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ESTIMATED GENERAL POPULATION CONTROL LIMITS FOR UNITARY AGENTS IN DRINKING WATER, MILK, SOIL, AND UNPROCESSED FOOD ITEMS

For Use in Reentry Decision-Making

Developed by the
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Reentry/Restoration Subcommittee
CSEPP Steering Committee

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1. INTRODUCTION

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. This White Paper has been prepared to provide technical bases for these decisions by developing working estimates of agent control limits in selected environmental media considered principal sources of potential human exposure. These estimated control limits were used, in draft form, for reentry decision making during the June, 1991, Service Response Force Exercise (SRFX-91) at TEAD.

To date, control limits for public exposure to unitary agents have been established for atmospheric concentrations only (see Table 1). These inhalation control limits were finalized in 53 FR 8504 (15 Mar, 1988) and are not at issue here. The current analysis builds on previous work to calculate working estimates of control limits for ingestion and dermal exposure to potentially contaminated drinking water, milk, soil, and unprocessed food items such as garden produce. Information characterizing agent desorption from, and detection on or in, contaminated porous media are presently too undeveloped to permit reasonable estimation of dermal exposure from this source. Thus, dermal contact with potentially contaminated porous surfaces is not considered in this document.

Table 1. 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 U.S. Surgeon General's Working Group after review of pertinent data and documented in *Federal Register*, 52: 48458 (December 22, 1987). Final promulgation in *Federal Register*, 53: 8504 (March 15, 1988).

[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. Final promulgation in *Federal Register*, 53: 8504 (March 15, 1988).

The unitary stockpile contains nerve and vesicant agents in a variety of munition forms (Carnes 1989). Presumably, a chemical agent incident could involve release of one or more of these munitions, singly or in combination. The control limit analysis thus considers both nerve and vesicant agents and makes no distinction between liquid, aerosol, or vapor forms of contamination.

This document is currently (January 1992) being submitted to review by the CSEPP Joint Steering Committee. As a result, the agent control limits presented and the logic supporting their calculation have not yet received approval for general-purpose emergency planning. They are offered here as a first approximation. The many assumptions necessary to derive estimated control limits are stated in the text below. The authors welcome critical review and presentation of alternate approaches. Our primary goal is to develop protective and reasonable values to guide reentry aspects for the Chemical Stockpile Emergency Preparedness Program (CSEPP) and future SRFX and CSEPP exercises.

2. CHARACTERIZING ACCEPTABLE BIOLOGICAL END POINTS

Field-observable threshold effects to the eye are commonly used for early diagnosis of agent exposure; pupil pin-pointing (miosis) is characteristic for organophosphate (OP) nerve agents, while conjunctivitis or inflammation is characteristic for vesicants, particularly the sulfur mustards. These signs are the basis for existing, acute no-effects dose levels in man, i.e., 0.5 mg-min/m^3 for GB (McNamara and Leitnaker 1971), 0.02 mg-min/m^3 for VX (McNamara, Vocci and Leitnaker 1971) and <12 mg-min/m^3 for H/HD (McNamara et al 1975). Under battlefield conditions, these biological end points are considered relatively minor in that they would not be expected to jeopardize most combat missions. Note, however, that <u>severe</u> miosis may compromise night vision and depth perception, resulting in a reduced capacity to aim and fire a weapon or operate a vehicle. The Ad Hoc Group does not consider an acute eye effects threshold to be sufficiently protective for the

general public, and sought alternative end points on which to base general population exposure limit estimates.

2.1 Nerve Agents

Data from laboratory animal experimentation and accidental human exposure indicate that there are no objective, reliably detectable, delayed effects of consequence following human nerve agent exposure. Delayed neuropathy is theoretically possible, but only among survivors of supra-lethal concentrations of G-agent. No human exposure to sub-lethal concentrations of G-agent has resulted in a case of delayed neuropathy. Nervous disturbances and EEG changes have been reported 12 months after munitions workers received acute exposures; however, these findings are so slight that they are difficult to detect and are of uncertain clinical significance.

A logical basis for nerve agent control limit determination is cholinesterase (ChE) activity depression:

- ChE activity depression is an objective and generally available biochemical indicator of excessive OP absorption (Morgan 1989)

- In the opinion of the USEPA's Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) Science Advisory Board and Scientific Advisory Panel, no adverse clinical signs or symptoms are associated with a 20% depression of red-blood-cell cholinesterase (RBC-ChE) (see p. 38 of Watson and Munro 1990 for more detail)

- Exposure criteria established by the DoA and recommended by Morgan (1989) require removing individuals from the work environment when RBC-ChE levels are 75% of individual baseline (i.e., a 25% depression). Return to the work environment is recommended only when the exposed individual has been not only asymptomatic for at least 7 days, but also when his/her RBC-ChE levels have attained 80% or more of the individual baseline (see p. 38 of Watson and Munro 1990).

Two classes of cholinesterase that are capable of deactivating acetylcholine exist in human blood. They are plasma cholinesterase (plasma ChE, butyrylcholinesterase, or "pseudocholinesterase") and red blood cell cholinesterase (RBC-ChE, acetylcholinesterase). Clinically normal human blood ChE values are summarized in Table 2. A depression of 50% from normal RBC-ChE or 75% from

Table 2. Approximate minimal cholinesterase activities in normal human plasma and red blood cells[a,b]

Method	Plasma	RBC	Whole Blood	Units
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
BTC colorimetric (Dupont Dimension®)	7.0-19.0			Units/mL
-- (BioScience Labs)	3.0-8.0	0.5-1.0		Units/mL for plasma pH units for RBC

[a]Morgan 1989.

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

normal plasma ChE is generally recognized as life-threatening (Gage 1967, Simpson and Penney 1974, as cited in Hayes 1982). Most clinical labs routinely measure either plasma ChE or RBC-ChE, but not both.

Based on our reading of an extensive literature review developed by Hayes (1982) and additional comments by Morgan (1989), **the Ad Hoc Group finds RBC-ChE to be a more stable parameter than plasma ChE.** Consideration of plasma ChE activity is compromised by its acknowledged utility as an indicator of liver function; plasma ChE activity is usually reduced in cases of liver disease such as hepatitis and cirrhosis. In normal, healthy populations, plasma ChE activity also exhibits wide variation by gender, race, time of day, and hormonal status. Large numbers of baseline blood samples would have to be collected and analyzed in order to make a reliable determination of nerve-agent induced plasma ChE depression (Table 3). Relatively fewer baseline samples would be necessary for reliably identifying RBC-ChE depression.

Further review indicates that some signs and symptoms may develop at exposures associated with RBC-ChE depressions of less than 20%. An IV injection of agent VX (at 0.12 μg/kg over 3.5 hours) that resulted in no detectable RBC-ChE depression in a human volunteer was associated with the development of frontal headaches, changes in respiratory and pulse rates, "lightheadedness," and abdominal cramps (Kimura, McNamara and Sim 1960). Admittedly, any exposures resulting from accidental agent release, as simulated in SRFX-91, will NOT be intravenous. The IV experiment was specifically designed to control for absorption losses expected from dermal or inhalation exposure. Thus, any effects noted from experimental IV exposure are considered maximal. Nevertheless, the Kimura, McNamara and Sim (1960) results cause **the Ad Hoc Group to recommend that RBC-ChE depression at some value less than 20% be considered an appropriate biological end point for nerve agent control limit determination.** Note that the lower limit of statistical reliability for human RBC-ChE determination approximates 11% (requires 10 baseline RBC-ChE samples; see Table 3); a 15% cholinesterase depression should be reliably detected with a minimum of pre-exposure baseline determination.

Table 3. Minimal differences for statistical recognition of abnormal plasma and red cell cholinesterase values[a]

No. of Preexposure Estimations	Percentage Differences	
	Plasma	Cells
1	19.9	15.3
2	17.3	13.3
3	16.3	12.5
4	15.7	12.1
5	15.5	11.9
10	14.7	11.3
∞	14.1	10.9

[a]Callaway et al. 1951, as cited in Hayes 1982.

2.2 Vesicants

Lewisite is stored in ton containers (a non-explosive munition form) and in limited quantities at TEAD. The risk of Lewisite release is thus very small, and will not be further considered in this assessment.

Sulfur mustard is a known human carcinogen. It is classified as a Group 1 carcinogen by the International Agency for Research on Cancer (IARC) (Saracci 1981), as a Class 1 carcinogen by the National Toxicology Program (NTP 1989), and as a Class IA Toxic Air Pollutant ("Known Human Carcinogen") under the Code of Maryland Regulations (Title 26, Department of the Environment, Subtitle 11, Air Quality; BNA 1990). These classifications represent consensus that there is sufficient evidence to support a causal relationship between agent exposure and human cancer induction. Note that these same review bodies admit that the evidence of sulfur mustard carcinogenicity supplied by laboratory animal data is limited. Note also that the record of human cancer induction is based on a very few data sets describing the response of soldiers and weapons plant workers exposed to toxic air concentrations under wartime conditions. In some cases, victims were exposed to atmospheric concentrations of mustard (some estimates are as great as 50 to 70 mg/m^3) sufficiently high to induce signs of acute toxic response shortly after chemical exposure (e.g., skin blistering, chemical burns of the eyes and mucous membranes, and respiratory distress) (Watson et al 1989a). Unless direct contact with liquid agent is made, comparable exposures would not occur during an emergency incident such as will be exercised during SRFX-91, nor during the CSDP. The Ad Hoc Group agrees that sulfur mustard has shown carcinogenic properties only at very high exposures, and that manifestation of this effect is delayed for several years. Nevertheless, EPA postulates a no-threshold effect for carcinogens and considers that any exposure has carcinogenic potential.

In 1990, the State of Maryland codified an acceptable cancer risk as follows:

"Insignificant risk concentration" (IRC) means a concentration of a Class I toxic air pollutant in the atmosphere that would result in an excess individual lifetime cancer risk of not more than 1 in 100,000 (1×10^{-5}) assuming continuous exposure for 70 years and using procedures consistent with

EPA's Risk Assessment Guidelines." [Code of Maryland Regulations, Title 26.11.15 Part .01A(8)] (BNA 1990)

The Ad Hoc Group considers that the 10^{-5} additional risk of delayed cancer induction deemed acceptable by the State of Maryland is a reasonable biological end point for calculating a dermal or ingestion control limit for sulfur mustard. To place the IRC in perspective, it is well to note that the current overall lifetime cancer risk (all cancers) for the U.S. population is 2.5×10^{-1} (25%, or 1 in 4) (Norman 1987).

In the event of an actual release, the period of post-acute exposure to sulfur mustard would likely be much less than a human lifetime due to the mitigative effects of decontamination, weathering, or chemical and biological decomposition on residual agent concentrations.

A semiquantitative method that utilizes EPA's Risk Assessment Guidelines for estimating the cancer risk of sulfur mustard exposure is available (Watson et al 1989a). This method has already been used to calculate the excess lifetime cancer risk from inhalation exposure for hypothetical individuals residing at sites along the Aberdeen Proving Ground fenceline boundary (Watson et al 1989a). The Ad Hoc Group intends to invoke this method in calculating cancer risk from dermal or ingestion exposure to sulfur mustard.

3. DETECTION LIMITS

Some analytical methods have been developed to detect unitary agents in environmental media (Table 4). Methods for soil and water analyses are the most completely developed of those compiled, but not all are THAMA- and/or EPA-certified. There are no analytical methods developed for unitary agents in vegetation, and only one for concrete.

Some experimental procedures are under development for quantitative agent simulant determination in crop plants, grains, meat, and milk (see Section 7.0 of Watson and Munro 1990), but these approaches will not be fully evaluated or documented until early FY92. In any case, experimental protocols developed with simulant spikes will require confirmation with "live" agent.

Table 4. Documented detection limits for unitary agents in environmental media

Agent	Soil	Water	Vegetation	Concrete
GA	ppb[a,b]	ppb[a,b] 5 to 200 ng/mL[c] 20 μg/L[d]	--	--
GB	0.075 μg/g[e] ppb[a,b]	0.5 ng/mL[f] ppb[a,b] 67 pg/mL[g] 2 to 500 ng/mL[c] 20 μg/L[d]	--	--
VX	5.9 μg/g[e] ppb[a,b]	37 μg/L[h] ppb[a,b] 5 to 500 ng/mL[c] 20 μg/L[d]	--	--
HD	2.0 μg/g[i] 0.095 μg/g[j] <100 pg[k]	0.25 μg/mL[f] 2000 μg/L[d]	-- --	0.095 μg/g[j] --
Lewisite	5 μg/g[l] 5 μg/g[n]	2 ng CVAA[m] 10^{-8}%[o] 2000 μg/L[d]	--	--

[a]Vujadinovic et al. [*Chem. Abs.* 97: 18503 (1982)] as cited in Reference [b].

[b]Witkiewicz et al. 1990.

[c]Shin and Ellin 1986. Method requires "10 min per sample after calibration."

[d]U.S. Dept. of the Army 1983.

[e]Rocky Mountain Arsenal 1987. Tested concentration range of 0.075 to 1.5 μg/g. Analysis rate of 10 samples/8 h.

Table 4 Continued

[f]Rocky Mountain Arsenal Laboratory (updated). Optimum range for HD is 0.25 to 1.0 μg/mL; for GB, optimum range is 0.5 to 2.0 ng/mL.

[g]Fowler et al. 1981.

[h]Rocky Mountain Arsenal 1986a. Analysis rate of 10 samples/8h.

[i]Rocky Mountain Arsenal 1989. Tested concentration range of 1.5 to 15 μg/g. Analysis rate of 10 samples/da.

[j]Hayes 1989. Tested calibration range of 0.095 to 19 μg/g. Analysis rate of 15 samples/24 h.

[k]Hendrickx et al. 1984.

[l]Rocky Mountain Arsenal Laboratory 1988. Analysis rate is 15 samples/24h.

[m]Bossle et al. 1989. Detection of Lewisite derivative, 2-chlorovinylarsonous acid (CVAA).

[n]Rocky Mountain Arsenal 1986b. Tested concentration in range of 5 to 25 μg/g. Analysis rate of 8 samples/da.

[o]Rozycki et al. 1987 [as cited in Reference [b]].

4. DRINKING WATER

In general, supplies from drilled or dug wells (i.e., groundwater) 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 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 1988 a,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). 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.

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: GA, GB and VX at 20 μg/L, sulfur mustard at 200 μg/L and Lewisite at 2000 μg/L (see Table 5). 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).

In addition, these criteria are to be followed only for short durations ($\leq$7 consecutive d). As such, **these combat drinking water standards are not comparable to occupational or general population 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. Nerve agent criteria were developed from data on, and models of, red blood cell cholinesterase (RBC-ChE) depression by OP compounds (see Daniels 1988a for detail). Proposed values for agents are presented in Table 5. Proposed combat drinking water standards for nerve agents may require additional development to accommodate the toxicity of agent hydrolysis products such as S-2-diisopropylaminoethylmethylphosphonothioic acid (hydrolysis product of VX) (Szafraniec, Beaudry, and Ward submitted; Daniels 1988b).

4.1 Nerve Agent

Calculated estimates for proposed combat drinking water standards are based on RBC-ChE depression of 50% of baseline (see Table 5), which is considered a level 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 control limits for 20% ChE inhibition be applied. The resulting water criteria (for 20% RBC-ChE depression) for

Table 5. Existing and proposed field standards for chemical agents in combat drinking water

Agent	Existing combat standard (μg/L)[a]	Proposed combat standard (μg/L)[a,b]		Suggested adult civilian standard (μg/L)[c]	
	5 L/day intake	5 L/day intake	15 L/day intake	2 L/day intake	5 L/day intake
GA	20[d]	12[e]	4[e]	1.5 - 3[f]	0.6 - 1.2
GB	20[d]	12[e]	4[e]	1.5 - 3[f]	0.6 - 1.2
VX	20[d]	12[e]	4[e]	1.5 - 3[f]	0.6 - 1.2
Sulfur mustard	200[g]	Under development[h]	Under development[h]	2.3×10^{-2} [i]	9.4×10^{-3}
Lewisite (L)	2000	Under development[g]	Under development[g]	Not addressed	Not addressed

[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.

[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]The estimated NOAEL for infants (see App. A for exposure assumptions) are 1.4×10^{-1} μg/L to 2.9×10^{-1} μg/L (body burden of 0.43 μg/d).

[g]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.

[h]Available data on vesicant agent oral toxicity in laboratory rats and rabbits currently under study by agencies of the Army, Air Force and Navy.

[i]The estimated NOAEL for infants (see App. A for exposure assumptions) is 2.2×10^{-3} μg/L.

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 days 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 days 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. It is assumed that most adults consume 2 L water/day (the maximum adult intake for normal activity and moderate environmental temperature as estimated by ICRP 1975); thus an estimate of safe agent intake based on 5 L water/day would be protective. Maximal water consumption for most adults undergoing moderate activity under high temperature loads approximates only 3 L/day (ICRP 1975). The limited data on human ChE depression following experimental nerve agent exposure includes a single case study where no RBC-ChE depression was observed at a VX dose approximating 10% of the VX dose at which 50% ChE depression is observed [no RBC-ChE lowering in a human volunteer was observed for an IV dose of VX at 0.12 μg/kg; approximately 50% RBC-ChE lowering in six volunteers was

observed for an IV dose of VX at 1 μg/kg (Kimura, McNamara and Sim 1960)]. This assessment assumes these limited data to be representative. 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 resulting overall adjustment to Daniels' proposed combat standard in Table 5 (calculated to result in 50% depression) would equal 0.05 [i.e., 0.10 (adjustment for human threshold RBC-ChE depression) x 0.50 (adjustment for lowered RBC mass in persons with anemia)]. The resulting modified water control limits suggested for consideration as civilian drinking water criteria for nerve agents GA, GB and VX are 0.6 μg/L for 5 L/day consumption (Table 5). For the more realistic 2 L/day water consumption rate, the modified civilian water control limit is 1.5 μg/L (Table 5). The limited human exposure data available indicate that any RBC-ChE depression obtained from drinking water containing nerve agents at this concentration would be indistinguishable from normal variability in RBC-ChE activity (see Table 3). Development of these water quality values assumes no other source of agent or anticholinesterase exposure.

An alternate method of estimating a nerve agent control limit has been proposed by CDC/CEHIC, which calculates an ingestion dose equivalent to the "No ChE depression" atmospheric concentration of GB, a volatile G agent known for its inhalation toxicity (Carnes 1989, Watson et al 1989b). The atmospheric Ct (Concentration x time) for GB at which "No ChE depression" is expected among humans is 0.5 mg-min/m^3 (McNamara and Leitnaker 1971). McNamara and Leitnaker (1971) state that the corresponding 24-h exposure for this Ct is 0.0003 mg/m^3. At the standard assumed adult breathing rate of 20 m^3/d (see App. A for exposure assumptions), this 24-h exposure results in a daily inhalation body burden of

$$(0.0003 \text{ mg/m}^3)(20 \text{ m}^3/\text{d}) = 0.006 \text{ mg/d} = 6 \ \mu\text{g/d}.$$

If we further assume drinking water consumption at 2 L/d (see App. A), this body burden could be attained by

$$(6\ \mu g/d)/(2L/d) = 3\ \mu g/L.$$

At 5 L/d intake, this body burden could be attained by

$$(6\ \mu g/d)/(5\ L/d) = 1.2\ \mu g/L.$$

The reader is directed to Table 5 for a summary of these civilian control limit estimates for drinking water.

The authors wish to point out that a VX hydrolysis product, S-[2-(diisopropylamino)ethyl] methylphosphonothioic acid ($C_9H_{22}NO_2PS$), is also an anticholinesterase agent with considerable toxic properties of its own and a potency similar to that of VX (Aaron and Szafraniec, as cited in Yang et al. 1990). The toxicity of other VX hydrolysis products has not been well-characterized. The halftime for spontaneous VX hydrolysis is 80h at 20°C (Yang et al. 1990). Thus, the known toxic metabolite would be quickly generated in water supplies contaminated with VX. To date, there are no military standards for drinking water consumption of this hydrolysis product. The current analysis recommends that S-[2-(diisopropylamino)ethyl] methylphosphonothioc acid be subject to the same drinking water control limits as VX. Furthermore, the yield and toxicity of other VX hydrolysis products should be characterized.

4.2 Mustard Agents

As earlier stated in Section 2.2, there exists a documented, semiquantitative method (Watson et al 1989a) that utilizes EPA's Risk Assessment Guidelines for estimating the cancer risk of sulfur mustard exposure. There may be other suitable methods available, and the authors welcome input for performing alternate estimates. The approach that will be employed here makes use of 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), and the EPA Criteria Document Committees (Jones et al 1988). The RASH relative potency or hazard assessment approach has been designed for ease and rapidity of evaluation. RASH is an integral part of the Defense Priority Model, the decision model of choice for prioritizing remedial actions at hazardous waste sites identified in the DoD Installation Restoration program (DoD 1987, 1989).

Protective assumptions embedded in the following estimate include

- daily intake at these levels for a 70-y lifetime
- no mitigation to reduce exposure (water treatment, quarantine, etc.)
- no agent degradation for the period of exposure
- ingestion absorption coefficient of 1.0
- target excess lifetime cancer risk of 1×10^{-5}, as codified in the Code of Maryland Regulations (Title 26.11.15 Part .01 A(8)) for inhalation exposure to sulfur mustard.

An accepted model for estimating lifetime cancer risk (assuming a linear nonthreshold response) is

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

where Risk is the additional lifetime risk of developing cancer based on a lifetime of continuous exposure to dose D or 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] (Anderson and U.S. EPA-CAG 1983; Watson et al 1989a). In the current analysis, the risk estimate is a measure of potential cancer incidence (i.e., tumorigenicity and <u>not</u> cancer deaths). Application of the RASH method to sulfur mustard toxicity (Watson et al 1989a) has allowed estimation of Q* for sulfur mustard ingestion (relative to that of benzo(a)pyrene) as 14.95 $[(\text{mg/kg})/\text{d}]^{-1}$.

For R $= 1 \times 10^{-5}$ and daily ingestion of 2 L/d by a 70 kg person,

$$R = Q^* D$$

$$1 \times 10^{-5} = [14.95\ (\text{mg/kg/d})^{-1}](X\ \text{mg/L})(2\ \text{L/d})(1/70\ \text{kg})$$

$$= 0.4271X$$

$$2.34 \times 10^{-5} = X \text{ in mg/L.}$$

Thus, X for adult water ingestion at 2 L/d is equal to 2.3×10^{-2} μg/L.

Similarly, for daily ingestion of 5 L/d, a risk-equivalent concentration of mustard agent in water would be 9.4 x 10^{-3} μg/L. Application of the mass and water ingestion values for infants as presented in App. A generated the mustard control limit estimate of 2.2 x 10^{-3} μg/L.

5. MILK INGESTION

Milk consumption among humans is maximal at approximately 5 to 6 months, after which it declines with the gradual introduction of semi-solid and solid foods into the diet (ICRP 1975). These maximal values are estimated at 1000 mL/d for male infants and 800 mL/d for female infants at 6 months' of age (ICRP 1975). Since infant agent control limit estimates for drinking water are based on 1400 mL/d intake (Table 5 and Appendix A), the values estimated for water should be protective for the smaller volume consumption of milk (800 to 1000 mL/d). Thus, the infant control limit estimates for water can be used interchangeably as an infant NOAEL estimate for milk.

If, as seems likely (see Table 4), analytical capability cannot reliably detect agent in milk at these calculated control limits, an alternate decision strategy is proposed (Leffingwell 1990). In the case of nerve agents, estimating a control limit for milk is moot, since nerve agents and their simulants are not known to be secreted in milk, even in severely exposed adult female livestock (e.g., sheep and dairy cattle)(Van Kampen et al 1969, Ivie 1980) . No extraordinary treatment of milk drawn from asymptomatic dairy animals is necessary to protect human health. (Precautions should be taken to ensure that milk, once drawn from the dairy animal, does not come into contact with agent-contaminated equipment.) Nevertheless, to assure public peace of mind, dairy products from animals in a potentially affected area should be discarded for 72 hours after the animals are first known to be asymptomatic (Leffingwell, 1990). Because the products will not be contaminated with agent (and could actually be consumed in an emergency), they may be disposed of in any manner which does not itself create a public health or environmental problem.

Antidotes to nerve agents (atropine or 2-PAM Cl) can, however, contaminate dairy products. If these antidotes have been used, the Food and Drug Administration (FDA), or appropriate State authority must determine acceptable antidote residue levels, or direct the disposition of dairy products (Leffingwell, 1990).

The disposition of milk from livestock contaminated with mustard is problematic. The finding of intact mustard (mg/kg) in the fatty tissues of a battlefield survivor examined 7 days after a mustard agent attack in the Iran-Iraq War (Drasch et al 1987) raises concerns that sulfur mustard may also be found in the milk of contaminated livestock. It is not clear how long a quarantine would have to be to ensure that internal fatty reservoirs of intact mustard become depleted.

If, on the basis of modeling or other information, dairy animals are believed to have been exposed to mustard agent at air concentrations greater than the 8-hour time-weighted average for human workers (see Table 1), the Ad Hoc Group recommends they be used only for breeding stock or be destroyed humanely and disposed of in an environmentally sound manner (Leffingwell 1990).

If dairy animals have been exposed to mustard agent at air concentrations less than the 8-hour time-weighted average for human workers (see Table 1), the Ad Hoc Group recommends that milk should be tested for presence of mustard agent and mustard hydrolysates by means of the best analytical methods available. The analytical method should be approved by the FDA and appropriate State authorities. Any dairy products found with elevated concentrations of mustard or mustard hydrolysates should be discarded in an environmentally sound manner. The Ad Hoc Group doubts that dairy products with detectable amounts of mustard agent would be encountered following a release; if they should be, they must be held for appropriate disposal by the Department of the Army (Leffingwell 1990).

6. FOOD INGESTION

The Rapid Screening of Hazard (RASH) method briefly described in Sect. 4.2 above can also be applied to the problem of estimating agent control limits for unprocessed foodstuffs, such as garden produce, that may be contaminated with nerve or vesicant agents. Details of the analysis can be found in Sect. 3 of Watson and Munro (1990).

6.1 Nerve Agents

The structure and function of nerve agents resembles that of organophosphate(OP) insecticides used in agriculture. Allowable insecticide residue concentration values for crops are established by the U.S. EPA Office of Pesticide Programs after analysis of available data on the product's toxicity, environmental persistence, chemical characteristics, normal ingestion rates for that crop, etc. VX is the only unitary nerve agent with sufficient persistence to be of concern for crop contamination (see Watson and Munro 1990 for review of environmental persistence). In the absence of VX-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.

By comparing LD_{50} data for a number of OP insecticides with those for VX, Watson and Munro (1990) determined that VX is approximately 10^3 to 10^4 times more potent than many commercially available insecticides. 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 established for the insecticides examined.

Guthion (Azinphos-methyl), one insecticide examined in the RASH analysis, is considered "relatively persistent" on leaf surfaces and is slow to leach or mobilize from soil (USEPA 1986b). As such, it is somewhat comparable to VX; residue tolerances established for Guthion are presented in Table 6. The RASH approach to hazard assessment indicates that allowable VX tolerances for specific food crops could be set by dividing each of the values in Table 6 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.

An alternate decision-making strategy would be to evaluate modeling or air-monitoring information to determine if any crops have been potentially exposed to nerve agent concentrations greater than the 8-hour time-weighted average for human workers (see Table 1). If so, the crops should be destroyed in an environmentally sound manner. Several suitable methods are described in Leffingwell (1990) and Watson and Munro (1990). Open burning is not recommended due to the risk of agent revolatilization and downwind spread.

6.2 Mustard Agents

The RASH approach is also used to estimate a total diet mustard control limit that is calculated to result in a lifetime cancer risk no greater than 1×10^{-5} (Code of Maryland Regulations; BNA 1990).

As documented in the Total Diet Study food lists developed by the FDA (Pennington 1983), the maximal dietary intake group in the U.S. population is the adult male between 25 and 30 years of age (3075 g/d). If the total diet were uniformly contaminated with any compound, this age-gender group would ingest the largest amount.

Using the previously described formula, Q*, and assumptions for estimating risk from ingestion exposure to sulfur mustard (see Sect. 4.2 and App. A), we obtain

$$R = Q^*D$$

$$1 \times 10^{-5} = [14.95\ (\text{mg/kg/d})^{-1}]\ [(3.075\ \text{kg/d})(X\ \text{mg/kg})/70\ \text{kg}]$$

$$= 0.66X$$

$$1.52 \times 10^{-5} = X \text{ in mg/kg, or } X = 1.52 \times 10^{-2}\ \mu\text{g/kg}.$$

This is the estimated mustard control limit (adult) for total diet unprocessed food items.

For toddlers, who ingest 1503 g/d (Pennington 1983) and weigh 10 kg, the estimated mustard control limit for total diet unprocessed food items is 4.5×10^{-3} μg/kg.

Table 6. 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	Rye, grain	0.2
Alfalfa, hay	5.0	Soybeans	0.2
Almonds	0.3	Spinach	2.0
Apples	2.0	Strawberries	2.0
Apricots	2.0	Sugarcane	0.3
Artichokes	2.0	Tomatoes	2.0
Barley, grain	0.2	Walnuts	0.3
Beans (dry)	0.3	Wheat, grain	0.2
Beans (snap)	2.0		
Blackberries	2.0		
Blueberries	5.0		
Boysenberries	2.0		
Broccoli	2.0		
Brussels Sprouts	2.0		
Cabbage	2.0		
Cauliflower	2.0		
Celery	2.0		
Cherries	2.0		
Citrus fruits	2.0		
Crabapples	2.0		
Cranberries	2.0		
Cucumbers	2.0		
Eggplant	0.3		
Filberts	0.3		
Gooseberries	5.0		
Grapes	5.0		
Kiwi fruit	10.0		
Loganberries	2.0		
Melons	2.0		
Nectarines	2.0		
Nut, Pistachio	0.3		
Onions (green)	2.0		
Parsley (leaves)	5.0		
Parsley (roots)	2.0		
Peaches	2.0		
Pears	2.0		
Peas, black-eyed	0.3		
Pecans	0.3		
Peppers	0.3		
Plums	2.0		
Potatoes	0.3		
Quinces	2.0		
Raspberries	2.0		

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

Note that these values assume no mitigation, such as washing or weathering. Furthermore, they are estimates for the entire diet that is assumed to be uniformly contaminated and to undergo no hydrolysis in the GI tract. An acceptable mustard agent residue for an individual foodstuff would need to be estimated on the basis of its observed consumption rate in an average total diet for the age-sex group of interest. Thus, some food items contaminated at much greater levels than the estimated control limits above could be ingested if the total quantity of that 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 the calculated levels presented above. An alternative decision strategy is presented (Leffingwell 1990). Any growing crops thought, on the basis of modeling or other information, to have been exposed to mustard agent at concentrations greater than the 8-hour time-weighted average for human workers (see Table 1) should not be harvested for use as human food. Any crops exposed to mustard agent should be sampled for the presence of the agent; if agent is detected at any level (see Table 4), said crop should be let stand (under quarantine) for a period of 12 months before the land can be used. Another alternative would be to quarantine on the basis of large-area sampling rather than individual field determination. Such sampling would bound areas of problematic deposition, allowing the region within the boundary to be geographically defined and quarantined (C. T. Woodard, AMSMC-SR, Headquarters, U.S. Army Armament Munitions and Chemical Command, Rock Island, Il., letter to A. P. Watson, Health and Safety Research Division, Oak Ridge National Laboratory, Oak RIdge, Tn., Aug. 1, 1991). Re-testing for agent should be performed near the end of the 12-month quarantine; under most conditions, agent will be undetectable and the quarantine could be lifted to allow the crop to be plowed under. If necessary, the crop could be removed for disposition elsewhere. Open burning is not recommended due to the risk of agent revolatilization and downwind spread.

7. SOIL INGESTION

A good source of soil ingestion estimates by age group is that of Sedman (1989), which includes an evaluation of mouthing behavior in toddlers as well as incidental soil ingestion in food items via analysis of Al, Si, and Ti in fecal matter. The Ad Hoc Group considers the Sedman estimates of normal soil ingestion (see App. A) to be superior to that presented in EPA's Superfund Manual (100 mg/d for toddlers and adults; USEPA 1986a).

7.1 Nerve Agents

Again, agent VX is the only nerve agent of sufficient persistence to be a reasonable candidate for soil ingestion exposure. If we assume that the no-adverse-effect adult body burden for nerve agent is 6 μg/d (as calculated in Sect. 4.1), then an adult consuming 100 mg/d of soil evenly contaminated at 6×10^{-2} μg/mg (i.e., 60 μg/g) should exhibit no adverse effects. Similarly, with adjustment for body mass (see App. A), a normal toddler (590 mg/d) could consume soil at 1.5×10^{-3} μg/mg (i.e., 1.5 μg/g), and a toddler with the pathological condition of pica (5000 mg/d) could consume soil at 1.7×10^{-4} μg/mg (i.e., 1.7×10^{-1} μg/g).

7.2 Mustard Agents

Using the RASH procedure as before, but with substitution of the soil ingestion assumptions presented in App. A, allows us to back-calculate control limits (CLs) for soil containing mustard. Again, the acceptable lifetime cancer risk value is 1×10^{-5} (defined in the Code of Maryland; BNA 1990) (see Section 2.2). The values are as follows

CL_{Adult} = 4.7×10^{-7} mg/mg or 4.7×10^{-1} μg/g

$CL_{Toddler}$ = 1.1×10^{-8} mg/mg or 1.1×10^{-2} μg/g

$CL_{Pica\ Toddler}$ = 1.3×10^{-9} mg/mg or 1.1×10^{-3} μg/g

CL_{Child} = 4.6×10^{-8} mg/mg or 4.6×10^{-2} μg/g

CL_{Teen} = 2.3×10^{-7} mg/mg or 2.3×10^{-1} μg/g

If we consider the Rocky Mountain Arsenal detection limit of 2 $\mu g/g$ as the soil mustard concentration (see Table 4; and set aside, for the moment, the potential use of various analytical concentration techniques that would provide reliable detection at lower concentrations), the following excess lifetime cancer risk estimates can be made:

$R = Q^{*}D$

Adults:

$R = [14.95\ (mg/kg/d)^{-1}]\ [(100\ mg/d)\ (1/70\ kg)]\ [2 \times 10^{-3}\ mg/10^{3}\ mg]$

$= 4.3 \times 10^{-5}$

Toddlers:

$R = 1.8 \times 10^{-3}$

Pica Toddlers:

$R = 1.5 \times 10^{-2}$

Children (3-10 y):

$R = 4.3 \times 10^{-4}$

Teen (10-18 y):

$R = 8.8 \times 10^{-5}$

Time-weighting suggests that lifetime risk is heavily dependent on ingestion during the toddler phase. Estimated risk does not greatly increase after age 3 years due to a major decline in mouthing behavior following the toddler stage (Sedman 1989).

For ingestion as the exposure route of concern, unprotected adults (>18 y) could be permitted into an area of soil contaminated with sulfur mustard at the detection limit (2 $\mu g/g$) if they take precautions against mouthing behavior (i.e., smoking, etc.). Although many people would not find a lifetime excess cancer risk estimate of 10^{-5} a concern (particularly with the protective assumptions embedded in the estimate), a further precaution would be to warn against ingesting produce from the contaminated area.

All other groups (teens, toddlers, children 3 to 10 y, and children with pica) should not be allowed into an area containing soil contaminated with mustard at concentrations ≥ 2 μg/g due to concerns re mouthing behavior.

8. DERMAL EXPOSURE TO SOIL

At present, there are insufficient data on dislodgeable residues and transfer factors for VX and mustard in soil to skin to perform a direct estimate of control limits governing soil dermal exposure. Approaches developed for OP insecticide exposure (Sedman 1989, McKone 1990, Iwata et al 1977, as well as some others) require data that are unavailable for VX and sulfur mustard agents. Decomposition studies have demonstrated enhanced agent degradation when G-agents are placed in contact with glass or other substrates possessing high silica or magnesia content (Ward et al. 1990; Kuiper, van Bokhoven, and Medema 1976; van Bokhoven, Kuiper, and Medema 1976). These minerals are present in most soils and can be expected to mediate G-agent degradation *in situ*. Data for mineral-enhanced VX decomposition in soils are less clear (Verweij and Boter 1976; Kaaijk and Frijlink 1977). This is clearly an area requiring additional experimental characterization.

The Ad Hoc Group on Agent Control Limits proposes two alternatives:

1) Assume that the maximally exposed individual (infant or toddler) would absorb no more agent through the skin than via ingestion. Thus the estimated control limits for soil ingestion could be used interchangeably as control limits for dermal exposure to soil (See Sect. 7.0). The resulting control limits for any soils or dusts that may come in contact with the skin would be 1.5 μg/g soil for VX and 1.1×10^{-2} μg/g soil for sulfur mustard agents.

2) Arbitrarily assume that the maximally exposed individual (infant or toddler) would absorb through the skin no more than 50% of that absorbed by a child who pathologically ingests soil at the rate of 5 g/day (a pica toddler). The usual soil ingestion rate for a toddler is

590 mg/day (See App. A and Sect. 7.0). The resulting control limits for any soils or dusts that may come in contact with the skin would be 8.5×10^{-2} $\mu g/g$ soil for VX and 6.0×10^{-4} $\mu g/g$ soil for sulfur mustard agents.

9. SUMMARY

Agent control limits developed in this white paper are summarized in Table 7 for easy reference. The user is advised to read the analyses and logic presented in sections 2.0 through 8.0 for perspective on how these estimates were derived and limitations to their use.

Table 7. Summary of estimated agent control limits for various media

	Drinking Water (μg/L/d)		Milk (μg/L/d)	Unprocessed Produce (per day)	Soil Ingestion (μg/g/d)	Soil Dermal Exposure (μg/g)
	2 L/d intake	5 L/d intake				
GA	1.5 - 3.0 (adult) 1.4×10^{-1} - 2.9×10^{-1} (infant)	0.6 - 1.2 (adult)	1.4×10^{-1} - 2.9×10^{-1}	0.02 - 10 ppb[a]	Not applicable	Not applicable
GB	1.5 - 3.0 (adult) 1.4×10^{-1} - 2.9×10^{-1} (infant)	0.6 - 1.2 (adult)	1.4×10^{-1} - 2.9×10^{-1}	0.02 - 10 ppb[a]	Not applicable	Not applicable
VX	1.5 - 3.0 (adult) 1.4×10^{-1} - 2.9×10^{-1} (infant)	0.6 - 1.2 (adult)	1.4×10^{-1} - 2.9×10^{-1}	0.02 - 10 ppb[a]	60 (adult) 1.5 (normal toddler) 1.7×10^{-1} (pica toddler)	1.5 (Assumption 1)[c] 8.5×10^{-2} (Assumption 2)[c]
Sulfur mustard	2.3×10^{-2} (adult) 2.2×10^{-3} (infant)	9.4×10^{-3} (adult)	2.2×10^{-3}	1.5×10^{-2} μg/kg (adult)[b] 4.5×10^{-3} μg/kg (infant)[b]	4.7×10^{-1} (adult) 1.1×10^{-2} (normal toddler) 1.1×10^{-3} (pica toddler)	1.1×10^{-2} (Assumption 1)[c] 6.0×10^{-4} (Assumption 2)[c]

[a]Depends on produce item in question (e.g., grains at 0.02 ppb and kiwi fruit at 10 ppb).
[b]Average value for entire dietary intake; based on excess lifetime cancer risk of 1×10^{-5}.
[c]See text of Section 8.0 for assumptions underlying these estimates.

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Appendix A
Assumptions for Estimating Agent Doses to Humans

Adult

Soil consumption (18-70 y) = 100 mg/d (USEPA 1986a; Sedman 1989).
Body mass = 70 kg (USEPA 1980 as cited in USEPA 1986a).
Water consumption (normal conditions) = 2 L/d (NAS 1977).
Water consumption (hi temp load, mod. activity) = ca 3 L/d (ICRP 1975).
Inspiration volume = 20 m^3/d (USEPA 1980 as cited in USEPA 1986a).
Total food consumption (ad male 25-30 y) = 3075 g/d (Pennington 1983).
Total food consumption (ad female 25-30 y) = 2173 g/d (Pennington 1983).

Teen

Soil consumption (10-18 y) = 170 mg/d (Sedman 1989).
Body mass = 58 kg (ICRP 1975).
Total food consumption (teen male 14-16 y) = 2677 g/d (Pennington 1983).
Total food consumption (teen female 14-16 y) = 1954 g/d (Pennington 1983).

Child

Soil consumption (3-10 y) = 390 mg/d (Sedman 1989).
Body mass = 27 kg (ICRP 1975).
Water consumption = 1 L/d (NAS 1977).
Inspiration volume = 5 m^3/d (USDHHS 1970 as cited in USEPA 1986a).
Fluid consumption = 1400 mL/d (USDHHS 1970).

Toddler

Soil consumption (1-3 y) = 590 mg/d (Sedman 1989).
Pathological soil consumption (pica; 1-3 y) = 5000 mg/d (USEPA 1986a).
Body mass = 10 kg (ICRP 1975).
Total food consumption (2 y) = 1503 g/d (Pennington 1983).

Infant and Newborns

Infant milk ingestion (male, 6 mos) = 1000 mL/d (ICRP 1975).
Infant milk ingestion (female, 6 mos) = 800 mL/d (ICRP 1975).
Body mass (newborn) = 3.4 kg (USDHHS 1970).
Body mass (3-5 mos) = 5.0 kg (Spector 1956).
Inspiration volume = 2.2 m^3/d (ICRP 1975).

Target Lifetime Cancer Risk

1×10^{-5} (Code of Maryland Regulations, Title 26; BNA 1990).

GLOSSARY

acetylcholine--a naturally occurring chemical neurotransmitter responsible for facilitating transfer of nerve impulses between nerves, and between nerves and muscles or glands

Al--chemical symbol for the element aluminum

cholinesterase--(acetylcholinesterase,butyrylcholinesterase) a naturally occurring enzyme that breaks down neurotransmitter at the synapse and prevents accumulation of the neurotransmitter at nerve endings. This enzyme is inhibited by organophosphate nerve agents and agricultural insecticides; resulting signs include uncontrolled stimulation of muscles and secretory glands.

CSDP--Chemical Stockpile Disposal Program

CSEPP--Chemical Stockpile Emergency Preparedness Program

delayed neuropathy--degeneration of certain peripheral nerves at some delayed time (days to weeks) after causative agent exposure. Observed in antidote-protected experimental chickens after supralethal doses of nerve agents GA and GB. Not observed in similar experiments with nerve agent VX.

DoA--Department of the Army

EEG--Electroencephalogram

GA--(tabun); lethal organophosphate nerve agent; ethyl ester of N,N-dimethyl phosphoroamidocyanidate; anti-cholinesterase compound. CAS No. 77-81-6.

GB--(sarin); lethal organophosphate agent; isopropyl ester of methylphosphonofluoridate; anti-cholinesterase compound. CAS No. 107-44-8.

H--sulfur mustard agent; unstable; manufactured by the obsolete Levinstein process; bis (2-chloroethyl)sulfide; vesicant (blister) compound. CAS No. 505-60-2. Used in World War I, the Iran-Iraq War and other conflicts. Lethal. Destroys epidermis, generates blisters, causes eye and pulmonary injury and, at high doses, bone marrow damage and immunosuppression. A human carcinogen.

HD--distilled sulfur mustard agent; this purified form is more stable than agent H. Same composition, CAS number, and properties as for agent H above.

HT--a vesicant agent mixture consisting of 60% HD and 40% T; the mixture is approximately twice as persistent as HD. "T" is bis [2(2-chloroethylthio)ethyl]ether, CAS No. 63918-89-8. Same pathology as H.

L--Lewisite; organic arsenical vesicant agent;dichloro (2-chlorovinyl)arsine; CAS No. 541-25-3. Lethal. Fast-acting, causing immediate pain to eyes, skin and respiratory tissues; very corrosive. Suspected human carcinogen.

LD_{50}--a calculated dose of a substance that is expected to cause the death of 50% of an entire defined experimental animal population. It is determined from the exposure to the substance, by any route other than inhalation, of a significant number of animals from that population (Tatken and Lewis, 1983).

M--mole; gram formula weight of a compound

pH--hydrogen ion index; a logarithmic measure of the relative acidity or alkalinity of a solution. A pH of 7 is neutral, a pH of 2 is very acid, and a pH of 10 is very alkaline.

IV--medical abbreviation for intravenous

Si--chemical symbol for the element silicon

SRFX--Service Response Force Exercise. The most recent SRFX (SRFX-91) was held in June, 1991, at the Tooele Army Depot.

TEAD--Tooele Army Depot

Ti--chemical symbol for the element titanium

tumorigenicity--capacity to give rise to tumors

U--unit; the international unit (IU) of enzyme activity; "that amount of an enzyme that will catalyze the transformation of 1 micromole of substrate per minute under standard conditions of temperature, optimal pH, and optimal substrate concentration" (Dorland's Illustrated Medical Dictionary, 27th ed., W. B. Saunders Co., Philadelphia. c. 1988.).

USEPA--U. S. Environmental Protection Agency

VX--lethal organophosphate nerve agent; S-(diisopropylaminoethyl)methyl-phosphonothiolate o-ethyl ester; anticholinesterase compound. CAS No. 50782-69-9. Persistent.