estimated emissions from construction activities. The emissions shown are based on the anticipated construction land disturbance and vehicle traffic (for dust particulate pollutants) and fuel and gas consumption. The column marked "Total" indicates the total amount of emissions that is estimated to occur over the entire construction period.

Emissions from construction worker commuter vehicles were estimated on the basis of the assumption that an average of 387 automobiles (1 car per construction worker) would be added to the area. Annual emission estimates due to the increased traffic are presented in Table 4.36.

Additional emissions would result from the use of paints and thinners, aerosols, and other area source emissions. These emissions are expected to be minor contributors to air pollution, however, and were not included in current estimates.

TABLE 4.35 Estimated Emissions during Construction of a Neutralization/Biotreatment Facility at PCD

Criteria Pollutant	Total (tons)	Annual (tons/yr)
CO	115	43
HC	48	18
NO _x	171	64
SO _x	12	4
PM ₁₀	377	141

TABLE 4.36 Estimated Emissions from Worker Commuter Vehicles during Construction of a Neutralization/Biotreatment Facility at PCD

Criteria Pollutant	No. of Auto Round Trips ^a	Emission Factor (g/km) ^b	One-Way Trip Distance (mi) ^c	Emission Rate (tons/yr)
HC	92,000	1.16	20	7.6
CO	92,000	11.38	20	75.0
NO _x	92,000	0.73	20	4.8
SO _x	92,000	0.12	20	0.8
PM ₁₀	92,000	0.055	20	0.4

^a Number of round trips to the construction site was estimated on the basis of the average construction workforce and 240 workdays per year.

^b Emission factors were determined by using EPA modeling software MOBILE5b (EPA 2000c) for HC, CO, and NO_x, and PART5 (EPA 2000b) for PM₁₀.

^c One-way trip distance based on DOE (1997).

Construction would generate solid wastes primarily in the form of excavation spoils and building material debris. These latter wastes would include concrete forms, equipment and hardware containers and packaging, paint cans, waste metal sheeting, pipe and wire, and landscaping debris. Small amounts of liquid wastes, such as solvents, cleaning solutions, and paint wastes, would also be generated. Wastes would be collected and disposed of in accordance with U.S. Army, federal, state, and local requirements. All construction debris would be removed from the site for disposal. Any batteries, used motor oils, and empty paint, solvent, and adhesive containers would be separated from the waste stream and recycled. Any wastes that are identified as hazardous would be stored and disposed of according to RCRA requirements. Sanitary wastes would be the only significant liquid effluents generated during construction.

Table 4.37 gives the estimated total quantities of solid and liquid wastes generated from activities associated with facility construction. The waste generation quantities are based on historic data on land area size and the construction labor force.

4.3.3.3 Operations Phase

Information on the operations phase of facility operations is presented in this section. Preoperational testing is discussed first, followed by facility inputs and resource requirements, workforce requirements, and emissions and waste estimates.

4.3.3.3.1 Preoperational Testing

A preoperational testing period assumed to last 18 months would begin following facility construction (Parsons/Allied Signal 1999). Often referred to as systemization, this period would be used to ensure that systems are operating as designed prior to full-scale operations. On the basis of the similarity with baseline operations, it is projected that a workforce of 315 FTEs would be needed at the peak of preoperational testing.

4.3.3.3.2 Operations Inputs and Resource Requirements

At full-scale operation, destruction of the mustard agent inventory at PCD is projected to require 731 days (Mitretek 2001a). Assuming 276 operating days per year, destruction operations would require about 32 calendar months (PMACWA 1999b) (see Table 4.38). The technology provider, however, estimates an operation duration of about 159 weeks, or about 37 months (Parsons/Allied Signal 1999).³⁸ This duration is based on a 12-hours-per shift, 6-days-per-week operation, 46 weeks per year.

Table 4.39 gives the annual utility consumption for facility operation, including electricity, fuel, and potable water usage. Process water requirements could not be ascertained from the information supplied by the technology provider. A qualitative assessment, however, indicates that there are no expected exceptional requirements. Water recovery and recycling may further mitigate water use. Table 4.40 shows annual usage of consumable chemicals and process materials. These estimates were based on an assumed average or normal throughput.

Transportation data for annual shipment of input material streams into the PCD are presented in Table 4.41. Hazardous materials shipped to the site include corrosives such as NaOH and sulfuric acid (H₂SO₄), oxidizer corrosives (H₂O₂), and nonflammable gases (ammonia [NH₃]).

TABLE 4.37 Estimated Total Wastes Generated during Construction of a Neutralization/Biotreatment Facility at PCD

Waste Category	Quantity
Hazardous solids	80 yd ³
Hazardous liquids	31,000 gal
Nonhazardous solids	
Concrete ^a	200 yd ³
Steel ^b	32 tons
Other ^c	1,600 yd ³
Nonhazardous Liquids	
Sanitary ^d	4.5 E+06 gal
Other	2.0 E+06 gal

- ^a Amount of concrete (non-hazardous solid) waste was estimated by assuming that 0.65% of concrete usage is spoilage.
- ^b Amount of steel waste stream was estimated as 0.5% of the steel requirement on the basis of LLNL et al. (1997).
- ^c Amount of other stream was estimated as 8 times the concrete stream on the basis of LLNL et al. (1997).
- ^d Amount of sanitary waste was estimated on the basis of the total construction workforce.

³⁸ The full-scale scenario has been selected as the bounding case for this analysis.

TABLE 4.38 Inventory and Estimated Processing Time for Neutralization/Biotreatment of ACW Containing Mustard Agent Stored at PCD

Munition	Quantity	Agent	Processing Rate (no. of munitions/h)	Processing Time		Changeover (weeks)	Total (weeks)
				Hours	Weeks ^a		
105-mm cartridge	383,418	HD	100	3,834	53.3	0.0	53.3
155-mm projectile	299,554	HD	100	2,996	41.6	2.0	43.6
4.2-in. cartridge	76,722	HD	50	1,534	21.3	2.0	23.3
4.2-in. cartridge	20,384	HT	50	408	5.7	2.0	7.7
Total	780,078			8,772	121.8	6.0	127.8
Total no. of months					30.5	1.5	32.0

^a Estimated by assuming operations of 6 days per week and 12 hours per day.

TABLE 4.39 Estimated Utilities Consumed during Destruction of ACW at the Neutralization/Biotreatment Facility at PCD

Utility	Average Daily Consumption	Peak-Day Consumption	Annual Consumption
Process water ^a	47,000 gal/d	1,100 gal/min	13,000,000 gal/yr ^c
Potable water ^b	17,500 gal/d	180 gal/min	6,400,000 gal/yr ^c
Fire water ^b	NA ^d	3,000 gal/min	NA
Sanitary sewer ^b	20,650 gal/d	395 gal/min	7,500,000 gal/yr ^c
Natural gas ^a	340,000 scf/h	27,000 scf/h	94,000,000 scf/yr ^e
Fuel oil	962 gal/d	406 gal/h	48,000 gal/yr ^f
Electricity	98 MWh	4.8 MW	35.7 GWh ^{c,g}

^a Estimated based on the ratio of the mustard agent processing rate at PCD to that at the Aberdeen Chemical Agent Disposal Facility.

^b Assumed to be similar to incineration because the number of operations and maintenance personnel and the land area are unchanged from incineration (PMCD 1997).

^c Based on 365 days per year.

^d NA = not applicable.

^e Based on 276 days of operation per year.

^f Estimated on the basis of 600 hours of emergency diesel generator operation per year.

^g Based on an annual power rating of 80%.

Source: COE (1987).

TABLE 4.40 Estimated Raw Materials Consumed Annually during Normal Neutralization/Biotreatment Operations at PCD

Material	Average Daily Consumption (lb/d)	Annual Consumption (tons/yr) ^a
Air for biotreater	2,000,000	280,000
Sodium hydroxide (NaOH)	7,000	970
Water (in caustic solution)	7,000	970
Sulfuric acid (H ₂ SO ₄)	245	34
Dipotassium phosphate (K ₂ HPO ₄)	333	46
Magnesium chloride (MgCl ₂)	125	17
Calcium chloride (CaCl ₂)	125	17
Ammonium phosphate ([NH ₄] ₂ HPO ₄)	624	86
Ammonia (NH ₃)	2,500	350
Ferrous sulfate (FeSO ₄)	42	6
Hydrogen peroxide (H ₂ O ₂)	999	138

^a Estimated by assuming 38% availability of operations (276 days per year, 12 hours per day).

Source: Mitretek (2001a).

4.3.3.3 Operations Workforce

The neutralization/biotreatment facility would be a government-owned, contractor-operated facility. The technology provider expects operating and maintenance labor for neutralization/biotreatment to be similar to that required for baseline incineration. Therefore, this analysis assumed that the estimated operations workforce needs are approximately 465 contractor employees for plant operations (Parsons 1995) and 170 government employees for munition handling, security, oversight, and other support activities (PMCD 1997).

4.3.3.4 Operations Emissions and Waste Estimates

Wastes from the neutralization/biotreatment process would include air emissions and solid wastes. According to the technology provider, the only liquid effluent expected from the facility would be sanitary waste. All liquids generated by the agent neutralization/biotreatment process and all liquid laboratory wastes would be disposed of internally by neutralization/biotreatment. Disposal facility operations, including waste management, would comply with U.S. Army, federal, state, and local requirements. Any wastes that are identified as hazardous would be stored and disposed of in accordance with RCRA requirements. A summary of the types of emissions and solid wastes is provided below.

TABLE 4.41 Transportation Data for Raw Materials for Neutralization/Biotreatment of ACW at PCD

Type of Data	Input Material No. 1	Input Material No. 2	Input Material No. 3	Input Material No. 4	Input Material No. 5
Transported materials					
Type/chemical	NaOH	H ₂ SO ₄	K ₂ HPO ₄	MgCl ₂	CaCl ₂
Physical form	Liquid	Liquid	Solid, granular	Solid, granular	Solid, granular
Chemical composition/temperature, pressure	NaOH/ ambient	H ₂ SO ₄ / ambient	K ₂ HPO ₄ / ambient	MgCl ₂ / ambient	CaCl ₂ / ambient
Packaging					
Type	55-gal drum	55-gal drum	55-gal drum	55-gal drum	55-gal drum
Container volume (ft ³)	7.35	7.35	7.35	7.35	7.35
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	Varies	Varies	Varies	Varies	Varies
Container weight (lb)	50	50	50	50	50
Material weight (lb)	700	840	1,080	1,060	990
Chemical content (wt%)	50% NaOH	93% H ₂ SO ₄	100% K ₂ HPO ₄	100% MgCl ₂	100% CaCl ₂
Shipments					
Average weight (tons/yr)	965.8	33.8	46.0	17.2	17.2
Average volume (ft ³ /yr)	20,524	593	629	240	257
Packages/yr	2,792	81	86	33	35
Packages/shipment	26	81	86	33	35
Shipments/yr	108	1	1	1	1
Form of transport/routing					
Form of transportation	Truck	Truck	Truck	Truck	Truck
Type of Data	Input Material No. 6	Input Material No. 7	Input Material No. 8	Input Material No. 9	
Transported materials					
Type/chemical	(NH ₄) ₂ HPO ₄	NH ₃	FeSO ₄	H ₂ O ₂	
Physical form	Solid, granular	Liquid	Solid, granular	Liquid	
Chemical composition/temperature, pressure	(NH ₄) ₂ HPO ₄ / ambient	NH ₃ /100 °F, 197 psig (max.)	FeSO ₄ /ambient	H ₂ O ₂ /ambient	
Packaging					
Type	55-gal drum	Tank truck 5,500-gal	55-gal drum	55-gal poly drum	
Container volume (ft ³)	7.35	735.24	7.35	7.35	
Certified by	DOT	DOT	DOT	DOT	
Identifier	Varies	MC-330, 331	Varies	Varies	
Container weight (lb)	50	N/A	50	50	
Material weight (lb) ^a	750	26,000	880	600	
Chemical content (wt%)	100% (NH ₄) ₂ HPO ₄	100% NH ₃	100% FeSO ₄	70% H ₂ O ₂	
Shipments					
Average weight (tons/yr)	86.2	344.7	5.7	137.9	
Average volume (ft ³ /yr) ^b	1,704	19,888	97	3,424	
Packages/yr	232	28	14	466	
Packages/shipment	40	1	14	40	
Shipments/yr	6	28	1	12	
Form of transport/routing					
Form of transportation	Truck	Truck	Truck	Truck	

^a Based on Mitretek (2001a).

^b Based on 276 days of operation per year.

Atmospheric Emissions. Atmospheric emissions generated by facility operation would originate from the facility neutralization units, the ICB units, the process area carbon filtration/HEPA filter system, steam boilers, and vehicles; from airborne dust from handling of solid residues; and from vehicular traffic. Handling and disposal of biotreatment residue in accordance with the provisions of RCRA would result in little potential for significant adverse impacts on air quality. Emissions from vehicles and combustion of natural gas and LPG are regulated by the EPA and the State of Colorado and also would result in little potential for significant adverse impacts on air quality. Dust emissions would be controlled during operations as well.

The process would be required to meet RCRA requirements and would operate under permit. The neutralization/biotreatment system would be required to destroy agent to a DRE of 99.9999% and to meet agent emission limits as established by the ASG. Other emissions,

TABLE 4.42 Stack Parameters for Neutralization/Biotreatment at PCD^a

Installation or Emission Point	Physical Stack Height (ft)	Stack Exit Diameter (ft)	Stack Exit Gas Flow (acfm)	Stack Exit Gas Velocity (ft/s)	Stack Exit Gas Temp (°F)	Stack Location ^b
Process steam boiler I ^c	70	1.1	3,308	60	325	Near southwest corner of PUB
Process steam boiler II ^c	70	1.1	3,308	60	325	Near southwest corner of PUB
Process steam boiler III ^c	70	1.1	3,308	60	325	Near southwest corner of PUB
Diesel generator exhaust I	47	0.67	6,765	323	925	Near northwest corner of PMB
Diesel generator exhaust II	47	0.67	6,765	323	925	Near northwest corner of PMB
Biotreatment vent (Waste gas) stack	80	1.5	5,150	48.57	143	Analogous to DUN Stack for incineration
Filter farm stack	120	6	96,000	56.58	77	Center of structure
Laboratory building stack ^d	50	2.5	NA ^e	NA	NA	Center of structure

^a Abbreviations: DUN = dunnage, PMB = Personnel and Maintenance Building, PUB = Process Utilities Building.

^b Based on Drawings AB-D-41-0012 and AB-D-41-0013 of Volume II of PMCD (1998a).

^c Stack exit gas flow modified to take into account differences in the process steam rate.

^d No emissions during normal (incident-free) operations; the stack is operational only during upset conditions.

^e NA = not applicable.

Source: PMCD (1998a).

including metals and HCl, would be regulated in accordance with the RCRA permit. The units also would be required to meet air pollution control requirements for conventional pollutants, such as CO, SO₂, and opacity.

All ventilation air would be processed through carbon filtration units before release to the atmosphere, except for that associated with the biotreatment units. Process off-gas from the various unit operations, including the biotreatment units, would be passed through catalytic converters (CatOx system) to oxidize compounds of concern. Facility effluent release points would include gaseous releases to the environment. Table 4.42 summarizes the facility effluent air release points.

Table 4.43 summarizes the estimated emission rates of criteria pollutants during operations. These rates were estimated on the basis of the annual fuel consumption rates shown in Table 4.39 and on normal biotreatment operations. Daily emission rates can be estimated from the hourly rates, on the basis of the assumption that there are 12 operating hours per day.

Small amounts of organic and metallic compounds would be emitted from the combustion of natural gas during normal boiler operations and the combustion of fuel oil during emergency diesel generator operations. Many of the TAPs that would be emitted from the pilot test facility stacks are HAPs, as defined in Section 112 of the CAA, Title III. As indicated in Section 4.3.2.3.4, the term TAP is broader in that it includes some pollutants that are not HAPs. Table 4.44 summarizes the TAP emission rates; these estimates were based on the annual consumption rate of natural gas shown in Table 4.39 and using FIRE 6.22 emission factors for

TABLE 4.43 Estimated Hourly and Annual Emission Rates of Criteria Pollutants during Normal Neutralization/Biotreatment Operations at PCD

Criteria Pollutant	Process Steam Boiler ^a		Diesel Generator Exhaust ^b	
	lb/h	tons/yr	lb/h	tons/yr
CO	2.4	3.95	10.4	3.12
NO _x	4.0	6.58	48.4	14.50
SO ₂	0.02	0.03	3.2	0.95
PM ₁₀	0.22	0.36	3.4	1.02
VOCs	0.16	0.26	4.0	1.18

^a Estimated from the daily requirement of process steam.

^b Based on 600 hours of operations per year

Source: APG (1997).

TABLE 4.44 Estimated Hourly and Annual TAP Emission Rates during Normal Boiler Operations for Neutralization/Biotreatment at PCD^a

Compound	Hourly Emission (lb/h)	Annual Emission (lb/yr)	Compound	Hourly Emission (lb/h)	Annual Emission (lb/yr)
2-Methylnaphthalene	6.8E-07	2.3E-03	Dimethylbenz(a)anthracene	4.5E-07	1.5E-03
3-Methylchloranthrene	5.1E-08	1.7E-04	Ethane	8.8E-02	2.9E+02
Acenaphthene	5.1E-08	1.7E-04	Fluoranthene	8.5E-08	2.8E-04
Acenaphthylene	5.1E-08	1.7E-04	Fluorene	7.9E-08	2.6E-04
Anthracene	6.8E-08	2.3E-04	Formaldehyde	2.1E-03	7.1E+00
Arsenic	5.7E-06	1.9E-02	Hexane(n)	5.1E-02	1.7E+02
Barium	1.2E-04	4.1E-01	Indeno(1,2,3-cd)pyrene	5.1E-08	1.7E-04
Benz(a)anthracene	5.1E-08	1.7E-04	Lead	1.4E-05	4.7E-02
Benzene	6.0E-05	2.0E-01	Manganese	1.1E-05	3.6E-02
Benzo(a)pyrene	3.4E-08	1.1E-04	Mercury	7.4E-06	2.4E-02
Benzo(b)fluoranthene	5.1E-08	1.7E-04	Molybdenum	3.1E-05	1.0E-01
Benzo(g,h,i)perylene	3.4E-08	1.1E-04	Naphthalene	1.7E-05	5.7E-02
Benzo(k)fluoranthene	5.1E-08	1.7E-04	Nickel	6.0E-05	2.0E-01
Beryllium	3.4E-07	1.1E-03	Pentane(n)	7.4E-02	2.4E+02
Butane	6.0E-02	2.0E+02	Phenanthrene	4.8E-07	1.6E-03
Cadmium	3.1E-05	1.0E-01	Propane	4.5E-02	1.5E+02
Chromium	4.0E-05	1.3E-01	Pyrene	1.4E-07	4.7E-04
Chrysene	5.1E-08	1.7E-04	Selenium	6.8E-07	2.3E-03
Cobalt	2.4E-06	7.9E-03	Toluene	9.6E-05	3.2E-01
Copper	2.4E-05	8.0E-02	Vanadium	6.5E-05	2.2E-01
Dibenzo(a,h)anthracene	3.4E-08	1.1E-04			
Dichlorobenzene	3.4E-05	1.1E-01			

^a Emission factors from EPA (2000a).

large wall-fired boilers with greater than 100 MMBtu/h of heat input (EPA 2000a). Daily emissions can be estimated from the hourly emissions on the basis of the assumption that there are 12 operating hours per day.

Table 4.45 summarizes the TAP emission rates that were estimated on the basis of the annual fuel oil consumption rates shown in Table 4.39 and FIRE 6.22 emission factors for reciprocating diesel engines (EPA 2000a). Daily emissions can be estimated from the hourly emissions on the basis of the assumption that there are 12 operating hours per day.

The neutralization/biotreatment facility at PCD would be equipped with building ventilation systems that would discharge, to the atmosphere, indoor air from the MDB process area, the Laboratory Building, and the Personnel and Maintenance Building through the filter farm stack. Of these three discharges, only the indoor air from the MDB process area would be potentially exposed to chemical agents during operations.

TABLE 4.45 Estimated Hourly and Annual TAP Emission Rates during Emergency Diesel Generator Operations for Neutralization/Biotreatment at PCD^a

Compound	Hourly Emission (lb/h)	Annual Emission (lb/yr)	Compound	Hourly Emission (lb/h)	Annual Emission (lb/yr)
Acenaphthene	3.1E-07	1.9E-04	Dibenzo(a,h) anthracene	1.3E-07	7.7E-05
Acenaphthylene	1.1E-06	6.7E-04	Fluoranthene	1.7E-06	1.0E-03
Acetaldehyde	1.7E-04	1.0E-01	Fluorene	6.4E-06	3.8E-03
Acrolein	2.0E-05	1.2E-02	Formaldehyde	2.6E-04	1.6E-01
Aldehydes	1.5E-02	9.2E+00	Indeno(1,2,3-cd)pyrene	8.2E-08	4.9E-05
Anthracene	4.1E-07	2.5E-04	Isomers of xylene	6.3E-05	3.7E-02
Benzene	2.0E-04	1.2E-01	Mercury	6.6E-08	4.0E-05
Benzo (a) anthracene	3.7E-07	2.2E-04	Naphthalene	1.9E-05	1.1E-02
Benzo (a) pyrene	4.1E-08	2.5E-05	Phenanthrene	6.5E-06	3.9E-03
Benzo (b) fluoranthene	2.2E-08	1.3E-05	Polycyclic aromatic hydrocarbons (PAHs)	37.5E-05	2.2E-02
Benzo (g,h,i) perylene	1.1E-07	6.4E-05	Propylene	5.7E-04	3.4E-01
Benzo (k) fluoranthene	3.4E-08	2.0E-05	Pyrene	1.0E-06	6.3E-04
1,3-Butadiene	8.6E-06	5.1E-03	Toluene	9.0E-05	5.4E-02
Chrysene	7.8E-08	4.6E-05			

^a Emission factors from EPA (2000a).

To estimate the maximum potential emissions of chemical agents, only the MDB process area is considered to be a significant potential source. The filter systems would be designed to remove chemical agents from the ventilation air streams to levels below the allowable stack concentrations that have been recommended by the U.S. Department of Health and Human Services, Centers for Disease Control (53 *Federal Register* 8504–8507, March 15, 1988). Estimated potential chemical agent emission rates are given in Table 4.46; the estimates were based on the assumption that the chemical agent concentrations in the air discharged from the filter farm stack would be at 20% of the recommended allowable stack concentrations (i.e., the level of quantification of the ventilation exhaust chemical agent monitors.)

Tables 4.47 and 4.48 summarize the estimated TAP emission rates from the biotreatment vent stack and the filter farm stack, respectively. Emission rates from the biotreatment process, with and without off-gas treatment, pending a decision by the vendor concerning the necessity of off-gas treatment, are provided in Table 4.47. The inclusion of off-gas treatment has a measurable impact on the emission rates of organic compounds, such as 1,2-dichloroethane and polychlorinated dioxins and furans, as shown in Table 4.47. Annual emission rates can be estimated from the daily values, assuming 276 days of operations per year.

Emissions from operations worker commuter vehicles were estimated on the basis of the assumption that an average of 635 automobiles (1 car per operations worker) would be added to the area of the site and that each worker would drive an average of 20 mi (32 km) to the site. Annual emission estimates due to the increased traffic are presented in Table 4.49.

TABLE 4.46 Estimated Maximum Hourly and Annual (Total) Agent Emission Rates from the Filter Farm Stack during Neutralization/Biotreatment at PCD

Chemical Agent	Emission Factor (mg/m ³) ^a	Stack Exit Gas Flow (acfm) ^b	Hours of Operation per Year ^c	Stack Emission Rate	
				(lb/h)	(tons/yr) ^d
HD, HT	0.006	96,000	3,312	2.2E-03	3.6E-03

^a Based on the monitor level of quantification, which is 20% of the allowable stack concentration recommended for each chemical agent in 53 CFR 8504-8507.

^b Filter farm stack exit flow based on building ventilation for the MDB.

^c Hours of operations based on the assumption that each pilot plant operates at the design throughputs specified in CBDCOM (1997).

^d Estimate based on number of hours of operation per year.

Liquid Wastes. As indicated previously, liquids from the biotreatment would be evaporated, condensed, and reused. Other liquids, such as spent decontamination solutions and laboratory wastes, would be fed to the neutralization/biotreatment system. According to the technology provider, domestic sewage is the only liquid effluent expected to be generated at the facility in major quantities. Small amounts of hazardous liquids could be generated from chemical makeup and reagents for support activities; it is anticipated that the quantities may be minor compared with those for domestic sewage (sanitary waste). Sanitary wastes would be managed on-site.

Solid Wastes. Solid wastes generated by the facility would consist primarily of biosolids and salts. Biosolids are the solid effluent from the bioreactor system; this effluent consists of microbial biomass and absorbed metals, grit, and dirt (see Table 4.50). Brine salts would result from the hydrolysis process, facility washdown, and biotreatment. The salts would contain metals derived from ACW components and would be disposed of as hazardous waste in a RCRA-permitted landfill (see Table 4.51). The sludge generated in the biotreatment system would be removed in the sludge treatment systems downstream of the ICB. The sludge would be separated from the water by means of a clarifier and would be dewatered and compacted by means of a filter press (see Table 4.52). Drummed filter cake would then be disposed of as hazardous waste in a RCRA-permitted facility.

Annual (total) waste generation rates can be estimated from the daily values on the basis of the assumption that there would be 276 days of operations per year.

TABLE 4.47 Estimated TAP Emission Rates from the Biotreatment Vent (Waste Gas) Stack during Neutralization/Biotreatment at PCD

Compound	Emission Rate (lb/d) ^a		Compound	Emission Rate (lb/d) ^b	
	With HVAC Carbon/HEPA Filters	Without HVAC Carbon/HEPA Filters		With HVAC Carbon/HEPA Filters	Without HVAC Carbon/HEPA Filters
Organic compounds			Dioxins/furans		
1,2-Dichloroethane	1E-10	7E-03	1,2,3,4,6,7,8,9-OCDD	3E-13	3E-06
Acetaldehyde	3E-10	2E-02	1,2,3,4,6,7,8,9-OCDF	6E-14	7E-07
Bis(2-chloroethyl)ether	8E-11	5E-03	1,2,3,4,6,7,8-HpCDD	6E-14	7E-07
Bis(2-ethylhexyl)phthalate	1E-10	7E-03	1,2,3,4,6,7,8-HpCDF	7E-14	8E-07
Bromomethane	3E-10	2E-02	1,2,3,4,7,8,9-HpCDF	2E-14	2E-07
Chloromethane	3E-10	2E-02	1,2,3,4,7,8-HxCDD	3E-15	3E-08
Diethylphthalate	1E-10	8E-03	1,2,3,4,7,8-HxCDF	2E-14	2E-07
Ethyl benzene	9E-10	6E-02	1,2,3,6,7,8-HxCDD	6E-15	7E-08
Formaldehyde	2E-09	2E-01	1,2,3,6,7,8-HxCDF	9E-15	1E-07
Glycol ethers (2-butoxy ethanol)	8E-10	5E-02	1,2,3,7,8,9-HxCDD	1E-14	1E-07
m/p-Xylene	8E-09	5E-01	1,2,3,7,8-PeCDD	3E-16	4E-09
Mercury	3E-08	4E-03	1,2,3,7,8-PeCDF	9E-15	1E-07
Methyl ethyl ketone/butyraldehydes	1E-10	6E-03	2,3,4,6,7,8-HxCDF	9E-15	1E-07
Methylene chloride	2E-09	2E-01	2,3,4,7,8-PeCDF	1E-14	2E-07
Naphthalene	7E-11	5E-03	2,3,7,8-TCDD	5E-16	5E-09
Phenol	3E-11	2E-03	2,3,7,8-TCDF	1E-14	2E-07
Propanal	1E-10	8E-03	OCDD	6E-14	6E-07
Toluene	2E-10	1E-02	OCDF	2E-14	3E-07
			Total HpCDD	1E-13	1E-06
			Total HpCDF	1E-13	1E-06
			Total HxCDD	8E-14	9E-07
			Total HxCDF	7E-14	8E-07
			Total PeCDF	1E-13	1E-06
			Total TCDD	3E-15	3E-08
			Total TCDF	5E-14	5E-07

^a Abbreviations: HEPA = high-efficiency particulate air filter, HVAC = heating, ventilation, and air-conditioning, HpCDD = heptachlorodibenzo-p-dioxin, HpCDF = heptachlorodibenzo-p-furan, HxCDD = hexachlorodibenzo-p-dioxin, HxCDF = hexachlorodibenzo-p-furan, OCDD = octachlorodibenzo-p-dioxin, OCDF = octachlorodibenzo-p-furan, PeCDD = pentachlorodibenzo-p-dioxin, PeCDF = pentachlorodibenzo-p-furan, TCDD = tetrachlorodibenzo-p-dioxin, and TCDF = tetrachlorodibenzo-p-furan.

^b Assumes 24 hour-per-day operations for a total of 731 days. Throughput rates assume 12 hours per day for batch operations.

Source: Mitretek (2001a).

Nonhazardous scrap metal from the munition bodies (5X condition) would be sold to a scrap dealer or smelter for reuse if approved by the regulatory authority (see Table 4.53). However, if it proves necessary, these metals could be disposed of off-site in a nonhazardous waste landfill or a RCRA-permitted hazardous waste landfill. Currently, the U.S. Army does not intend to dispose of any waste materials from the destruction process on-site.

Nonprocess waste streams include decon solution, DPE suits, spent carbon, waste oils, trash, debris, and spent hydraulic fluid, which are assumed to be potentially agent-contaminated and would be processed in the dunnage/waste processing system. After this processing, the only streams with a significant solid residue would be the decontamination solution (containing NaOH and NaOCl) and miscellaneous metal parts from equipment operation. Table 4.54 provides information on the daily and annual generation rates of treated nonprocess wastes for ACW containing mustard agent.

TABLE 4.48 Estimated TAP Emission Rates from the Filter Farm Stack during Neutralization/Biotreatment at PCD

Compound	Emission Rate (lb/d) ^a	Compound	Emission Rate (lb/d) ^a
1,1,1-Trichloroethane	1E-14	Selenium	2E-13
1,2-Dichloroethane	2E-09	Styrene	8E-17
1,2-Dichloropropane	3E-14	Tetrachloroethene	2E-14
1,4-Dichlorobenzene	3E-13	Toluene	4E-12
3/4-Methyl phenol	1E-13		
3/4-Methyl phenol	4E-14	Polychlorinated dioxins/furans	
Benzene	8E-13	1,2,3,4,6,7,8,9-OCDD	3E-17
Bis(2-ethylhexyl)phthalate	8E-13	1,2,3,4,6,7,8,9-OCDF	7E-17
Bromomethane	2E-11	1,2,3,4,6,7,8-HpCDD	6E-17
Carbon disulfide	2E-11	1,2,3,4,6,7,8-HpCDF	6E-17
Carbon chloride	3E-13	1,2,3,4,7,8,9-HpCDF	6E-18
Chlorobenzene	3E-11	1,2,3,4,7,8-HxCDD	6E-18
Chloroethane	4E-13	1,2,3,4,7,8-HxCDF	6E-17
Chloroform	5E-11	1,2,3,6,7,8-HxCDD	2E-17
Chloromethane	3E-10	1,2,3,6,7,8-HxCDF	3E-17
Chromium	2E-11	1,2,3,7,8,9-HxCDD	2E-17
Cobalt	2E-11	1,2,3,7,8,9-HxCDF	3E-18
Dimethylphthalate	2E-12	1,2,3,7,8-PeCDD	6E-18
Ethyl benzene	8E-14	1,2,3,7,8-PeCDF	1E-17
Lead	7E-13	2,3,4,6,7,8-HxCDF	3E-17
m,p-Xylene	3E-12	2,3,4,7,8-PeCDF	4E-17
Manganese	6E-12	2,3,7,8-TCDF	1E-16
Mercury	2E-12	Dibenzofuran	3E-13
Methyl ethyl ketone)	1E-09	Total HpCDD	1E-16
Methylene chloride	2E-12	Total HpCDF	8E-17
Naphthalene	4E-12	Total HxCDD	2E-16
Nickel	1E-11	Total HxCDF	2E-16
o-Xylene	2E-13	Total PeCDD	2E-16
Particulates	2E-09	Total PeCDF	4E-16
Phenol	5E-13	Total TCDD	1E-16
Phosphorus	2E-12	Total TCDF	2E-12
Polycyclic organic matter (fluorene)	3E-12	Particulates	5E-08

^a Assumes six carbon filters in series, each at 95% efficiency for organic compounds and two HEPA filters in series, each at 99.97% efficiency for metals, and 24-hour-per-day operations for a total of 731 days. Throughput rates assume 12 hours per day for batch operations.

Source: Mitretek (2001a).

TABLE 4.49 Estimated Emissions from Worker Commuter Vehicles for Neutralization/Biotreatment Operations at PCD

Criteria Pollutant	No. of Auto Round Trips ^a	Emission Factor (g/km) ^b	One-Way Trip Distance (mi) ^c	Emission Rate (tons/yr)
HC	175,000	1.16	20	14.4
CO	175,000	11.38	20	141.5
NO _x	175,000	0.73	20	9.1
SO _x	175,000	0.12	20	1.5
PM ₁₀	175,000	0.055	20	0.7

^a Number of auto round trips to the operation site was estimated on the basis of annual operating personpower and 16 campaign days.

^b Emission factors determined using EPA modeling software MOBILE5b (EPA 2000c) for HC, CO, and NO_x, and PART5 (EPA 2000b) for PM₁₀.

^c One-way trip distance based on DOE (1997).

TABLE 4.50 Estimated Generation Rates of Biomass (lb/d) from Neutralization/Biotreatment at PCD To Be Sent Off-Site for Land Disposal or Recycling

Compound	Generation Rate (lb/d)	Compound	Generation Rate (lb/d)	Compound	Generation Rate (lb/d)
Total biomass (including water)	7,000	4-Methylphenol	1E-02	Fluoranthene	5E-04
Biomass solids	5,000	Acetaldehyde	4E-03	Lead	6E-03
1,2-Dichloroethane	2E-03	Acetone	3E-01	Mercury	E-05
1,2-Dimethyl hydrazine	1E-02	Acetonitrile	2E-03	Methyl nitrate	E-03
1,3,5-Trithiane	2E-02	Aluminum	3E+00	Nickel	E-02
1,3-Oxathiolane	3E-03	Barium	8E-03	Nitrite	1
2-(2-Methoxyethoxy) ethanol	4E-03	Benzeneacetic acid	5E-03	Octadecanoic acid	5E-03
2,3-Butanedione	2E-02	Arsenic	9E-02	Phenanthrene	1E-03
2-Butanone	1	Bis(2-ethylhexyl)phthalate	2E-03	Phenol	1E-03
2-Methyl benzaldehyde	3E-02	Bromomethane	4E-03	Selenium	8E-03
2-Methyl butanoic acid	4E-03	Butyrolactone	1E-03	OCDD	5E-09
2-Methyl-1,3-oxathioane	4E-03	Carbon disulfide	2E-02	Silver	4E-03
2-Pentanone	1E-02	Carbonyl sulfide	1E-03	Sulfide, reactive	5
3-Hydroxy-2-butanone	5E-03	Chloromethane	6E-02	Tetrahydro-2-methyl thiophene	3E-03
3-Methyl butanoic acid	1E-02	Copper	4E-02	Tin	1E-01
3-Penten-2-one	4E-03	Diethylphthalate	9E-04	Vanadium	5E-03
4-Hydroxy-4-methyl-2-pentanone	2E-03	Ethanol	1E-02	Xylenes	5E-02
4-Methyl benzaldehyde	4E-03	Ethyl acetate	9E-03	Zinc	2E-01
4-Methylbenzene methanol	3E-03	Ethyl benzene	7E-03	Water in biomass	3,000

TABLE 4.51 Estimated Generation Rates of Brine Salts from Neutralization/Biotreatment at PCD To Be Sent Off-Site for Land Disposal or Recycling

Compound	Generation Rate (lb/d)	Compound	Generation Rate (lb/d)	Compound	Generation Rate (lb/d)
Total brine salts (including water)	10,000	2,3-Bitanedione	1E-02	Dibromochloromethane	1E-02
Sodium sulfate	4,000	2-Butanone	8E-01	Ethylbenzene	2E-02
Sodium bisulfate	1,000	2-Hexanone	1E-02	Formaldehyde	10
Ferrous sulfate	40	4-Methyl-2-pentanone	1E-02	Maltol	9E-03
Sodium chloride	5,000	4-Methylphenol	2E-02	Manganese	2
Magnesium chloride	20	Acetaldehyde	2	Mercury	2E-03
Calcium chloride	20	Acetone	6E-01	Methyl benzaldehyde	7E-03
Sodium nitrite	100	Aluminum	2	Molybdenum	4E-02
Ammonium phosphate	300	Antimony	1E-01	m-Tolualdehyde	4E-02
Dipotassium phosphate	200	Arsenic	8E-02	Nickel	2E-01
Sodium hydroxide	30	Barium	2E-02	Phenanthrene	4E-03
Lead oxide	1	Benzene	1E-02	Propanal	1
Potassium chlorate	3E-02	Bromodichloromethane	1E-02	Propanedioic acid	7E-03
Antimony sulfate	5E-02	Bromoform	1E-02	Selenium	6E-02
1,1,1-Trichloroethane	1E-02	Bromomethane	1E-02	Silver	3E-02
1,1,2,2-Tetrachloroethane	1E-02	Carbon disulfide	4E-02	Styrene	1E-02
1,1,2-Trichloroethane	1E-02	Carbon tetrachloride	1E-02	Sulfur dioxide	1E-02
1,1-Dichloroethane	1E-02	Chlorobenzene	1E-02	Tetrachloroethene	1E-02
1,1-Dichloroethene	1E-02	Chloroethane	1E-02	Toluene	1E-02
1,2,5-Trithiepane	6E-02	Chloroform	1E-02	Trans-1,3-dichloropropene	1E-02
1,2-Dichloroethane	1E-02	Chloromethane	2E-02	Trichloroethene	1E-02
1,2-Dichloroethene (total)	1E-02	Chromium	7E-02	Vinyl chloride	1E-02
1,2-Dichloropropane	1E-02	Cis-1,3-dichloropropene	1E-02	Xylenes	1E-01
1,3-Dithilane-2-thione	6E-03	Cobalt, total	4E-02	Zinc	5
1,3-Dithiolane	1E-01	Copper	4E-02	Water in salt cake	2000
1,4-Oxathiane-4,4-oxide	1E-01	Copper, total	4E-02		
1,4-Oxathiane-4-oxide	1E-01	Cyclohexanone	3E-01		

TABLE 4.52 Estimated Generation Rates of Scrubber Sludge from Neutralization/Biotreatment at PCD To Be Sent Off-Site for Land Disposal or Recycling

Compound	Generation Rate (lb/d)
Sodium sulfate (Na ₂ O ₄ S)	1.7E+03
Sodium chloride (NaCl)	6.8E+02
Water in salt cake	4.2E+02
Total	2.8E+03

TABLE 4.53 Estimated Generation Rates of 5X Solids from Neutralization/Biotreatment at PCD To Be Sent Off-Site for Land Disposal or Recycling

Compound	Generation Rate (lb/d)
Aluminum	1.9E+02
Steel and iron	5.1E+04
Copper	1.1E+03
Zinc	1.9E+02
Total	5.3E+04

TABLE 4.54 Calculated Quantities of Solid Residues from Nonprocess Wastes from Neutralization/Biotreatment of ACW Containing Mustard Agent at PCD

Waste Type	Inlet Waste Composition	Treatment Process	Product	Daily Quantity (lb/d)	Annual Quantity (tons/yr)
Decon solution	18 wt% NaOH, NaOCl ^a	MPT	50% NaOH, 50% NaOCl	960	132.5
Miscellaneous metal parts	Nonmunition scrap metal	MPT	100% metal	430	59.3
Total				1,400	192

^a Source: APG (1997).

The above waste streams may be shipped from the on-site facility to off-site locations. Table 4.55 provides transportation data for solid wastes from neutralization/biotreatment. It was assumed that all wastes would be packaged in 55-gal (208-L) drums prior to off-site shipment.

The types and quantities of nonhazardous (nonprocess) solid and liquid wastes that could be generated from facility operations are shown in Table 4.56. Waste generation is based on historic data on building size, utility requirements, and facility workforce.

4.3.3.4 Activities and Schedules

The PMACWA described activities for installation of the neutralization/biotreatment system (PMACWA 1999a). The major phases of the project are shown in Table 4.57.

4.3.3.5 Uncertainties

Each of the individual technologies that form the neutralization/biotreatment system has either been previously proven as a successful technology or has been demonstrated by the PMACWA to be an acceptable technology for application at PCD. However, demonstration testing focused on individual technologies and sometimes employed less than full-scale units. In addition, although EDSs were conducted to evaluate the long-term adequacy of individual technologies, it was not possible to evaluate the long-term viability and performance of the entire, integrated system. Thus, the primary uncertainty associated with neutralization/biotreatment is that the entire, integrated treatment system, with all its component units, has not been assembled and tested. The pilot program, if implemented for this technology system, would be designed to evaluate overall operability and long-term performance.

TABLE 4.55 Transportation Data for Solid Wastes from Neutralization/Biotreatment at PCD

Type of Data	Output Material No. 1	Output Material No. 2	Output Material No. 3	Output Material No. 4	Output Material No. 5
Transported materials					
Type/chemical	Biomass – waste	Scrubber sludge – waste	Brine salts – waste	5X Solids – waste	Nonprocess waste
Physical form	Solid	Solid	Solid	Solid	Solid
Chemical composition/ temperature, pressure	See Table 4.46	See Table 4.48	See Table 4.47	See Table 4.49	See Table 5.52
Packaging					
Type	55-gal drum	55-gal drum	55-gal drum	55-gal drum ^a	55-gal drum
Container volume (ft ³)	7.35	7.35	7.35	7.35	7.35
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	Varies	Varies	Varies	Varies	Varies
Container weight (lb)	50	50	50	50	50
Material weight (lb)	610	490	340	450	494
Chemical content (wt%)	See Table 4.46	See Table 4.48	See Table 4.47	See Table 4.49	See Table 5.52
Shipments					
Average weight (tons/yr) ^b	651	1,540	1,803	7,294	191
Average volume (ft ³ /yr)	15,370	46,660	80,130	242,610	5,700
Packages/yr	2,091	6,347	10,899	32,998	776
Packages/shipment	48	48	48	48	48
Shipments/yr	44	133	228	688	17
Form of transport/routing					
Form of transportation	Truck	Truck	Truck	Truck	Truck
Destination - facility type	Land disposal ^c	Land disposal ^c	Land disposal ^c	Recycle	Land disposal ^a

^a Review of the disassembly process indicates that the dimensions of the 5X solids would allow disposal in standard 55-gal drums. Further validation with the vendor may be required.

^b Estimated by assuming 276 campaign days per year.

^c Depending on the results of the test for hazardous constituents, off-site disposal at a RCRA-permitted facility may be required.

4.3.4 DISMANTLING AND CLOSURE

The legislation that established the ACWA (Public Law 104-208) instructed the DOD to demonstrate alternatives to the baseline incineration process for the demilitarization of ACW. Subsequent legislation specified the continued management of the development and testing of technologies for the destruction of lethal chemical munitions. The status and disposition of ACWA pilot test facilities were not addressed in the legislation. An ACWA pilot facility could be (1) closed and decommissioned (i.e., operations terminated and the site secured) after the conclusion of testing; (2) converted to an operational chemical weapon destruction facility (this option assumes that there would be chemical weapons remaining at the site); or (3) assigned

TABLE 4.56 Estimated Annual Nonhazardous (Nonprocess) Waste Generated during Neutralization/Biotreatment Operations at PCD

Category	Solid (yd ³)	Liquid (gal)
Nonhazardous (sanitary) wastes	NA ^a	6.4E+06
Nonhazardous (other) wastes ^b	1,600	NA
Recyclable wastes ^c	640	NA

^a NA = not applicable.

^b Nonhazardous (other) wastes include domestic trash and office waste.

^c Recyclable wastes include paper, aluminum, etc., generated by the facility.

Source: Mitretek (2001a).

functions other than the demilitarization of weapons in the chemical weapons stockpile (within the constraints imposed by the National Defense Authorization Act for Fiscal Year 2000). The latter two options, however, are beyond the scope of the ACWA EIS and this TRD. The future use of the current chemical weapons storage and related facilities is also beyond the scope of the ACWA EIS and this TRD. Only closure and decommissioning of an ACWA pilot facility can be addressed in the ACWA EIS and this TRD.

The closure and decommissioning of an ACWA pilot facility would require compliance with the provisions of any permits issued by regulatory agencies for the construction and operation of the facility. This would include compliance with RCRA requirements for the closure of a hazardous waste treatment, storage, or disposal facility. The PMACWA and other parties involved in the closure and decommissioning of an ACWA pilot facility also would have to meet U.S. Army and DOD requirements for managing and disposing of facilities involved in the handling of chemical warfare materials.

The closure and decommissioning of an ACWA facility would likely be similar to the closure of baseline incineration facilities (such as JACADS and TOCDF) and destruction facilities using alternative technologies (located at APG in Maryland and NCD in Indiana). The JACADS site closure plan (Washington Demilitarization

TABLE 4.57 Activities for Neutralization/Biotreatment at PCD

Key Milestones
EIS Start
EDS Testing Start
Final EIS/ROD
Final Design (65% Completion)
RCRA Part B Issued
MDB Construction Start
MDB Construction Finish
Systemization Start (Pilot Train)
Systemization Start (All Trains)
Operations Start
Operations Finish

Source: PMACWA (1999a).

Company 2000) and the APG and NCD RCRA permit applications (APG 1997, NCD 1998a) contain general concepts for facility closure and decommissioning.

On the basis of the general requirements for a treatment, storage, or disposal facility under RCRA, U.S. Army, and DOD policies and regulations, and concepts for the decommissioning of chemical destruction facilities, the following steps would likely be involved in the closure and decommissioning of an ACWA pilot facility:

- Removal of all hazardous wastes from the site;
- Decontamination of the structures and equipment (to include piping and tankage) to allow safe handling;
- Removal of all or part of the remaining equipment;
- Demolition of all or part of the facility;
- Removal or abandonment of all or part of the supporting infrastructure; and
- Grading and revegetation, as needed, of the areas after removal of structures and infrastructure.

These actions would generate wastes similar to those created during the operation of the facility. Wastes would include decontamination solutions consisting of water or caustic solutions containing agent and energetic by-products (similar to agent and energetic hydrolysates), contaminated and noncontaminated debris (such as metals, wood, and concrete that are similar to dunnage and maintenance wastes), protective clothing, wastes from administrative and maintenance areas, petroleum products, and industrial chemicals. To the degree feasible, these materials would be processed through the ACWA facility in the same manner as like materials during pilot testing. Once the facility is rendered nonoperational, these materials would be collected, containerized, and treated or disposed of in accordance with environmental regulations.

Equipment removed from the facility would be decontaminated and reused or recycled when possible. Structures would be decontaminated to the degree required by U.S. Army and DOD regulations to allow their reuse or demolition. Demolition debris would be disposed of in accordance with environmental, U.S. Army, and DOD regulations.

Removal, demolition, grading, and revegetation operations would be similar to the activities during construction. Disassembly of the facility would involve equipment and actions very much like those used to prepare the site and to erect the facility. Materials used in the construction of the facility would be conveyed out of the area in a manner similar to that used to

bring them into the area; for example, concrete and steel would be trucked away from the site. The area required to support removal and demolition operations would not exceed that needed for material staging and facility construction.

The operation of an ACWA facility would cease with the termination of pilot testing or the elimination of the chemical weapons stockpile. Unless the ACWA pilot facility was converted to some other use, closure and decommissioning would be unavoidable. Thus, both the potential positive and negative impacts of closure and decommissioning would be unavoidable.

4.3.5 COMBINATION TREATMENT TECHNOLOGIES

As indicated previously, the elements of the various unit operations could be combined into different but viable ACW treatment alternatives. A number of different combination technologies may be considered. Supplemental information is not provided here for combination technologies. However, on the basis of the information provided in Sections 4.3.2 and 4.3.3, it appears that system inputs and resource requirements, routine emissions and wastes, activities and schedules, and uncertainties would not differ appreciably from the basic systems described in this document.

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