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REENTRY PLANNING: THE TECHNICAL BASIS FOR OFFSITE RECOVERY FOLLOWING WARFARE AGENT CONTAMINATION

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SUMMARY

In the event of an unplanned release of chemical agent during any stage of the Chemical Stockpile Disposal Program (CSDP), the potential exists for contamination of drinking water, forage crops, grains, garden produce and livestock. Persistent agents, such as VX or sulfur mustard, pose the greatest human health concern for reentry.

The purpose of this technical support study is to provide information and analyses that can be used by federal, state, and local emergency planners in determining the safety of reentry to, as well as the potential for recovery of, contaminated or suspect areas beyond the installation boundary. Guidelines for disposition of livestock, agricultural crops and personal/real property are summarized. Advisories for ingestion of food crops, water, meat and milk from the affected zones are proposed. This document does not address potential adverse effects to, or agent contamination of, wild species of plants or animals.

A relative potency approach comparing the toxicity of VX to organophosphate insecticide analogues was developed and used to estimate potential allowable residues for VX in foodstuffs. Analysis of mammalian LD_{50} data indicates that VX is 10^3 to 10^4 times more toxic than most commercially available organophosphate insecticides. Thus, allowable residues of VX could be considered at concentration levels 10^3 to 10^4 lower than those established for insecticide analogues by the United States Environmental Protection Agency (U.S. EPA). A similar approach was developed and proposed for the carcinogenic potency of sulfur mustard.

Other issues addressed in this analysis include the problem of contaminated porous surfaces, current and potential capabilities for reproducible detection, the handling of potentially contaminated human remains, and the utility of these findings in training/equipping host communities.

A major outstanding issue is the development of "safe" exposure levels for public use of potentially contaminated water and food items and public access to potentially contaminated real and personal property. For unlimited public access involving possible combined dermal, inhalation, and ingestion exposure pathways, it is not yet clear at what concentration(s) to establish safe exposure levels. No Observed Adverse Effect Levels (NOAELs) need to be developed for agent exposure via single or multiple pathways.

Reentry intervals developed for certain potent agricultural insecticides indicate that restricted access for VX may be on the order of weeks following an unplanned agent release. It is also clear that more involvement by services responsible for food safety and

inspection (the USDA Food Safety and Inspection Service and the Agricultural Marketing Service; the DHHS Food and Drug Administration) and veterinary/crop management (USDA, veterinary associations) is needed in reentry planning at the federal, state, and local levels. Mechanisms to implement this involvement as well as treatment/information resources are outlined in extensive tables and accompanying text. Readers with a particular interest in recommended treatment and decontamination of crops, livestock, and water should focus on Sections 2 and 3.

1.0 INTRODUCTION

The Department of Defense Authorization Act of 1986 (PL 99-145) directed and authorized the Secretary of Defense to destroy the United States stockpile of lethal unitary chemical munitions (chemical agent contained within the munition at the time the weapon is loaded; as opposed to binary weapon design) and agents by September 30, 1994; the Act was amended in 1988 to permit operations testing of commercial-scale incinerator design and to allow for unitary munition disposal completion by September 30, 1997. The inventory of material in this category includes the organophosphate nerve agents GA, GB, and VX as well as the vesicant (blister) agents H, HD, HT (various formulations of sulfur mustard) and Lewisite (an organic arsenical). The chemical, physical, and toxicological properties of these agents are detailed in Tables 1.1 and 1.2. These agents are presently stored at eight separate locations in the continental United States as bombs, cartridges, mines, projectiles, rockets, spray tanks, and ton containers (See Figure 1.1). The current method of choice for agent destruction is high-temperature (1130°-1400°C) incineration.

The process of "reverse assembly" and munition disposal that precedes agent incineration is thoroughly addressed in the final programmatic environmental impact statement (U.S. Dept. of the Army 1988) commissioned by the Chemical Stockpile Disposal Program (CSDP) activity of the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA). The contents of this document led to the February, 1988, decision by then-Undersecretary of the Army, James R. Ambrose, to proceed with onsite incineration disposal pending completion of site-specific analyses.

The largest single quantity (approximately 42% by agent tonnage) in the United States' unitary chemical weapons stockpile is stored at Tooele Army Depot (TEAD), south of Tooele and southwest of Salt Lake City, Utah. The smallest quantity (approximately 1.6%) is stored at Lexington-Blue Grass Army Depot (LBAD), immediately southeast of Richmond, Kentucky. The Umatilla Depot Activity (UMDA; near Hermiston, Oregon), Pine Bluff Arsenal (PBA; near Pine Bluff, Arkansas), Anniston Army Depot (ANAD; near Anniston, Alabama), and Tooele Army Depot have the most heterogeneous inventories in terms of both agent and munition type. Aberdeen Proving Ground (APG; near Edgewood, Maryland) and Pueblo Depot Activity (PUDA; near Pueblo, Colorado) store only mustard agent (in bulk containers at APG and in explosively configured munitions at PUDA). Lexington-Blue Grass Army Depot, APG, and the Newport Army Ammunition Plant

Table 1.1 Chemical and physical properties of chemical munitions

	GA[a,b]	GB[a,b]	VX[a,b]
Chemical name	N,N-dimethyl phosphoramidocyanidate, ethyl ester	Methyl phosphonofluoridate, isopropyl ester	S-(diisopropyl aminoethyl) methyl phosphonothiolate, O-ethyl ester
Chemical formula	$C_5H_{11}N_2O_2P$	$C_4H_{10}FO_2P$	$C_{11}H_{26}NO_2PS$
Chemical Abstract (CAS) No.	77-81-6	107-44-8	50782-69-9
Molecular weight	162.1	140.1	267.4
Description	Colorless, odorless liquid	Colorless, odorless liquid	Colorless, odorless liquid
Melting point	-50°C	-56°C	-39°C (calculated)
Boiling point	245°C	158°C	298°C
Density (liquid)	1.08 g/mL (25°C)	1.09 g/mL (25°C)	1.0083 g/mL (25°C)
Volatility	610 mg/m^3 (25°C)	2.2×10^4 mg/m^3 (25°C)	10.5 mg/m^3 (25°C)
Solubility, water	98 g/L (25°C), miscible	Miscible	30 g/L (25°C) 75 g/L (15°C) miscible <9.4°C
Solubility, other	Very soluble in most organic solvents	Readily soluble in organic solvents	Readily soluble in organic solvents
Biological activity	Lethal anticholinesterase agent	Lethal anticholinesterase agent	Lethal anticholinesterase agent
Storage location	TEAD	ANAD, LBAD, PBA, TEAD UMDA	ANAD, LBAD, NAAP, PBA, TEAD, UMDA
Munition type[c]	TC	P, R, B, C, TC	P, R, M, ST, TC

Table 1.1 Chemical and physical properties of chemical munitions (continued)

	H, HD[a,b]	HT[a,b]	Lewisite[a,b]
Chemical name	Bis(2-chloroethyl)sulfide	Plant-run mixture containing about 60% HD and <40% "T" or Bis-[2(2-chloroethylthio)ethyl]ether	Dichloro(2-chlorovinyl)arsine
Chemical formula	$C_4H_8Cl_2S$	"T" = $C_8H_{16}Cl_2OS_2$	$C_2H_2AsCl_3$
Chemical Abstract (CAS) No.	505-60-2	"T" = 63918-89-8	541-25-3
Molecular weight	159.1	"T" = 263.26	207.31
Description	Oily, pale yellow liquid	Clear, yellowish liquid	Liquid with faint odor of geranium
Melting point	13-15°C	0-1.3°C	0.1°C (purified form) (-18.0 to 0.1°C, depending on purity and isomers present)[e]
Boiling point	215-217°C	>228°C (not constant)	190°C
Density (liquid)	1.27 g/mL (25°C)	1.27 g/mL (25°C)	1.89 g/mL (20°C)
Volatility	920 mg/m^3 (25°C)	831 mg/m^3 (25°C)	6.5×10^3 mg/m^3 (25°C)
Solubility, water	0.68-0.92 g/L (25°C)	Insoluble	Insoluble (slightly soluble in distilled water)
Solubility, other	Very soluble in organic sovents	Soluble in organic solvents	Soluble in ordinary organic solvents
Biological activity	Blister agent	Lethal blister agent	Lethal blister agent
Storage location	APG, ANAD, LBAD, PBA, PUDA	ANAD, TEAD, PUDA, PBA, TEAD, UMDA	TEAD
Munition type[c]	TC, P, C	TC, S	TC

[a]U.S. Department of the Army 1974. Note that agent GA and L are stockpiled in small quantities as ton containers and are not available in munition form.
[b]Windholz et al. 1983.
[c]B = bombs, C= cartridges, M = mines, P = projectiles, R = rockets, S = shells, ST = spray tanks, TC = ton containers.
[d]Fox and Scott 1980.
[e]U.S. Army and U.S. Air Force 1975.

Table 1.2 Chemical agents and biological/physical characteristics relevant to agent toxicity[a]

Chemical Agent/ CAS No.	Mode of Action	Short-term Effects	Long-term Effects
GA (tabun)/77-81-6	Anticholinesterase	Less volatile and more persistent than GB Less toxic than GB by vapor inhalation; equally toxic by skin absorption (liquid) More effective than GB in producing miosis GB is 2-4 times more effective in terms of incapacitating dose	No information; Army has studies planned
GB (sarin)/107-44-8	Anticholinesterase	Volatile, therefore poses less of a threat by absorption through the skin either as aerosol or liquid than it does by inhalation About half as toxic as VX by inhalation Less effective than GA or VX in inducing miosis	Some information at present; studies in progress Low-dose study did not show carcinogenic activity Teratogenicity study results were negative; other reproductive parameters were unaffected Potential for a delayed neuropathy syndrome at supralethal doses if protection from short-term lethality is achieved with drug therapy Changes in electroencephalographic recordings after short-term exposure; consequences unknown
VX/50782-69-9	Anticholinesterase	Less volatile than G agents; very effective through skin penetration; persistent Many times more toxic in man as GB via skin absorption Head and neck areas of man are very sensitive Effective percutaneous lethal dose decreases with increasing windspeed Contaminated vegetation can cause toxic effects on ingestion VX is approximately 25 times more potent than GB in inducing miosis	Mutagenicity study results were negative Teratogenicity study results were negative; other reproductive studies in progress No delayed neuropathy induction Carcinogenic activity unknown
H/HD (mustard gas, sulfur mustard)/505-60-2	Blister agent	Low volatility; very persistent on earth and solid surfaces Produces skin blisters and damage to eyes and respiratory tract Toxic effects are delayed (latent period); therefore, exposed personnel do not seek immediate treatment Secondary infections of damaged tissue can occur easily	Carcinogenic under appropriate conditions of exposure Potential increased risk of chronic bronchitis Mutagenic in a variety of test systems Teratogenicity study results were negative; one dominant lethal mutagenic study had positive results, others are in progress Potential permanent impairment of vision if eye damage is severe

Table 1.2 Chemical agents and biological/physical characteristics relevant to their toxic activity[a] (continued)

Chemical Agent/ CAS No.	Mode of Action	Short-term Effects	Long-term Effects
H/HD (mustard gas, sulfur mustard)/505-60-2 (cont.)	Blister agent	Eye is most sensitive organ; instant removal of agent is required to prevent damage High doses can induce acute systemic reactions and injury to the immune system	Skin lesions may show permanent changes in pigmentation and be hypersensitive to mechanical injury
HT (60% HD and 40% T)/ T/63918-89-8	Blister agent	Very persistent on terrain Less volatile and more stable than HD More active toxicologically than HD 1% lethality dosage is half that of HD HT is more toxicologically active than HD for skin-blister development and inhalation lethality Eye is most sensitive organ; exposures can result in permanent eye damage	Probably carcinogenic and mutagenic due to presence of HD T is strongly mutagenic No experimental information on HT is available
L (Lewisite)/541-25-3	Blister agent	Intermediate persistency in soils Much greater volatility than HD; hence, it is an irritant over great distances Skin burns are more corrosive than those from HD Similar to HD on inhalation Eye very sensitive; permanent blindness may result if not decontaminated in 1 min A systemic poison when absorbed by tissues (liver and kidneys) Immediate severe pain on contact with skin or eyes	Mutagenicity experiment results were negative; other experiments planned Possible carcinogenic properties Teratogenic potential suspected Teratogenicity and reproductive toxicity studies planned

[a]Data from U.S. Department of the Army 1988.

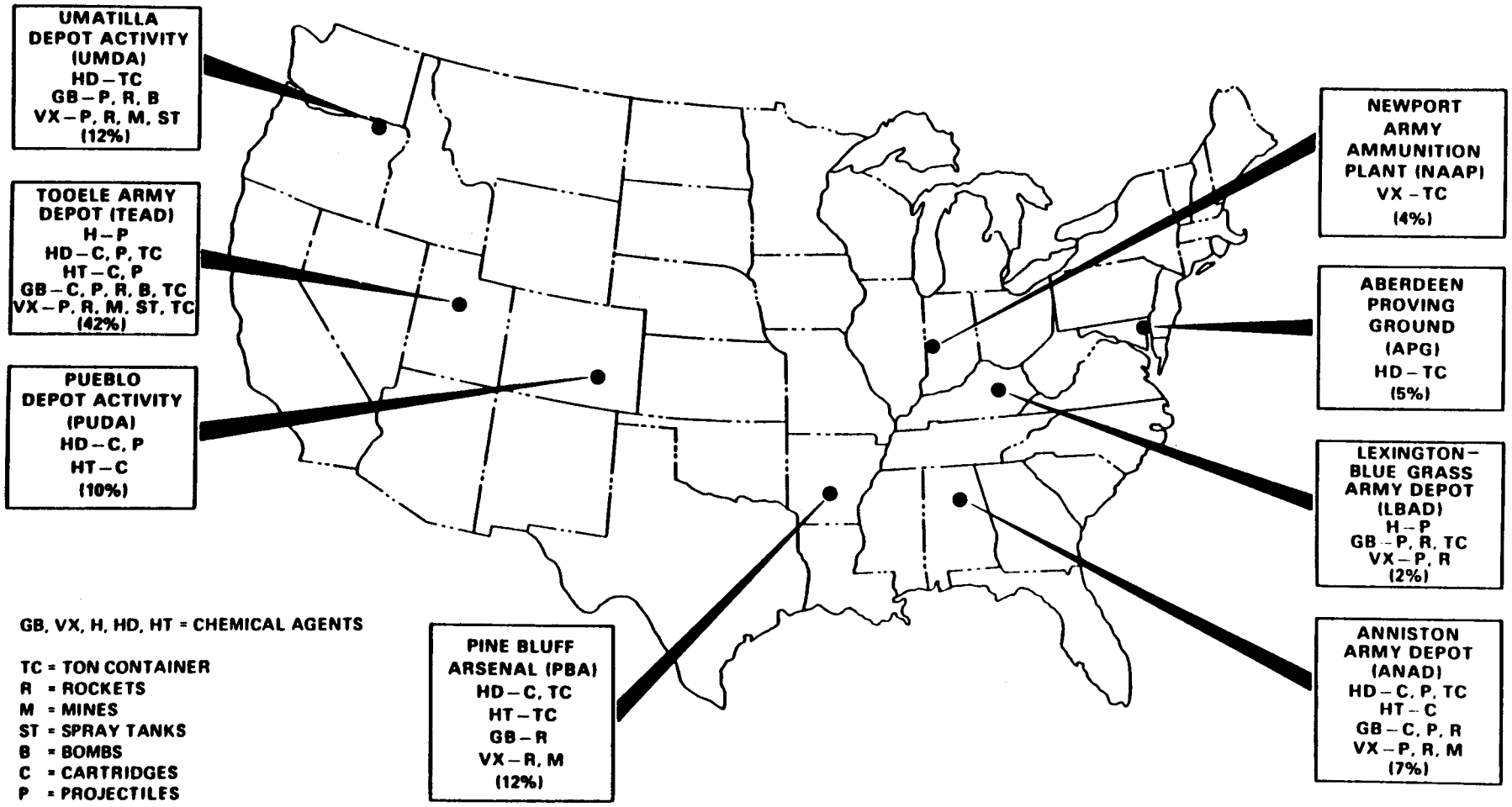

Figure 1.1 Distribution of the unitary chemical weapons stockpile throughout the continental United States (small quantities of GA and Lewisite are also stored at Tooele Army Depot)

(NAAP; near Newport, Indiana) have the smallest quantities of agent (<5% at each site). Only ton containers of VX are stored at NAAP (Figure 1.1).

Although agents are stored in a variety of configurations, most (approximately 60% by agent tonnage) are stored in bulk as ton containers, spray tanks, and bombs. The explosively configured munitions (e.g., M55 rockets, M23 land mines, mortars, cartridges, and some projectiles) present a greater challenge for disposal since the separation of explosive materials from the agent is itself a hazardous activity. Explosively configured weapons are, by army regulation, stored in earth-bermed bunkers or igloos. The only items stored in the open are ton containers of mustard agent.

The stockpile inventory includes both organophosphate (nerve) and vesicant (blister) agents. The nerve agents include agents GA (tabun; "G" for German, identifying this agent as one found among German military stores captured at the close of World War II), GB (sarin) and VX ("V" for venom). Agents held in research and development quantities, such as the nerve agent GD (soman), are not considered part of the retaliatory stockpile (quantities are too small to be considered militarily significant) and are not included in the CSDP. The vesicant agents include H, HD, HT (various formulations of sulfur mustard) as well as Lewisite (an organic arsenical). The small quantities of GA and Lewisite in the unitary stockpile will likely be wholly destroyed during near-term test burns of the Chemical Agent Munitions Disposal System (CAMDS; the prototype incinerator design currently undergoing operation testing) at TEAD. Thus, the unitary stockpile of interest is comprised of the nerve agents GB and VX and the mustard agents H, HD, and HT.

Each of these agents was formulated especially to cause major injuries or death to enemy forces in wartime and is acutely or subacutely lethal at sufficiently high doses. A description of agent toxicity and the related issues of variable human response to agent dose, utility of agent antidotes, and toxicity of agent decomposition products make up a lengthy appendix to the final programmatic environmental impact statement (U.S. Dept. of the Army 1988). Tables 1.1 and 1.2 summarize pertinent physical and biological characteristics for each agent. Table 1.3 documents agent control limits in air for maximum worker and public exposure. At or below these levels, no adverse health effects are expected. These exposure limits are based on values initially developed by the Department of Defense (DoD), but modified by recommendations arising from technical review by the

Table 1.3 Maximum Agent Control Limits Recommended by the Surgeon General's Working Group[a]

Agent	Workplace (8 h) (mg/m^3)	General Population (72-h Time-Weighted Average) (mg/m^3)
H/HD/HT	3×10^{-3}	1×10^{-4}
GA/GB	1×10^{-4}	3×10^{-6}
VX[b]	1×10^{-5}	3×10^{-6}
Lewisite	3×10^{-3}	3×10^{-3}

[a]Values recommended by Surgeon General's Working Group after review of pertinent data and documented in *Federal Register*, 52: 48458 (December 22, 1987).

[b]Notice and request for public comment on VX values in *Federal Register*, 52: 19926 (May 28, 1987). Comment period closed July 29, 1987. Control limits recommended by the U. S. Department of Health and Human Services to the Secretary of the Army in October 1987.

Centers for Disease Control (CDC) and several working groups convened by the U.S. Surgeon General. In the absence of federal regulations, these control limits in air establish standards for the safe handling and treatment of nerve and mustard agents during the disposal process.

In the event of an unplanned chemical agent release during any stage of the disposal process, the potential for contamination of drinking water, soil, forage crops, grains, garden produce, and livestock exists. Persistent agents, such as VX or the mustards, pose the greatest health concern for post-incident reentry. Each of the eight sites houses munitions containing one or the other or both of these agents (Table 1.4); APG and NAAP are the only two sites that do not stockpile a persistent agent in an explosive configuration (i.e., H/HD in ton containers at APG and VX in ton containers at NAAP). The following analysis summarizes current knowledge for determining the safety of reentry to, as well as the potential for recovery of, agent-contaminated or suspect areas.

Table 1.4 Location and type of VX and mustard munitions in unitary stockpile

Site	Munition Type[a]		
	VX	H/HD	HT
APG	--	TC	--
ANAD	P, R, M	C, P, TC	C
LBAD	R, P	P	--
NAAP	TC	--	--
PBA	R, M	C, TC	TC
PUDA	--	C, P	C
TEAD	P, R, M, ST, TC	P, C, TC	C, P
UMDA	P, R, M, ST	TC	--

[a]C=cartridges, M=mines, P=projectiles, R=rockets, S=shells, ST=spray tanks, TC=ton containers.

2.0 PROTECTION AND DECONTAMINATION OF AGRICULTURAL RESOURCES

2.1. CROPS AND FORAGE

Although limited in number and scope, studies of agent uptake by plants from hydroponic solutions containing VX indicate minimal VX translocation (i.e., the movement of materials in solution from one plant organ to another) from the root zone to leaves, stems, or fruit. Species tested included oat (Avena, sativa), tomato (Lycopersicum esculentum Mill.), petunia (Petunia hybrida), and the ornamental foliage plants coleus (Coleus blumei Benth.), wandering jew (Zebrina pendula Schnizl.), and arrowleaf (Maranta bicolor Kev.) (Ballard, Siegsmund, and Owens 1968, as cited in Sage and Howard 1989; Worthley 1971). Maximal transfer (7.8%) of tagged VX took place in the seed capsule and seed of petunia after a 42-d growing period (Worthley 1971). In tomato, maximal activities were detected after 12 d' growth; 1.4% and 2.9% of the tagged VX was observed in tomato roots and leaves, respectively. Tomato stem activity was 0.8% on the same harvest date. No tomato flowers or fruit had developed by the 42nd day of growth, when the experiment was terminated (Worthley 1971). There are no other readily available data for edible plant parts or species.

There is no evidence to indicate that mustard agents undergo translocation (Sage and Howard 1989; U.S. Dept. of the Army 1988). Agent GB in solution has been demonstrated to translocate from roots to all portions of experimental bean plants (Houle et al 1972, 1976 as cited in U.S. Dept. of the Army 1988). Agents VX and GB are phytotoxic to plants in concentrations as low as 10 ppm (VX in aqueous solution; Worthley 1970 as cited in U.S. Dept. of the Army 1988).

These results indicate that the tissue concentrations of non-leafy, edible plant parts such as tomato fruits, green beans, or grains should contain little, if any, VX or mustard if grown on contaminated soil or in proximity to contaminated water. Nevertheless, the surface of the harvestable portion of the crop plant may be coated with agent and should be treated (washing with a high-pH solution such as chlorine bleach or other decontaminant) before processing for human or animal consumption. Thus, the VX or mustard contamination of principal concern will be composed of surface deposits that could be dislodged onto the skin, inhaled, or ingested by humans or grazing animals. Leafy vegetables with much surface area (leaf lettuce, spinach, chard, etc.) would present a

particular concern. Agricultural workers could be at special risk from exposure to dislodgeable residues while managing or harvesting VX- or mustard-contaminated crops.

The quantity of VX residue on vegetation or harvestable plant parts will be largely determined by weather conditions (primarily temperature; at 37°C, 90% of a 1 mm VX droplet is expected to volatilize in somewhat over 24 h; at 10°C, the same degree of volatilization will require 45 d) (Leggett 1987 as cited in Sage and Howard 1989; Trapp 1985). Of secondary significance is the availability of moisture (the hydrolytic half-time for VX is 57 d at 21°C; Sage and Howard 1989). VX hydrolysis is base-catalyzed (Sage and Howard 1989) and would thus proceed more rapidly under alkaline conditions on plant surfaces. In general, the half-time of VX on plant surfaces is 1 to 2 d (Sage and Howard 1989), although cold weather will appreciably slow degradation.

Samples of vegetation (black sage, *Salvia mellifera*; shad scale, *Atriplex confertifolia*; bud sage *Artemisia spinescens*; cheat grass, *Bromus tectorum*) collected 18 d after the March 13, 1968, "Skull Valley incident" near Dugway Proving Ground (Utah) contained sufficient organophosphate (OP) material to significantly lower the blood cholinesterase (ChE) levels of sheep fed the suspect vegetation by rumen fistula or stomach tube (Van Kampen et al 1969). The Skull Valley incident resulted from an inadvertent, high altitude release of VX from an aircraft on a training mission from the Dugway Proving Ground on the afternoon of March 13, 1968. A passing storm front generated showers and wind shifts implicated in transporting the VX plume over the boundaries of the Proving Ground and into the adjacent Skull Valley. Over 4000 sheep died and approximately 2000 sheep sickened from VX ingestion exposure via contaminated forage and/or snow (Boffey 1968). Monitored test animals allowed to graze in the suspect area three weeks after the agent release (April 4) exhibited clear symptoms of organophosphate poisoning (Boffey 1968). If this agent had been released in the summer, similar levels of persistence would probably not have been observed. Low winter temperatures were also a factor in attaining confirmatory findings of intact VX in snow and grass samples collected from suspect areas 8 to 11 d after the VX release (Sass et al. 1970). These samples arrived in the analytical lab three weeks after the incident and some were found to still contain microgram or nanogram quantities of unreacted agent VX (Sass et al. 1970). Forage collected three to four months after the incident (June, August) and fed to experimental sheep induced no clinical signs of OP poisoning, although one ewe fed June-collected vegetation developed depressed cholinesterase activity. Experimental sheep and cattle grazing in the contaminated area five

or more months after the incident (August, September) did not exhibit any signs of OP toxicosis or erythrocyte cholinesterase depression (Van Kampen et al. 1970).

Comparable detail on the behavior of mustard agent on vegetation has not been identified in the course of the present analysis. Mustard is known to evaporate from grassland more rapidly than from permeable surfaces such as sand (Pasquill 1943, as cited in Sage and Howard 1989) and reacts with photochemically produced hydroxyl radicals in air with a half-time equal to 1.4 d at average hydroxyl radical concentrations (Atkinson 1987, as cited in Sage and Howard 1989). Direct photolysis is a possible, but not significant, mode of mustard degradation (Rewick, Schumacher, and Haynes 1986). Evaporation (mp of 13 to 15 °C) and dissipation appear to be the most significant sources of mustard degradation. The World Health Organization (WHO) has categorized mustard persistence under various weather conditions as follows (Small 1983, as cited in Sage and Howard 1989):

(1) "12-48 h at 10 °C with rain and moderate wind,"

(2) "2-7 d at 15 °C with sun and light breeze, and"

(3) "2-8 weeks at -10 °C with sun, no wind, and a snow cover"

Once the above conditions have been met, WHO considers a mustard-contaminated area safe for reentry by military personnel.

The above empirical evidence indicates that unharvested food or forage crops in the field would be inaccessible to the grower or grazing livestock for a period of weeks to months if VX or mustard contamination occurred in late fall, winter, or early spring. Regional variation is likely. Little could be done to protect most standing crops from agent deposition; there is a possibility that spray irrigation with alkaline solutions could reduce the degree of initial agent contamination and expedite agent degradation (Trapp 1985). Aerial crop dusting with lime before a rain may accomplish similar results. However, these and other related concepts would require testing before they could be recommended as mitigative actions.

If warning time is sufficiently great, harvested food and forage crops should be brought under shelter or covered. In agent permeability tests of various packaging materials, polyethylene films were found to be superior to polyvinyl chloride or waxed films when challenged with liquid VX at 20 °C (McDowall and Thorp 1970, as cited in NATO 1983). Polyethylene sheets greater than 0.02 in thick provide better protection than thinner sheets, and "will resist penetration by ...V agents for up to 48 h and mustard gas liquid

agent for 7 to 8 h" (NATO 1983). Polyethylene films would thus serve as excellent protective coverings for harvested crops (e.g., hay, ensilage, grains in open cribs) that cannot be moved to shelter in time. Polyethylene has the additional advantage of ready decontamination (greater than 50% of nerve agent and over 90% of mustard agent can be removed by usual decontamination methods), and any remaining absorbed agent has been found to vaporize from polyethylene in a matter of days (NATO 1983).

All terrain decontamination methods for agents examined during the current analysis were developed by military institutions for the standard military reasons of

(1) increasing the period of time that military personnel could remain in the contaminated area, and

(2) providing passageways for personnel or vehicles through the contaminated area.

These procedures were not developed to decontaminate crops for future use as food or forage. A decontamination manual prepared by the U.S. Dept. of the Army Headquarters (U.S. Dept. of the Army 1967) lists four methods for decontaminating "grass or low vegetation." A summary of procedures for technical escort operations (U.S. Dept. of the Army 1981) has also provided background information as follows:

(1) Burning. Does not destroy agent and can loft agent vapor to further contaminate downwind areas ("units downwind must be warned") (U.S. Dept. of the Army 1967). Personnel using the area after burning will still have to wear protective clothing. Agent hazard could be further reduced in the burn area by spreading dry mix (2 parts supertropical bleach to 3 parts earth or sand; supertropical bleach [STB] is commercial bleaching powder formulated with the addition of approx. 6% CaO; STB has 30-35% available Cl).

(2) Detonation. "Paths through low vegetation" could be cleared with the firing of detonation cord or other incendiary devices.

(3) Spraying with slurry (50 lbs of STB or HTB [high test bleach; powdered 70% $CaCl_2O_2$] to every 6 gal of H_2O) from a power-driven sprayer. Slurry should remain in contact with contaminated surfaces for at least 30 min after which it should be rinsed off with clear water. Monitoring will be required to determine if retreatment is necessary.

(4) Dispersal of chlorine bleach into the area from upwind. A military method is to detonate drums of STB or HTB at 10 m intervals. Other methods would need to be developed for civilian application (U.S. Dept. of the Army 1967, 1981).

Unless the crop is of particularly high value (e.g., seed stock), application of the decontamination procedures described above may not be practical when one takes into consideration the resultant crop damage and uncertainties about marketability of produce from heavily contaminated areas. An alternate approach is presented by Mershon and Tennyson (1987), who consider it more reasonable to dispose of agent-contaminated agricultural commodities. Crops considered salvageable would be those present in peripheral areas or which have otherwise become lightly contaminated. The logic here is that a country with abundant food supplies, such as the United States, has no pressing need to place its civilian population at risk from ingesting contaminated food when necessary foodstuffs can be readily transported to affected sites from uncontaminated areas and available commodity food stockpiles. If rigidly enforced and mobilized quickly, this approach would eliminate any potential for human exposure via ingestion and reduce the potential for human surface contact with contaminated crops. However, many agricultural resources that would naturally decontaminate with time would be unnecessarily destroyed by implementing the Mershon and Tennyson (1987) approach. In any case, some criteria to distinguish between "contaminated" and "uncontaminated" would still need to be established. A definition of "disposal" for agent-contaminated agricultural comodities would also require development (controlled burn at elevated temperatures? Open-pit burial with excess lime? Other options?) and must take into account the potential for secondary contamination of field workers. Transportation and treatment of large volumes of bulky plant material such as cornstalks, hay, and grain would need to be factored into any aggressive disposal plan. This issue is more closely addressed in Section 7.

Weathering as a decontamination procedure has much merit in that it is simple and requires no special equipment to implement (Trapp 1985). However, it is neither precise nor fast and would require use of rigidly enforced quarantine restraints to prevent unprotected individuals or livestock from entering the contaminated area before agent concentrations degrade to non-hazardous levels. Monitoring will also be necessary before unlimited access can be declared. Weathering decontamination occurs via evaporation and chemical decomposition (photochemical in part) and is largely temperature dependent, as discussed above. NATO considers weathering to be the preferred option for decontaminating lawns, gardens, pastures and woods unless the contaminated areas are in immediate proximity to occupied buildings (NATO 1983). In the latter case, NATO (1983) recommends covering the contaminated area with "chloride of lime" (e.g., calcium

oxychloride, a commercial bleaching powder composed of varying proportions of $Ca(OCl)_2$, $CaCl_2$, $Ca(OH)_2$ and H_2O) to reduce the acute hazard of vapor exposure. NATO recommendations consider grass to retain hazardous concentrations of mustard for "2 h in the sun, [and] several d in cold, dry winter weather" (NATO 1983). Note that mustard freezes at 13 to 15°C and that the NATO quarantine period should be modified to accommodate local terrain features; sulfur mustard agents are denser than air and will settle in low places. In field situations where sunlight and ventilation are limited (long, thick vegetation; underbrush; accumulated vegetation or leaves; wooded areas), NATO considers that agent "contamination may remain for 2 to 3 weeks" (NATO 1983). NATO recommendations to expedite weathering decontamination include "cutting tall grass and clearing and burning wooded areas." The reader should note that the current analysis strongly recommends against open burning of potentially agent-contaminated vegetation due to the high probability of vapor inhalation exposure and downwind transport.

2.2. LIVESTOCK AND COMPANION ANIMALS

The most likely modes of VX or mustard exposure to livestock in the field are dermal/ocular contact or ingestion of contaminated food/water or snow from aerosol or spray droplet release. In the event of a large vapor release of VX, mustard or G agents, inhalation exposure is possible under appropriate meteorological conditions. Companion animals such as dogs or cats would not normally be subject to ingestion exposure because pet food is usually pre-packaged; however, grooming behavior, particularly among cats, could transfer agent from an animal's coat or paws to the gut. Domestic and wild bird species are known to absorb insecticides through the skin of the feet. However, generalizations about the toxicity of nerve agents to bird species are not possible due to the paucity of data (U.S. Dept. of the Army 1988). The acute toxicity of each unitary nerve or vesicant agent to livestock or pet species is summarized in Table 2.1.

The best protection is to prevent or reduce the potential for agent exposure. Recommended methods include either confining livestock or pets to shelter or precautionary evacuation from the affected area. Either approach will control direct dermal or inhalation exposure, prevent or reduce oral contact/licking of contaminated surfaces and exposure to degassing vapors from fouled objects (Mershon and Tennyson 1987). If possible, ventilation systems should be turned off to prevent drawing contaminated air into the buildings where livestock are confined. This step may be problematic for poultry and

Table 2.1 Acute toxicity of agents to livestock and companion animal species

Species	Nerve Agents				Vesicant Agents		
	GA	GB	VX (vapor)	VX (aerosol)	H/HD	HT	Lewisite
			Inhalation, LCt_{50} (mg-min/m^3)				
Dog	320[a]	60[a]	--	15[a,b]	600[c]	100-200[a]	--
Rabbit	960[a]	120[a]	--	25[a,b,d]	1025[a]	3000-6000[a]	--
Guinea Pig	--	180[a]	--	8, 30 [a,b,d]	1700[a]	3000-6000[a]	--
Cat	--		--	--	700[a,c]	--	--
			Percutaneous, LCt_{50} (mg-min/m^3) (body exposed, head protected)				
Cat	--	--	--	--	8700[a]	--	30,000 (30-45 min)[a]
Dog	--	--	4.6, 89[a,e] (clipped)	3.5, 31.8[a,f] (clipped)	7700[a]	--	40,000 (10 min)[a]
Rabbit	--	2000[a](clipped)	8.3, 28[a,g] (clipped)	124, 180[a] (clipped)	5000[a]	--	15,000 (10 min)[a]
Guinea Pig	--	--	--	3.1[a]	20,000[a]	--	20,000-25,000 (10-40 min)[a]
Goat	--	1.4-5.0[a] (clipped or depilated)	100-150[a] (clipped)	--	--	--	--
			Skin, LD_{50} (mg/kg)				
Goat	--	--	--	--	--	--	15[h]
Guinea Pig	--	--	--	--	--	--	12[i]
Pig	--	115.9[a] (clipped)	<0.40[a] (clipped)	--	--	--	--
Dog	~45[a]	10.8[a](depilated)	0.054[a] (depilated)	--	--	--	15[h]
Cat	--	6.2[a] (depilated)	0.012[a] (depilated)	--	--	--	--
Rabbit	3[a]	4.4[a] (depilated)	0.025, 0.205[j] (depilated)	--	100[a]	--	4[k], 6[h]

Table 2.1 Acute toxicity of agents to livestock and companion animal species (continued)

Species	Nerve Agents				Vesicant Agents		
	GA	GB	VX (vapor)	VX (aerosol)	H/HD	HT	Lewisite
			Intravenous, LD_{50} (mg/kg)				
Goat	--	0.015[a]	<0.005[a]	--	--	--	--
Dog	0.084[a]	0.010[a]	0.0063[a]	--	0.2[a]	--	2.0[a,i]
Cat	--	0.015-0.018[a,j]	~0.0025[a]	--	--	--	--
Rabbit	0.063[a]	0.0147[m]	0.0084[a,n]	--	~1.1 to 4.5[a]	--	0.5[b], 2.0[a]
			Minimum effective dose, ED ($mg\text{-}min/m^3$)				
Rabbit skin	--	--	--	--	250-2000[o] (erythema)	--	~25 (30 min)[a] (skin lesions)
Rabbit eyes	--	--	--	--	--	--	~1 (30 min)[a] (eye lesions)
Dog skin	--	--	--	--	--	--	~50 (30 min)[a] (skin lesions)
					--	--	~20 (30 min)[a] (skin lesions)
			Oral LD_{50} (mg/kg)				
Rabbit	2.5[p]	--	0.123[p]	--	40[q]	--	--
Guinea Pig	--	--	--	--	45[q]	--	--
Sheep	--	--	0.030[r]	--	--	--	--
Young steer	--	--	0.026[r]	--	--	--	--

[a]U.S. Department of the Army 1974, percutaneous values at different windspeeds.
[b]Only head exposed.
[c]Robinson 1967.
[d]Windspeed 0.01 mph.
[e]Windspeed 20 and 0 mph, respectively.
[f]Windspeed 15 and 5 mph, respectively.
[g]Windspeed 8 and 0 mph, respectively.
[h]Cameron, Carleton and Short 1946.
[i]National Technical Information Service 1946.
[j]Wiles and Alexander 1960; bare, clipped; and clothed, unclipped, respectively.
[k]Danielli et al. 1947.
[l]Murtha and Harris 1980.
[m]O'Leary, Kunkel, and Jones 1961.
[n]Fielding 1960.
[o]Schoene et al. 1989.
[p]Owens et al. 1973.
[q]Boyland 1944.
[r]Sutton and Salomon 1975; U.S. Congress 1969.

dairy farmers, particularly during warm weather when brooder houses or dairy barns can overheat and noxious gases such as methane, ammonia, and H_2S can attain toxic levels. Ventilation requirements for several livestock species are summarized in Table 2.2. Some method of notifying livestock growers when atmospheric concentrations of agent decline to acceptable levels is necessary so that ventilation systems can be reactivated. Otherwise, interior agent concentrations may attain hazardous levels via infiltration and accumulation after the exterior plume has passed (Rogers et al in press; Mershon and Tennyson 1987).

A recent survey of beef producers in Tennessee indicates that nearly 100% of all Tennessee beef cattle can be placed under shelter within 2 h from time of notification (R. D. Linnaberry, Assoc. Prof., College of Veterinary Medicine, University of Tennessee, Knoxville, Tenn., personal communication to N. Munro, Health and Safety Research Division, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 27, 1989). Similar surveys are needed in the eight communities that host portions of the unitary stockpile. Regional differences resulting from variation in animal husbandry practices (especially East vs West) are expected. For example, it would not be practical to consider shelter as a reasonable option for cattle or sheep on open range.

During the confinement period (length to be determined by agent, extent, and degree of contamination, meteorological conditions, decontamination procedures implemented, and monitoring results), precautions should be taken to provide stock with uncontaminated food and water. Unless advance preparations have been made, stored reserves of animal feed on individual farms will, in most cases, be inadequate. A sufficient water supply is far more significant than adequate quantities of food, particularly during warm or hot weather. Daily water requirements for several livestock species are summarized in Table 2.2. Feed "should be selected from lots stored in protected areas (silos, barns, bins, bags) and under protective layers (plastic, bales, discardable feed)" (Mershon and Tennyson 1987). Note that regional differences in barn construction will determine the degree of protection provided to stored feed. The topmost layers of unprotected hay or grain should be destroyed after removal by workers in protective clothing. Cross- or self-contamination could be a problem during this process. Some investigators recommend that, after the plume has passed, animals could be removed from shelter and confined in the open on areas plowed after all remaining agent had opportunity to settle (Mershon and Tennyson 1987).

Table 2.2 Estimated (summer) requirements for water and air by several livestock species[a]

Livestock	Water[b]		Air (minimum)
	Normal	Minimum	
	(gallons/day)		(cubic ft/min/animal)
Cattle			
400-lb calf	8	4	100
800-lb dairy[c]	17	10	225
1000-lb beef	12	6	220
1400-lb dairy[c]	22	14	300
Hogs			
Sow and litter	8	2.5	150
100-lb hog	1.5	0.8	50
200-lb hog	2.5	1.0	85
Sheep			
Nursing ewe	4	1.5	--
60-lb lamb	1	0.5	--
Poultry			
Hen	0.5	0.2	6
25-lb turkey	0.8	0.4	15
Horses	11	7	300

[a]Byrne and Bell 1973 as presented in Schulte 1987.

[b]Animals not fed in shelter.

[c]Moderate to good producers.

Soviet emergency planners have recommended that animals confined to buildings with possible agent-contaminated floors could be protected from agent exposure by placing at least one foot of clean soil over the suspect floor surfaces (Sterlin et al. 1971; as cited in Mershon and Tennyson 1987). Some consideration among Soviet planners has also been given to providing "gas masks" to "the most important animals" (presumably breeding stock) and housing/maintaining them in state buildings pre-stocked with food and water reserves (Sterlin et al. 1971; as cited in Mershon and Tennyson 1987). This latter idea would be difficult to implement.

The clinical history of organophosphate insecticide poisoning cases has identified several factors that determine susceptibility to toxic effects from a given OP exposure. In the absence of comparable data for OP nerve agents, it would be prudent to incorporate knowledge of these factors in planning for potential releases of stockpiled GB, GA, or VX. Young animals are generally more sensitive due to their underdeveloped detoxification systems (Meerdink 1989). Their small body weight and thin skin would also be factors. Old or disabled animals have less resistance to the effects of toxicants in general (Osweiler et al. 1985). Meerdink (1989) has determined that "tired, stressed or chilled animals are more susceptible to these [OP and carbamate] insecticides." No differences between maternal and fetal plasma cholinesterase sensitivity to inhibition have been noted in sheep exposed to several OP insecticides (Bell and van Petten 1976); it is not known if this lack of age-specific sensitivity to cholinesterase inhibition occurs in other livestock species (see Section 3.3 for summary of OP effects on cholinesterase levels). Sheep are well-documented "sentinel" species and exhibit extraordinary susceptibility to anti-cholinesterase compounds (Boffey 1968; Van Kampen et al. 1969; Hoeber and Douglass 1978; and Begovic, Stern, and Sabjan 1955 as cited in Mershon and Tennyson 1987). Gender susceptibility has been noted in livestock species for one OP insecticide (chlorpyrifos or Dursban, used as a pour-on treatment for control of hornflies and lice). Sexually mature sire bulls of several cattle breeds (primarily dairy; Holstein and Simmental bulls were specifically noted) exhibited symptoms of acute OP poisoning after treatment according to label directions (Carson and Dominick 1980 as cited in Osweiler et al. 1985; Lein et al. 1982, Haas et al. 1983). It was later found that elevated bovine plasma testosterone led to significantly reduced blood cholinesterase in Dursban-treated animals (Haas et al. 1983; Lein et al. 1982). Spermatogenesis was significantly reduced from normal in survivors monitored months after initial Dursban exposure (Lein et al. 1982). Dursban is now

manufactured under a restricted label which does not allow treatment to "bulls of any breed over 8 months of age" (Meerdink 1989). It is not known if testosterone would be a factor in OP inhibition of cholinesterase in other livestock species. Until and unless data to the contrary are presented, this analysis recommends that special precautions be taken for protecting bulls and other stud animals from OP agent exposure.

In contrast, female laboratory rats are more sensitive than male rats to the OP insecticide parathion (Dubois et al. 1949). Initial findings were confirmed by injection of testosterone propionate, which decreased the parathion sensitivity in female rats; injection of diethylstilbestrol increased the parathion sensitivity of male rats (Dubois et al. 1949). It is not known if the enhanced toxicity of parathion in female rats is exhibited by livestock species.

Transdermal skin absorption of OP compounds is a slower route of livestock exposure than inhalation or ingestion (Meerdink 1989). The same can be said of OP nerve agents in vapor form or vesicant agents in any form. Thus, the stock or pet owner has somewhat more time to decontaminate flocks, herds, or individuals if exposure has been topical. The most available all-purpose decontaminant is household bleach (5% NaClO solutions) (U.S. Dept. of the Army 1989a,b), although other alkaline materials such as ammonia, lye, alkaline carbonates, silicates, phosphates and borax would also hydrolyze OP nerve agents (Mershon and Tennyson 1987). Soap, detergent, or shampoo and warm water are also effective (U.S. Dept. of the Army 1967; Osweiler et al. 1985; Koehler and Butler undated; Dorman 1989). The animal(s) should first be removed from the source of contamination, washed with bleaching solution or some of the other alkaline materials listed above, and then rinsed with quantities of clean water. Precautions should be taken to avoid supplies of potentially contaminated water for this task. Without sufficient rinsing, skin may be damaged by the decontaminant solution. The operator should wear protective clothing adequate to prevent secondary self-contamination. Thickened agent (particularly the thickened sulfur mustard formulations) may require wiping with an absorbent pad dampened with acetone or other hydrocarbon solvent (Mershon and Tennyson 1987). Care should be taken to prevent spread of contamination by dripping contaminated solution onto a "clean" area or wiping outward from the exposed site. Irrigation (20-30 min) of exposed eyes with water or physiological saline should begin immediately (Dorman 1989). Note that rapid cleansing within 3 min after exposure is considered far more effective than later

careful decontamination (Crone 1983). Clipping may facilitate removal of dermal contamination (Osweiler et al. 1985) but care should be taken to avoid nicking.

Ingestion exposure is more problematic. Depending on the amount of time elapsed since ingestion of contaminated food, water, or snow, standard veterinary procedures can be performed to decontaminate the gastrointestinal tract and prevent further absorption (Osweiler et al. 1985; Koehler and Butler undated; Dorman 1989). Recommended compounds and dose(s) as derived from Osweiler et al. (1985) and Dorman (1989) are summarized in Table 2.3. Best results are obtained if initiated shortly after suspected ingestion.

(1) Emesis (vomiting). Never induced in horses, rodents or rabbits. Not effective for ruminants; most effective in dogs, cats and swine when food is still present in stomach. Contraindicated for unconscious or semicomatose animals, animals experiencing seizures or dyspnea, or lacking normal pharyngeal reflexes. Also contraindicated for corrosive materials such as sulfur mustard.

(2) Gastric lavage. Neither safe nor effective for ruminants. Lavage fluids should be introduced via lavage tube to stomach of unconscious or anesthetized animal fitted with endotracheal tube. Remove lavage fluid by gravity or aspiration until lavage fluid clear. May be combined with enema to accomplish enterogastric lavage or modified by use of stomach tube to flush out ruminal contents. Unless animal is particularly valuable, rumenotomy not recommended in cases of agent exposure.

(3) Gastrointestinal containment. When ingested agent cannot be physically removed, absorption by activated charcoal recommended for OP poisoning. Provide in water slurry at recommended dose (See Table 2.2).

Even after removal of OP material (data for insecticides only), signs of poisoning may persist for up to 48 h in non-ruminants and 8 d for ruminants (Koehler and Butler undated).

In the event of a major agent release, there will likely be more animals affected than can be decontaminated or treated during the critical time period before severe or life-threatening symptoms develop (See Section 3.4 for treatment protocols). Triage will be necessary. To be performed competently, triage will require considerable knowledge of agent characteristics and training in animal handling/treatment. It may be more practical and less hazardous to the herd or flock owner to humanely destroy heavily contaminated stock and petition for compensation. In peripherally contaminated areas, agent decontamination would be more successful and entail less risk of secondary contamination

Table 2.3 Veterinary compounds and doses recommended for decontaminating the gastrointestinal tract

Procedure	Compound	DOSE			Reference
		Dog	Cat	Cattle	
Dilution	Water or milk	As much as feasible	As much as feasible	As much as feasible	Dorman 1989
Emesis	Syrup of ipecac	1-2 mL/kg	3.3 mL/kg	Not recommended	Dorman 1989
		10-20 mL oral	--	Not recommended	Osweiler et al. 1985
	Apomorphine[a]	0.03 mg/kg i.v.	--	Not recommended	Dorman 1989
		0.05-0.10 mg/kg i.v., i.m., s.q., s.c.	--	Not recommended	Osweiler et al. 1985
		0.04 mg/kg i.m.	--	Not recommended	Dorman 1989
	$CuSO_4$	25-75 mL of a 1% solution	--	Not recommended	Osweiler et al. 1985
	Ground mustard seeds	2-4 tsp in cup hot water	--	Not recommended	Osweiler et al. 1985
	H_2O_2 (3%)	5-25 mL orally[b]	--	Not recommended	Osweiler et al. 1985
		5-10 mL/5 kg	5-10 mL/5 kg	Not recommended	Dorman 1989
	Xylazine[c]	--	1.1 mg/kg IM, SQ	Not recommended	Dorman 1989
Lavage	Tap water	10 mL/kg	10 mL/kg	Not recommended	Osweiler et al. 1985
	Saline	10 mL/kg	10 mL/kg	Not recommended	Osweiler et al. 1985

Table 2.3 Veterinary compounds and doses recommended for decontaminating the gastrointestinal tract (continued)

Procedure	Compound	DOSE			Reference
		Dog	Cat	Cattle	
GI containment	Activated charcoal (water slurry)	2-8 g/kg	2-8 g/kg	250-1000 g	Osweiler et al. 1985
Catharsis	Mineral oil[d]	5-15 mL	2-6 mL	1-3 L	Osweiler et al. 1985

[a]For veterinary clinic use; apomorphine solutions unstable and must be made fresh (Dorman, 1989).

[b]Repeat in 5-10 min if no response.

[c]Xylazine may aggravate respiratory depression and induce bradycardia. Treat these side effects with yohimbine at 0.1 mg/kg IV for dog or cat (Dorman 1989).

[d]Cathartic for oil-soluble materials such as sulfur mustard.

to the care-giver. Heroic measures are recommended only for valuable breeding or show stock. In any case, it would be prudent to have decision protocols established prior to the occurrence of an emergency.

The need for evacuation and shelter programs for livestock and companion animals is well recognized (Morrison 1987) and was recently highlighted during a chemical emergency drill in Louisiana (NAPINet Report 1989). The exercise, performed in cooperation with the Louisiana Veterinary Medical Association, identified several unmet emergency requirements:

(1) "Pre-emergency designation of potential [animal] shelters"

(2) "Pre-emergency designation of transportation resources"

(3) "Coordination [among] emergency management officials, veterinarians, [state] Department of Agriculture, state university schools of veterinary medicine, and various humane groups"

(4) "A ready supply of volunteers [and stockpiled] food and medication" (NAPINet Report 1989).

There is precedent in Louisiana for meeting these needs during chemical emergencies; similar precedents may also exist for the unitary stockpile host states. During the 1982 chemical tank car derailment in Livingston, La., companion animals, cattle, horses, hogs, poultry, goats, and rabbits had to be left behind when townspeople were ordered to evacuate (Morrison 1987). Local veterinarians, state police, and state-employed livestock inspectors formed teams to feed, water, and observe animals for the 2 weeks that elapsed before Livingston inhabitants could return. Hay and feed were obtained through donation or outright purchase with reimbursement by the railroad. Expenses of the Louisiana Department of Agriculture were also reimbursed by the railroad (Morrison 1987).

The current analysis strongly recommends that local expertise, such as that provided by veterinarians and veterinary medical associations, the state veterinarian's office, USDA and state department of agriculture staff and local growers' associations be incorporated into reentry planning at the community and state level early in the process. Planning emphasis should be on preventing or reducing animal exposure rather than post-incident treatment. See Section 2.4 for specific USDA responsibilities in this area and Section 3.4 for a discussion on treatment regimens and veterinary resources available for advice on prognosis.

2.3. SOIL

Agent persistence in soil is largely dependent on the amount and form of the agent as well as ambient and soil temperature. The G agents are not expected to be persistent on soils due to their high volatility (GA, volatility of 610 mg/m^3 at 25°C; GB, volatility of 2.2 x 10^4 mg/m^3 at 25°C) (U.S. Dept. of the Army 1974). Greater than 90% of GB deposited on soil is expected to be lost within the first 5 d or less (Sass, Zenk, and Hillard 1953 and USATECOM undated as cited in Small 1984; see also Table 2.4). VX is considered persistent in or on soil in part due to its low volatility (VX, volatility of 10.5 mg/m^3 at 25°C; U. S. Dept of the Army 1974).

A factor in sulfur mustard's (H/HD) persistence is its characteristic freezing at moderate temperatures [13 to 15°C (55° to 59°F); U.S. Dept. of the Army 1974]; droplets or bulk quantities would thus be expected to remain where initially deposited during cool weather or under winter/arctic conditions. Another factor is that mustard agents do not readily dissolve in aqueous solution (water solubility of 0.68 to 0.92 g/L at 25°C for H/HD; HT is considered insoluble; U.S. Dept. of the Army 1974). If HD is introduced into water at a slow enough rate to permit dissolution, hydrolysis can proceed rapidly and produce mustard chlorohydrin (C_4H_9ClOS) and thiodiglycol ($C_4H_{10}O_2S$) (Sage and Howard 1989). Estimated hydrolysis half-times for HD are 1.75 h, 4 min and 43 sec at 0°, 25° and 40°C, respectively (Sage and Howard 1989). However, the rate of hydrolysis is effectively limited to the rate of dissolution for volumes larger than droplets (Small 1984). Thus, bulk quantities of mustard agent spilled or splashed onto soil would not degrade in a matter of d (see Table 2.4). The hydrolysis of concentrated sulfur mustard is complex and involves several stages; at least one reaction product ($C_{12}H_{28}O_4S_3^+$) is reported to be more toxic than agent H (Aleksandrov 1969; Franke 1967; Yang et al. 1988).

Reports exist of burns to military personnel who came in contact with soil contaminated by HD three years previously as well as decades-long persistence of HD in military land dumps (Small 1984). In all cases of such lengthy persistence, the source was spilled or leaked mustard in bulk quantities:

> (1) "An incident at Edgewood Arsenal (now the Edgewood Area of Aberdeen Proving Ground), probably around 1921, reported by Walker et al. [1928] 'men digging in an area where there had been no new mustard for at least three years...were definitely burned. The mustard contaminated the soil due to leakage, but the total amount in the soil was not known. It was probably very great.'" (Small 1984).

Table 2.4 Persistence times (τ, hours)[a] predicted for HD or GB droplets on soil under various weather conditions[b]

Agent	Temperature, °C	Calm, Dry[c,d]	Windy, Dry	Light Rain[e]	Heavy Rain[e]
HD	0	1530	1743	2215	1122
HD	25	41.5	47.3	51.2	30.5
GB	0	274	238	434	279
GB	25	8.9	7.8	14.2	9.1

[a]Time required for agent to degrade to 0.033 mg/m^2 (i.e., 1500-fold degradation from initial concentration of 50 g/m^2).

[b]Data from Puzderliski 1980 as presented by Small 1984.

[c]Calm indicates wind speed < 3 m/sec.

[d]Dry indicates rainfall intensity < 0.05 mm/h (0.047 in/d).

[e]Light rain indicates an intensity between 0.05 mm/h and 0.3 mm/h (0.28 in/d).

(2) "Epstein et al. [1973] cite a source that reported that mustard dumped at Edgewood Arsenal in 1941 was still detectable in 1971. The area involved was known to have been used as a dump for munitions for several years." (Small 1984).

(3) "One positive detection of HD in surface soil samples was reported from a closed training area at Fort McClellan in January 1973 [U.S. Army Toxic and Hazardous Material Agency 1977]. This occurred several months after last known agent presence in the area, which had been used for storage. Spills of agent had been previously reported." (Small 1984).

(4) During the recent Iran-Iraq conflict, samples of air from within bomb craters 14 to 15 d after enemy attack contained "detectable" to 2.5 mg/m^3 mustard vapor concentrations, even though the craters had undergone decontamination and excess water was present (Dunn 1986).

Persistence of mustard sprayed on snow has been reported to range from 14 to 56 d, with little migration from the contaminated surface into the snowpack (Sage and Howard 1989). Simulated snowfall (5 cm new snow) after initial HD deposition increased persistence, probably by means of reduced volatilization and dissolution (Johnsen and Blanch 1984 as cited in Sage and Howard 1989). Observation of sulfur mustard spray degradation on various soil types (50 g/m^2 on "sand, cultivatable soil, uncultivatable soil and gravelly soil") under ambient conditions demonstrated that sand exhibited the longest persistence (68 h) and gravelly soil the least persistence (27 h) (Puzderliski 1980 as cited in Sage and Howard 1989). Puzderliski defined persistence as the time (τ) required for the initial contamination to degrade 1500-fold (i.e., to 0.033 mg/m^2) (see also Table 2.4). At 0 °C, the greatest persistence was observed in the uncultivatable soil (92.3 d) with the least persistence noted for gravelly soils (49.7 d). Cultivated soil at 0 °C exhibited a persistence of 72.6 d (Puzderliski 1980 as cited in Small and Howard 1989).

VX is much more soluble than mustard in water (30 g/L at 25 °C; Sage and Howard 1989) and undergoes base-catalyzed hydrolysis. Extremes of pH-mediated hydrolysis half-times calculated for VX range from approx. 3000 h (pH 4) to approx. 4 h (pH 12) (Epstein, Callahan, and Bauer 1974 as presented in Small 1984). The principal hydrolysis product of VX is S-2-diisopropylamino ethyl methyl phosphonothioic acid (EA 2192); production of this compound is greatest at neutral pH. Acute toxicity data indicate that EA 2192 is toxic via ingestion or i.v. exposure (Szafraniec, Beaudry and Ward, submitted).

VX persistence in soil is considered a function of soil temperature, organic carbon content, and moisture content; greater persistence has been observed in soils at low

temperatures/soil moisture and high organic carbon content (Epstein et al. 1959 as cited in Sage and Howard 1989). A VX application (200 ppm) to humic sand, humic loam, and clayey peat soils was degraded after 8 d to 30%, 65% and 77% of the initial concentration in the three soil types, respectively (Kaaijk and Frijlink 1977). With other soils and experimental conditions, VX exhibited initial rapid degradation over a period of d, followed by a more gradual decline over a period of weeks and consistent with first-order kinetics: 95% degradation was observed in one study of soils with varying cation exchange capacity, pH, and moisture (Epstein et al. 1959 as cited in Sage and Howard 1989); 97% degradation was noted one day after VX application to humic loam while 80% breakdown was observed after one day in clayey peat (Verweij and Boter 1976); 90% of initial VX activity had dissipated within one week's incubation at room temperature for 9 different soils (Demek and Epstein 1959 as cited in Sage and Howard 1989). Note that several products of VX hydrolysis possess anticholinergic properties (e.g., diethyl dimethylpyrophosphonate [$C_6H_{16}O_5P_2$], among others) that can be detected in some soils 3 months after initial application (Demek and Epstein 1959 as cited in Sage and Howard 1989).

As noted for HD, VX does not migrate into snow after surface application. Less than 10% of the initial concentration remained 14 to 28 d later (Johnsen and Blanch 1984 as cited in Sage and Howard 1989).

On the ground, VX is considered "moderately persistent" and has been found in significant quantities for a period of 2 to 6 d following initial application (Sage and Howard 1989). Soil collected from the area of sheep kill defined in the Skull Valley incident (discussed in Sections 2.1 and 2.2 above) 8 to 10 d after agent release contained detectable quantities of VX (Sass et al. 1970). Analytical results were unclear for two other soil samples collected from different sites in the contaminated area 10 and 11 d after the release; VX traces were "possible" but not confirmed due to insufficient sample (Sass et al. 1970). In the course of the present evaluation, no other data on soil samples collected from Skull Valley at later dates have been located.

The very fact that VX and sulfur mustard are so persistent on certain soils effectively limits the area to be decontaminated and reduces the potential for secondary contamination of adjacent areas or water supplies. Best conditions for containment would occur during cold weather (below 14.5°C for H/HD , 0° to 1.5°C for HT, and -39°C for VX) (see Table 1.1). Several approaches can be followed in decontaminating soils on which these agents may have been deposited. The most appropriate choice is somewhat

incident-specific and will depend on the quantity of agent involved, weather conditions and soil type. The following summary is derived from material presented in NATO (1983) and the U.S. Dept. of the Army (1967, 1981). The reader is cautioned that these methods were primarily developed to expedite military missions and have not been evaluated for soils that would serve future agricultural or domestic purposes.

(1) Weathering. Not advised when contaminated area is in close proximity to unprotected personnel or occupied buildings. Strongly dependent on agent, weather (temperature, wind, moisture) and soil type. "Usually from 3 to 7 d are required in warm weather (75° to 85°F)." (U.S. Dept. of the Army 1967). Would require quarantine restraints.

(2) Covering and burying. Does not wholly solve the problem but drastically reduces vaporization in warm weather while alternative procedures are being put in place, particularly if spill or contaminated area is large. Enhances agent penetration into deeper soil layers. Involves covering with soil (at least 4 in) or other material soaked with decontaminant. Requires quarantine restraints.

(3) Absorption. Use of porous materials (activated charcoal, fullers' earth, sawdust, peat, coke, ashes, sand) to absorb liquid agent. Contaminated adsorbents can then be removed and incinerated. Requires quarantine restraints.

(4) Removal. It is suggested that most liquid agents do not penetrate more than 5 cm (2 in) below the soil surface (U.S. Dept. of the Army 1967); removal of contaminated soil to a depth of 5 to 10 cm (2 to 4 in) with earthmoving equipment or hand tools can be effective for small areas but is impractical for large sites. Does not destroy agent; contaminated soil will have to be contained and transported to a final disposal site or incinerated. Flushing with water or solvents can be performed if precautions are taken to collect runoff or drain runoff to a sump containing excess quantities of decontaminant. This procedure requires close supervision to prevent secondary contamination.

(5) Chemical neutralization. Cover contaminated soil with dry mix (2 parts STB or HTB to 3 parts earth or sand) or rake dry bleaching powders (STB or HTB) into surface to the depth of agent penetration. Can also spray with slurry (50 lb STB or HTB to every 6 gal of water) from power-driven sprayer and let soak in. Other alkaline compounds such as chloride of lime (calcium oxychloride, defined in Section 2.1), NaOH and household bleach are also effective. DS-2 [decontaminating solution No. 2; made up of 70% active agent diethylenetriamine, 28% solvent ethylene glycol ($C_2H_6O_2$) and 2% NaOH] is an effective, all-purpose military-issue decontaminant for G and vesicant agents (10 min contact) as well as VX (30 min contact). If available, DS-2 could be poured onto small areas and mixed into the surface. Operators must work upwind and wear protective clothing. Will require monitoring to determine when safe levels are attained. NOTE: dry, undiluted STB or HTB ignites on contact with sulfur mustard.

Implementation of appropriate decontamination procedures for agent-contaminated soils will require the knowledge and expertise of local soil conservation and agricultural extension agents. The current analysis strongly recommends their early involvement in reentry planning at the community and state level. See Section 2.4 for pertinent USDA responsibilities for reentry readiness.

2.4. FOODSTUFFS

All foodstuffs located in an agent-contaminated area should be considered contaminated. The degree of handling or ingestion hazard posed by foodstuffs is dependent on the type and form of the agent involved and the degree of protective wrapping or containerization surrounding the food item. The U.S. Dept. of the Army (1967) and NATO (1983) recommend segregating suspect items into categories for disposition.

Group I: packaged (glass, metal, plastic, cellophane), sealed, unopened items that have been exposed only to agent vapor.

Group II: packaged, unopened items that include an impermeable wrapper or container (e.g., foil pouch) and that have been exposed to agent liquid. Shrink-wrap packaging films have been found to protect from agent penetration for days; polyethylene films at least 0.02 inches thick are protective against nerve agents for at least 1 d, but only hours against sulfur mustard; waxed and greaseproof papers are readily penetrated by agent (McDowall and Thorp 1970 as cited in NATO 1983).

Group III: unpackaged items (e.g., fresh fruit), opened packaged items or items packaged in untreated (i.e., no plastic or foil) paper or cardboard.

Foodstuffs in Group I can be used after they are subjected to "prolonged airing" (NATO 1983). Group II items may be decontaminated with slurry or DS2 (see Section 2.0 and 6.0). Group III items can "be trimmed or peeled" or "washed in water or a 2% bicarbonate solution" (U.S. Dept. of the Army 1967). Another recommendation is to boil the item in water for ≥ 30 min (U.S. Dept. of the Army 1967). The reader should keep in mind that these Group III treatments were developed for military situations where personnel in the field may have no other sources of food. Such would not be the case in the event of a civilian reentry emergency. This analysis recommends that Group III foodstuffs be destroyed.

Disposition of foodstuffs into the treatment categories above will require extensive procedures for handling and managing food items from groceries and private dwellings in

the contamination zone. Compensation mechanisms for loss or damage of food stocks should also be considered.

2.5. IMPLEMENTATION

Protocols for crop treatment and handling in the event of agent release off-post should be somewhat site-specific to

(1) address the seasonal dynamics and composition of crops in each host community (see Figure 1.1),

(2) incorporate the unique munition and chemical configurations of each unitary stockpile, and

(3) include special features of local climate.

The USDA generically considered these aspects of decision making when Departmental Regulation 1800-1, "Departmental Emergency Preparedness Responsibilities" was promulgated in September of 1983. Specific responsibilities for protecting, and responding to threats against "food resources, farm equipment, fertilizer, and food resource facilities" in the event of a chemical, biological or radiological emergency have been provided to the Agricultural Stabilization and Conservation Service, Agricultural Marketing Service, Animal and Plant Inspection Service, Food Safety and Inspection Service, and the Extension Service, among others. The authority to carry out these responsibilities was granted to USDA by several acts of Congress (Commodity Credit Corporation Charter Act of 1948, Defense Production Act of 1950, Federal Civil Defense Act of 1950, Flood Control Act of 1950, Disaster Relief Act of 1974, Strategic and Critical Materials Stockpiling Act of 1979) and Presidential Executive Order (EO 11490, "Assigning Emergency Preparedness Functions to Federal Departments and Agencies"; October 1969). However, these general guidelines require further development in collaboration with local and state officials to address specific agricultural planning needs of communities affected by the Chemical Stockpile Disposal Program. For example, county and state Extension Service staff would be the most likely individuals to know the distribution/composition of local crops and the age, breed, location, etc. of herds/flocks in host communities. Food safety and inspection will be critical responsibilities of the USDA (Stalheim 1987). This analysis recommends that USDA agencies and veterinary associations be closely integrated into local planning activities in fulfillment of the guidelines outlined in the enabling legislation and Executive Order identified above.

Apart from the need to develop disposition criteria, there is also concern about identifying the institution(s) with appropriate inspection expertise. Such institutions have already been put in place to monitor pesticide and drug residues in food and feed. Allowable residues of agricultural chemicals in foods are established and/or enforced by three federal agencies whose responsibilities are outlined below (OTA 1988).

USDA

Food Safety and Inspection Service (FSIS) monitors and enforces residue tolerances in meat and poultry. Trains food inspectors, food technologists, and veterinarians who are posted to slaughterhouses and processing facilities to monitor for residues/evidence of animal diseases in meat and condemn carcasses as necessary. Authorized by Federal Meat and Inspection Act of 1967 (PL 90-201).

Agricultural Marketing Service (AMS) monitors and enforces residue tolerances in raw and processed egg products. Authorized by Egg Products Inspection Act of 1970 (PL 91-597).

U.S. EPA

Establishes residue tolerances for pesticides and other compounds in agricultural commodities and environmental media; monitors and regulates pesticide levels in water, air and soil; some food monitoring to determine pesticide misuse or spray drift. Authorized by Federal Insecticide, Fungicide and Rodenticide Act of 1947.

U.S. DHHS

Food and Drug Administration (FDA) enforces pesticide residue tolerances established by U.S. EPA in raw agricultural food items (but not meat, poultry or raw or processed eggs and egg products; has jurisdiction over raw, unbroken eggs) and enforces the prohibition of residues in food or feeds which have no established tolerances. Authorized by Federal Food, Drug and Cosmetic Act of 1938.

The regulatory authority each of these agencies possesses could be utilized to ensure that no contaminated commodities enter the market. Policies and mechanisms to incorporate these inspection resources need to be included in the planning process.

3.0 ACTION LEVELS FOR DISPOSITION OF WATER AND AGRICULTURAL RESOURCES

Due to the intended use of these agents against enemy forces in wartime, there has been little need or incentive to develop allowable residue tolerances for public use of potentially contaminated water and foodstuffs. With the notable exception of the Skull Valley incident described in Section 2 above, production, transportation, and storage of the unitary stockpile in the United States has been performed in a manner resulting in no known contamination of public drinking water supplies or agricultural resources. The CSDP is designed to improve upon the existing record and place extraordinary engineering and operations constraints on emission control (Carnes and Watson 1989; U.S. Dept. of the Army 1988). Nevertheless, the probability of an uncontrolled release that could result in health-threatening concentrations of agent in water, crops or animal products off site is not zero (U.S. Dept. of the Army 1988). In the absence of existing ingestion criteria for agent in public water and/or food supplies, alternative means of deriving approximations of safe levels are explored in Sections 3.1 and 3.2 below. Even if the eventually acceptable emergency sequence is to quarantine/destroy all suspect produce and remove access to all suspect water supplies, some guideline for "safe" concentrations will be necessary. The following two sections present some approaches to resolving the quandary.

3.1 WATER

Existing water criteria for warfare agents have been developed to meet the militarily strategic need of determining safe drinking water concentrations for troops performing missions in the field. Application of these criteria assumes exposure only to healthy adult combat personnel between the ages of 18 and 45. At present, all three defense services allow the following maximum concentrations (also termed maximum permissible concentrations or MPCs): GA, GB and VX at 20 μg/L, sulfur mustard at 200 μg/L and Lewisite at 2000 μg/L (See Table 3.1). These values are considered combat zone criteria and were developed to guide field command decisions under threat conditions regarding

(1) the safety of local raw water supplies,

(2) the need for water treatment before ingestion by troops, and

(3) the need for personnel prophylactic pretreatment to reversibly inhibit acetylcholinesterase (see Dunn and Sidell 1989 for pretreatment protocols).

Table 3.1 Existing and proposed field standards for chemical agents in combat drinking water[a]

Agent	Existing standard (μg/L)	Proposed standard (μg/L)[b]		Suggested civilian standard (μg/L)[c]	
	5 L/day intake	5 L/day intake	15 L/day intake	5 L/day intake	15 L/day intake
GA	20[d]	12[e]	4[e]	1.2	0.4
GB	20[d]	12[e]	4[e]	1.2	0.4
VX	20[d]	12[e]	4[e]	1.2	0.4
Sulfur mustard	200[f]	Under development[g]	Under development[g]	To be derived from forth-coming military standard	To be derived from forth-coming military standard
Lewisite (L)	2000	Under development[g]	Under development[g]	To be derived from forth-coming military standard	To be derived from forth-coming military standard

[a]Assume combat drinking water contains no other toxic materials and that period of consumption does not exceed 7 consecutive days.

[b]Not yet finalized; standardization will require establishment of acceptable risk levels by Offices of Surgeon General of Army, Air Force and Navy. Assumes 50% depression of RBC-ChE.

[c]Derived in current analysis; see p. 39-40.

[d]U.S. Department of the Army 1986.

[e]Daniels 1988a; calculated maximum permissible concentration (MPC) based on estimated human ChE_{50} threshold for GD drinking water exposure. GD considered to pose greater threat to military personnel than GA, GB, or VX because of GD's ability to quickly and stably bond to ChE ("aging"; makes ChE resistant to therapeutic reactivation) and its potency as a ChE inhibitor. Though VX is a more potent inhibitor, it is not as cumulative.

[f]Ward 1970; Headquarters, U.S. Department of the Army 1982, 1986. Recommended MPC for consumption period in excess of 7 days is 50 μg/L.

[g]Available data on vesicant agent oral toxicity in laboratory rats and rabbits currently under study by agencies of the Army, Air Force and Navy. Proposed standards may be released in early 1990.

In addition, these criteria are to be followed only for short durations ($\leq$7 consecutive d). As such, these standards are not comparable to occupational limits. Current criteria assume individual adult water consumption of 5 L/day and that the water contains no other toxic materials.

For situations that require military units to operate >7 d under field or combat conditions, different standards apply. The long-term standard for Lewisite is 200 μg/L (0.2 mg/L) and that for mustard agent is 50 μg/L (0.05 mg/L) (U.S. Dept. of the Army 1986). Dept. of the Army Headquarters considers that "there is not yet enough data to set a practical long-term standard" for OP nerve agents (U.S. Dept. of the Army 1986).

Combat drinking water guidelines for nuclear, biological and chemical agents are undergoing re-evaluation by the three U.S. military services; proposed standards for all are expected to be released sometime in 1990. Several recent studies that address water criteria for the unitary stockpile agents are in the process of review (Daniels 1988a,b; Dacre and Burrows 1988; Sasser et al. 1989a,b); proposed values for the nerve agents are presented in Table 3.1 for projected water consumption rates of 5 L/day and 15 L/day. Vesicant data from these studies are still under consideration and proposed standards have not yet been released. Since there are no controlled human exposure data for ingestion of sulfur mustard or Lewisite, human drinking water criteria for these agents must necessarily be extrapolated from laboratory animal data. There is still some toxicological debate over species sensitivity and the appropriate uncertainty (safety) factors to apply in extrapolating from the very few animal studies available for evaluation. Proposed vesicant standards may be released in early 1990 (S.A. Schaub, U.S. Army Medical Research and Development Command, Ft. Detrick, Md., personal communication to A. P. Watson, Health and Safety Research Division, Oak Ridge National Laboratory, Oak Ridge, Tenn., Nov. 13, 1989). Nerve agent criteria were developed from data on, and models of, red blood cell cholinesterase (RBC-ChE) depression by OP compounds (see text below and Daniels 1988a for detail).

The proposed combat drinking water standards for nerve and vesicant agents may require additional development to accommodate the toxicity of agent hydrolysis products such as S-2-diisopropylaminoethylmethylphosphonothioic acid (hydrolysis product of VX) and chlorovinyl arsenous oxide, HCl and sodium arsenate (the latter are all hydrolysis products of Lewisite) (Szafraniec, Beaudry, and Ward submitted; Daniels 1988b).

Depression of RBC-ChE activity in humans is a common and clinically observable endpoint used as a determinant of OP exposure among agricultural workers (Morgan, 1989) and military or contract personnel who may undergo occupational exposure or come in contact with OP agents during missions. The reader is cautioned that measurement of cholinesterase activity depression provides retrospective confirmation of OP exposure but is not likely to be helpful in managing the patient during acute phases of poisoning (Watson et al. 1989). A finding of 20% depression from individual baseline RBC-ChE levels (i.e., 80% of normal) among agricultural workers has been recommended as evidence of OP exposure by the U.S. EPA's Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) Science Advisory Board and Scientific Advisory Panel (27 September, 1989; *Inside EPA*, 1989). Prior to September 1989, the Agency defined a 20% RBC-ChE depression as an adverse human health effect. In the opinion of the Science Advisory Board and Science Advisory Panel, existing human response data (Marquis 1988) do not indicate that adverse clinical signs or symptoms are associated with a 20% depression of baseline RBC-ChE. Exposure criteria established by the U.S. Department of the Army (1989a) require

(1) removing individuals from the work environment when RBC-ChE levels are reduced to 75% from individual baseline (i.e., a 25% RBC-ChE depression), and

(2) restoring individuals to the work environment when

a. RBC-ChE levels are 80% or more of individual baseline (i.e., a 20% or less RBC-ChE depression), and
b. suspect individuals are asymptomatic for at least 7 d.

Calculated MPC estimates for combat drinking water are based on RBC-ChE depression of 50% of baseline (see Table 3.1). A 50% lowering is considered "a conservative estimate of the threshold above which performance-degrading effects could occur" that would alter the ability of military personnel to perform routine duties (Daniels 1988a). If performance criteria for military personnel charged with accomplishing highly technical tasks or operating complex equipment such as aircraft or weapons systems is a consideration, Daniels (1988a) recommends that the MPCs for 20% ChE inhibition be applied. The resulting water criteria for agents GA, GB and VX would be 4.7 μg/L at 5 L/day consumption and 1.6 μg/L at 15 L/day consumption (Daniels 1988a). Daniels acknowledges that these values are quite protective and based on speculation that RBC-ChE lowering to 80% of individual baseline would result in noticeably impaired performance.

Note that occurrence of RBC-ChE activity depression can be related to the rate at which ChE activity is inhibited. That is, a nerve agent dose administered in small increments over a period of d or weeks can be tolerated without toxic manifestations. For example, VX administered to human volunteers in four doses of drinking water a day (2 L/day; 500 mL/dose in concentrations of approximately 50 μg/L; individual daily dose was 100 μg/70 kg individual or 1.43 μg/kg body weight) for 7 d did not induce signs or symptoms of OP poisoning even though the average RBC-ChE for the experimental group was 40% of baseline (i.e, a 60% RBC-ChE depression) on the seventh day (Sim et al. 1964). The same nerve agent dose, administered rapidly over a period of minutes, could have severe or lethal consequences. Ingestion of potentially contaminated water is likely to occur over an extended period. The present analysis assumes prompt physiological response and is thus likely to be protective.

Daniels' (1988a) estimates can be modified for application to civilian populations whose drinking water supplies could become contaminated through unplanned agent releases. The object of the following analysis is to develop a reasonable nerve agent MPC for threshold RBC-ChE depression. It is assumed that most adults consume 2 L water/day [the usual adult intake as estimated by Snyder et al. (1975)]; thus an estimate of safe agent intake based on 5 L water/day would be protective. It is known that threshold RBC-ChE depression is noted at a dose approximating 20% of the dose at which 50% ChE depression is observed [threshold ChE lowering in human volunteers has been obtained at an i.v. dose of 0.225 μg/kg, and 50% ChE lowering has been observed at an i.v. dose of 1 μg/kg (Kimura, McNamara and Sim 1960)]. If an additional adjustment of 0.5 is incorporated to accommodate anemic individuals (who have abnormally low RBC mass) in the general population (a maximal estimate of RBC mass reduction for victims of anemia is 50% of normal)(S.S. Leffingwell, Center for Environmental Health and Injury Control, DHHS, Atlanta, Ga., letter to A.P. Watson, Health and Safety Research Division, Oak Ridge National Laboratory, Oak Ridge, Tenn., June 25, 1987), the overall adjustment to Daniels' recommended MPCs in Table 3.1 (calculated to result in 50% depression) would equal 0.1 [i.e., 0.20 (adjustment for human threshold RBC-ChE depression) x 0.50 (adjustment for lowered RBC mass in persons with anemia)]. The resulting modified MPCs suggested for consideration as civilian drinking water criteria for nerve agents GA, GB and VX are 1.2 μg/L for 5 L/day consumption and 0.4 μg/L for 15 L/day consumption (Table 3.1).

Development of these values assumes no other source of agent exposure. Other protective factors could also be used to adjust the proposed combat drinking water standards.

The standard method for monitoring agents in field drinking water is the M272 Chemical Agents Water Testing Kit developed by the U.S. Department of the Army (1983). Agent detection limits are as follows: 20 μg/L (0.02 mg/L) for OP nerve agents, and 2000 μg/L (2 mg/L) for vesicants (sulfur mustard and Lewisite). These detection limits meet the current short-term combat drinking water standard for OP nerve agents and Lewisite (Table 3.1). However, the kit's sensitivity neither meets the current short-term standard for sulfur mustard (difference of an order of magnitude, see Table 3.1), nor the proposed OP agent standard for combat drinking water (approximate 20-fold difference for 5 L/day consumption and approximate 50-fold difference for 15 L/day consumption; see Table 3.1). Combat drinking water standards in effect at the time the M272 kit was fielded (May 1984) were established by TB MED 229 (U.S. Dept. of the Army 1975), which set a short-term consumption level of 2000 μg/L (2 mg/L) for mustard. This level was superseded by TB MED 577 (U.S. Dept. of the Army 1986) which established a short-term mustard consumption level of 200 μg/L (0.2 mg/L) (see Table 3.1). The suggested civilian standards for OP agents in drinking water lie between one and two orders of magnitude below the kit's present detection capabilities. There is clear need for development of protocols and instrumentation to reliably identify mustard at 0.2 mg/L and other agents at proposed military and suggested civilian levels.

Treatment of the numerous existing private water supplies, particularly in rural areas, is problematic and will require additional consideration. In general, supplies from drilled or dug wells should be free of agent unless secondary contamination from external surfaces occurs. Surface water supplies from springs, reservoirs, streams, or rivers would be most likely to receive agent via deposition, spills or leaks; human and animal consumption of water from these sources is considered to pose greater risk. One solution is to protect surface supplies from obvious potential sources of agent contamination. Possibilities include diversions for drainage ways that may transport agent from a spill upstream or shelters to prevent deposition on small reservoirs.

Field-water purifiers for military use rely on reverse osmosis (Daniels 1988a,b; U.S. Dept. of the Army 1967). This would be suitable for treating small volumes when no other water supplies were available, but is not practical for large volumes. The most effective procedure for removing nerve and vesicant agents from public water supplies is filtration

by activated charcoal (Lindsten and Schmitt 1975; Lindsten and DesRoches 1977). Pass-through efficiencies and filtration capacity are currently unknown. Pre-treatment of raw water with excess chlorine may sufficiently degrade agent such that activated charcoal filtration will be necessary only for finish water. Consideration of these options for protection and treatment of water supplies at greatest potential risk will require site-specific expertise from local water authorities.

3.2 ESTABLISHING ACCEPTABLE RESIDUES

Many chemicals are of human health concern, but only a few possess epidemiologically derived risk estimates. The persistent agents of the unitary stockpile are good examples (Watson, Jones, and Griffin 1989; U.S. Dept. of the Army 1988), but so are numerous industrial and commercial compounds such as benzyl chloride, methyl chloride, 1-naphthylamine, and saccharin (all potential carcinogens for which there is limited evidence of carcinogenicity in animals and no evidence of carcinogenicity in humans; U.S. EPA 1986b). Because it is necessary for regulators to estimate permissible concentrations of pollutants in water, food and air without the benefit of complete data bases, numerous decision protocols have been developed to obtain an approximate idea of the relative hazard of an untested chemical or a well-studied chemical under untested conditions.

One promising approach is the "Rapid Screening of Hazard (RASH)" method, which provides results that compare favorably with findings of the traditionally laborious and deliberative review process as practiced by committees such as EPA-CAG (the Carcinogen Assessment Group of the U.S. EPA), the ACGIH [American Conference of Governmental Industrial Hygienists; develops threshold limit values (TLVs) for workroom environments] and the EPA Criteria Document committees (Jones et al. 1988; Watson, Jones, and Griffin 1989). The RASH relative potency or hazard assessment approach was designed for ease and rapidity of evaluation.

RASH is an integral part of the Defense Priority Model, recently announced as the decision model of choice for prioritizing remedial actions at hazardous waste sites identified in the DoD Installation Restoration Program (*Federal Register* 1989). The RASH approach is applied below to develop disposition criteria for the persistent OP agent VX and the persistent "H" (sulfur mustard) agents.

3.2.1. Method

The RASH approach converts all documented toxic chemical effects to some effective dose of a reference chemical (usually the polynuclear aromatic hydrocarbon benzo[a]pyrene (B[a]P), $C_{20}H_{12}$)(Jones, Walsh, and Zeighami 1985; Jones et al. 1988). Other reference compounds can also be used, such as OP insecticides for comparison with VX (see below). Based on what is known at this time, this method is prudent and reasonable with respect to safety. The RASH calculations do not support the argument that a human population will host the calculated effect. The appropriate interpretation is that, if the effect does occur, the RASH index is a realistic predictor of potency. The method makes use of the availability of single-source documents for extensive toxicity information. At present, the most useful document for this purpose is the Registry of Toxic Effects of Chemical Substances (RTECS), published annually by the U.S. DHHS. Other sources exist and are described in Jones, Walsh, and Zeighami (1985). The analysis outlined below relies on the toxicological data summarized in RTECS and available on updated compact disc every quarter; the September 1989, version was accessed. An example of a relative comparison follows.

According to the RTECS listings, one may find that x (mg/kg) of a chemical has produced a particular effect such as LD_{50} (i.e., median acute mortality) in a particular species and y (mg/kg) of B[a]P or some other reference chemical tested by some other investigator was required to induce LD_{50} in the same species. The potency of the first chemical relative to the standard or reference chemical would be y/x. Thus, if the reference chemical was considered by the CAG or some other regulatory body to be safe in water at a concentration of 1 mg/L, then the unregulated chemical could be limited to (1 mg/L)/(y/x). Likewise, if the U.S. EPA considers that the reference chemical is safe at a concentration of 1 mg/m^3 in air, then the unregulated chemical could be limited to (1 mg/m^3)/(y/x). Procedures used to standardize the RASH method for computing relative potency values are summarized in Jones et al. (1988) and Watson, Jones, and Griffin (1989).

We chose the median potency as characteristic of the "interviewing" chemical relative to the standard because the nature of the underlying statistical distribution(s) of toxicological data are unknown. Selection of a mean value would assume normality of all interrelated sources of data in the data base used; it has been previously determined that not all toxicological data are normally distributed (Glass 1987). Similarly, we chose to use the interquartile range describing dispersion about the median as a practical estimate of

uncertainty. Other spans could be used, such as 90%. For many chemicals, the effect would not be statistically different; but for some chemicals, the 90% span could be very large. In such cases, the spread could reflect inflated observational ranges due to random error combined with results obtained from extremely sensitive or extremely resistant animal models. We are fully aware of the variable quality of data available for analysis. Further, we consider that the RASH range (interquartile range if the number of ratios is sufficiently large) of uncertainty associated with the best estimate of maximum plausible risk serves to indicate how the response of an untested heterogeneous population (i.e., man) may deviate from the central tendency of bioassay results (Watson, Jones, and Griffin 1989).

3.2.2. Organophosphate Analogues

The structure and function of nerve agents closely resembles that of OP insecticides used in agriculture. As expected, the nerve agents are far more potent than any OP insecticide formulation (Watson et al. 1989). Commercially available OP insecticides are registered by the U.S. EPA for control of specific pests on specific crops or livestock species. The residue concentrations of any marketed crop or animal product must be in compliance with acceptable values established by the U.S. EPA Office of Pesticide Programs under authority of the Federal Insecticide, Fungicide, and Rodenticide Act of 1972 (PL 92-516) and the Federal Food, Drug, and Cosmetic Act of 1938. Allowable residue concentrations are derived by the agency after analysis of available data on the product's toxicity, environmental persistence, chemical characteristics, etc. (See Pesticide Fact Sheets periodically published by the U.S. EPA in the *Federal Register* for results of such analyses. The Fact Sheet for Guthion, published on Sept. 30, 1986, and compiled in U.S. EPA 1988a, is an example.) In the absence of warfare agent-specific data for developing comparable allowable residue concentrations, application of the RASH method for estimating the potency of VX relative to commercial OP insecticide analogues (for which residue tolerances have been developed) appears to be a reasonable approach. The resulting potency estimates can then be used to derive working values of acceptable VX concentrations in foodstuffs.

For clarity of presentation, LD_{50} values were selected as the single isoeffect concentration to use in comparing potencies between compounds. The LD_{50} is an unequivocal biological endpoint and does not require the degree of interpretation necessary for comparing mutagenic or carcinogenic exposures (Jones et al. 1988; Watson, Jones, and Griffin 1989). It also avoids uncertainties in the study-specific definition of LD_{Lo} as a

toxicity endpoint. Relative potency estimates based on LD_{50} data are generally within one order of magnitude of an overall estimate based on other toxicity endpoints as defined in RTECS (Jones et al. 1988).

To reduce the potential for variability in the estimate, data were compared for the same routes of exposure and experimental species, i.e., i.v. doses were not compared with i.m. doses nor were LD_{50}s for rats compared with LD_{50}s for mice. Application of the method is outlined in the following examples.

Given:

LD_{50} dose (mg/kg) for VX in species 1 via route 1 is D_{VX}

LD_{50} dose (mg/kg) for regulated compound in species 1 via route 1 is D_R

Then:

Potency of VX relative to the regulated compound (i.e., "relative potency") is the ratio of the two doses, or

$$\frac{D_R}{D_{VX}}$$

The median of all values of this ratio is the relative potency factor, or RPF

If:

The residue tolerance for the regulated compound is 1 ppm, then risk-equivalent residues of VX could be limited to

$$1 \text{ ppm} \div \left(\frac{D_R}{D_{VX}}\right)$$

The example below is for the insecticide Parathion (CAS No. 56-82-2) as the reference chemical.

For skin exposure:

Mouse LD_{50}: D_P = 32.4 mg/kg

Mouse LD_{50}: D_{VX} = 0.046 mg/kg

$$RP = \frac{32.4}{.046} = 704.4$$

Calculated RP values for ratios of oral, skin, inhalation and intravenous LD_{50} doses in rat, mouse, rabbit, dog, and cat are listed in ascending order as follows: 20, 68, 481, 600, 704, 922, 1186, 1200, 1234, 1905 (n=10, interquartile range = 481 to 1200, and median = 813).

This calculational method was followed for a total of 13 OP insecticides chosen on the basis of availability of compound-specific regulatory requirements for residue tolerances

and reentry intervals (see Section 4.0 for discussion of reentry intervals), past history in the causation of ChE depression, and poisoning among farm workers, and the volume of their commercial use. Except for Demeton (CAS No. 8065-48-3) and EPN (CAS No. 2104-64-5), insecticides that were applied in annual quantities $\leq 2 \times 10^5$ lbs for a recent (1984) year in California (a major agricultural state) were not considered as reference compounds in this analysis. The OP compounds in the deleted category comprised 9.4% by weight of all OP insecticides applied in California for 1984 (Brown, Ames and Mengle 1989) (Table 3.2). Demeton and EPN were included because they possess well-established reentry intervals.

The relative potency ratios of VX in relation to commercial OP insecticides range from 60 (N=3) to 44000 (N=2) (Table 3.2). In other words, comparison of mammalian LD_{50} data for VX and the reference insecticides indicates that VX is from 60 to 44,000 times more potent for inducing lethality. Experience with the RASH approach has taught us that the least variable RPF (relative potency factor) estimates are obtained when the number of ratios calculated per compound is six or greater (Watson, Jones, and Griffin 1989). Applying this rule of thumb to the present analysis gives preference to the RPF estimates developed for Azinphos-methyl (Guthion, CAS No. 86-50-0), Diazinon (CAS No. 333-41-5), Malathion (CAS No. 121-75-5), Methyl Parathion (CAS No. 298-00-0) and Parathion (CAS No. 56-38-2) (Table 3.2). The range of potency factors from this subset is 7.2×10^2 (i.e., 1×10^3) to 9.7×10^3 (i.e., 1×10^4), or an approximate variation of one order of magnitude. Compared with the results of hundreds of other RASH comparisons (see Table III in Jones et al. 1988), one order of magnitude is a narrow range and indicates excellent agreement among the estimates. Specific examples of greater ranges include strychnine, nicotine, and potassium cyanide, all with interquartile ranges of 2 orders of magnitude; and carbon monoxide, with an interquartile range of 3 orders of magnitude (Jones et al. 1988).

3.2.3. Suggested Disposition Levels for VX

The RASH logic indicates that risk-equivalent residues of VX in foodstuffs could thus be limited to values between 10^3 and 10^4 less than those of the five OP insecticides in the subset identified above. To accommodate uncertainties inherent to the data and/or assessment approach, additional safety factors could also be incorporated into the estimate of allowable agent residue tolerances.

Table 3.2 Relative Potency Factors (RPF) Estimates Calculated for VX Relative to Several Reference OP Insecticides

Reference OP Insecticide	Commercial Applic. in CA (1984)(x 10^3 lbs)[a]	CAS #	Estimated RPF[b]	N[c]
Acephate (Orthene)	409.0	30560-19-1	43,500	2
Azinphos-methyl (Guthion)	467.2	86-50-0	949	7
Carbophenothion (Trithion)	NA	786-19-6	185	4
Chlorpyrifos (Lorsban, Dursban)	1070.3	2921-88-2	1495	4
Diazinon	694.7	333-41-5	5875	10
Dimethoate (Cygon)	361.4	60-51-5	2525	4
Demeton (Systox)	36.8	8065-48-3	222	5
Disulfoton (Di-Syston)	230.3	298-00-0	60	3
EPN	NA	2104-64-5	250	5
Malathion	509.0	121-75-5	9690	6
Methamidophos (Monitor)	407.4	10265-92-6	883	4
Methyl Parathion	229.6	298-00-0	720	11
Parathion (Ethyl parathion)	745.5	56-38-2	813	10

[a]Brown, Ames, and Mengele 1989. (Note: total OP usage in CA for 1984 = 7442.4 x 10^3 lb).

[b]Potency of VX relative to that of reference insecticide as ratio $\left(\frac{D\ \text{insecticide}}{D_{VX}}\right)$ for comparisons of values. LD_{50} used as isoeffect concentration for RPF calculation. The RPF of 813 for the reference insecticide Parathion indicates that agent VX is 813 times more potent than Parathion for inducing the LD_{50} response. (See Jones et al. 1988 for method).

[c]Number of ratios calculated.

One insecticide in the subset for which tolerances have been established in a variety of raw agricultural commodities, animal products, processed food and feed is Azinphos-methyl, or Guthion. It is considered "relatively persistent" on leaf surfaces and is slow to leach or mobilize from soil (U.S. EPA 1986a). Measured half-lives of Guthion in soil are comparable to those of VX: 21 d (in non-sterile soil) to 68 d (under anaerobic conditions) (U.S. EPA 1986a). Residue tolerances established for Guthion are presented in Table 3.3. The RASH approach to hazard assessment indicates that allowable VX tolerances could be set by dividing each of the values in Table 3.3 by 10^3 or 10^4. Note that it is unclear whether existing detection equipment and protocols are sufficiently sensitive to reliably monitor VX at these levels. Analytical protocols for sample preparation, extraction, and confirmation of Guthion (and other insecticides or food additives) in food and feed are jointly established by the U.S. FDA in collaboration with the U.S. EPA and are documented in the multi-volume *Pesticide Analytical Manual.* The most recent issue, published in 1987, indicates that Guthion can be detected with colorimetric or spectrophotofluorometric methods at a sensitivity of 0.02 ppm to 0.3 ppm, depending on analytical method and foodstuff (U.S. FDA 1987a).

3.2.4. Sulfur Mustard Analogues

In a similar fashion, sulfur mustard was evaluated by the RASH method to derive an estimate of its carcinogenicity relative to the well-characterized carcinogen benzo(a)pyrene (B[a]P, CAS No. 50-32-8)(Watson, Jones, and Griffin 1989). Sulfur mustard is a known carcinogen (Saracci 1981; IARC 1975). For the sake of rigor and as a response to public concerns regarding the carcinogenicity of possible long-term, low-dose mustard exposure, the assessment is limited to an analysis of tumorigenic data only. Acute effects of H agent exposure such as chemical burns of the skin, eyes, and respiratory tract, were not assessed in the current evaluation. Results indicate that the best estimate of RPF for sulfur mustard relative to B[a]P is 1.3, with an interquartile range of 0.6 to 2.9 (Watson, Jones and Griffin 1989). In other words, the carcinogenicity of sulfur mustard is comparable to that of the industrial compound B[a]P. This finding can be used to estimate the potential carcinogenic risk of ingesting foodstuffs contaminated with sulfur mustard agent.

Table 3.3 Established residue tolerances (ppm) for the OP insecticide Azinphos-methyl (Guthion) on or in foodstuffs[a]

Foodstuff	Established U.S. tolerance (ppm)	Foodstuff	Established U.S. tolerance (ppm)
Alfalfa	2.0	Melons	2.0
Alfalfa, hay	5.0	Nectarines	2.0
Almonds	0.3	Nut, Pistachio	0.3
Almonds, hulls	10.3	Oats, grain	0.2
Apples	2.0	Oats, straw	2.0
Apricots	2.0	Onions (green)	2.0
Artichokes	2.0	Parsley (leaves)	5.0
Barley, grain	0.2	Parsley (roots)	2.0
Barley, straw	2.0	Peaches	2.0
Beans (dry)	0.3	Pears	2.0
Beans (snap)	2.0	Peas, black-eyed	0.3
Birdsfoot Trefoil	2.0	Pecans	0.3
Birdsfoot Trefoil, hay	5.0	Peppers	0.3
Blackberries	2.0	Plums	2.0
Blueberries	5.0	Potatoes	0.3
Boysenberries	2.0	Quinces	2.0
Broccoli	2.0	Raspberries	2.0
Brussels Sprouts	2.0	Rye, grain	0.2
Cabbage	2.0	Rye, straw	2.0
Cattle, fat	0.1	Sheep, fat	0.1
Cattle, meat by-product	0.1	Sheep, meat by product	0.1
Cattle, meat	0.1	Sheep, meat	0.1
Cauliflower	2.0	Soybeans	0.2
Celery	2.0	Spinach	2.0
Cherries	2.0	Strawberries	2.0
Citrus fruits	2.0	Sugarcane	0.3
Clover	2.0	Tomatoes	2.0
Clover, hay	5.0	Walnuts	0.3
Cottonseed	0.5	Wheat, grain	0.2
Crabapples	2.0	Wheat, straw	2.0
Cranberries	2.0	Milk	0.04
Cucumbers	2.0	Soybean oil	1.0
Eggplant	0.3	Dried citrus	5.0
Filberts	0.3	Sugarcane bagasse	1.5
Goats, fat	0.1		
Goats, meat by product	0.1		
Goats, meat	0.1		
Gooseberries	5.0		
Grapes	5.0		
Grass, pasture	2.0		
Grass, pasture, hay	5.0		
Horses, fat	0.1		
Horses, meat by products	0.1		
Horses, meat	0.1		
Kiwi fruit	10.0		
Loganberries	2.0		

[a]From U.S. EPA 1986a.

An accepted model for estimating lifetime cancer risk assuming a linear nonthreshold dose-response relationship is

$$\text{Risk} = (Q^*)(D),$$

where Risk is the additional individual lifetime risk of developing cancer based on a lifetime of continuous exposure to dose D of a compound with the potency factor Q^*. Units of Q^* are dose reciprocal, i.e., $[\text{mg/kg})/\text{day}]^{-1}$, and units of dose are [(mg/kg)/day]. In the current analysis, the risk estimate is a measure of potential cancer incidence (i.e., tumorigenicity and *not* cancer deaths). Common assumptions for ingestion exposure are a 70-kg person ingesting food at a rate of 0.028 times the body weight per day (i.e., a food factor of 0.028; U.S. EPA 1988b). Values of Q^* are based on the upper 95% confidence limit of the linearized dose response for animal test results judged by expert selection to be most representative of man. Thus, any cancer risk estimate derived by use of Q^* will represent an upper bound.

The value Q^* used in subsequent calculations,

$$11.5 \left(\frac{\text{mg/kg}}{\text{day}}\right)^{-1},$$

is the ingestion potency factor for B[*a*]P documented in the Superfund Public Health Evaluation Manual (U.S. EPA 1986b, Exhibit A-4). For ease of calculation, a 1 ppm concentration of sulfur mustard in food is assumed.

The estimated dose resulting from ingestion of a diet containing 1 ppm sulfur mustard is

$$\text{Dose} = \left(1 \frac{\text{mg}}{\text{kg}}\right) \left(\frac{0.028}{\text{day}}\right) \left(70 \text{ kg}\right) \left(\frac{1}{70 \text{ kg}}\right)$$
$$= 0.028 \frac{\text{mg/kg}}{\text{day}}$$

In the following estimates of lifetime cancer risk, we have adjusted the mustard RPF (derived from i.v. and subcutaneous exposure data) by the absorption coefficient of B[a]P ingestion (0.50)(Jones, Owen, and Wells 1987). The absorption coefficient of an injection route is assumed to equal 100%.

For Risk = (Q^*) (D) (RPF) and an RPF = 1.3,

$$\text{Lifetime Risk} = \left(11.5 \left(\frac{\text{mg/kg}}{\text{day}}\right)^{-1}\right) \left(0.028 \frac{\text{mg/kg}}{\text{day}}\right) \left(1.3\right) \left(0.5\right)$$
$$= 0.209 = 2.1 \times 10^{-1}$$

Thus, the upper-bound estimated excess individual lifetime cancer risk due to ingestion of a diet hypothetically contaminated with sulfur mustard at 1 ppm is

approximately 21%. Note that this risk estimate approximates the current overall lifetime cancer risk in the United States of 0.25 or 25% (Norman 1987). The above estimated risk value from sulfur mustard ingestion assumes lifetime (i.e., 70 years) dietary intake of agent at a 1 ppm level of contamination.

This maximal estimate may be adjusted to accommodate observed persistence of mustard agent in the environment. At 0 °C, measured persistence in soil contaminated with mustard at 50 g/m^2 has ranged between 50 and 92 d (Puzderliski 1980 as cited in Small 1984; see Section 2.3). If it is assumed that dietary exposure to mustard would be limited to the maximum period of mustard persistence under the experimental conditions outlined above (i.e., 90 d for clarity), the estimated cancer risk from consuming 1 ppm dietary sulfur mustard would be

$$(2.1 \times 10^{-1}) \left(\frac{90 \text{ day}}{25550 \text{ day}/70\text{y}}\right) = 7.4 \times 10^{-4}$$

If large quantities of sulfur mustard were involved, such as in the case of the mustard dump at Edgewood Arsenal (see Section 2.3), detectable levels could be observed after a lapse of years. If it is further assumed that edible vegetation underwent surface contamination by continual resuspension of soil containing mustard at 1 ppm, the estimated cancer risk for exposure over a 1-year time period would be

$$(2.1 \times 10^{-1}) \left(\frac{1\text{y}}{70\text{y}}\right) = 3.0 \times 10^{-3}$$

Similarly, the risk estimate for 2 years' exposure is 6 x 10^{-3} and 9 x 10^{-3} for 3 years' exposure. The same technique can be followed for any specific time period of interest. Note that mustard persistence on vegetation is not well characterized (see Section 2.1).

3.2.5. Suggested Disposition Levels for H Agents

Lifetime cancer risk estimates on the order of 10^{-6} are considered insignificant by most individuals and regulatory authorities. Releases that generate cancer risks equal to values less than 10^{-6} are not usually regulated by the U.S. EPA or the U.S. FDA. For comparison, the limit of regulatory acceptability for some "grandfathered" pesticides in foodstuffs is a lifetime cancer risk of 10^{-4} (Norman 1987).

To reduce the estimated risk of dietary carcinogenesis to regulatory acceptable levels (i.e., Lifetime Risk approximately equal to 10^{-6}), the concentration of sulfur mustard in the total diet would need to be a factor of 10^{-5} less than 1 ppm for an estimated lifetime exposure. This is equivalent to a total dietary concentration of less than or equal to 10 ppt. Adjustment of this value to accommodate varying periods of exposure can be made

(see Section 3.2.4). An allowable agent residue for an individual foodstuff would need to be estimated on the basis of its observed consumption rate in an average total diet. Thus, some food items contaminated at much greater than 10 ppt could be ingested if the total quantity of that particular item did not constitute a major portion of the diet.

It is not clear that existing analytical capability can reliably detect sulfur mustard in foodstuffs at these concentration levels.

3.2.6. General Findings Regarding Disposition of Food Items

Meat and milk from animals not actually killed by nerve agents could be used without concern provided external contamination could be eliminated. The logic here is that an animal survivor of nerve agent exposure would contain no unreacted agent of sufficient concentration in muscle tissues to be toxic. In contrast, the muscle tissue and blood of a dead animal could contain unreacted agent, depending on the dose received. The general public is often especially concerned about dairy products. If there is reluctance to consume or market milk from dairy herds potentially contaminated with nerve agent immediately after a major release, the discarding of milk produced during the first three to seven d post release should provide adequate assurance of safety. Note that lambs suckling VX-poisoned ewes with clinical manifestations of organophosphorus toxicity demonstrated no signs of illness during the Skull Valley incident of 1968 (Van Kampen et al. 1969). This is strong evidence that VX is not secreted in milk.

The disposition of meat and milk from livestock contaminated with mustard is problematic. The finding of intact mustard (1 to 30 ppb) in the urine and fatty tissues of battlefield survivors examined 7 to 10 d after a mustard attack during the Iran-Iraq War (Vycudilik 1985, 1987 as cited in Sage and Howard 1989) raises concerns that sulfur mustard may also be found in the meat and milk of contaminated livestock. The absorbed dose of mustard received by these survivors is unknown. It is not clear how long a quarantine would have to be to ensure that internal fatty reservoirs of intact mustard were depleted.

Meat and milk from animals killed by agent exposure or exhibiting severe toxic response should not be salvaged for hides, meat, or other animal products. Severely affected animals should be humanely destroyed. Destruction criteria should be developed in collaboration with appropriate federal, state, and local agencies on a site-specific basis.

Special precautions to prevent surface contamination would be required if residually contaminated animals without visible signs of toxicity were slaughtered or milked.

Forage, grains, and garden produce should probably be quarantined until tested.

3.3 BLOOD CHOLINESTERASE

Organophosphate (OP) nerve agents function much like OP pesticides in that they combine with acetylcholinesterase (AChE), inactivating the enzyme, and permitting the buildup of excess acetylcholine (ACh) at synapses. Thus, the signs of OP agent poisoning include a variety of effects of excess ACh wherever it is the neural transmitter, in certain parts both of the central nervous system (CNS) and of the peripheral nervous system. The CNS effects may include confusion, anxiety, incoordination of voluntary movement (ataxia), convulsions, and coma. Overstimulation of peripheral nerve endings may result in signs such as excess salivation, tearing, nasobronchial secretion, pinpoint pupils (miosis), diarrhea, incontinence, nausea and vomiting, and abdominal cramping resulting in pain. ACh is also the neurotransmitter at junctions of motor nerves with skeletal muscles. Overstimulation by ACh here may result in tremors of skeletal muscles, or in more severe cases, in weakness or paralysis of muscles including the respiratory muscles. Effects on facial muscles can include lockjaw (trismus) with resulting difficulty in clearing the respiratory tract of secretions. Ventilatory assistance may be needed.

A more complete description of OP nerve agent effects together with antidotes and human treatment protocols is given in U.S. Dept. of the Army (1988) and is discussed in Watson et al. (1989). Meerdink (1989) presents a detailed description of OP pesticide poisoning effects and discusses both the role of AChE and the use of cholinesterase (ChE) monitoring as an aid in diagnosis of OP poisoning in food-producing animals.

3.3.1 Baseline Levels for Target Species

Blood contains both AChE and other cholinesterases, mainly butyrylcholinesterase ("pseudocholinesterase"). Within blood, AChE is found only in erythrocytes (RBC-ChE) although its function there is unknown. While human plasma contains substantial amounts of ChE activity, in most domestic animals 80 percent or more of the total blood ChE activity is in the erythrocytes so that whole blood ChE is a good indicator of AChE activity. One exception is the domestic cat in which most of the blood ChE activity is plasma ChE (Hooser et al. 1988). Avian species including domestic poultry present a different problem

in that blood ChE is very low relative to brain AChE and is so low that measurement of blood ChE is not particularly useful.

A lowering of erythrocyte (or whole blood) cholinesterase activity may be indicative of OP exposure but does not differentiate between nerve agent or OP/carbamate pesticides as the source of exposure. Even in the cat, whole blood as well as plasma ChE depression was shown to be indicative of OP exposure, although not of the severity of exposure (Hooser et al. 1988). The doses of OP nerve agents needed to effect a 50 percent reduction in ChE activity (ChE_{50}) for various species are presented in Table 3.4. A lowering of brain AChE is a clearer indication of exposure than blood ChE but can not be monitored in living animals without harm.

Blood cholinesterase activity varies with species and many other factors; there is a sufficiently wide range of normal values for a given species that ChE determination is a diagnostic aid rather than a means of definitive diagnosis. Normal blood ChE activities and ranges found in the literature for food-producing and companion animal species are displayed in Table 3.5. It can be seen that there are numerous measurement methods for ChE activity; the units are different and cannot be interconverted so that direct comparisons can be made only where the same assay has been used. A summary of commonly used methods is given in Section 3.3.3.

Normal blood ChE activities and ranges for most of the same species from several university veterinary diagnostic laboratories are reported in Table 3.6. The values from the University of Illinois and University of Tennessee laboratories are results of sample analysis from healthy animals. The values from Iowa State and Michigan State Universities are based on samples from sick or diseased animals with no known organophosphate or carbamate pesticide exposure. The mean values of the Iowa State data set agree with (dog, cattle) or are somewhat higher (horse, sheep) than those for normal animals shown in Table 3.5 for the Michel method as used at Iowa State (Osweiler et al. 1985) . Since only a few horse and sheep values were available in the Iowa data set, a difference in means is not surprising; the upper end of the range of baseline values for these two species may be somewhat higher than expected from Osweiler et al. 1985. The range of values for cattle was wider than that given in Osweiler et al. (1985). Veterinary toxicologists generally expect to observe blood ChE activity less than 20 or 25 percent of baseline associated with initial clinical signs of severe OP poisoning (Osweiler et al. 1985, Meerdink 1989). Blood cholinesterase depression to 50% of baseline is considered a significant change and grounds

Table 3.4 ChE_{50} values (RBC-ChE) for nerve agent exposure to vertebrates

Species	Agent		
	VX dose, μg/kg	GB dose, μg/kg	GA dose, μg/kg
Monkey	1.3[a]	--	--
Pig	1.2[a]	--	--
Rabbit	2.1[a]	--	--
Guinea pig	0.9[a]	--	--
Dog	1.3[a]	--	--
Goat	0.4[a]	--	--
Mouse	--	41[b]	188[b]
Human	5 mg-min/m^3 (inhalation)[c] 100 mg-min/m^3 (vapor)[c] 1.0 (i.v)[d] 1.1 (i.v.)[e] 2.3 (oral)[e]	20 mg-min/m^3 (inhalation)[d] 3.0 (i.v.)[f] 10 (oral)[f]	--

[a]Marzulli et al. 1959.

[b]Tripathi and Dewey 1989; mice sacrificed 10 min after single iv injection; brain AChE activity as endpoint.

[c]McNamara, Vocci, and Leitnaker 1971.

[d]McNamara and Leitnaker 1971.

[e]Kimura, McNamara, and Sim 1960.

[f]Grob and Harvey 1958.

[g]Sidell and Groff 1974.

Table 3.5. Normal cholinesterase (ChE) activity levels and ranges from the literature for food-producing and companion animal species

Species	Assay	N	Tissue	Baseline ChE					Comments	References
				Mean	Minimum	Maximum	Measure of Variability[a]	95% confidence limits ΔpH/h		
Bovine (Cow)	Ellman	5	Plasma	--	67±7 U/L	74±14 U/L	--	--	Crossbred Hereford steers	Khan et al. 1988
		5	RBC	--	4.3±0.8 U/mL	4.4±0.7 U/mL	--	--	Measured once/d for 3d	"
		40	Whole blood	4.34 μmol/mL/min	3.40	5.40	0.68 (S.D.)	--	Calves (3-6 mo)	Abdelsalam and Ford 1985
			Plasma	0.39 "	0.24	0.65	0.11 (S.D.)			"
		40	Whole blood	5.51 "	4.20	6.00	0.60 (S.D.)		Steers (1-2 yr)	"
			Plasma	0.19 "	0.16	0.24	0.03 (S.D.)			"
		40	Whole blood	4.47 "	3.60	6.00	0.66 (S.D.)		Cows (2 yr or older)	"
			Plasma	0.22	0.12	0.26	0.04 (S.D.)			"
	Levine	10	RBC	199.6 "	145.7	253.5	11.7 (S.E.M.)	--		Hazelwood & Heath 1976
		10	Plasma	10.1 "	7.6	13.2	0.5 (S.E.M.)	--		"
		10	Cerebrospinal fluid (CSF)	2.0 "	1.4	2.9	0.2 (S.E.M.)	--		"
	Michel	--	Whole blood	0.40-0.55ΔpH	0.30 ΔpH	0.75 ΔpH	--	--		Osweiler et al. 1985
	Michel	10	Whole blood	0.68 ΔpH/h	--	--	--	--	Adult animals	Kruckenberg & Vestweber 1973
		10	RBC	0.65 "	--	--	--	--		"
		10	Plasma	0.03 "	--	--	--	--		"
		6	Whole blood	0.35 "	0.29	0.41		3 Brahman heifers, 3 bulls, 6-8 mo.		Palmer 1971
		4	Whole blood	0.37 ΔpH/h	0.30	0.40		4 Hereford hiefers, 8-16 mo.		"
		253	RBC	0.46-0.47 "	0.17	0.96		Compared steers and cows		Radeleff & Woodard 1956
Porcine (Pig)	Modif. Michel	135	RBC	0.123 ΔpH/h	0.050	0.159	0.018 (S.D.); 15 (C.V.)	0.087-0.160		Callahan & Kruckenberg 1967
	Levine	10	RBC	124.6 μmol/mL/4 min	67.3	168.4	8.9 (S.E.M.)	--		Hazelwood & Heath 1976
		10	Plasma	13.4 "	10.0	23.2	1.2 (S.E.M.)			"
		10	CSF	2.2 "	1.6	3.3	0.2 (S.E.M.)	--		"
	Michel	493	Whole blood	0.29-0.3 ΔpH/h	0.10	0.65			No difference between male and female; 226 swine used to get 493 samples	Moncol & Battle 1964
Equine (Horse)	Ellman	5	RBC	--	2343±279 IU/L[b]	3243±150 IU/L[b]	--	--	Range of 22 sample values each for 5 horses, 5 on d 1 5 on d 35, 6 on succeeding days	Gingerich 1981
	Michel	--	Whole blood	--	0.20 ΔpH	0.65 ΔpH	--	--		Osweiler et al. 1985
	Michel	10	Whole blood	0.80 ΔpH/h	--	--	--	--		Kruckenberg & Vestweber 1973
		10	RBC	0.18 "	--	--	--	--		"
		10	Plasma	0.62 "	--	--	--	--		"
	Michel	9	RBC	0.088 "	0.077	0.107	0.009 (S.D.); 10 (C.V.)	0.068-0.108		Callahan & Kruckenberg 1967
		85	Whole blood	0.39 ΔpH/h	0.19	0.65		0.18-0.60		Palmer et al. 1963

Table 3.5. Normal cholinesterase (ChE) activity levels and ranges from the literature for food-producing and companion animal species (continued)

Species	Assay	N	Tissue	Baseline ChE: Mean	Minimum	Maximum	Measure of Variability[a]	95% confidence limits ΔpH/h	Comments	References
Ovine (Sheep)	Levine	10	RBC	59.4 μmol/mL/4 min	46.0	82.1	3.0 (S.E.M.)	--		Hazelwood & Heath 1976
		10	Plasma	7.3 "	5.6	8.8	0.4 (S.E.M.)	--		"
		8	CSF	1.5 "	1.2	1.8	0.1 (S.E.M.)	--		"
	Michel	--	RBC	--	0.20 ΔpH/h	0.25 ΔpH/h	--	--	Includes ≤5 repeat measurements at 2 d intervals on each sheep	Van Kampen et al. 1969
		10	RBC	--	0.06 "	0.20 "	--	--		"
	Michel	10	Whole blood	0.45 ΔpH/h	--	--	--	--		Kruckenberg & Vestweber 1973
		10	RBC	0.39 "	--	--	--	--		"
		10	Plasma	0.06 "	--	--	--	--		"
	Michel	--	Whole blood	0.15-0.2 "	0.10	0.30	--	--		Osweiler et al. 1985
		180	RBC	0.16-0.17 "	0.08	0.40				Radeleff and Woodard 1956
Caprine (Goat)	Ellman	1	RBC	16.0-23.5 μmol/g Hb/min x 10	--	--	--	--	Adult female lactating goats; 7 obs. at intervals of 0 to 14 d	Mount 1984
		1	Plasma	100-118 nmol/mL/min	--	--	--	--	"	"
		7	RBC	21.1 μmol/g Hb/min x 10	16	23.5	1.0 (S.E.M.)	--	"	"
		7	Plasma	104 nmol/mL/min	92	118	3.2 (S.E.M.)	--		"
	?	10	Whole blood	4.8 μmol/min/mL	4.2	5.4	--	--	6-12 mo male Nubian goats	Abdelsalam 1987
	?	10	Plasma	0.84 μmol/min/mL	0.6	1.0	--	--		
	McAllister	18	Serum	--	168 μM/mL[c]	174 μM/mL[c]	--	--	3-6 mo male Nubian goats	Wahbi et al. 1987
	Michel	10	Whole blood	0.51 ΔpH/h	--	--	--	--		Kruckenberg & Vestweber 1973
			RBC	0.35 "	--	--	--	--		"
			Plasma	0.16 "	--	--	--	--		"
	Michel	33	RBC	0.093 "	0.047	0.128	0.021 (S.D.); 23 (C.V.)	0.050-0.136		Callahan & Kruckenberg 1967
	Michel	?	Whole blood	0.14 ΔpH/h	0.04	0.24	--	--		Osweiler et al. 1985
		317	Whole blood	0.14 "	0.05	0.39	0.05 (S.D.)	0.04-0.24		Palmer et al. 1963
Avian (Poultry)	Ellman	4-6	Brain	16 μmol/min/g	--	--	±1 (S.E.M.)	--	5 mo White Leghorn chickens	Jortner & Ehrich 1987
		4-6	Plasma	0.96 μmol/min/mL	--	--	±0.04 (S.E.M.)	--	"	"
	Ellman	5-6	Brain	15.2 μmol/min/g	--	--	±0.3 (S.E.M.)	--	7 wk White Leghorn chickens	Brown et al. 1986
		9-10	Plasma	0.55 μmol/min/mL	--	--	±0.01 (S.E.M.)	--	"	"
	Ellman	3-5	Brain	16.44 μmol/min/g	--	--	±0.42 (S.E.M.)	--		
		3-7	Plasma	0.010 μmol/min/mL	--	--	±0.0008 (S.E.M.)	--	6 d female Peterson-Hubbard chicks	Farage-Elawar et al. 1988
		3-5	Brain	15.27 μmol/min/g	--	--	±0.61 (S.E.M.)	--		
		3-7	Plasma	0.012 μmol/min/mL	--	--	±0.008 (S.E.M.)	--	11 mo White Leghorn roosters	"
Lapine (Rabbit)	Levine	10	RBC	184.8 μmol/mL/4 min	136.5	242.0	7.3 (S.E.M.)	--		Hazelwood & Heath 1976
		10	Plasma	30.3 "	14.2 "	44.4 "	2.8 (S.E.M.)	--		"
		8	CSF	7.3 "	5.2 "	10.2 "	0.6 (S.E.M.)	--		"
	Michel	204	RBC	0.039 ΔpH/h	0.011	0.060	0.008 (S.D.); 21 (C.V.)	0.024-0.055		Callahan & Kruckenberg 1967
	"	10	Whole blood	0.42 ΔpH/h	--	--	--	--		Kruckenberg & Vestweber 1973
	"	10	RBC	0.20 "	--	--	--	--		"
	"	10	Plasma	0.22 "	--	--	--	--		"

Table 3.5. Normal cholinesterase (ChE) activity levels and ranges from the literature for food-producing and companion animal species (continued)

Species	Assay	N	Tissue	Baseline ChE					Comments	References
				Mean	Minimum	Maximum	Measure of Variability[a]	95% confidence limits ΔpH/h		
Canine (Dog)	Ellman, Siakatos	6	Whole blood	205±31 nmol substrate/mL/h	136.0±6.3	245.5±32.8	4/6 dogs: C.V. ≤ 5% over 15 min 1/6 dogs: C.V. = 13% 1/6 dogs: C.V. = 24%	--	9-12 mo male & female beagle dogs	Caldwell et al. 1989
	Levine	9	RBC	48.3 μmol/mL/4 min	31.0	59.3	3.0 (S.E.M.)	--		Hazelwood & Heath 1976
		9	Plasma	55.1 "	33.0	72.7	4.1 (S.E.M.)	--		"
		9	CSF	2.4 "	1.8	3.9	0.2 (S.E.M.)	--		"
	modified pH Stat method	A.3♂	Plasma	~1.1 μmoles ACh/mL plasma/min	--	--	±~0.15 (S.D.)	--	Adult beagles, male & female; data given in bar graphs, read as approximations; Phase A (1 year study) and Phase B (2 year study)	McCollister et al. 1974
		3♀	Plasma	~1.25 "	--	--	±~0.4 (S.D.)	--	"	"
		3♂	RBC	~1.35 "	--	--	±~0.02 (S.D.)	--	"	"
		3♀	RBC	~2.05 "	--	--	±~0.3 (S.D.)	--	"	"
		B.4♂	Plasma	~1.1 "	--	--	±~0.02 (S.D.)	--	"	"
		4♀	Plasma	~1.3	--	--	±~0.3 (S.D.)	--	"	"
		4♂	RBC	~1.1 "	--	--	±~0.3 (S.D.)	--	Adult beagles, male & female; data given in bar graphs, read as approximations; Phase A (1 year study) and Phase B (2 year study)	McCollister et al. 1974
		4♀	RBC	~1.5 "	--	--	±~0.2 (S.D.)	--	"	"
	Michel	--	Whole blood	0.43 ΔpH/h	--	--	--	--		Osweiler et al. 1985
	Michel	115	RBC	0.058 "	0.035	0.081	0.011 (S.D.); 19 (C.V.)	0.036-0.080		Callahan & Kruckenberg 1967
	Michel	10	Whole blood	0.29 "	--	--	--	--		Kruckenberg & Vestweber 1973
			RBC	0.13 "	--	--	--	--		"
			Plasma	0.16 "	--	--	--	--		"

Table 3.5. Normal cholinesterase (ChE) activity levels and ranges from the literature for food-producing and companion animal species (continued)

Species	Assay	N	Tissue	Baseline ChE					Comments	References
				Mean	Minimum	Maximum	Measure of Variability[a]	95% confidence limits ΔpH/h		
Feline (Domestic Cat)	Ellman	1	Whole blood	--	0.91 μmol/L/min	1.13	--	--	Adult male short-hair cats; ranges for single, control cat shows variability over seven samples taken 2 x/wk.	Hooser et al. 1988
	"	1	Plasma	--	0.75 μmol/L/min	1.01[d]	--	--		"
	"	1	Brain	1.844 μmol/g/min	--	--	--	--		"
	"	6	Whole blood	--	~0.7 μmol/L/min	~1.0	--	--	Ranges of values for 6 cats at days 0, 7, 28 and day 56 for 4 cats. Approximate values read from graph.	"
	"	6	Plasma	--	~0.6 μmol/L/min	~0.9	--	--		
	Michel	15	RBC	0.015 ΔpH/h	0.004	0.028	0.007 (S.D.); 47 (C.V.)	0-0.030		Callahan & Kruckenberg 1967

[a]S.D. = Standard deviation; S.E.M. = standard error of the mean; C.V. = coefficient of variation (%).

[b]IU = μmol substrate/min/L.

[c]Range of means of McAllister values (μM/mL).

[d]Mean of duplicate samples from one cat; N=2.

Table 3.6. Normal blood cholinesterase (ChE) activity levels and ranges for food-producing and companion animal species: recent data from four veterinary diagnostic laboratories

Species	N	Mean ChE	S.D.	Minimum Value	Maximum Value	S.E. of Mean	C.V.
Food-Producing							
Bovine (Cow)							
Blood	73	2.453 μmol/L/min[a]	0.630	1.120	3.830	0.074	25.667
RBC-ChE	10	3.62×10^{-22} moles/min/RBC[c]	--	5.11×10^{-24}	9.00×10^{-22}	--	--
Blood	53	0.5 ΔpH/h[d]	0.17	0.2	1.3	--	--
Porcine (Pig)							
Blood	23	1.451 μmol/L/min[a]	0.329	0.790	2.110	0.069	22.677
Blood	17	1.60 μmol/L/min[b]	--	1.16	1.91	--	--
Blood	6	0.38 ΔpH/h[d]	0.07	0.28	0.45	--	--
Equine (Horse)							
Blood	44	1.878 μmol/L/min[a]	0.306	1.280	2.740	0.046	16.287
RBC-ChE	1	2.21×10^{-22} moles/min/RBC[c]	--	--	--	--	--
Blood	4	0.64 ΔpH/h[d]	0.14	0.46	0.86	--	--
Ovine (Sheep)							
Blood	4	1.380 μmol/L/min[a]	0.354	0.900	1.740	0.177	25.688
Blood	3	0.33 ΔpH/h[d]	0.08	0.24	0.44	--	--
Caprine (Goat)							
Blood	1	0.950 μmol/L/min[a]	--	0.950	0.950	--	--
Avian (Poultry)							
Brain	9	27.864 μmol/L/min[a]	6.293	19.560	38.400	2.098	22.585
Blood	17	0.334 μmol/L/min[a]	0.165	0.020	0.700	0.040	49.339
Whole Blood	4	0.19 ΔpH/h[d]	0.04	0.14	0.25	--	--

Table 3.6 Normal blood cholinesterase (ChE) activity levels and ranges for food-producing and companion animal species: recent data from four veterinary diagnostic laboratories (continued)

Species	N	Mean ChE	S.D.	Minimum Value	Maximum Value	S.E. of Mean	C.V.
				Companion			
Canine (Dog)							
Blood	47	1.460 μmol/L/min[a]	0.332	0.700	2.110	0.048	22.725
	8	1.02 μmol/L/min[b]	--	0.74	1.16	--	--
	19	3.27×10^{-22} moles/	--	1.09×10^{-22}	7.20×10^{-22}	--	--
	18	min/RBC[c]	0.12	0.23	0.68	--	--
		0.43 ΔpH/h[d]					
Feline (Cat)							
Blood	38	1.365 μmol/min/L[a]	0.419	0.660	2.220	0.068	
	2	0.90 μmol/L/min[b]	--	0.897	0.91	--	30.675
	15	2.47×10^{-22} moles/	--	5.55×10^{-23}	1.32×10^{-21}	--	--
	4	min/RBC[c]	0.07	0.22	0.42	--	--
		0.31 ΔpH/h[d]					--

[a]Modified Ellman method (Harlin and Ross 1988), units = μmol/L/min for blood; μmol/g/min for brain; data from healthy animals. (K.S. Harlin, Supervisor, Animal Diagnostic Laboratory, University of Illinois at Champaign-Urbana, Urbana, IL, personal communication to N. B. Munro, Health and Safety Research Division, ORNL, Oak Ridge, TN, December 1989).

[b]Modified Ellman method (Harlin and Ross 1988), units = μmol/L/min for blood; data from diseased animals with no known OP exposure (W. E. Braselton, Jr. and R. H. Poppenga, Animal Health Diagnostic Laboratory, Michigan State University, East Lansing, MI, personal communication to N. B. Munro, Health and Safety Research Division, ORNL, Oak Ridge, TN December 21, 1989).

[c]Ellman method (Ellman et al 1961), units = moles substrate/min/RBC; data from healthy animals. (S. Cox, Supervisor, Veterinary Toxicology Laboratory, University of Tennessee, Knoxville, TN, personal communication to N. B. Munro, Health and Safety Research Division, ORNL, Oak Ridge, TN, December 18, 1989).

[d]Michel method (Michel 1949), units = ΔpH/h for whole blood; data from diseased animals with no known OP exposure. (G. D. Osweiler, Veterinary Diagnostic Laboratory, Iowa State University, Ames, IA, personal communication to N. B. Munro, Health and Safety Research Division, ORNL, Oak Ridge, TN, December 18, 1989).

for diagnosis of likely OP or carbamate poisoning. Lesser degrees of depression may be caused by OP exposure but, in the absence of baseline values for individual animals, may not be distinguishable from ChE values in the low normal range for a given species. Observation of increasing ChE values over a period of a few d after suspected exposure is indicative of initial ChE lowering but is not helpful in determining an appropriate course of treatment when signs and symptoms are present.

3.3.2 Sources of Variability

A wide range of blood cholinesterase levels is observed in normal populations of animal species. Some of the sources of data variability include interlaboratory variability, even when using the same protocol for a given method (Harlin and Ross 1988, Ames et al. 1989), age, gender and reproductive status, climate, season, and state of health. Fetal or neonatal ChE levels have been shown to differ from adult levels in sheep (Bell and Van Petten 1976); elevated testosterone levels in dairy bulls have been associated with elevated baseline ChE activity and greater sensitivity to certain OP insecticides (Lein et al. 1982; Haas et al. 1983). Gender differences are also noted for mice and rats (R. M. Parker, National Center for Toxicological Research, Jefferson, AR, letter to S. Leffingwell, Center for Environmental Health and Injury Control, CDC, DHHS, Atlanta, GA, May 22, 1987). Male beagle dogs appear to have had slightly lower plasma and RBC-ChE levels than females and exhibit less variation, although no statistical analysis for significance was performed (McCollister et al. 1974). Health and nutritional status can also affect cholinesterase levels (Coye, Lowe, and Maddy 1986). Climate differences have been observed; calves raised in Iowa have higher ChE levels than calves raised in Texas (W. B. Buck, National Animal Poison Information Network, University of Illinois at Champaign-Urbana, Urbana, Ill., personal communication to N. B. Munro, Health and Safety Research Division, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 30, 1989). A better understanding of the contribution of climate or region might be obtained by further study of data from laboratories located in widely differing locations.

3.3.3 Cholinesterase Measurement Methods and Recommendations

A variety of laboratory methods has been used for measuring cholinesterase activity in various species. While no method is currently approved by a certifying body, a modified Ellman assay procedure (Harlin and Ross 1988) has gained interim status (official first action status) in the course of becoming an official method of the American Association of Analytical Chemists (K. S. Harlin, Laboratories of Veterinary Diagnostic Medicine,

University of Illinois, Urbana, Ill, personal communication to N. B. Munro, Health and Safety Research Division, Oak Ridge National Laboratory, Oak Ridge, Tenn., December 15, 1989). Coye, Lowe and Maddy (1986) describe and evaluate several current methods for measuring cholinesterase activity, both in the laboratory and in the field. Magnotti et al. (1988) describe an Ellman-based field method for plasma and RBC-ChE determination. A list of methods, the units in which results are obtained, and references to the original descriptions of the most pertinent methods are presented in Table 3.7. By far the most commonly used procedures are the Ellman and its modifications and the Michel methods. In recent years, the trend in veterinary toxicology appears to be moving away from the Michel method to the Ellman and related methods despite somewhat higher costs. The Ellman method is faster, giving results in a few minutes compared to an hour or more. It also provides more information (the kinetics of the reaction can be observed), and the results are linear (unlike the ΔpH units of the Michel method). Procedures for obtaining tissue samples and preparing them for transmission to analytical laboratories for analysis are well developed and are outlined in Osweiler et al. (1985). If any doubt exists as to appropriate procedure, the analytical laboratory should be consulted in advance.

3.4 VETERINARY DIAGNOSIS AND TREATMENT GUIDELINES

While the chemicals in the unitary weapons stockpile contain both vesicant (blister) agents and OP nerve agents (see Section 1.0), this section will focus on treatment guidelines for the OP nerve agents. For exposure to the mustard agents, H, HD, and HT, only decontamination and symptomatic treatment are available as no antidotes exist.

3.4.1 Treatment Guidelines for Target Species

Upon inadvertent offsite release of chemical agents and exposure of animals, prompt decontamination and/or immobilization (as described in Sect. 2.2, doses given in Table 2.3) and treatment must ensue. Very mild exposure to organophosphate nerve agents may result in minimal signs and symptoms and require only careful monitoring. Moderate to severe exposure will result in effects similar to those of organophosphate pesticide poisoning; treatment techniques are essentially the same. In humans, the time course of recovery from nerve agent exposure is much shorter than that from OP pesticide exposure (h or d as opposed to d or weeks); this may also be true for some animal species, depending on the route of exposure and anatomy of the gastrointestinal tract. A summary of antidote dosages for various species and approaches to their administration is given in Table 3.8.

Table 3.7 Methods for cholinesterase determination[a]

Method	Units	Comments	Reference
pH (Michel); electrometric	ΔpH/mL/h	Inexpensive; not sensitive, slow	Michel 1949
pH Stat (Nabb-Whitfield); titrimetric	μmol/mL/min		Nabb and Whitfield 1967
Ellman; colorimetric	Moles substrate/ min/RBC	Fast, can observe kinetics	Ellman 1961
Modified Ellman	Blood: mmol/L/min Brain or retina: μmol/ g/min		Harlin and Ross (in press)
BMC Reagent Set (Ellman-Boehringer)	mU/mL/min	Stable reagents	
Dupont ACA	Units/mL		
Garry-Routh (Micro)	μmol-SH/3 mL/min		
Technicon	μmol/mL/min		

[a]Adapted from Table 1, p. 5, Morgan 1989.

Table 3.8. Veterinary treatment guidelines for target species[a]

Antidote	Small Animal Dose	Large Animal Dose	Route	Use	Comments	Reference
Atropine sulfate	0.2-0.5 mg/kg; all species		i.v., s.c., i.m.	Blocks excess ACh[b] accumulation at nerve endings	Give ⅙ initial dose i.v.; the rest s.c. or i.m. Repeat as necessary until respiratory secretions diminish and pinpoint pupils relax; repeat at ½ initial dose as necessary every 2 to 4 h for up to 2 d to counter parasympathetic signs, especially with ingestion exposure of ruminants	Osweiler et al 1985
	------	------	------	-------	Repeated doses may be needed every 5-10 min for species other than cattle	Koehler and Butler undated
	------	0.25-0.5 mg/kg (cattle) Up to 1.0 mg/kg (sheep) A total of 65 mg for average horse	------	-------	------	Meerdink 1989
	0.05-0.125 mg (cat)	------	i.v. initial dose		Follow initial dose as needed with half the initial dose to maintain control of secretions and other symptoms	Hooser et al 1988
	0.15-0.375 mg (cat)	------	s.c. initial dose			
	0.1-0.2 mg/kg (dogs & cats)	------	------	-------	------	Koehler and Butler undated
Oximes: Pralidoxime chloride (Protopam® chloride, 2-PAM)	20-50 mg/kg	25-50 mg/kg	i.v., i.m.	Regenerates blocked ChE	Give slowly i.v., up to maximum of 500 mg/min; second dose may be given after 1 h	Osweiler et al 1985
		4 mg/kg (Horse)	i.v.	-------	------	Koehler and Butler undated
	20 mg/kg (cat)	------	i.m. or i.v.	-------	Give every 12 h	Hooser et al 1988
	20 mg/kg (dog)	------	i.v.	-------	-------	Koehler and Butler undated
Diazepam	2-5 mg/kg	------	i.v., i.m.	Controls seizures	-------	Osweiler et al 1985
Contraindicated: Physostigmine Phenothiazine Morphine Pyridostigmine Neostigmine Succinylcholine Aminophylline	------	------	------	-------	Anything that inactivates ChE or is metabolized by ChE	Meerdink 1989

[a]Adapted from Osweiler et al. 1985, Table 3, pp. 55-58.
[b]ACh = acetylcholine.

Atropine sulfate is the primary antidote of choice for nerve agent exposure; it prevents the accumulation of excess ACh at the muscarinic synapses (in smooth muscles, heart, and exocrine glands) of the parasympathetic nervous system and also blocks some of the CNS effects of OP agents. Oximes such as pralidoxime chloride (Protopam® Chloride, 2-PAM) help counter the effects on skeletal muscle if they are given before the agent-ChE bond stabilizes by "aging" or dealkylation. However, Protopam® is quite expensive. As of January, 1990, the quoted price was $106.14 per hospital package of six vials containing 1 g oxime (50 mg/mL) each, or $54.28 per emergency package of 1 g vial together with dilutant, syringe, needle, and alcohol swab (M. Jones, Wyeth-Ayerst Labs, New York, N.Y., personal communication to N. B. Munro, Health and Safety Research Division, Oak Ridge National Laboratory, Oak Ridge, Tenn., January 2, 1990). Protopam® may thus be impractical for use with large animal species except for highly valuable breeding, racing, or show stock.

Protopam® was effective in treating dairy bulls poisoned with chlorpyrifos (Dursban-44®), even when initial treatment began 10 to 11 d post-exposure. This treatment was effective only if exposed skin had been washed with detergent and water within 48 h of exposure (Lein et al.. 1982). Protopam® was of questionable efficacy when washing was delayed for longer than 11 d. Failure to curtail exposure by prompt decontamination led to continuing development of toxic symptoms, and death ensued in some cases. Atropine administration was contraindicated due to the pesticide-induced immobility of the gastrointestinal tract. In cases of acute Dursban poisoning, Protopam® injections were coupled with the repeated administration of an 8:1 mixture of activated charcoal and kaolin, first by stomach tube and later by direct feeding. Subcutaneous injection of Protopam® was repeated up to three times as symptoms warranted, with larger, older bulls receiving 10-25 g per injection and younger bulls receiving 6 g per injection (i.e., a dose of 5-8 mg/lb) (Lein et al.. 1982).

Both atropine and oximes are toxic in themselves and should not be used in the absence of known exposure, at least in the massive doses needed to counter severe OP exposure. A "challenge dose" of atropine is commonly given to dogs and cats by some veterinarians in the absence of access to rapid laboratory ChE determination in order to differentiate OP-mediated symptoms from other causes; this practice may be acceptable for

some species but is not recommended for horses (G. L. Meerdink, College of Veterinary Medicine, University of Illinois, Urbana, Ill., personal communication to N. B. Munro, Health and Safety Research Division, Oak Ridge National Laboratory, Oak Ridge, Tenn., November 27, 1989).

3.4.2 Resources for Diagnosis and Treatment

3.4.2.1 Laboratories and emergency investigation teams

Several resources exist for obtaining assistance in the event of suspected OP poisoning. Basic information on these resources, a list of veterinary diagnostic laboratories accredited by the American Association of Veterinary Laboratory Diagnosticians (AAVLD), and a list of state veterinarians are presented in Table 3.9.

The National Animal Poison Information Network (NAPINet) currently offers services throughout the United States via the Illinois and Georgia Animal Poison Information Centers (IAPIC and GAPIC) (Buck 1987; Buck, Cote, and Trammel 1989). The Georgia center covers six southern states including one (Alabama) in which chemical weapons are stored. The rest of the country and Canada are served at present by the Illinois center although additional regional centers are in the formation stage and some are expected to be in place before the active phase of the CSDP gets underway. Each center offers a 24-h/day hotline staffed by veterinary toxicologists to handle telephone inquiries from veterinarians and animal owners and also provides diagnostic laboratory support. The IAPIC also offers field investigation capability for emergency assistance with diagnosis, decontamination, and treatment anywhere in the United States or Canada. The IAPIC, together with the Veterinary Diagnostic Laboratory of the University of Illinois College of Veterinary Medicine, can develop workshops or seminars tailored to a particular information need for local veterinarians. Consideration should be given to using this resource for local veterinary associations in the vicinity of chemical weapons stockpiles prior to the onset of the CSDP.

The National Veterinary Services Laboratory at Ames, Iowa, has been suggested as a possible resource in the event of OP nerve agent exposure. However, although staff from this facility participated in the investigation of the Skull Valley VX poisoning incident in sheep, the laboratory no longer has a capability for doing ChE determinations on animal blood and does not consider itself a resource (P. Clark, National Veterinary Services

Table 3.9 Veterinary diagnostic/treatment resources, accredited laboratories, and state veterinarians

Resource	Address and phone number	Special services
National Animal Poison Information Network (NAPINet)		
1. Illinois Animal Poison Information Center (Dr. William B. Buck)	Univ. of Ill. at Champaign-Urbana College of Veterinary Medicine Vet. Med. Basic Sci. Bldg. 1220 Veterinary Medicine 2001 S. Lincoln Avenue Urbana, IL 61801 217/333-3611 (Hotline)[a]	•24-hour-hotline for veterinarians and others to consult in events of actual or suspected poisonings. Serves all of USA and Canada except six Southern states (see below) •Emergency on-site investigator; decontamination and treatment assistance anywhere in US or Canada
2. Georgia Animal Poison Information Center (Dr. John Bowen)	University of Georgia College of Vet. Medicine Athens, GA	•24-hour hotline for veterinarians and others in Alabama, Florida, Georgia, North and South Carolina, and Tennessee
Nebraska Veterinary Medical Association (antidote depot) (Dr. Norman R. Schneider)	Department of Veterinary Science Inst. of Agr. and Nat. Resources University of Nebraska Lincoln, NE 68583-0907	•Model for systems of antidote stockpiling and distribution within a state for emergencies
National Veterinary Services Laboratory (Dr. Delmar Cassidy)	USDA/Agricultural Res. Serv. Box 844 Ames, IA 50010 FTS 515/862-8521	•Not a resource for organophosphate poisoning emergencies. No laboratory capability at present for ChE assays on animal blood, only human

Table 3.9 Veterinary diagnostic/treatment resources, accredited laboratories, and state veterinarians (continued)

Resource	Address and phone number	Special services
AAVLD[b]- accredited laboratories		
East		
Dept. of Path., Avian Species	University of Connecticut Storrs, CT	•Cholinesterase analysis
The Div. of Diag. Laboratories	Tufts University Jamaica Plains, MA	
Veterinary Diagnostic Lab	New York State College of Vet. Med. Cornell University Ithaca, NY	
Pennsylvania Dept. of Agriculture Bureau of Animal Industry Lab.	Summerdale, PA	
Southeast		
Florida Vet. Med. Diag. Lab System	Kissimmee, FL	
The Div. of Comparative Path.	University of Miami Miami, FL	
Diagnostic Assistance Laboratory	College of Veterinary Medicine University of Georgia Athens, GA	
Vet. Diagnostic and Investig. Lab.	University of Georgia Tifton, GA	
Murray State Univ. Vet. Diag. and Res. Ctr.	Hopkinsville, KY	
N.C. Vet. Med. Diag. Lab. System	Raleigh, NC	•Cholinesterase analysis

Table 3.9 Veterinary diagnostic/treatment resources, accredited laboratories, and state veterinarians (continued)

Resource	Address and phone number	Special services
AAVLD[b]- accredited laboratories (cont.)		
South		
Mississippi Vet. Diag. Lab.	P. O. Box 4389 Jackson, MS	
Louisiana Vet. Med. Diag. Lab.	School of Veterinary Medicine Louisiana State University Baton Rouge, LA	
Midwest		
Laboratories of Vet. Diag. Med. (Dr. Gavin Meerdink) (Ms. Karen Harlin)	University of Illinois 2001 S. Lincoln Ave. Urbana, IL 61801 217/333-1620	•Cholinesterase det'n; OP/carbamate analysis; field investigations, by board-certified toxicologists. Emergency services in support of 24-h hotline
Illinois Dept. of Agriculture Laboratory (Mr. Steve Ross)	Shattuc Road Centralia, IL 62801-9289 618/532-6701	•Cholinesterase det'n
Animal Disease Laboratory	1801 N. Seminary St. Galesburg, IL	
Animal Disease Diag. Lab. & Southern Indiana Purdue Agric. Ctr. (Dr. Robert Everson)	Purdue University West Lafayette, IN 47907 317/494-7440	•Cholinesterase det'n
Veterinary Diagnostic Laboratory (Dr. Gary Osweiler) (Dr. Tom Carson)	Iowa State University Ames, IA 50011 515/294-1950	•Cholinesterase det'n; OP/carbamate analysis; field investigations by board-certified toxicologists. Emergency service available as appropriate to needs

Table 3.9 Veterinary diagnostic/treatment resources, accredited laboratories, and state veterinarians (continued)

Resource	Address and phone number	Special services
AAVLD[b]- accredited laboratories (cont.)		
Midwest (cont.)		
Veterinary Diagnostic Laboratory	College of Vet. Medicine Kansas State University Manhattan, KS	
Animal Health Diag. Lab. (Dr. W. Emmett Braselton) (Dr. R. H. Poppinga)	Michigan State University B-142 Life Science Bldg. P. O. Box 30076 East Lansing, MI 48824 517/355-7441	•Cholinesterase det'n
Veterinary Med. Diag. Lab.	College of Veterinary Medicine University of Missouri Columbia, MO	
Minnesota Vet. Diag. Lab.	University of Minnesota St. Paul, MN	
Nebraska Vet. Diag. Center (Mr. Mike Carlson)	University of Nebraska Lincoln, NE 68583-0907 402/472-1434	•Cholinesterase det'n
North Dakota State Vet. Diag. Lab.	North Dakota State University P. O. Box 5406 Fargo, ND 58105 701/237-7529	•Cholinesterase det'n

Table 3.9 Veterinary diagnostic/treatment resources, accredited laboratories, and state veterinarians (continued)

Resource	Address and phone number	Special services
AAVLD[b]- accredited laboratories (cont.)		
Midwest (cont.)		
Oklahoma Animal Dis. Diag. Lab.	College of Veterinary Medicine Oklahoma State University Stillwater, OK	
Animal Disease Res. and Diag. Lab.	South Dakota State University Brookings, SD	
Central Animal Health Laboratory (Mr. David Zoromski)	6101 Mineral Point Road Madison, WI 53705 608/266-2465	•Cholinesterase det'n
Southwest		
Texas Vet. Med. Diag. Lab.	P. O. Box 3200 Amarillo, TX	
Texas Vet. Med. Diag. Lab.	College of Veterinary Medicine College Station, TX	
West		
County of Los Angeles-Department of Health Services Division	Compar. Med. and Vet. Pub. Hlth. Serv. Downey, CA	
Colorado Vet. Diag. Lab.	Fort Collins, CO	
Wyoming State Vet. Lab.	Laramie, WY	
State of Montana Animal Health Division	Diagnostic Laboratory Bozeman, MT	

Table 3.9 Veterinary diagnostic/treatment resources, accredited laboratories, and state veterinarians (continued)

Resource	Address and phone number	Special services
AAVLD[b]- accredited laboratories (cont.)		
Pacific Northwest		
Washington Animal Disease Diag. Lab.	Washington State University Pullman, WA	
State Veterinarians		
Alabama		
Dr. J. Lee Alley, State Veterinarian and Director, Animal Industry Division	Dept. of Agriculture and Industries 1445 Federal Drive, Room 222 P. O. Box 3336 Montgomery, AL 36193 Phone: 205/242-2647 (Office) 205/240-3135 (FAX)	
Arkansas		
Dr. Taylor H. Woods, Director	Livestock and Poultry Commission No. 1 Natural Resources Drive P. O. Box 5497 Little Rock, AK 72215 Phone: 501/225-5138	
Colorado		
Dr. James M. Williams, State Veterinarian	408 State Services Bldg. 1525 Sherman Street Denver, CO 80203 Phone: 303/865-2828 (Office) 303/866-4073 (FAX)	

Table 3.9 Veterinary diagnostic/treatment resources, accredited laboratories, and state veterinarians (continued)

Resource	Address and phone number	Special services
State Veterinarians (cont.)		
Indiana		
Dr. Thomas W. Freas State Veterinarian	700 N. High School Rd., Suite 200 Indianapolis, IN 46214 Phone: 317/232-1344 (Office) 317/248-4083 (FAX)	
Kentucky		
Dr. D. L. Notter State Veterinarian	635 Comanche Trail Frankfort, KY 40601 Phone: 504/564-3956	
Maryland		
Dr. A. B. Park, Assistant Secretary	Animal Health and Consumer Services 50 Harry S. Truman Parkway Annapolis, MD 21401 Phone: 301/841-5810 (Office) 301/841-5914 (FAX)	
Oregon		
Dr. Ramsay G. Burdette State Veterinarian Livestock Health and Identification Div.	Department of Agriculture 635 Capitol Street, NE Salem, OR 97310 Phone: 503/378-4710 (Office) 503/378-5529 (FAX)	

Table 3.9 Veterinary diagnostic/treatment resources, accredited laboratories, and state veterinarians (continued)

Resource	Address and phone number	Special services
State veterinarians (cont.)		
Utah		
Dr. Michael R. Marshall State Veterinarian	Utah State Dept. of Agriculture 380 N. Redwood Road Salt Lake City, UT 84116 Phone: 801/538-7160 (Office) 801/538-7126 (FAX)	

[a]Hotline users pay fee via VISA or MasterCharge number furnished at time of call.

[b]AAVLD = American Association of Veterinary Laboratory Diagnosticians; Ruby Idle, AAVLD, personal communication to N. B. Munro, Health and Safety Research Division, Oak Ridge National Laboratory, Oak Ridge, Tenn., January 24, 1990.

Laboratory, Ames, Iowa, personal communication to N. B. Munro, Health and Safety Research Division, Oak Ridge National Laboratory, Oak Ridge, Tenn., December 11, 1989).

Most state agriculture departments maintain veterinary diagnostic laboratories that can provide emergency on-site investigations as needed within their respective states. The state and university facilities available to communities near weapons stockpile sites should be assessed for the availability of Board-certified veterinary toxicologists and the extent of emergency assistance they can offer. Should a stockpile site be served neither by a state nor a university diagnostic laboratory with emergency aid capabilities, consideration should be given to providing the local veterinary community with access to the IAPIC or GAPIC hotline and emergency capabilities. In some states, any toxic chemical exposure to animals must be reported to the state veterinarian's office. It would be prudent to contact the state veterinarian in each CSDP host state to determine in advance all relevant planning responsibilities and reporting or regulatory requirements.

The Nebraska Veterinary Medical Association has established a statewide network of antidote depots for use in veterinary emergencies (Schneider 1987). This depot system could serve, with some modification, as a model for antidote depots in the vicinity of each of the chemical weapons stockpile sites. Other states may have similar depot systems; this should be investigated on a site-specific basis. Because of limited availability, stockpiling a supply of oxime such as Protopam®, (despite its high costs) should be seriously considered for CSDP antidote depots in the vicinity of all sites where OP nerve agents are housed and valuable animals are located. Even the readily available substances such as atropine sulfate may not be locally available in adequate quantities for treatment of large numbers of affected animals.

3.4.2.2 Sources of antidotes

Current sources of absorbants and antidotes pertinent to treatment of OP and mustard poisoning are listed in Table 3.10. While most of the drugs and absorbants are readily available to most veterinarians, Protopam® can be difficult to obtain through usual channels (it is not commonly used, it is expensive and has a 60-month shelf life). It is available direct from the manufacturer as well as through wholesalers but only in formulations manufactured to human treatment specifications. Wyeth-Ayerst Laboratories is the sole Protopam® supplier in the U.S. It is supplied in hospital packages (six 1g vials

Table 3.10 Sources of veterinary drugs and absorbants

Compound	Trade Name	Units Available	Source
Atropine Sulfate		100 mL, multiple dose vial	Med-Tech, Inc. Elwood, KS 913/365-9076
Pralidoxime	Protopam® (2-PAM)	1g vials (50 mg/mL)	Wyeth-Ayerst Labs 685 Third Avenue New York, NY 10017 800/666-7248, ext. 2049
Diazepam	Valium®		Roche Laboratories Nutley, NJ 201/235-5000
Activated Charcoal	Toxiban	45-lb. bag	Vet-A-Mix, Inc. Shenandoah, IA 51601 712/246-4000
	Darco G®		Sigma Chemical P. O. Box 14508 St. Louis, MO 63178 314/771-5765
	Activated Charcoal USP-Humco	Powder, 30g per 8-oz. jar 120g per 16-oz. jar 240g per 32-oz. jar	Humco Laboratories 1008 Whitaker Texarkana, TX 75504 214/793-3174
	Activated Charcoal USP-Mallinkrodt	454g powder (1 lb) per jar	Mallinkrodt, Inc. Box M Paris, KY 40361 606/987-7000
	LIQUI-CHAR®	In liquid base, water/propylene glycol: 12.5g in 60 mL bottle; 25g or 30g in 120 mL squeeze bottle with spout; 50g in 240 mL squeeze bottle with spout; 25g in 120mL bottle with sorbitol base	Jones Medical Industries, Inc. P. O. Box 28627 St. Louis, MO 63146 314/432-7557
	Bowman Poison-Antidote Kit	(1) In water/propylene glycol liquid base; 4 bottles, 12.5g/60 mL (2) One bottle, Ipecac syrup, 30 mL	Jones Medical Industries, Inc. P. O. Box 28627 St. Louis, MO 63146 314/432-7557
	Charcoaid®	In liquid base, 30g/150 mL sorbitol solution, squeeze bottle with spout	Requa Manufacturing Co. 1 Seneca Place Greenwich, CT 06830 203/869-2445

Table 3.10 Sources of veterinary drugs and absorbants (continued)

Compound	Trade Name	Units Available	Source
Activated Charcoal (Cont.)			
	Insta-Char®	In aqueous suspension, 15g/120 mL squeeze bottle with spout 50g/250mL squeeze bottle with spout	Frank W. Kerr Chemical Co. 43155 SW Nine Mile Road Northville, MI 48167 313-349-5000
	Norit USP XX®	In bulk, 15 kg containers (This is the activated charcoal used in most or all of above formulations)	American Norit Co. 6301 Glidden Way Jacksonville, FL 32208 904/783-6406
	Actidose®	Premixed suspension in 70% sorbitol (also available without sorbitol) 25g/120 mL, 50g/240 mL	Paddock Lab., Inc. P.O. Box 27286 3101 Louisiana Ave., N Minneapolis, MN 55427 612/546-4676

per package) or in emergency packages (1g/vial); the total national civilian inventory as of early January, 1990, was 6600 vials in hospital packages and 372 vials in emergency packages (J. Guerin, Wyeth-Ayerst Laboratories, New York, NY, personal communication to N. B. Munro, Health and Safety Research Division, Oak Ridge National Laboratory, Oak Ridge, Tenn., January 4, 1990). To put this in perspective for veterinary use, a market-weight steer of 1100 pounds or 500 kg would require an initial dose of 12.5-25 g (at 25-50 mg/kg). At 25 vials per steer, the total current national inventory of 6600 vials in hospital packages would be sufficient to provide 1 to 2 doses for 264 steers; repeated doses may be necessary in cases of severe poisoning.

The Army Mark I Nerve Agent Antidote Kit includes an autoinjector containing 2 mg of atropine citrate and one containing 600 mg of Protopam® (Dunn and Sidell 1989). Whether the military inventory of antidote kits would be suitable or be made available for veterinary use is currently unknown and should be determined.

4.0 REENTRY INTERVALS

A working concept of reentry intervals has been developed by regulatory authorities responsible for safeguarding the health of agricultural workers exposed to toxic concentrations of pesticides in the field or while loading/mixing pesticide formulations for field application. The pesticide formulations inducing the overwhelming majority of poisoning cases are organophosphates or carbamates, both of which depress blood and brain cholinesterases. The existing regulatory concept and method are pertinent to the basic issue of reentry in the event of off-post agent contamination, particularly for the nerve agents. Current guidelines are summarized below.

4.1 U.S. EPA GUIDELINES

The occurrence of numerous multiple-case poisoning episodes involving OP insecticide exposure among orchard workers in California and Washington state prompted the passage of protective legislation in California in 1972 (Knaak, Iwata, and Maddy 1989). The "Worker Safety Regulations" created by this legislation were some of the nation's first attempts at establishing safe reentry intervals. These early projections have since been expanded by principal agricultural states (California in particular) as well as the U.S. EPA (under authority of the Federal Insecticide, Fungicide, and Rodenticide Act of 1972 as amended, Part 170 "Worker Protection Standards for Agricultural Pesticides").

Reentry intervals or reentry times are defined by the U.S. EPA as "the period of time immediately following the application of a pesticide to a field when unprotected workers should not enter..." (40 CFR 170.2). These intervals are the estimated periods of time necessary for an individual formulation to degrade or dissipate to the reentry level, i.e., that concentration of surface residue (in ng of pesticide/m^2) that would produce no toxic response in exposed individuals. The principal route of pesticide exposure is dermal.

Protected workers are considered to be those wearing "at least a hat or other suitable head covering, a long-sleeved shirt and long-legged trousers or a coverall type garment (all of closely woven fabric covering the body, including arms and legs), shoes and socks" (40 CFR 170.2). The California Dept. of Food and Agriculture (1989) defines protective clothing to be, at minimum, work clothing and gloves that are clean daily (made of either cloth, rubber, or plastic) and shoes plus socks. Precedence is given to clothing requirements specified by regulations or product labels. Early entry by workers operating irrigation equipment is disallowed unless the irrigation worker is protected by one or more

of the following clothing items: chemical resistant boots, chemical resistant gloves, or chemical resistant coat, hat, or pants (California Dept. of Food and Agriculture 1989).

Establishment of reentry intervals is an ongoing process; those current to 1986 are presented in Table 4.1. These 12 intervals are in the process of being updated and intervals for other pesticides are under development. Note that the majority of established intervals are for OP compounds.

To determine appropriate values for reentry intervals, the U.S. EPA Office of Pesticide Programs evaluates available toxicity data, residue dissipation, information on dislodgeable residues, and any data on human exposure monitoring (Adams 1984). Field measures of dislodgeable pesticide residues on leaf surfaces incorporate established leaf-punch sampling techniques based on leaf shape, plant configuration (tall, upright crops such as tree fruit or corn vs. small, low crops such as lettuce or cauliflower) followed by detergent stripping and solvent extraction of the aqueous phase (Gunther, Westlake, and Barkley 1973; Iwata et al. 1977). Physical factors such as dew, rainfall, solar radiation, temperature, smog, and dust are also considered. Dissipation rates of OP insecticides appear to be governed more by moisture in the form of high rainfall, dew or fog than by the other factors listed above (J.D. Adams, Office of Pesticide Programs, U.S. Environmental Protection Agency, Washington, D.C., personal communication to A. P. Watson, Health and Safety Research Div., Oak Ridge National Laboratory, Oak Ridge, Tenn., Aug. 29, 1989).

The federal standards presented in Table 4.1 are considered minimum values; state regulatory authorities are permitted to set and enforce more restrictive standards (40 CFR 170.4). Such has been the case for several of the pesticides previously considered in Section 3.2 above (see Table 3.2). The California Departments of Health Services, and Food and Agriculture have established more restrictive standards based on their appraisal of data for each compound's foliar residue dissipation, degree of residue transfer to farm workers' skin and clothing, and percutaneous absorption/dermal dose-ChE response (Knaak, Iwata, and Maddy 1989). In Table 4.2, federally established intervals are compared with California reentry intervals for the OP insecticides addressed in Section 3.2 above. Worth noting are the lengthy intervals established for citrus crops and/or grapes treated with either azinphos-methyl (Guthion; range of 21 to 30 d depending on concentration applied) or ethyl parathion (range of 21 to 60 d depending on concentration, application rate and treatment frequency). In certain California counties (Fresno, Kern, Madera, and Tulare)

Table 4.1 Reentry intervals for pesticides established by the USEPA[a]

Pesticide	Reentry Interval (h)
Ethyl parathion	48
Methyl parathion	48
Guthion (Azinphos-methyl)	24
Demeton	48
Azodrin	48
Phosalone	24
Carbophenothion	48
Metasystox-R	48
EPN	24
Bidrin	48
Endrin	48
Ethion	24

[a]40 CFR 170.3 (July 1, 1988 edition).

Table 4.2 Pertinent reentry data for some OP insecticides

OP Insecticide	CAS No.	MPI[a] (mg/da)	ADI[b] (mg/kg/da)	Reentry Interval							Reference
				Federal	California						
				Minimum for all Crops	Apples	Citrus	Corn	Grapes	Peaches & Nectarines	All others	
Acephate	30560-19-1	--	--	--	--	--	--	--	--	--	--
Azinphos-methyl (Guthion)	86-50-0	0.075 (60 kg indiv.)	--	24h	14d	30d	--	21d	14d	--	EPA Pesticide Fact Sheet #100 1986; Knaak et al. 1989
Carbophenothion (Trithion)	786-19-6	--	--	48h	2d	14d	2d	14d	14d	2d	EPA Pesticide Fact Sheet #25 1984; Knaak et al. 1989
Chlorpyrifos (Lorsban, Dursban)	2921-88-2	0.18	0.003	24h	--	2d	--	--	--	--	EPA Pesticide Fact Sheet #37 1984; Knaak et al. 1989
Demeton (Systox)	8065-48-3	--	--	48h	2d	5d	2d	7d	7d	2d	EPA Pesticide Fact Sheet #45 1985; Knaak et al. 1989
Diazinon	333-41-5	--	--	--	--	5d	--	5d	5d	--	EPA Pesticide Fact Sheet #96 1986; Knaak et al. 1989
Dimethoate (Cygon)	60-51-5	--	--	--	--	2d	--	2d	--	--	Knaak et al. 1989
Disulfoton (Di-Syston)	298-00-0	--	0.0015[c] (PADI)	48h	2d	2d	2d	2d	2d	2d	EPA Pesticide Fact Sheet #43 1984; Knaak et al. 1989

Table 4.2 Pertinent reentry data for some OP insecticides (continued)

OP Insecticide	CAS No.	MPI[a] (mg/da)	ADI[b] (mg/kg/da)	Reentry Interval							Reference
				Federal	California						
				Minimum for all Crops	Apples	Citrus	Corn	Grapes	Peaches & Nectarines	All others	
EPN	2104-64-5	0.0006	0.00001[c] (PADI)	24h[e]	14d	14d	[d]	14d	14d	[d]	EPA Pesticide Fact Sheet #127 1987; Knaak et al. 1989
Malathion	121-75-5	--	--	--	--	1d	--	1d	1d	--	Knaak et al. 1989
Methamidophos (Monitor)	10265-92-6	--	--	--	2d	2d	2d	2d	2d	2d	Knaak et al. 1989
Methyl Parathion	298-00-0	--	0.0015[c] (PADI)	48h	14d	14d[f]	14d[f]	14d	21d	14d[f]	EPA Pesticide Fact Sheet #117 1986; Knaak et al. 1989
Parathion (ethyl parathion)	56-38-2	--	0.005	48h	14d	30-60d[g]	14d[b]	21d	21d	14d[b]	EPA Pesticide Fact Sheet #116 1986; Knaak et al. 1989

[a]Maximum Permissible Intake.

[b]Acceptable Daily Intake.

[c]Provisional Acceptable Daily Intake.

[d]When more than 1 lb/A of EPN is applied, there is a 14d reentry interval.

[e]7d for corn or cotton, 35d for citrus, 2d for all other crops.

[f]When $\leq$1 lb/A methyl parathion applied there is a 2d reentry interval.

[g]Reentry interval varies with concentration, rate of application, and treatment frequency. See Knaak et al. 1989.

[b]7d reentry interval for ethyl parathion applications of 0.5 to 1.0 lb/A.

of the San Joaquin Valley, applications of ethyl parathion made after May 15 "shall have a 90-day reentry interval..." (Knaak, Iwata, and Maddy 1989). The long intervals for ethyl parathion are primarily due to its high acute toxicity to humans and birds and its extensive history as the causal toxicant in numerous cases of severe occupational poisoning among farm workers (Knaak, Iwata, and Maddy 1989).

Organophosphate absorption in exposed farm workers is confirmed by measured depression of plasma pseudocholinesterase and/or RBC-ChE activity. Details of antidote treatment and clinical signs/symptoms are summarized elsewhere (Munro et al. in press; U.S. Dept. of the Army 1988). In general, a human ChE activity depression of 25% or more from normal baseline "is...regarded as evidence of excessive absorption" (Morgan 1989). Morgan recommends that victims of OP poisoning not be re-exposed until all signs and symptoms are resolved and blood ChE levels are at least 80% of normal baseline. Lower limits of normal ChE activities in humans as determined by several measurement techniques are summarized in Table 4.3.

Reentry guidelines based on measured ChE activity could also be used to manage access to a suspect area by emergency workers and the public. Implementation of this concept would require further development, including an appraisal of the range of normal ChE levels in human blood, identifying sources of normal variability (pregnancy, use of birth control pills, liver disease, malnutrition, chronic alcoholism, dermatomyositis, hemolytic anemia, genetically low levels of plasma pseudocholinesterase) (Morgan 1989), identifying reliable laboratory facilities for ChE monitoring, and developing normal baseline data for first responders and other emergency personnel who have the greatest exposure potential.

4.2 APPLICATION TO UNITARY STOCKPILE AGENTS

This analysis recommends that established techniques developed for estimating reentry intervals for pesticides (i.e., Adams 1984; Knaak, Iwata and Maddy 1989) be applied to the problem of estimating reentry intervals for the persistent agents VX and sulfur mustard. The carcinogenic potency of sulfur mustard (see Section 3.2.4) will need to be incorporated into the analysis. Staff of the U.S. EPA Office of Pesticide Programs and the California Departments of Health Services and Food and Agriculture, who have much experience in appraising data and performing the necessary calculations, would be invaluable resources from which to request assistance in resolving this issue. Until and unless such an

Table 4.3. Approximate minimal cholinesterase activities in normal human plasma and red blood cells[a,b]

Method	Plasma	RBC	Whole Blood	Units[c]
pH (Michel)	0.45	0.55		ΔpH per mL per hr
pH Stat (Nabb-Whitfield)	2.3	8.0		μM per mL per min
BMC Reagent Set (Ellman-Boehringer)	1875		3000	mU per mL per min
Dupont ACA	<8			Units per mL
Garry-Routh (Micro)			Male 7.8 Female 5.8	μM-SH per 3 mL per min
Technicon	2.0	8.0		μM per mL per min

[a]Morgan 1989.

[b]Measurement techniques and protocols vary among laboratories; more accurate estimates are usually provided by individual labs.

[c]See Section 3.3 for further explanation of units.

agent- and site-specific assessment is performed, it is sensible to consider the utility of the reentry standards summarized in Table 4.2.

The authors have previously demonstrated (Section 3.2) that several OP insecticides are approximately 10^3 to 10^4 less acutely toxic than nerve agent VX. Knowing this, the authors recommend that the reentry intervals outlined in Table 4.2 should be considered as minima for agent reentry planning purposes. The most toxic insecticide on the list, ethyl parathion, has an established reentry interval of between 30 and 60 d for most agricultural areas in California with the exception of four counties in the San Joaquin Valley, where a 90-day reentry interval period is in effect if application occurs after mid-May. Presumably, this additional restriction is due to the stabilizing effect of local climatic conditions.
With the present absence of other alternatives, establishing a reentry interval of less than 60 to 90 d for VX (a much more toxic compound than ethyl parathion), would not be prudent unless environmental monitoring can demonstrate that the suspect area is safe and/or that local meteorological conditions (e.g., high humidity or rainfall) are such that nerve agent dissipation is more rapid than what would be expected in the San Joaquin Valley. There is much regional and seasonal variability in atmospheric moisture between host sites. These and other factors that may alter agent dissipation need to be evaluated on a site-specific basis to determine reasonable estimates of reentry intervals for each of the eight individual unitary stockpiles (see Fig. 1.1). The issue of liquid contamination by "neat" liquid mustard or VX will be particularly problematic; the reentry interval analysis developed above may not fully apply in this latter case.

5.0 HUMAN REMAINS AND PERSONAL EFFECTS

In the event of civilian or military fatalities resulting from agent exposure, the potential for secondary contamination will make positive identification, recovery of the victim's remains/personal effects, and their return to the next-of-kin problematic. The mission of the U.S. Army Mortuary Affairs Program is to perform these tasks for all Army personnel killed while on military duty. There is no comparable civilian institution.

The Mortuary Affairs Program has developed a number of protocols to fulfill its mission in a timely manner while preventing secondary exposure to mortuary personnel and the victim's family. Some of their procedures are best suited to initial handling of human remains under combat conditions and will be only briefly addressed here. However, much of what the Mortuary Affairs Program has already considered is pertinent to community planning for this contingency during the CSDP. Policies for handling remains have also been developed by the Pine Bluff Arsenal (PBA, Jefferson County, Ark.) in cooperation with the Jefferson County Coroner's Office, and are presented in section 5.2 below as an example of a site-specific protocol that is already in place. Alternate procedures are under consideration by the surety officers at each host facility. This analysis recommends that a consistent policy of agent-specific protocols applicable to all sites be developed. This effort should involve site surety officers in a coordinated manner.

Extensive engineering and operational safeguards of the CSDP are designed so that there should never be occasion to implement the protocols discussed below. Nevertheless, it is a subject that should be addressed well in advance of any potential need; to do otherwise would be to deny the possibility of fatalities under certain extraordinary conditions. While the chance of a lethal exposure during the CSDP is slight, it is not zero (U.S. Dept. of the Army 1988).

5.1 U.S. ARMY MORTUARY AFFAIRS PROGRAM

Only limited data are available from which to determine the fate and penetrability of chemical agents on dead tissue (Metz, Grove, and Hutton 1988). It is clear, however, that the likely sources of secondary contamination would be external liquid contamination, vapor exposure from volatilizing agent still present on the remains or clothing, and unbound agent contained in body fluids. The first two sources can be largely dealt with by removing or discarding all clothing (assumed to contain agent) and decontaminating the remains by means of the several approaches described in Table 5.1. Confirmation of adequate

Table 5.1 Decontaminants[a] that could be used to remove chemical agent from human remains[b]

Decontaminant	Deleterious Effects on Skin	Limitations
STANDARD (MILITARY)		
M258A1 Skin Decontaminating Kit	No	Assumed to be effective on surface contamination but not on absorbed agent. Capable of decontaminating only small areas of skin. Contains phenol; waste solutions will need to be treated as hazardous
M280 Decontaminating Kit	No	Assumed to be effective on surface contamination, but not on absorbed agent. Contains phenol; waste solutions will need to be treated as hazardous.
M291 Decontaminating Kit	No	Resin-based powder assumed to be effective on surface contamination but not on absorbed agent. Does not contain phenol
Decontaminating Agent DS2	Yes	May cause fire if it comes in contact with raw STB or HTH
Decontaminating Agent STB (super tropical bleach)	Yes	Interaction of STB and DS2 may produce heat and flame Interaction of STB and liquid HD usually produces sufficient heat to cause flame. Not capable of decontaminating absorbed agent
NONSTANDARD		
Household Bleach (Sodium Hypochlorite)	No	If undiluted, harmful to skin. May be capable of decontaminating absorbed agent
High Test Hypochlorite (HTH) (Calcium Hypochlorite)	Yes	May be capable of decontaminating absorbed agent
Hypochlorite Solution Wrap[c]	Probably not	May be capable of decontaminating absorbed agent
Activated Charcoal Packet	No	Agent absorption effectiveness of charcoal sprinkled in a body bag must be determined

[a]The standard and nonstandard decontaminants, except the hypochlorite body wrap and the activated charcoal packet, have been proven to be effective against GD, HD, and VX. All except the charcoal packet would be labor intensive to use when applied manually.

[b]Adapted from Table 2 (Metz, Grove, and Hutton 1988).

[c]The hypochlorite solution wrap is a sheet or shroud saturated with hypochlorite solution in which contaminated remains are wrapped.

decontamination will be necessary before the body is released to the public. Managing unbound agent in body fluids is more difficult.

The degradation half-time in body fluids is pH-dependent for VX and the G agents, but is primarily temperature-dependent for HD. Estimated agent degradation half-times are 40 h for VX, 45 h for GD and 3 min to "several" h for HD, depending on temperature of the body and the ambient air (U. S. Dept. of the Army 1974; Metz, Grove, and Hutton 1988; Penski 1983 as cited in Metz, Grove, and Hutton 1988).

Sulfur mustard and G agents are considered bound to components of body fluids and would thus not pose a hazard to morticians or pathologists once external contamination was adequately removed. VX does not bind so readily to proteins; body fluids contaminated with this agent are considered a potential hazard for at least 5 half-times (i.e., 200 h)(Metz, Grove and Hutton 1988). A period of hazard this lengthy would certainly pose difficulties for mortuary and autopsy personnel.

Generic handling and processing procedures suitable for civilian casualties are derived from the U.S. Army Mortuary Affairs Program and are summarized in Table 5.2. On-site implementation of these recommendations is dependent upon the number of fatalities and the availability of necessary equipment, supplies and manpower. In a multi-casualty emergency, priority will be given to decontamination and medical support of living victims.

Metz and his co-authors identified a number of important data gaps in the recommended Mortuary Affairs Program process, including the fate of the agent in body fluids, fate of the agent and effects of decontamination on nonliving tissue, the persistency of agents on clothing and personal effects, the effectiveness of the decontamination process and existing body bags, and the effectiveness of field and mortuary personnel while working in full chemical protective gear. Data to evaluate the effectiveness of personnel working in full protective clothing was scheduled for collection during a mock disinterment and processing exercise by a Graves Registration Unit of the Army Mortuary Affairs Program in October, 1989 (EAI Corporation 1989). Each stage of the disinterment and decontamination procedure was to be timed and the number of containment breaches tabulated. Analysis of the findings from this exercise are not available for inclusion here.

Table 5.2 Recommended procedures for handling civilian remains potentially contaminated with chemical warfare agents[a]

Collection Point	Procedure
Point of Recovery	Search and recovery of all remains and personal effects by individuals in chemical protective gear. Identify remains, collect personal effects and place them, together with remains, in Type I or Type II pouch (body bag). Transcribe available identification data from victim and belongings. Transport to field collection point
Field Collection Point	Personnel with training in handling/registering fatalities shall, in full chemical protective gear, strip the remains of all outer clothing, and place the remains in a body bag containing activated charcoal. Body bag shall be clearly marked with victim's identification and that contents are chemically contaminated Catalog all personal effects and place them in leak proof container. Mark the container with appropriate identification information and that contents are chemically contaminated. Place personal effects with the victim's remains Transport to especially designated mortuary unit with appropriate decontamination facilities
Mortuary/Decon Unit	Mortuary personnel should be dressed in full chemical protective gear. Contaminated remains are removed from body bag, stripped of all clothing and decontaminated, preferably with DS2 or a hypochlorite solution. Once decontamination is complete, remains are moved to a "clean" area of the mortuary and placed in an uncontaminated body bag containing activated charcoal. At this time, remains could be dressed in other clothing provided by the family Embalming can take place according to the family's wishes. Body fluids should be considered contaminated waste and all contact with them should be avoided. Body fluids should be disposed of as befits agent-contaminated material. The bag containing decontaminated remains should be clearly marked as such and sealed. The bag should also be clearly marked with the victim's identification.

Table 5.2 Recommended procedures for handling civilian remains potentially contaminated with chemical warfare agents[a] (continued)

Collection Point	Procedure
Mortuary/Decon Unit (cont.)	All instruments used in the mortuary process should be cleaned with hypochlorite solution to prevent cross-contamination If the family wishes casket burial, the casket should be hermetically sealed before leaving the mortuary. It is not to be opened at any time during the service or interment

[a]Adapted from Table 17 (Metz, Grove and Hutton 1988).

5.2. PINE BLUFF CAIRA PLAN

The procedures for handling/processing chemical agent fatalities at PBA are reproduced in toto below. The procedures have been approved by the Jefferson County Coroner's Office.

"1. Pine Bluff Arsenal

a. PBA fire department personnel will transport fatalities from the chemical accident/incident area to the triage point, near the hot line. Army medical personnel will decontaminate the fatality and prepare to transfer across the hot line.

b. PBA fire department personnel will transport the fatality to the hot line, where decontamination will again be accomplished in accordance with routine procedures. Body(s) will be checked for contamination before transporting.

c. Fatalities, after decontamination will be placed on a litter and wrapped with a sheet or blanket. They will then be placed in a holding area to await transportation to the U.S. Army Toxic Exposure Aid Station (TEAS).

d. Upon arrival at the TEAS, the fatality will again be decontaminated and the attending physician will perform pronouncement of death.

e. Upon pronouncement of death, the body will be tagged (left thumb and right great toe) for identification purposes and placed within a body bag. The zipper will be completely zipped and the entire zipper will be sealed with 2 inch duct tape.

f. The body will be transported to an area where bubbler sampling will be effected." [Note: bubbler sampling refers to an approved method for detecting low-level concentrations of agent vapor by means of drawing air over or from the contaminated item through a vessel packed with glass beads and a scrubbing solution (U.S. Dept. of the Army 1987). Desorption from the vessel is performed in an analytical laboratory elsewhere. Response time is 2 to 4 h; sensitivity is 0.003 mg/m^3 for sulfur mustard agents, 0.0001 mg/m^3 for GB and 0.00001 mg/m^3 for VX]. "When XXX certification has been achieved, the body/body bag will be placed in a second body bag and taped as mentioned above." ["XXX" refers to a level of decontamination as defined in the U.S. Army Material Command safety regulations (U.S. Dept. of the Army 1987). A 3X item has been surface-decontaminated by approved procedures and then monitored to confirm that agent vapor concentrations from the item are $\leq$0.003 mg/m^3 for sulfur mustard agents, 0.0001 mg/m^3 for GB and 0.00001 mg/m^3 for VX]. "(If after bubbling, fatalities cannot be certified XXX, they will be decontaminated until XXX is obtained before transporting).

g. Fatalities will be transported to refrigerated storage, secured and remain in place until interface has been achieved with the Jefferson County Coroner concerning disposition of the body(s)."

"2. Jefferson County Coroner's Office

a. The Jefferson County Coroner will ensure the proper ID of each fatality. Photographs and fingerprints will be taken.

b. Arrange for the joint signing of death certificates by the Chief Medical Officer and Coroner.

c. Personal effects and property of fatalities will be held and stored.

d. Assist in the notification of the next of kin.

e. Establish separate files for ID of each fatality and log personal property.

f. Determine the necessity of blood/tissue samples and autopsies of selected fatalities.

g. Initiate procedures to arrange for the body(s) to be transported to the final resting place.

h. Make arrangement for possible aid from Jefferson Regional Medical Center if the number of fatalities is excessive, requiring the use of their refrigerator facilities" (PBA 1989).

Procedures for processing personal effects are still under development at PBA. In all likelihood, contaminated civilian clothing will not be returned to the family, but will be assessed for its value and compensation provided to the next-of-kin. Since there is at present no certain method for decontaminating paper, currency will also be confiscated and a like amount returned to the family in the form of compensation. Coinage could undergo chemical decontamination or high-temperature thermal desorption with safety. Jewelry could be treated in a similar fashion if the set is a simple one and any mounted stones are resistant to chemical or heat treatment. A protocol has not been developed for timepieces.

5.3. POLICIES OF STATE MEDICAL EXAMINER(S)

In most states, one of the charges of the state medical examiner's office is to develop systematic procedures for investigating individual cases of unnatural death and multi-fatality incidents. Depending on individual state laws and their interpretation, local implementation is often relegated to local coroners, with the option of additional assistance from the state medical examiner's office if conditions warrant. Pertinent issues gleaned from discussions with staff of the medical examiner's offices in Kentucky and Tennessee are summarized below. A more detailed appraisal of applicable state and local procedures needs to be performed for each of the eight host states (see Fig. 1.1).

(1) A full forensic investigation of the incident site and victims is recommended. Standard techniques of dividing the site into numbered and lettered quadrats and plotting location of victims should be used for multi-fatality incidents. Photography of the site with victims in place should be mandatory to assist in identifying remains, determining the time and sequence of death, foreknowledge (if any) of impending death on the part of the victim, and boundaries of plume dispersal. Bodies should not be moved until the responsible coroner is notified and grants permission. Autopsy is strongly recommended (with the family's permission).

(2) Some states mandate autopsy for unnatural deaths. In any case, there would be legal and civil reasons to obtain tissue and blood samples prior to any mortuary treatment of the remains. There may be other restrictions specific to state and/or local jurisdictions; these should be identified beforehand.

(3) Pre-planning to identify technical and physical resources needed at the scene is important. Suggested human resources are medical examiners, odontologists, pathologists, toxicologists, histologists, X-ray technicians, etc. The option of a mobile "tent city" with facilities for autopsy, mobile X-ray, medical records processing and mortuary activities is suggested. In some states, the Reserve National Guard maintains mobile hospital units and facilities that would be suitable. Funeral directors should be involved in this phase of planning.

(4) Establishing a cooperative agreement between the Department of the Army or its local agent and the medical examiner's office of each state is strongly recommended. This provision will involve both major parties in advance planning, streamline implementation of any incident investigation, and ensure appropriate attention to state and local requirements.

(5) The Armed Forces Institute of Pathology (AFIP) has capacity to provide trained and equipped teams for investigative support. If this resource is seriously considered by state and local planning bodies, the composition of the team and the supplies they may require need to be developed in advance.

(6) Employ experience gained by the state in managing other catastrophic incidents such as commercial air crashes, train derailments, and multi-car traffic accidents.

5.4. RECOMMENDATIONS

The procedures outlined above should be considered as working guidelines. The Army Mortuary Affairs program is testing several aspects of the process/handling procedure for effectiveness; other issues need further analysis as well. Metz and his colleagues (1988) recommend further examination and/or testing of the following points:

1. "Conduct laboratory testing to quantify the penetration and evaporation characteristics of both thickened and unthickened chemical agents on nonliving tissue. Determine whether "unbound" agent is present in the blood plasma of tissue.

2. Conduct laboratory testing to determine decontamination effectiveness on nonliving tissue. Both standard and nonstandard decontaminants should be evaluated.

3. Conduct laboratory testing to determine the persistency of chemical agents on clothing, personal effects, and individual items of equipment. Concurrent testing of methods of decontamination of these items should also be done.

4. Conduct a field exercise to operationally evaluate the impact of a chemical environment on the ability of a GRREG [GRaves REGistration] unit to perform its mission.

5. Testing is needed to develop methods of agent detection to enable personnel on the battlefield to identify contaminated remains, and also for verification of the effectiveness of decontamination of remains.

6. Testing is needed to determine the effects of burying contaminated nonliving tissue in a body bag.

7. Testing is needed to determine the effectiveness of proposed decontamination procedures, which are (1) charcoal inside human [remains] pouch, (2) hypochlorite solution wrap on remains inside human remains pouch, and (3) bathing or dipping remains in decontamination solution prior to insertion into human remains pouch" (Metz, Grove, and Hutton 1988).

Note that certain exclusions of the Resource Conservation and Recovery Act of 1976 (RCRA) as amended [40 CFR 270.1(c)(3)] would likely exempt treatment and/or burial of agent-contaminated remains from any permitting requirements of the Act. Under these exclusions, any decontamination or containment procedures applied to contaminated or suspect remains and/or personal effects could be interpreted as an immediate response activity that reduces the "imminent and substantial threat of a discharge of hazardous waste" (unitary stockpile agents are federally listed). Clarification has been requested in the form of a letter determination from the U.S. EPA Office of Solid Waste (A. Watson, Health and Safety Reserach Division, Oak Ridge National Laboratory, Oak Ridge, Tenn., letter to S. Lawrence, Director, Office of Solid Waste, U.S. EPA, Washington, D.C., April 2, 1990).

The current analysis further recommends that community planners make use of the experience and preliminary thinking already performed by the U.S Army Mortuary Affairs Program, either in the report summarized here (Metz, Grove, and Hutton 1988) or by direct interaction with staff of the four programs managed by the Army Mortuary Affairs Program, i.e., Graves Registration, Current Death, Concurrent Return, and Return of Remains.

6.0 CONTAMINATED BUILDINGS AND PERSONAL PROPERTY

There are presently no criteria or monitoring equipment suitable for designating potentially contaminated masonry, wood, fabric, paper, plastics or other "porous media" as free of hazardous agent concentrations. Concepts that have been considered include treating the suspect item or surface as if it were a piece of military hardware being prepared for sale to the public as scrap, wipe sampling of the suspect surface, or enclosing the item or area in an airtight manner followed by surface heating and airstream sampling. There are sampling and interpretation problems inherent to each of these approaches, not the least of which is how to determine safe agent concentrations for conditions of unlimited public access.

Most military guidelines for reentry and reuse of resources and material exposed to agent liquid or long-term agent vapor contamination are primarily mission-oriented for application under combat conditions or post-attack occupation. As such, these guidelines seek to limit personnel exposure by decontaminating often-used items such as weapons, ammunition, hatches and seats of vehicles, etc, rather than totally eliminating the source (Speirs 1986). Military guidelines for release of agent-contaminated items to the public were originally developed to clean metal scrap for salvage. Application of this thinking to the problem of public reentry to an agent-contaminated area is thus limited.

It is evident that some new and basic policies specific to this issue will have to be developed. Agencies and institutions such as the Army Material Command, DHHS, FEMA, U.S. EPA, and state and local health departments will need to be involved.

6.1. EXISTING TREATMENT GUIDELINES

U.S. military guidelines for release of agent-contaminated items to the public are process standards developed for the treatment of equipment and weapons before salvage sale as metal scrap. These guidelines were never intended for application to the treatment of public or private property under civilian, not military, control. Nevertheless, they are the only U.S. standards governing agent decontamination of material that can be released to the public.

The U.S. Army Material Command has assigned categorical levels of decontamination to any item that has been "subject to liquid contamination or long-term vapor contamination" (U.S. Dept. of the Army 1987). Each category is coded and tagged by a specific number of "Xs" as defined below (U. S. Dept. of the Army 1987). "Bubbler"

sampling refers to an Army-approved method for detecting low-level concentrations of agent vapor by means of drawing air over or from the contaminated item through a vessel packed with glass beads and a scrubbing solution, such as sulfuric acid solution at pH 4.5 for capture of GB vapor (U.S. Dept. of the Army 1987; Flamm and McNulty 1987). The scavenged agent can then be detected in the scrubbing solution by several means, such as gas chromatography or colorimetry with enzyme detection kits (Flamm and McNulty 1987). Response time is usually 2 to 4 h; sensitivity is 0.003 mg/m^3 for sulfur mustard agents, 0.0001 mg/m^3 for GB and 0.00001 mg/m^3 for VX.

(1) X (1X). Indicates that the degree of decontamination is unknown, or that vapor emissions from the item exceed 0.003 mg/m^3 for sulfur mustard agents and/or 0.0001 mg/m^3 for GB and/or 0.00001 mg/m^3 for VX.

(2) XXX (3X). Indicates that the item has undergone surface decontamination such that vapor emissions from the item do not exceed 0.003 mg/m^3 for sulfur mustard agents and/or 0.0001 mg/m^3 for GB and/or 0.00001 mg/m^3 for VX.

(3) XXXXX (5X). Indicates that "the item is clean and may be released from government control without precautions or restrictions." An approved method for disassembled items is to hold them at a minimum temperature of 538°C (1000°F) for 15 min to destroy all agent. Agent destruction for assembled objects will require holding at the minimum temperature for longer periods of time. The "5X condition must be certified by commander's designated representative" (U. S. Dept. of the Army 1987). In the past few months, a new interpretation of 5X has emerged: "An item may also be considered 5X when analyses approved by the Dept. of Defense Explosives Safety Board verify that the total quantity of residual agent is less than the no-effects dosage under the worst-case conditions of exposure" (Hennies 1989).

(4) Clean conditional. A thermal process standard designed to decompose agents to compounds of lesser toxicity and thus permit testing "such as metallurgical investigations" outside the installation boundaries (U.S. Dept. of the Army 1987). Agents are considered sufficiently decomposed by exposure to 177°C (350°F) for 4 h. Before the item can leave the installation, "bubbler" samples of vapor from the suspect item should meet the agent concentration limits given in the "3X" standard above. After the desired tests are completed, the item should be further decontaminated to "5X" levels as above or placed in approved storage as "3X." A "3X" item cannot be released from government control.

Although suitable for many metal objects, the "5X" or "clean conditional" thermal treatment outlined above would destroy or severely damage wood, plastics, textiles, and paper. Additional problems might be encountered in gaining possession of objects to be "5X'd" and in determining which articles have actually been contaminated. An alternative, nondestructive protocol is obviously needed.

Existing Army regulations state that high-temperature treatment at 538 °C (1000 °F) for 15 min is "an approved method" for achieving 5X decontamination (U.S. Dept. of the Army 1987). There may be other, less destructive, methods that would provide a similar level of decontamination and be suitable for treating personal and real property not under government control. These methods and the analytical protocols to monitor them are not yet identified by the Dept. of Defense Explosives Safety Board. Contamination by persistent agents such as VX or sulfur mustard is likely to be problematic.

This analysis strongly recommends that alternatives to thermal decontamination be examined and tested for personal and real property. Without application of such nondestructive techniques, the period of restricted access to homes, workplaces, and personal property could be indefinite and the Army could force itself into condemnation proceedings for all suspect private and/or public properties. The economic implications of potential private property restrictions are great.

6.2 EXISTING DECONTAMINATION CAPABILITIES

A number of sources were examined to compile existing recommendations for removing or reducing agent contamination on porous, contaminated surfaces. All recommend initial abandonment of the building or object with later determination of safe exposure levels after treatment.

Basic approaches to decontaminating porous materials employ either heat, dilution, chemical solutions to denature the agent, or a combination of the above. It is clear from the summary presented in Table 6.1 that there are practical limitations of time, personnel (skilled and fully protected), and physical resources to decontamination if the affected area is large or many buildings/interiors are involved. To our knowledge, the effectiveness of these procedures has been tested only for application to the strategic problem of reducing exposure to military personnel who have combat or other military missions to fulfill. The adequacy of decontamination is uncertain for safe and immediate post-treatment access by a heterogeneous, unprotected population. Persistent agents such as VX or sulfur mustard are a special concern even after thorough surface decontamination; agent desorption from porous surfaces could continue over a currently unknown period of time.

Table 6.1 Capabilities for decontaminating porous materials

Composition	Decontamination Procedure	Reference
Asphalt, tar	Must be rapid to reduce agent liquid dissolution in asphalt. Sprinkle with mixture of earth and bleaching powder ("chloride of lime")	NATO 1983
	Depending on descending level of contamination: - Cover area with dry mix[a] or bleach - Power spray with slurry[b] - Flush with water - Allow to weather	U.S. Dept. of the Army 1967
Brick, Concrete, Masonry	Preliminary spray with firehose followed by brushing with bleaching powder ("chloride of lime") solution. Repeat as necessary - Use dry mix or STB where waste water drains - Weather	NATO 1983
	Easily penetrated by liquid agents; "seal" contamination inside masonry surface by thick coating of slurry. Renew every 24h. Neutralizes only agent in direct contact with slurry and cannot make area safe for unprotected personnel indefinitely. Cracks will channel agent to interior Cover area with dry mix; renew as necessary	U.S. Dept. of the Army 1967
Fabrics	Depends on fabric, weave and agent; Launder with soap and warm water containing bleaching solution or boil for at least 1 h; (wool: solution of mild soap at 100°F for ≥1 h). 5% washing soda solutions effective for G agents on cotton fabric but not clothing of any kind or for any other agent. Chloramide powders effective if used promptly. Slurry recommended for canvas or webbing with thorough rinsing in soapy water. Aeration for days in bright sunlight effective except for V-agents and gross contamination. Aeration recommended after all laundering procedures	U.S. Dept. of the Army 1967

Table 6.1 Capabilities for decontaminating porous materials (continued)

Composition	Decontamination Procedure	Reference
Fabrics (cont.)	Fabrics and bedding "may be decontaminated in boiling water (½ h) or in a sterilizer." If lightly contaminated, aerate carpets and blankets for 1 week. If heavily contaminated, carpets and blankets should be destroyed	NATO 1983
Glass	Boiling water	NATO 1983
	Wash with hot soapy water, blot off surface, aerate. DS2[c] solution, blot off surface, aerate	U.S. Dept. of the Army 1967
Leather	Discard[d]	Morgan 1989
	Hot air; solvents	NATO 1983
	Light contamination: scrub with hot soapy water (5% washing soda solution for G-agents), rinse, aerate Heavy contamination: immerse 4 h in soapy water at 120°F, rinse, aerate Chloramide powders for localized contamination	U.S. Dept. of the Army 1967
Linoleum	If relatively sound, treat with paste of bleaching powder "chloride of lime" for 6 h; rinse. If worn, agent penetration likely; destroy	NATO 1983
Painted surfaces	Metal: - DS2 solution - Wash with hot soapy water - Apply slurry and leave for 1 h, rinse and oil - Weather	U.S. Dept. of the Army 1967

Table 6.1 Capabilities for decontaminating porous materials (continued)

Composition	Decontamination Procedure	Reference
Painted surfaces (cont.)	Plaster: - Oil-based paints problematic due to dissolution of agent - Remove paint with blowtorch, followed by treatment with bleaching powder paste - Rinse	NATO 1983
	Wood: - Oil based paints problematic due to dissolution of agent - Remove paint if possible. If not and wood is heavily contaminated, destroy	NATO 1983
	"Vapor flux reduction that can be expected by chemical decontamination of painted surfaces is on the order of 100X-1000X"	Carlon 1988
	Urethane: - "simple wiping would appear to reduce the vapor fluxes from all agents tested [HD,GF,GD,VX] by 10-100X"	Carlon 1988
	See Figures 6.1 and 6.2	
Paper and Papered Surfaces	No decontamination procedures for paper *per se*	NATO 1983
	Papered walls, etc. should have paper scraped off and destroyed; underlying wall treated with paste of bleaching powder and left for 1-2 d. Walls then washed.	

Table 6.1 Capabilities for decontaminating porous materials (continued)

Composition	Decontamination Procedure	Reference
Plastic	Treat with DS2 and rinse Wash with hot soapy water and rinse Aerate	U.S. Dept. of the Army 1967
Porcelain	Treat as glass	NATO 1983
Rubber	Impermeable: treat with DS2 for 30 min, rinse Immerse in soapy water at boiling point for 1 h; rinse with clear water; aerate and dry Use 10% Na_2CO_3 solution for G-agents Apply hot soapy water, rinse Spray with slurry and allow 1-2 min, rinse Aerate	U.S Dept. of the Army 1967
	Natural and synthetic: spray with DS2 and rinse Immerse in slurry solution 4 h; rinse, aerate Immerse in boiling soapy water 2-8 h, rinse Chloramide powders for local contamination Aerate	U.S. Dept. of the Amry 1967
Tile	Wash and brush with solution or paste of bleaching powder "chloride of lime"; leave for several hours and rinse. Agent penetration at joints and cracks problematic	NATO 1983

Table 6.1 Capabilities for decontaminating porous materials (continued)

Composition	Decontamination Procedure	Reference
Wood	Slurry application with sprayer, swabs, etc. Allow to remain 12-24 h and flush. Repeat at least twice. Scrub with hot soapy water, rinse. Aerate or weather.	U.S. Dept. of the Army 1967
	Remove visible liquid by absorption with soil or sand; remove and then treat surface with paste of bleaching powder with special attention to spaces between floorboards. Leave paste on for ≥24 h, wash with hot water. Repeat 2-3 times. If heavily contaminated, remove and incinerate.	NATO 1983

[a]Dry mix is 2 parts super tropical bleach (STB) and 3 parts earth or sand (U.S. Dept. of the Army 1981).

[b]Slurry is a mixture of either 6 gal. of water to every 50 lb. of STB or 6 gal. of water to every 50 lb. of high-test hypochlorite or high-test bleach (HTH/HTB) (U.S. Dept. of the Army 1981).

[c]DS2 is Decontaminating Solution No. 2 (70% diethylenetriamine, 28% ethylene glycol monomethyl ether and 2% NaOH).

[d]Recommended for contaminated leather goods implicated in OP poisoning cases among farm workers.

Some data describing the behavior of agents on painted surfaces treated with decontaminants is presented in Figures 6.1 and 6.2 (data of Day et al. 1975 as presented in Carlon 1988). Alkyd and urethane paint formulations tested with HD and two G agents (GF, or EA 1212 [cyclo hexylmethylphosphonofluoridate] and GD, or Soman [pinacolyl methylphosphonofluoridate, $C_7H_{16}FO_2P$] with thickener PMMA) desorb at different rates at constant temperature (25°C) and wind speed (0.5 km/h). More rapid agent flux was observed from urethane-painted surfaces than from alkyd-painted surfaces. Washing with soapy water, followed by wiping with a paper towel, reduced HD desorption by a factor of 100 or more within 2 h on either painted surface (data of Day et al. 1975 as presented in Carlon 1988). The work of several authors examined by Carlon (1988) suggest a desorption level of 5 $\mu g/cm^2$-15 min as a "'safe' vapor flux rate for unprotected personnel in the vicinity of ...contaminated surfaces," for HD and the G agents GF and GD. Further examination of the basis for this determination and the consideration of similar determinations for VX and GB is needed.

Temperature change was the controlling parameter identified in separate studies of agent evaporation/desorption on various undecontaminated surfaces (McGrath, Lindsay, and Thompson 1985). HD and GD applied to fabrics, painted and unpainted metal, plexiglass, polyethylene, cardboard, rubber, and wood were exposed to varying windspeeds and temperature in permeation cells over time. An arbitrary desorption rate of 0.5 $\mu g/cm^2/h$ was chosen as a categorical value for segregating the tested surfaces on their ability to "self-clean" without the use of decontaminants. The desorption rate of Group I surfaces fell to less than the target value within 4 h of agent contamination; Group II includes surfaces for which the target desorption rate was attained between 4 and 24 h after agent contamination; Group III includes surfaces with desorption rates in excess of the target value more than 24 h after agent contamination (McGrath, Lindsay, and Thompson 1985). The findings of this grouping study are presented in Table 6.2; the study's authors recommend more detailed experimentation but consider their current results to indicate a general appraisal of surface types that would pose most/least hazard to unprotected populations after agent contamination. Additional data plotting and tabulating agent evaporation rates as a function of wind speed, temperature and agent drop weight are available in McGrath, Lindsay, and Thompson (1985).

Table 6.2 General categorization of various surfaces on the basis of observed time to attain a desorption rate of 0.5 $\mu g/cm^2/h$ after initial agent contamination[a,b]

Agent	Category I	Category II	Category III
HD	None	Aluminum Aluminum with urethane paint Smooth glass Plexiglass Polyethylene Cotton duck Nylon duck Cotton sateen Cardboard	Aluminum with acrylic paint Aluminum with alkyd paint Rubber tire Wood
GD	Aluminum with acrylic paint Aluminum with urethane paint Plexiglass Polyethylene Cotton duck Nylon duck	Aluminum Cotton sateen Cardboard	Aluminum with alkyd paint Rubber tire Wood

[a]Category I: desorption rate $\leq$ 0.5 $\mu g/cm^2/h$ within 4 h after agent contamination.
Category II: desorption rate = 0.5 $\mu g/cm^2/h$ between 4 and 24 h after agent contamination.
Category III: desorption rate > 0.5 $\mu g/cm^2/h$ more than 24 h after agent contamination.

[b]Adapted from McGrath, Lindsay, and Thompson 1985.

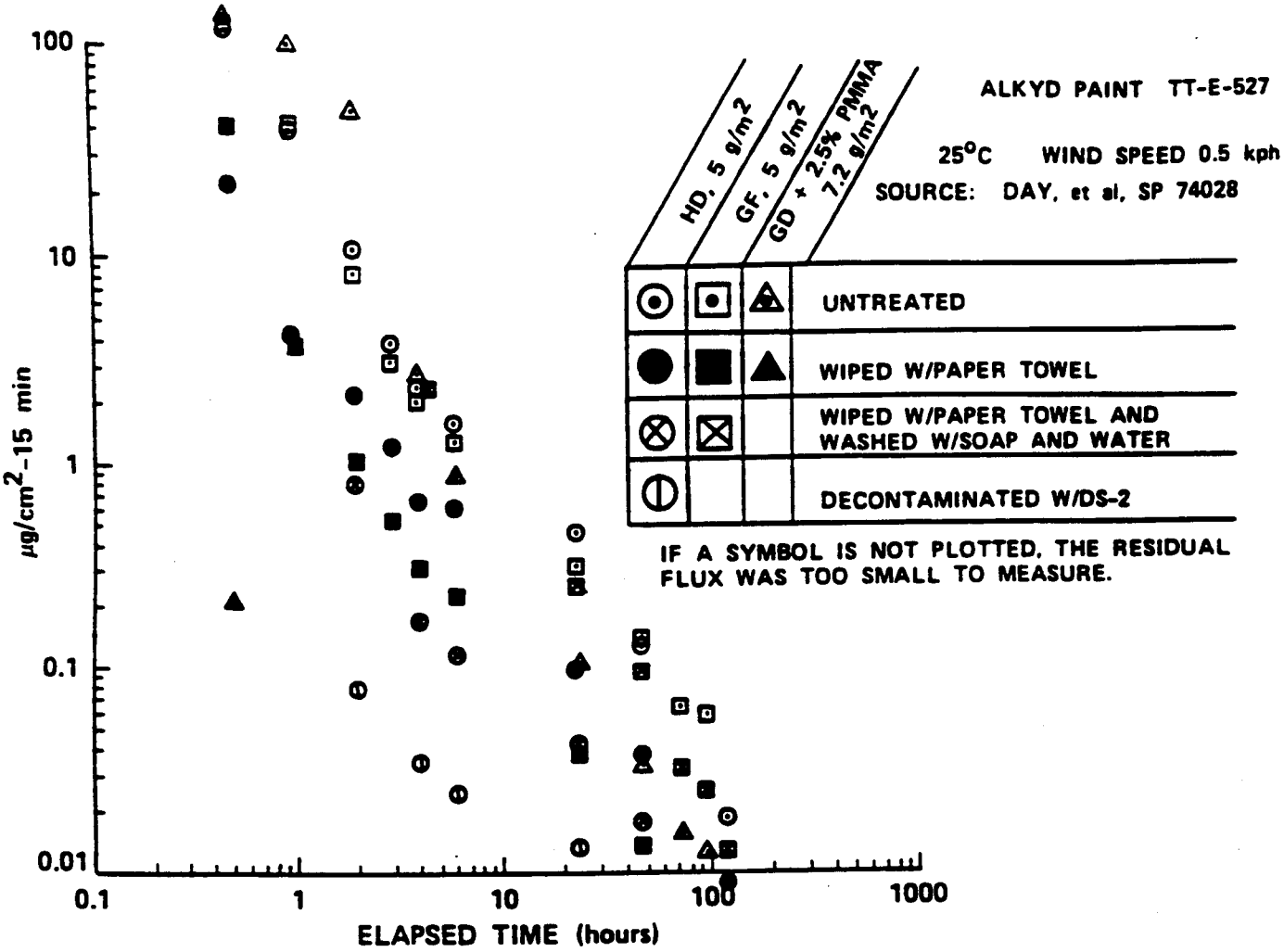

Figure 6.1 Agent desorption from alkyd-painted surfaces with time and various decontamination treatments at 25°C and 0.5 km/h windspeed. Level of initial agent contamination provided in legend. PMMA is a thickener. (Data of Day et al. 1975 as presented in Carlon 1988).

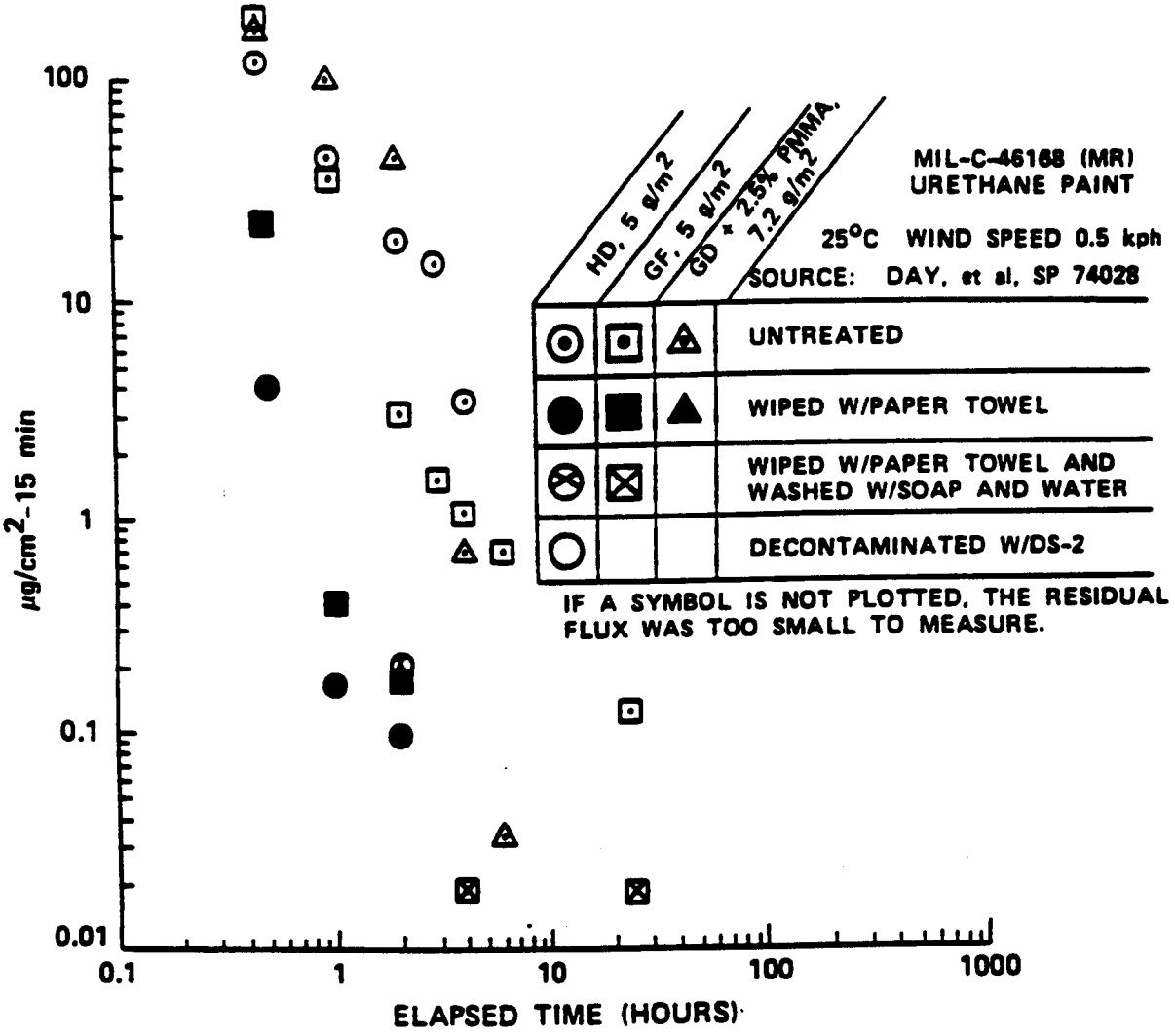

Figure 6.2 Agent desorption from urethane-painted surfaces with time and various decontamination treatments at 25 °C and 0.5 km/h windspeed. Level of initial agent contamination provided in legend. PMMA is a thickener. (Data of Day et al. 1975 as presented in Carlon 1988).

The issue of agent desorption requires more critical thinking, comparison with reentry concepts developed by the U.S. EPA Office of Pesticide Programs, and laboratory examination. New research that will address some of the critical unknowns and is outlined below.

6.3. DATA GAPS

For unlimited public access involving possible combined dermal, inhalation, and ingestion exposure pathways, it is not clear at what concentration(s) to establish safe exposure levels. Determining the absence of contamination at preset levels of sensitivity will aid in the establishment of quarantine zones. Problems arise when one considers

(1) appropriate sample sizes and sampling designs, and

(2) the interpretation of results near the limits of instrument sensitivity.

These points will be partly addressed by a one-year research program "Agent Contamination of Porous Media" approved for FY90 funding, and to be performed by research staff of the Analytical Chemistry, Environmental Sciences, and Health and Safety Research Divisions at ORNL. Samples of simulant-contaminated wood, masonry, household plasticware, etc. will be evaluated by means of ion trap mass spectrometry for degree of simulant penetration, decontamination efficacy under controlled conditions of temperature and pressure, and simulant weathering times. Critical sample size will also be examined. Destructive and nondestructive methods for direct analysis of agent simulants in porous materials are to be investigated. In addition, the rates of simulant diffusion into various materials commonly found in dwellings will be determined. The ion trap mass spectrometry technology to be implemented has been modified from commercially available designs to minimize sample preparation, expedite direct sampling, and reduce turn-around time (Buchanan, Wise, and Guerin in press). Direct-air sampling detection limits of approximately 1 ppb have been demonstrated for several volatile organic compounds; preconcentration has permitted reproducible detection at 1 ppt levels (Buchanan, Wise, and Guerin in press). This technology is currently being tested for use as a perimeter and workplace monitor at CAMDS (Chemical Agent Munitions Disposal System at Tooele Army Depot, UT).

The new work outlined above can only address a segment of what is a very large issue. Much more work will be needed to determine suitable sampling protocols in the event of agent contamination of private dwellings or factories. Field techniques that can

reliably detect agent at "all-clear" levels will also need to be identified and made readily available. Other technologies that could detect agent in complex media are summarized in Section 7.0 below.

Nevertheless, the basic data gap is still that of clear guidelines to determine a safe level of residual agent exposure that may never be quantified to everyone's satisfaction. Perhaps a process standard could be a reasonable alternative when coupled with a period of high-temperature weathering. Any experimental data on re-occupation or re-use of contaminated buildings or vehicles following a chemical agent exercise would be invaluable here.

7.0 DETECTION CAPABILITIES AVAILABLE FOR MONITORING TISSUE/FOOD AND POROUS MEDIA

7.1. CURRENT APPROVED METHODS

Current, U.S. Army-approved methods and equipment for detecting agents in air or liquids are summarized in Table 7.1 (U.S. Dept. of the Army 1987). With the exception of the colorimetric papers, tickets, tubes, and kits, these procedures could not be directly used for monitoring suspect vegetation, foodstuffs, masonry, etc. in the field. The field methods are not quantitative, but could be used to screen samples at +/- levels of gross agent contamination. For more quantitative information, it would be necessary to collect samples, followed by extraction and concentration of the analyte in a laboratory setting to provide a method adequate to detect and quantify the agent as well as accommodate instrument sensitivities in mg/m^3. Only certain equipment configurations described in Table 7.1 would be suitable (i.e., "bubbler" described in Section 6.0 above, and HYFED, Hydrogen Flame Photometric Emission Detector for flame photometry of phosphorus and sulfur). The other systems are specifically designed for air monitoring and alarm at various levels of sensitivity and are based on sample concentration steps followed by gas chromatography (DAAMS, ACAMS), electrochemistry (M8 and M43 systems, DCAC), or enzymatic chemistry (RTM). Some of these units are in the process of being phased out, i.e., the Real-Time Monitor (RTM) is no longer manufactured. Other equipment designs and techniques are in use abroad (USSR, France, Sweden) (NRC 1984) but, for practical reasons of availability, are not evaluated here.

The Chemical Agent Monitor (CAM), a hand-held, battery-operated, vapor detection unit incorporating an ion mobility spectrometer and microprocessor, can detect and discriminate between mustard and nerve agents in the field. It has been used to identify the presence of sulfur mustard in bomb craters in Iran (Dunn 1986) and could presumably be used to detect agent desorbing from other contaminated surfaces. The CAM is commercially available through Bendix Corporation.

Table 7.1 Army-approved detector sensitivity and response/processing time[a] for agents[b]

Equipment	Sensitivity (mg/m^3)			Response Time	Limitations
	Mustard	GB	VX		
Detector Paper, M8/M9[c]	Positive or Negative only for liquid agent			Immediately	Not effective in water, false positive from interferents and scuffs, effective temperature between 32 °F and 125 °F
Detector Ticket	Not Capable	0.1	0.1	3 min	--
Blue Band Tube	0.5	1.0	Not Capable	3 min	--
White Band Tube	Not Capable	1.0	Not Capable	3 min	First entry monitoring to igloo
M256 Kit	2.5	0.05	0.1	12-15 min	False positive from battlefield interferents; detection capability in field
M256A1 Kit	2.5	0.005	0.02	3-5 min	--
Bubbler	0.003	0.0001	0.00001	2-4 h	--
DAAMS (Depot Area Air Monitoring System)	0.003	0.0001	0.00001	1 h	--
ACAMS (Automated Continuous Air Monitoring)	0.003	0.0001	0.00001	3-5 min	Can detect at fractions of TWA levels (see Table 1.3) if air samples aspirated for 12 h with sorbent

Table 7.1 Army-approved detector sensitivity and response/processing time[a] for agents[b] (continued)

Equipment	Sensitivity (mg/m^3)			Response Time	Limitations
	Mustard	GB	VX		
RTM (Real-Time Monitor)	Not Capable	0.0001	0.00001	8-12 min	--
DCAC (Demilitarization Chemical Agent Concentrator)	Not Capable --	0.001 0.2	-- 0.4	33 min 2-3 min	-- --
M8	Not Capable	0.2	0.4	2-3 min	Requires extensive servicing with electrolyte solution; no agent specificity
M8A1	Not Capable	0.2	0.4	1-2 min	Requires extensive servicing with electrolyte solution; no agent specificity
M43A1	Not Capable	0.2	0.4	2 min	Requires extensive servicing with electrolyte solution; no agent specificity
HYFED (Hydrogen Flame Photometric Emission Detector)	0.003	0.001	0.001	1-2 min	--

Table 7.1 Army-approved detector sensitivity and response/processing time[a] for agents[b] (continued)

Equipment	Sensitivity (mg/m^3)			Response Time	Limitations
	Mustard	GB	VX		
CAM (Chemical Agent Monitor)	0.1	0.1	0.1	Minutes, depending on agent concentration	Cannot simultaneously detect nerve and blister agents, which requires change in drift tube polarity accomplished by control switch. Field portable, semiquantitative

[a]Processing time, if required, includes transport time from the site to the lab, set-up time, and analysis. Times are approximate and may vary from installation to installation.

[b]From U.S. Dept. of the Army 1987; Mengel et al 1988; P. Wojciechowski, Office of Program Manager for Chemical Demilitarization, Aberdeen Proving Ground, Md., personal communication to A. P. Watson, Oak Ridge National Laboratory, Oak Ridge, Tenn., March 15, 1990; E. Peterson, Armament Munitions and Chemical Command, Rock Island, Ill., personal communication to A. P. Watson, Oak Ridge National Laboratory, Oak Ridge, Tenn., Jan. 17 and April 5, 1990; and C. Campbell, U.S. Army Material Command, Charlestown, IN, memorandum to Program Manager for Chemical Demilitarization, Aberdeen Proving Ground, Md., October 26, 1989.

[c]M9 paper does not distinguish between mustard and nerve agents.

The U.S. Air Force offers a Surface Contamination Module (SCM) that detects liquid and vapor of agents GB, GD, VX, HD and L by means of a portable, battery-operated mass spectrometer (ion mobility). Its major advantages are its ability to perform point sampling as well as detect desorbed agent vapor from contaminated surfaces in 15 sec (Mengel et al. 1988). It is described as agent-specific, but detection limits were not provided in Mengel et al. (1988). This instrument sounds worthy of further consideration and application to reentry monitoring of building exteriors, interiors, vehicles, etc.

Detection with the instruments described in Table 7.1 at levels of sensitivity much less than those depicted would require extensive preconcentration and sample preparation by methods that have not been standardized by the U.S. Army Materiel Command. For example, lower detection limits would be necessary to determine allowable levels of OP agents in foodstuffs by the logic outlined in Section 3.0 above. Routine analysis of agent concentrations in vegetation, meat or milk has not previously been considered by installation laboratories; historically, analytical methods for these media have been the responsibility of the U.S. FDA, U.S. EPA, and USDA.

Note that Army analytical laboratories are not without experience in analyzing for agent in plant tissue and animal products. Following the Skull Valley incident of March, 1968, samples of vegetation and raw wool were sent to what was then the Chemical Research Laboratory at Edgewood Arsenal for VX analysis (Sass et al. 1970). Grass samples were subjected to solvent extraction (chloroform), extract concentration by rotary evaporation and lyophilization, and analysis by gas liquid chromatography, thin-layer chromatography, quantitative enzyme inhibition, mass spectrometry, and infrared spectroscopy. VX in μg quantities (in grass) was identified; extraction efficiencies were estimated to be 50%. Analysis of the wool sample was unsuccessful due to the presence of bulk extraneous residue (Sass et al. 1970). The Chemical Research Laboratory was able to make a confirmatory finding because it had already developed expertise in the detection and identification of various insecticides from samples of environmental media. A similar approach will again be necessary to meet the needs of reentry monitoring for the OP nerve agents. There are a number of analytical methods available for OP pesticide determinations in foodstuffs that should be considered and perhaps adapted for detection of VX or GB (U.S. FDA 1987b); generic approaches are outlined in Section 7.2 below.

Sulfur mustard detection is likely to be more difficult because of this agent's ability to rapidly alkylate proteins. Determining H, HD, or HT contamination of biological media may need to rely on detection of unique metabolites.

7.2. ALTERNATIVE APPROACHES

7.2.1. Modification of Standard Methods for Pesticide Residues

As a result of regulatory requirements governing sale and use of agricultural pesticides, there exists an extensive literature describing the numerous analytical methods for determining OP pesticide residues in foodstuffs (U.S. FDA 1987b, OTA 1988, among others). Sample preparation, extraction, and cleanup of complex environmental media have also been well developed for the OP formulations with established reentry intervals (see Tables 4.1 and 4.2 and U.S. FDA 1987a,b). The chemistry of OP agents is not unusual (see Table 1.1) and there are many structural and chemical similarities to the OP insecticides subjected to frequent monitoring in various agricultural commodities. For determining presence and concentration of OP agents or their metabolites in plant or animal tissue or suspect processed foods, it is reasonable to consider modification of sample preparation techniques and/or analytical methods established for regulated OP insecticides (i.e., nerve agent analogues).

A generalized scheme used by most federal analytical laboratories for determination of pesticide residue on or in plant tissue is presented in Figure 7.1. In broad terms, this schematic represents the approach employed by Sass and his colleagues in their analysis of grass samples from Skull Valley (Sass et al. 1970). Much the same procedure is used for samples of animal origin, with the use of different solvents for fatty tissues. New materials and technology are generating improvements in the clean-up and purification steps, particularly solid-phase extraction (SPE). Available SPE cartridges are unusually well adapted for application to residue analyses of food items because they can be substituted for the traditional extensive extraction and elution steps that consume quantities of expensive and environmentally harmful solvents (OTA 1988).

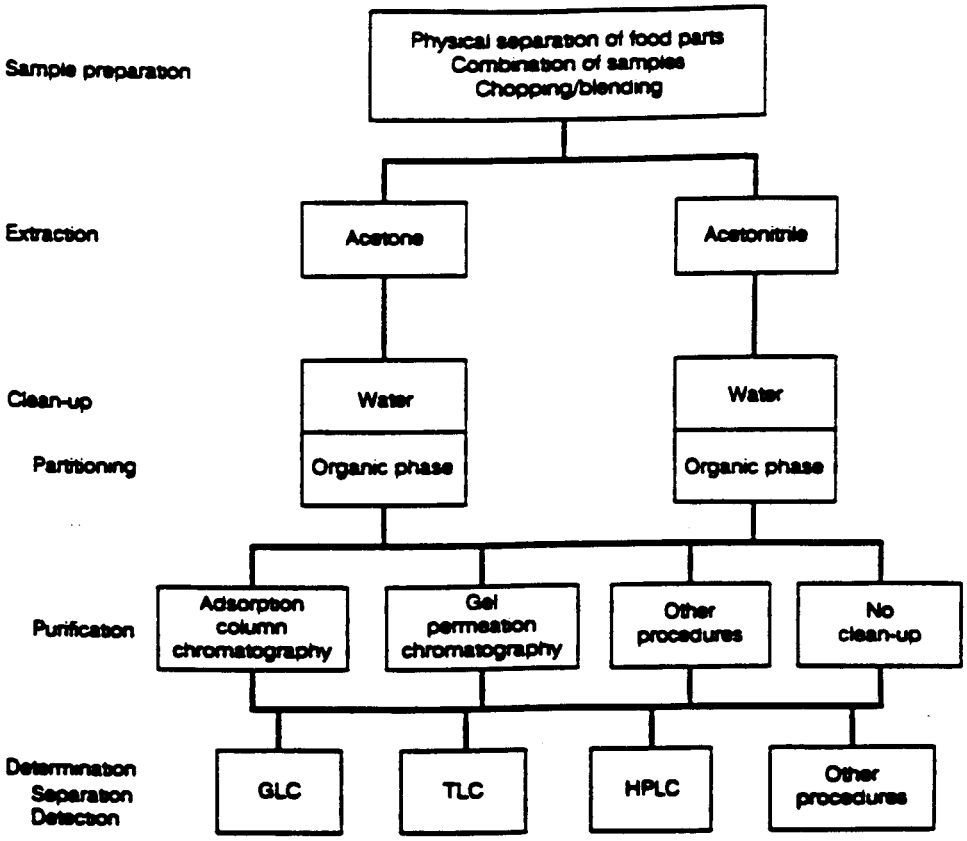

Figure 7.1 Generalized scheme used by regulatory laboratories for analysis of pesticide residues in plant tissue (Sources: OTA 1988; Ambrus and Thier 1986; Reprinted with permission from OTA).

All multiresidue methods for OP formulations that are approved by regulatory authorities employ gas chromatography (GC) (Table 7.2). The GC is usually coupled with a specialized detector, depending on the extraction method and sample type. The flame photometric (FPD) and nitrogen-phosphorus detectors (NPD) are most often used for OP insecticide determinations (Table 7.3). Both are reliable, and the FPD is highly selective for molecules containing not only P, but also S. This detector's potential for reliable determination of sulfur mustard compounds in tissue should be investigated.

This analysis recommends that analytical methods for reliable detection and quantitation of OP agents and sulfur mustard in plant and animal tissue be developed by the responsible Army agencies in collaboration with the federal bodies charged with monitoring pesticides in agricultural commodities. These are the U.S. FDA (raw agricultural produce except for meat, poultry and raw and processed eggs or egg products; U.S. FDA has jurisdiction over raw, unbroken eggs and animal feed), the Food Safety and Inspection Service (FSIS) (meat, poultry, and their products) and the Agricultural Marketing Service (AMS) (raw and processed egg products). The FDA is an arm of the DHHS, while the FSIS and the AMS are services of the USDA. The point of departure for establishing suitable analytical techniques should be the existing multiresidue methods outlined in Table 7.2 and described more fully in Volume I of the *Pesticide Analytical Manual: Methods Which Detect Multiple Residues* (U.S. FDA 1987b).

7.2.2. Uncommon Approaches

Direct sampling methods that can be applied to monitoring of surfaces or tissue are limited (Table 7.4). All those that are identified here should be considered experimental devices/techniques; none have been validated for agent determination for the media of interest and all require further development. For example, state and federal agencies do not use immunoassays in their current food regulatory programs (OTA 1988). However, each method presented in Table 7.4 could be considered an alternative to more traditional approaches.

Table 7.2 Multiresidue methods approved by regulatory authorities for analysis of OP pesticide residues in foods[a]

Authority[b]	Method[c]	Food type
FDA	GC-multiple detectors	
	(Luke method)	Nonfatty
	(Mills method)	Fatty
	(MOG method)	Nonfatty
	(Storherr method)	Nonfatty
USDA-FSIS	GC-NPD (eastern method)	Liver
CDFA	GC-NPD or FPD	Nonfatty

[a]Adapted from OTA 1988.

[b]FDA = U.S. Food and Drug Administration (DHHS).
USDA-FSIS = U.S. Dept. of Agriculture, Food Safety and Inspection Service.
CDFA = California Dept. of Food and Agriculture.

[c]GC = gas chromatography; GC-NPD = gas chromatography with nitrogen-phosphorus detector; FPD = flame photometric detector.

Table 7.3 Features of gas chromatography detectors used by regulatory authorities for monitoring OP residues[a]

Detector Type	Approximate Detection Limits	Reliability	Special Features
Flame Photometric Detector (FPD)	10^{-12}g P/sec	Excellent	Rugged, stable, selective. Can also detect S. Useful for analysis of unclean food extracts
Nitrogen-Phosphorus Detector (NPD)	$<0.2 \times 10^{-12}$ g P/sec	Good	Little interference from other atoms, simple operation, reproducible response. Replacing alkali flame detectors

[a]Adapted from OTA 1988.

Table 7.4 Developmental methodologies for direct sampling of agent on surfaces or in tissue/food

Medium/Technique	Detection limit	Tested Matrix	Features	Reference
Surfaces				
SERS[a] monitor with fiberoptics microprobe	30 ng (methyl chlorpyrifos)	Ethanol solution	Reproducible detection of trace quantities; Field portable design	Alak and Vo- Dinh 1988
IMS (PC)[b]	0.2 μg/L (4 ppb; DMMP)[c]	Air	Detection and alarm in 5-10 sec; Ni^{63} as electron source; field portable (11 kg) requires external DC power	Carrico et al. 1986
Infrared photo acoustic meter	15 ppb (G agents)	Air	Under test by Danish Civil Defence Service, manuf. by Bruel and Kjaer. 45 sec/ measurement; 1 reading/10 min. Can be alarmed	Fox 1989
MM-1 (Mobile Mass spectro-meter) (German Mass Spectro-meter GEMS)	?	Air	High specificity for lab anal. Not man portable, high cost and servicing time. Sample probe for surface contam. monitoring	Mengel et al. 1988
Tissue/Food				
ELISA[d]	10 ppb (Parathion)	Water/fruit juice	Fast; minimal cleanup for aqueous solutions, multiple samples analyzed simultaneously. Laboratory procedure	OTA 1988
Enzyme ticket	0.7 to 1 ppm (chlorpyrifos) 2 ppm (malathion and parathion) 4 ppm (methyl parathion)	Aqueous solution,[e] wipe sample of suspect surface; dislodgeable residues from foliage or fruit	COMMERCIAL, colorimetric, fast (3 min) field technique (qualitative); based on Army enzyme ticket technology	EnzyTec, Inc. 1989

Table 7.4 Developmental methodologies for direct sampling of agent on surfaces or in tissue/food (continued)

Medium/Technique	Detection limit	Tested Matrix	Features	Reference
Colorimetry of phosphorothionates, phosphorodithioates and phosphates	0.05 $\mu g/cm^2$ of parathion, ethion, dioxathion and paraoxon	Acetone/water solvent extract of foliar dislodgeable residues	Field qualitative reflectometry	Smith, Gunther, and Adams 1976
Colorimetric determination of ChE enzyme inhibition for presence of OP and carbamate compounds	0.1 to 2 ppm for many OP and carbamate pesticides	Aqueous/organic solvent extraction of suspect solution can be used for analysis of foliar dislodgeable residues	COMMERCIAL, colorimetric, rapid (5-30 min) field technique based on ChE inhibition. Interference by some water-soluble and organic solvents. Currently undergoing test by CA Dept. of Food and Ag.	Shape-Actio, Inc. 1990

[a]SERS = Surface Enhanced Raman Spectroscopy.

[b]IMS = ion mobility spectrometry; PC = plasma chromatography.

[c]DMMP = dimethyl methylphosphonate; VX simulant.

[d]ELISA = Enzyme-Linked Immunosorbent Assay.

[e]Protocol for analysing wash water from suspect food or foliage is available; organic solvent wash in laboratory has been incorporated into method for measuring dislodgeable residues.

New work approved for FY90 funding and designed to address the issue of agent monitoring in foodstuffs and forage is a one-year research program "Agent Contamination of Agricultural Resources" to be performed by research staff of the Environmental Sciences, Analytical Chemistry, and Health and Safety Research Divisions at ORNL. This work will be performed in parallel with the new "porous media" research outlined in Section 6.3 above. There are two objectives. The first is to isolate agent simulants from sample matrices such as tissue homogenates, milk, and urine by means of solid-phase extraction. Suitable conditions for efficient solid-phase extraction of agent simulant from tissues and milk will be established by spiking. Monitoring will be accomplished using gas chromatography and combined gas chromatography/mass spectrometry; results are to be compared with standard solution analysis. The second objective is to test the direct thermal desorption of SPE cartridges into an ion-trap mass spectrometer (ITMS) for quantitative detection without chromatographic isolation. Linearity of response and detection limits will be determined. Replicate samples will be analyzed, along with blanks and blind samples, to establish the precision and accuracy of the approach.

Complete data analysis from this new work will be available sometime in 1991. The purpose of the work is to develop and test a rapid and reliable method for detecting agents and/or their metabolites in media for which no agent detection capability currently exists. However, it is not likely that the ITMS method for tissue analysis could complete agent validity testing for some time. Some interim resolution of the tissue analysis issue will need to be made by joint decision involving the appropriate Army and federal regulatory agencies.

8.0 RECOMMENDATIONS FOR COMMUNITY EMERGENCY PLANNING

The information and findings summarized in Sections 1 through 7 above have direct bearing on the training and equipping of host communities that face the (remote) possibility of an unplanned agent release. Local and state officials have expressed the need for data characterizing agent persistence on surfaces and in environmental media; in some regions, concern is additionally focused on protection and treatment of agricultural resources. Many communities are sensitive to the possibility of another Skull Valley incident and wish to prepare themselves for such an eventuality. This section organizes available information under topics of particular interest to concerned communities and emergency planners. Redundancy is avoided where possible by reference to other sections or tables in this report.

This chapter can be used as a tool and guide for planning state and local actions in the event of an incident resulting in off-post agent contamination. As a reference, this document serves to identify major issues that require resolution and provides technical background.

8.1 GENERAL FINDINGS

The ultimate responsibility for implementing any post-incident action outside the installation boundaries rests with civil authorities at the state and local level. Federal agencies (such as the Department of the Army, USDA, U.S. EPA, FEMA, and the FDA) can provide advice, expertise and training, but jurisdiction off-post is a civil one. To adequately prepare for the reentry issues addressed in this analysis, a number of planning decisions need to be considered by the responsible civil authorities. The following are recommended:

(1) Cooperative agreements between state/local authorities and the installation/Department of the Army need to be put in place to address a number of issues. Several are summarized below; many others will occur to the reader. If cooperative agreements are already in place, they should be updated;

a. identify which governmental body(ies) has(ve) first response authority; identify duties of first responders (state and local police and fire personnel);

b. establish protocols for handling casualties (Office of State Medical Examiner, National Guard, office of the local coroner, other pertinent government agencies; see Section 5.3);

c. designate emergency shelters; consider capabilities for decontamination, staffing, and stocking (civil defense authorities). Consider special concerns of pet owners who often refuse to abandon companion animals during emergency evacuations (animal shelters with capability for decontamination and veterinary care?) (local veterinarians, humane societies)(see Section 2.2);

d. establish responsibility for impounding potentially contaminated personal property (e.g., vehicles, clothing), their decontamination (if possible) and release or disposition;

e. establish responsibility for monitoring and maintaining quarantine zone(s) and determining an "all-clear" status (state and local health/environmental protection authorities, state and local police);

(2) Identify, assemble, and train state and local teams of individuals with expertise and/or civil responsibilities to address reentry topics (e.g., state department of agriculture, veterinarians, coroner). These teams are needed to consider pertinent technical issues in depth, develop survey protocols and advise the governor of each host state as well as civil authorities of each host community;

(3) Establish site-specific inventories of pertinent resources (reservoirs, wells, alternate water supplies, principal herds/flocks, crops, etc.) and agent baseline concentrations. Special attention should be paid to the problem of false positives. State and federal agencies can provide expertise and assistance in addressing this task.

8.2. RELOCATION AND MASS CARE

The concept of reentry intervals as developed by the U.S. EPA and state departments of food and agriculture describes the post-treatment time period during which unprotected agricultural workers are not to enter the treated area (see Section 4.0). The impetus for mandating "no access" periods was the occurrence of acute, multiple poisoning episodes among workers exposed to OP or carbamate insecticides soon after their application; parallels with the acute effects of potential OP nerve agent exposure for an unprotected public are direct.

Reentry intervals established by the U.S. EPA as national minima range between 24 and 48 h; agricultural states such as California have established longer intervals for certain potent pesticides applied at rates or under weather conditions that enhance persistence (see Table 4.2). Until agent-specific reentry intervals can be developed (hopefully, with the assistance of the U.S. EPA Office of Pesticide Programs), use of the intervals developed for agricultural pesticides offer the best compromise for determining a quarantine period after off-post contamination by the nerve agents GA, GB or VX. The

G agents are volatile (see Table 1.1) and could be reasonably compared with non-persistent OP insecticides. The high toxicity and persistence of agent VX would be more readily comparable to Guthion or ethyl parathion (see Table 4.2). Available information at this time is too uncertain to establish an exact value for a nerve agent reentry interval, but it would certainly be on the order of d for the G agents and weeks or months for agent VX unless it can be demonstrated that agent concentrations in environmental samples have attained non-hazardous levels. To date, non-hazardous levels for the general public have been determined only for atmospheric exposures (see Table 1.3). More appraisal by appropriate Army agencies, the U.S. EPA and DHHS are needed for resolution of this issue.

Nevertheless, current analysis indicates a need for relocation plans and mass care centers for a period of approximately 48 h post-release for G agents, depending on the size of the area affected. For liquid VX contamination, it would be difficult to justify a reentry interval any less than that used to protect agricultural workers from the acute effects of ethyl parathion exposure unless environmental monitoring indicates otherwise. In California, the maximum interval is 90 da for ethyl parathion treatment in citrus groves (under maximum conditions of concentration, application rate and seasonal treatment frequency) (see Section 4.1).

Specific recommendations are included below:

(1) Develop reentry intervals that consider the carcinogenic potential of sulfur mustard; prevention of acute effects alone (particularly in cold weather) would require a quarantine interval of d to weeks (see Section 2.0);

(2) Develop site-specific appraisal of reentry intervals and reentry concentrations. Local meteorological data and stockpile characteristics should be utilized in the appraisal;

(3) Develop nondestructive decontamination protocols for private property (includes personal property and real estate). The duration of the relocation phase following agent release off-post will be largely determined by the decontamination process(es) deemed appropriate for attaining "5X" (see section 6.2). The issue is complex and will require policy decisions by several agencies (DoD Explosives Safety Board, FEMA, Army Environmental Hygiene Agency, DHHS, and others);

(4) Determine safe exposure levels from contaminated surfaces and the necessary analytical methods to measure them. Agent desorption from porous surfaces (construction materials, textiles, etc.) is considered problematic for VX and sulfur mustard. Critical thinking will be needed before any "all-clear" decision protocol can be developed (see Sections 6.2 and 6.3);

(5) Develop reliable monitoring methods to determine the physical extent of agents at concentrations that are not threatening to life or health. Non-hazardous concentrations of agent in water, food and on surfaces also need to be determined for unlimited access by the public, livestock and companion animals. If a reliable monitoring method is not available or practical for a given agent in a given medium, perhaps a process standard would be a reasonable alternative. In any case, clear decision protocols need to be developed (numerous local, state and federal agencies responsible for public health, food safety, clean water);

(6) This issue is extremely complex and involves numerous jurisdictions and overlapping agency responsibilities. Adequate time needs to be allotted for full exploration of all implications.

8.3 HUMAN REMAINS

The extensive engineering and operational safeguards of the Chemical Stockpile Disposal Program (CSDP) are designed to prevent the occurrence of injuries or fatalities to worker populations and the general public. Nevertheless, the consequences of a severe incident that may result in fatalities is a subject that should be addressed well in advance of any potential need; to do otherwise would be to deny the possibility of fatalities under certain extraordinary conditions. While the chance of a lethal exposure during the CSDP is slight, it is not zero (see Section 5.0).

Some of these concepts have been considered by the Jefferson County, Arkansas, Coroner's Office in developing a chemical accident/incident response plan for the civilian community surrounding Pine Bluff Arsenal. A working draft of the resulting policy for safe and timely handling of fatalities is included in Section 5.2; this draft is presented for use as a point of departure for other host states.

Specific recommendations are provided below.

(1) Develop site-specific plans for handling remains resulting from an agent release. To be most efffective, the plan(s) needs to be mutually agreeable to the installation command, the state medical examiner's office and the office of the local coroner. A cooperative agreement between all responsible parties is highly recommended;

(2) Develop protocols for handling personal effects. Special attention should be paid to the problem of decontaminating suspect items and a mechanism for compensation if adequate decontamination can not be performed (timepieces will probably be problematic, as will leather goods and personal papers);

(3) Policies and procedures for investigating individual cases of unnatural death and multi-fatality incidents vary between and among states and local coroners' offices. A full forensic investigation of the site of death or injury and the victim is often mandatory and is strongly recommended for any incident related to the CSDP. A detailed appraisal of applicable state and local procedures needs to be performed for each of the eight host states (involves the offices of state medical examiner and coroner, among others) (see Section 5.3);

(4) Technical and physical resources that will be needed at the scene and as part of the investigation need to be identified in advance. Local resources should be inventoried and involved in drills (see Section 5.3);

(5) Consider planning assistance from the Armed Forces Institute of Pathology;

(6) Make use of the experience and preliminary thinking already performed by the U.S. Army Mortuary Affairs Program. The Program's mission is to make positive identification, recover remains/personal effects and notify next-of-kin for all Army personnel killed while on military duty. In recent years, the Program has paid special attention to the problems of performing these duties for military personnel who may become victims of chemical attack (see Section 5.1).

8.4. LIVESTOCK, PETS AND CROPS

8.4.1. Animal Husbandry

Any quarantine or relocation period would require planning provisions for care of pets left behind as well as livestock in agricultural areas. This need was recently documented (May 1989) during a chemical emergency response exercise in Baton Rouge Louisiana, when residents refused to leave their homes because pets would have to remain behind (*NAPINet Report* 1989). For a lengthy human relocation, the feeding and/or control of stray or deserted animals could create problems of secondary agent contamination and public health. An obvious solution for the issue of pet management would be temporary emergency shelters with medical and decontamination facilities for companion animals (*NAPINet Report* 1989). Abandoned livestock would require tending and some provision for their care would have to be made. One practical suggestion is the establishment of animal husbandry units composed of several trained individuals in protective clothing who could travel through contaminated zones to feed and water livestock. These individuals could also treat or decontaminate as necessary (S. Leffingwell, Center for Environmental Health and Injury Control, CDC, Atlanta, Ga., personal communication to A. P. Watson, Health and Safety Research Division, ORNL, Oak Ridge, Tenn., October 24, 1989). If there is sufficient time and transportation available, livestock could be evacuated; in most cases, it would be more practical to shelter farm animals in place (see Section 2.0). Time

is also critical here, and fast-moving events would preclude any protective action for livestock.

Site-specific plans for these contingencies need to be developed with substantial involvement by local stock growers, veterinarians, humane societies, and the USDA Extension Service. Local management (e.g., feedlot or open range), animal distributions, and stockpile characteristics will need to be incorporated into any plans.

Additional, specific recommendations follow.

(1) Develop inventory of species composition and flock/herd size of livestock populations in the various response zones surrounding the eight stockpile sites. State and local agencies responsible for safeguarding agricultural resources in the event of an emergency will need these data to determine local capacity for sheltering, feeding and watering livestock, particulary if local supplies of food/water become suspect or livestock growers must evacuate. Inventory would be facilitated by the cooperation of local Agricultural Extension personnel (USDA) and veterinarians (see Section 2.2);

(2) Livestock management planning should emphasize prevention/reduction of animal exposure rather than post-incident treatment. Local expertise of veterinarians, veterinary medical associations, agricultural schools, USDA staff and growers' associations is unique to each host community and can be invaluable. State veterinarians with their expertise in investigating and reporting toxic chemcial exposures in animals would also be useful (see Section 3.4);

(3) Heroic measures of decontamination and/or antidote treatment (see Section 2.2 and 3.4) are recommended only for valuable breeding or show stock. It is prudent to establish decision protocols prior to the occurrence of an emergency (veterinarians, veterinary medical associations, growers and grower associations, Agricultural Extension);

(4) Establish livestock triage decision protocols. In the event of a major agent release, there will likely be more animals affected than can be decontaminated or treated during the critical time period before severe or life-threatening symptoms develop. Decision protocols for this contingency need to be established with an understanding of agent characteristics and livestock management as well as involvement of local growers (veterinarians, veterinary medical associations, growers and grower associations, Agricultural Extension). This issue assumes a mechanism for compensation (installation command, state insurance authority(ies));

(5) Develop quarantine measures for meat and milk from suspect areas. Animal evidence indicates that VX is not secreted in milk from contaminated dams; intact mustard is found in fatty tissues and is likely to be problematic (see Section 3.2)(state agricultural and health authorities);

(6) Develop acceptable residue concentrations for each agent in animal tissue/milk. Sulfur mustard formulations (carcinogenic) will be problematic (will require involvement of various offices of the U.S. EPA and agencies responsible for safeguarding public health) (see Section 3.2 and Section 7.0);

(7) Determine analytical protocols for measuring agent concentrations in meat or milk that may be used for human food. Some interim resolution of the tissue analysis issue will need to be made by joint decision involving the appropriate Army and federal/state regulatory agencies;

(8) Identify reputable laboratories with sufficient capacity and stable analytical methods to perform livestock blood ChE analyses, thereby providing an approach that could use local flocks/herds as biomonitors. There are many sources of biological and analytical variability in the determination of normal baseline cholinesterase levels in livestock (see Section 3.3). State-specific laboratories may be most suitable, since it is thought that there are regional differences in normal baseline levels of cholinesterase activity;

(9) Analytically define unique metabolites of specific agent exposure in order to reliably distinguish between nerve agent and OP insecticide exposure (research need);

(10) Consider accessing the training and information resources of the Illinois Animal Poison Information Center to educate local livestock growers and veterinarians in current management procedures for potentially poisoned animals (see Section 3.4);

(11) Consideration should be given to providing the local veterinary community with access to the Illinois Animal Poison Information Center hotline and emergency response services (involves request by appropriate state and local agencies and involvement of installation command as well as various Army Commands) if a host community is served neither by a state nor a university diagnostic laboratory with emergency aid capabilities;

(12) Consider stockpiling antidotes on a site-specific basis (see Section 3.4).

8.4.2 Agricultural Commodities

(1) Little could be done to protect most standing crops from agent deposition; there are some theoretical techniques that could reduce the degree of initial agent contamination and/or expedite agent degradation (such as spray irrigation with alkaline solutions or aerial crop dusting with agricultural lime before a rain). These and other related concepts would require testing before they could be recommended as mitigative actions (research need);

(2) Need for formulating site-specific decontamination or other disposition criteria for suspect crops. These criteria will need to address seasonal dynamics and composition of crops in each host community, incorporate the unique munition and chemical configurations of each unitary stockpile and include special features of local climate (local, state, and federal agencies responsible for food monitoring, agricultural production and agricultural marketing, among others)(see Section 2.4);

(3) Reliable monitoring methods to determine the physical extent of agents on crops at concentrations that are not threatening to life or health are needed. Non-hazardous concentrations of agent in plant tissue also need to be determined for unlimited access by the public, livestock and companion animals (local, state and federal agencies responsible for health protection, agricultural production and marketing, food monitoring) (see Section 7);

(4) Acceptable residue concentrations for each agent in crops need to be developed (will require involvement of various offices of the U.S. EPA as well as agencies responsible for safeguarding public health) (see Sections 3.2 and 7.0);

(5) Forage, grains and garden produce should probably be quarantined until tested. Implementation plans for this safeguard will need to be developed on a site-specific basis (local, state, and federal agencies responsible for food monitoring, public health, agricultural production and agricultural marketing);

(6) At present, there are no established protocols for determining agent concentrations in meat or milk that may be used for human food. Some interim resolution of the tissue analysis issue will need to be made by joint decision involving the appropriate Army and federal/state regulatory agencies.

8.5. FOODSTUFFS

(1) All foodstuffs located in an agent-contaminated area should be considered contaminated. For ease in managing the potential ingestion hazard posed by foodstuffs, all suspect items can be categorized into the following groups.

Group I: packaged (glass, metal, plastic, cellophane), sealed, unopened items that have been exposed only to agent vapor.

Group II: packaged, unopened items that include an impermeable wrapper or container (e.g., foil pouch) and that have been exposed to agent liquid.

Group III: unpackaged items (e.g., fresh fruit), opened packaged items or items packaged in untreated (i.e., no plastic or foil) paper or cardboard.

(2) Group III items should be destroyed and not used for human or animal food.

(3) Group I items can undergo surface decontamination by approved methods and be eventually used. This analysis suggests a combined approach of surface decontamination and weathering before any use as human food.

(4) Group II items are problematic. If the degree of liquid contamination is high, decontamination may never be sufficient to allow safe consumption by the most sensitive members of a heterogeneous civilian population. Unless no other sources of food are available, this analysis suggests that Group II items also be destroyed.

(5) Disposition of foodstuffs into the treatment categories above will require extensive procedures for handling and managing food items from groceries and private dwellings in the contamination zone. Compensation mechanisms for loss or damage of food stocks should also be considered.

8.6. WATER

Allowable concentrations of agent in water supplies accessible to the public have not yet been developed. An approach based on forthcoming standards for combat drinking water is presented in Section 3.1. Other approaches are under development.

There is a clear need for developing detection equipment and protocols to reliably identify mustard in water at 0.2 mg/L and other agents at proposed military and suggested civilian levels (see Table 3.1). Once an allowable value and appropriate monitoring technology are determined, the question of water treatment to attain allowable agent concentrations remains. Available information is summarized in Section 3.1.

Consideration of these options for protection and treatment of water supplies at greatest risk will require site-specific expertise from local water authorities.