

## INFORMATION PAPER:

### MANAGEMENT CRITERIA FOR CHEMICAL WARFARE AGENT (CWA)- CONTAMINATED WASTE AND MEDIA

Existing Department of the Army (DA) approaches to environmental and waste management decisions regarding CWA contaminated waste and media, have, at times, tended to be extremely conservative and not based on assessment of the scenario specific health/environmental risks and benefits. The DA now recommends future applications of situation-specific, health-based criteria for assessing the chemical warfare agent contaminated media. The U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) Specifically recommends the use of U.S. Environmental Protection Agency (USEPA) risk assessment methods and, where possible, site-specific exposure information, to establish criteria for determining safe and appropriate dispositions of CWA contaminated waste and media. This does not preclude application of other approaches when deemed more practical or cost-effective, and still protective of public health. As appropriate, existing Federal, state, and local requirements must be complied with. In addition, site-specific risk assessment should involve appropriate stakeholders.

- 1. Purpose.** This paper summarizes historically used terminology and approaches used to categorize and manage chemical warfare agent (CWA) contaminated waste and media. It also describes how health-based risk assessment methodologies should be used to expand and clarify safe and appropriate management criteria.
- 2. Introduction.** While existing waste management approaches have provided adequate and effective protection to workers and the public, the Army has taken steps to further ascertain mechanisms for ensuring the protection of public health to address evolving concerns, inconsistencies at different Army sites, and alternative waste management practices. Part of the problem stems from the fact that Federal, State, and local regulators as well as the public are not generally familiar with DA safety procedures, as these do not always parallel activities associated with toxic industrial compounds. On the other hand, the USACHPPM has identified that many of the chemical agent waste management criteria used by the Army are overly conservative. While USACHPPM is committed to ensuring that Army activities are performed in a manner that protects and preserves human health and the environment, it also wishes to ensure that environmental management decisions are balanced with appropriate scientific rationale and identified health benefits.
- 3. Background.** Management and disposition of CWA contaminated waste and media (or even potentially contaminated waste and media) have often relied on different measures, including concentration limits, analytical sensitivity, and decontamination/treatment technologies. Quite often, different types of concentration levels and terms have been applied erroneously. The terms that have been associated with some of the concentration levels and procedural requirements for managing contaminated waste or media include: "agent free", "risk free", "zero agent", "detection limits," Field Drinking Water Standards (FDWS), Waste Control Limits (WCL), "3X" and "5X," and "risk based" or "health-based". Many of these terms have been or are being used interchangeably, or without clear or uniform definition. The interpretations of these terms have in many cases been negotiated with local regulators for specific purposes, which results in the same term having a different meaning in different states.

**4. Health-Based Approach.** The USACHPPM recommends future applications of more situation-specific, health-based criteria for assessing the safety and appropriateness of environmental management decisions. Specifically, the USACHPPM recommends the use of “health-based” environmental management criteria over some of the historical approaches and terms described in paragraph 5, below. Health-based criteria are developed by considering a specific chemical, a specific scenario in which individuals may be exposed, characteristics regarding those individuals and their activities results in an estimate of the overall dose of the chemical they are going to be receiving. That dose is compared with existing reference toxicity thresholds. This comparison allows one to characterize or quantify the degree of risk a person is at, and allows risk managers to determine how much to limit exposure in order to reduce risk to acceptable levels. In order to address several areas of scientific uncertainty, there are several steps to ensure conservative (protective) criteria are determined through the health risk assessment process. Use of a health-based approach ensures appropriate use of science and consistency in decision-making.

**5. Existing Terminology and Applications.**

a. “Agent-free,” “risk-free,” or “zero agent”. The DA, civilian regulators, and the public have not interpreted these terms consistently. The terms agent-free or zero agent can be read as “absolutes,” and in several instances have been interpreted as ‘removal of every molecule.’ Likewise, while decisions should be “risk-based,” it is generally impossible to prove a completely risk-free environment. Thus, “risk-free” is also seen as too absolute a statement. Despite theoretical beliefs, successful achievement of such absolutes is difficult if not impossible to ‘prove.’ The only occasions where such terminology may be appropriate is where evidence is available to indicate that no contamination has occurred. In such cases, “agent free” may be an acceptable description.

b. “Detection /Quantitation Limits”. The use of a detection limit to make environmental risk management decisions is not good science. In addition, analytical detection/quantification limits are often also interpreted differently in various circumstances. As detection limits can vary per laboratory, equipment, analytical method, matrix sampled, and specific sample, and other factors, this criterion still needs clarification. More importantly, the use of the detection limit in risk management decisions is not “good science” and in some cases could result in significant expenditure of resources for limited or no health benefit. In fact, the USEPA is incorporating health-based approaches in nearly all its new initiatives and only defers to detection limits when a health-based value is below analytical sensitivity. Unless a health-based assessment can delineate the need for specific detection requirements or goals, the detection limit should not be cited as a required standard.

c. Field Drinking Water Standards (FDWS) and Waste Control Limits (WCL). Specific concentration limits were developed to address the potential of purposeful contamination of drinking water supplies on the battlefield by US adversaries (reference 1). Monitoring of water supplies requires field commanders to ensure that any CWA in water is below the established FDWS before allowing soldiers to use the water source. These levels were developed assuming 7 days of consumption of up to 15 liters of contaminated water a day. The FDWS have for many years been the only cited CWA concentration limits for media other than air. For lack of an alternative, these concentration levels (20 ppb for nerve agents and 200 ppb for HD) have been used as the acceptable levels for disposal of CWA waste off Army sites as well as to ascertain effectiveness of decontamination procedures. These FDWS have also been referred to as Waste Control limits (WCL). While the “WCL” is an appropriate term, application of the drinking water levels as the WCLs is overly conservative when applied as a hazardous waste indicator, and presumably results in excessive resource expenditure without a commensurate increase in health benefits.

d. "3X" and "5X". The terminology here refers to an Army-based safety marking system that signifies to Army personnel (workers) the level of potential contamination (or decontamination) associated with an item/materiel (references 2, 3). The various levels represent increasing levels of decontamination and therefore are associated with decreasing risk.

(1) X. Indicates agent (including neat agent) is presumed present; decontamination/destruction has partially been performed and further decontamination and/or use of personal protective equipment (PPE) prior movement.

(2) 3X. The 3X decontamination standard indicates surface decontamination and reduction of volitalized agent. It describes a method for headspace air monitoring of items materiel/waste and the comparison of the detected airborne air concentrations to the 8-hour time-weighted average (TWA) worker population. When below the 8-hour TWA, the items can be safely handled by unprotected workers. The DA considers the use of 3X criteria in addition to established packaging requirements as appropriate measures of protection to workers against any resual risk associated with such items. However, because of recent concerns addressed by various stakeholders and regulators regarding the potential health risks from additional pathways, the USACHPPM selected a scientifically acceptable health (risk)-based approach to quantify levels which may pose unacceptable risks to persons potentially exposed through these pathways. This was documented in Section XI of the Army proposed Draft Utah Chemical Agent Rule (reference 4) and includes derivation of solid and liquid "Land Disposal Restriction (LDR)" concentration levels.

(3) 5X. The most thorough level of decontamination is the Army's "5X" level which indicates that the materiel has been completely decontaminated of the indicated agent. This has occasionally been referred to as "agent-free" though for reasons previously cited, this is not advised. Currently, the only approach specified by existing Army regulation is to achieve this level is by incineration. This process is believed to achieve a complete agent destruction health impacts to be attributed to the materiel's disposition to the general public. In other words, Army regulation defines "5X" items/materiel/waste are considered safe and may be released to the general public. Other alternatives are permitted, per approval of the site commander and deemed safe by the Army's Office of the Surgeon General. Alternative approaches that have been proposed (though none have yet been approved) include a head-space type approach ensuring volitalization below General Population Limits. As environmental risks to the public are routinely quantified using USEPA health risk models, the USACHPPM evaluated and selected the USEPA Region IX Preliminary Remediation Goal approach for deriving a concentration level that established appropriate criteria for contaminated media that would be in retained in a restricted setting, off-limits to children but with relatively high probabilty for occasional/repeated adult exposures. This methodology is described in reference 5 and has been endorsed by DA headquarters for future applications of determining situation-specific, health-based criteria for assessing the safety and appropriateness of environmental management decisions (reference 6).

## 6. Specific Guidance.

a. As the term "health-based" refers to criterion that is suited to protecting human health and the environment under a given set of circumstances, it is important not to misapply one set of criteria for an unrelated scenario. As an example, while the use of soldier field drinking water standards as a determination of suitability for release to a hazardous waste treatment facility may be considered conservatively protective, it is overly costly and limits management decision options. Therefore, as described in references 1, 2, and 6, the use of scientifically accepted, and preferably USEPA endorsed, environmental risk-assessment methodology (e.g., USEPA Region IX) is currently recommended by the

USACHPPM as the means to tailor certain criteria to specific applications, such as for waste management decisions and environmental cleanup decisions.

b. The USCHPPM is continuing to evaluate guidance describing sampling methodology for various types of waste matrices, analytical methodologies, and health-based concentrations to assess waste management and disposal options. Where feasible, USACHPPM recommends the use of current USEPA environmental and hazardous waste guidance – particularly to address requirements for sampling (example: sampling frequency is to be determined based on degree of generator knowledge and process consistency) and analyses (where performance-based testing procedures are a useful approach to validate methods).

**References:**

1. DA Technical Bulletin –Medical (TB-Med) 577, Sanitation and Surveillance of Field Drinking Water, 1999.
2. AR 385-61: *The Army Chemical Agent Safety Program*; Safety; 28 February 1997.
3. DA Pam 385-61: *Toxic Chemical Agent Safety Standards*; Safety; 31 March 1997.
4. Army-proposed Draft Utah Chemical Agent Rule; May 1999.
5. Health Based Environmental Screening Levels for Chemical Warfare Agents; USACHPPM/ORNL technical report; March 99.
6. DASA (ESOH) AILE Memorandum, Subject: Health Based Environmental Screening Levels for Chemical Warfare Agents, May 99.

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## ATTACHMENT

**USACHPPM Technical Paper:  
Chemical Warfare Agent Health-Based Waste Control Limits**

1. **PURPOSE.** This document describes how an existing environmental health risk assessment model can be used to determine concentration levels in chemical agent-related wastestreams which represent minimal or acceptable levels of risk to potentially exposed populations.

2. **INTRODUCTION.**

a. General. Determining chemical concentrations(s) which ensure a minimal or acceptable level of risk requires the:

- (1) Identification of the population at greatest risk to exposure and information regarding the scenario/conditions by which such exposure may occur;
- (2) Selection of a method/model describing the process of potential exposure; and
- (3) Determination of what is considered an acceptable level of risk.

b. Scenarios and Population of Concern. The conditions under which persons may theoretically be exposed to chemical agent residues in waste materials/items will depend on the mechanism of waste management and disposal. As such, this document describes two general chemical agent-related waste management options and resulting waste control limits for items/materials that the Army designates for disposal:

(1) Hazardous Waste Control Limits (HWCLs): HWCL represent criteria below which wastes may be safely disposed as a hazardous waste at a Resource Conservation and Recovery Act (RCRA) permitted facility. While such facilities may very well be expected to safely manage/treat/dispose of chemical agents at much higher levels, the conservative HWCL values are provided as documented, toxicologically derived criteria. Two sets of HWCLs are derived. One set is based on exposures to a solid waste matrix, the other is based on a liquid waste matrix. The HWCL values were referred to as Land Disposal Restriction (LDRs) in previous documentation (UCAR, 1999).

(2) Non-Hazardous Waste Control Limits (NHWCLs). NHWCLs are concentrations below which wastes may be managed as non-hazardous under RCRA Subtitle D provisions. These criteria are based on the assumption that associated wastes/materials, though not considered a 'hazard' requiring specialized disposal/treatment, will be managed in a way that the general population will not have routine and repeated exposures. These values were referred to as exemption levels in previous documentation (UCAR, 1999). Scenarios in which there is potential for repeated general population exposure exists should be assessed using assumptions such as those described for residential scenarios (USACHPPM, 1999).

c. Methods. The method by which the described health-based waste control limits have been developed involves the use of standardized models derived by the USEPA for use in environmental investigations. The USEPA risk assessment guidance was originally established to determine cleanup goals/screening levels for Superfund sites. This approach has been endorsed by the Headquarters DA (DA, 1999). The USEPA risk assessment screening methodology involves the use of mathematical

algorithms which are used to back-calculate an environmental standard from a chronic toxicity constant. The chronic toxicity constant is a chemical unique indicator of an acceptable daily dose (for a lifetime) of a compound. The USEPA methodology assumes that the chemical comes from an environmental source (such as the soil or water) and that not all the chemical residue will actually enter the exposed person's body. Thus, the 'back-calculation' is a mathematical model which begins with the chronic toxicity constant and then takes into account the process of the chemical residue coming from its source through the environment to an exposed person. The USEPA screening levels are based on assumptions that describe how certain generalized situations would theoretically result in the exposure of a given chemical to certain persons. These assumptions are reflected by the parameters described in the mathematical equations. All parameters are reflected as single numerical values, though recently the USEPA has endorsed site-specific application of a "probabilistic" approach that involves incorporation of ranges of possible parameter values. Some values are specific to the chemical, and are therefore constant for risk assessments to that chemical, while other parameters are dependent on the scenario in which exposure will occur. In the process of establishing screening levels, site-specific exposure conditions can only be theorized, and are therefore generally selected to fit the most reasonable worst-case conditions. Though USEPA risk assessment screening methodology is generally standardized, several USEPA Regional Offices have established specific guidance that contains certain variations. The risk assessment guidance from several USEPA Regions (Regions III, IX, and IV) as well as the USEPA Superfund guidance and USEPA OSWER Soil Screening Guidance were considered for purposes of this document (USEPA 1996a and 1997a, USEPA 1998, USEPA 1995a, USEPA 1989a and 1991a, and USEPA 1996b and 1996c). The USEPA region IX Preliminary Remediation Goals (PRGs) approach was specifically used in this analysis to address multiple exposure routes.

### 3. ASSUMPTIONS AND DERIVATION OF HWCLs.

a. Background. Waste items or materials that are potentially or known to be contaminated with or contain chemical agents are required to be managed, decontaminated, and/or monitored in accordance with specific Army safety regulations and policies (DA, 1997). In accordance with these Army requirements, waste materials may be treated and disposed as hazardous wastes at permitted RCRA Subtitle C Treatment, Storage, and Disposal Facilities (TSDFs) if air monitoring ensures that agent concentrations are below levels of health concern. Hazardous wastes are managed by specifically trained personnel with specialized equipment to include protective clothing and respirator devices. Treatment and disposal operations at TSDFs are performed in a strictly regulated environment that is scrutinized by means of audits, inspections, and submittal of various documents. These TSDFs are designed to meet requirements that ensure hazardous wastes are controlled and treated as to minimize the possibility of release or threat to the general population. One such requirement includes the treatment of wastes to federal Land Disposal Restriction (LDR) standards before the waste can be placed in a hazardous waste landfill. The RCRA LDR standards ensure that the potential for future releases from hazardous waste landfill containment systems will not pose an environmental health hazard. (b) Though not listed under Federal RCRA hazardous waste rules, chemical warfare agents and related wastes are listed as "Hazardous wastes" by several State RCRA programs. To date, none of these states have designated "LDRs" for such wastes. However, LDRs for CWA related wastes have been initially addressed by the State of Utah and the Army (UCAR, 1999). As the primary intent of the Federal LDR requirements was to protect against potential future leaching and migration to groundwater, the Army first assessed and determined that potential release of chemical agent residues from disposed waste materials followed by migration to groundwater was not a probable scenario (USACHPPM, 1999). The basis for this conclusion includes (1) the unique chemical and physical properties of the chemical agents, (2) the types and quantities of wastes that are generated, and (3) the geological setting and construction requirements of hazardous waste landfills. Despite the conclusion that groundwater was not at risk of contamination, the State of Utah identified concerns regarding

potential risks to the general population and non-DoD workers from other pathways. The analysis that follows is designed to address these concerns.

b. Scenario – Management of CWA-related wastes as Hazardous Wastes. Wastes that are identified and managed as hazardous wastes undergo strict controls which minimize human exposures. Due to the strict management controls, there are no defined civilian (general population) persons who would be exposed repeatedly to chemical agent wastes identified as a hazardous waste (accident scenarios could theoretically result in an area near members of the general population, but exposure would be negligible and not re-occurring). However, certain members of the civilian *workforce*, specifically those at the TSDFs, may theoretically be exposed to the hazardous waste chemical agent residues. Army air monitoring (3X) requirements (DA, 1997) ensure that the workers are adequately protected from potentially volatilized agent. In addition, there are significant occupational safety requirements established by OSHA that mandate protective equipment, clothing, and engineering controls to prevent exposures to such personnel. However, some state regulators (e.g. Utah) have noted that the Army's 3X air standards do not necessarily address the potential for incidental ingestion or dermal exposure. Even though there are specific protections (equipment and clothing) required at hazardous waste facilities, concerns centered on those instances where equipment is faulty or not appropriately utilized. By identifying specific potential insufficiencies in occupational protective measures (such as through assessment of OSHA noncompliance findings), the potential for repeated exposures to the worker population was established. Therefore, workers at a hazardous waste landfill were identified as the population of concern for deriving the HWCLs.

c. Assumptions and Derivation of HWCLs. The models described below are specific to the type of matrix represented by a waste. Two basic matrices were assumed – solid (with soil as the assumed matrix) and liquid (water being the assumed matrix). Specific numerical assumptions selected for calculations in this proposed rule are described in sections below. The majority of the parameters described are used in the calculations for both  $HWCL_{sol}$  and  $HWCL_{liq}$  values; however, some the parameters are specific to the model and assumptions regarding the individual matrices.

(1) Solid Matrices. As indicated, the USEPA Region IX Preliminary Remediation Goals (PRG) methodology (USEPA, 1998) is the particular USEPA model used in this document. This model is particularly comprehensive in that it estimates an acceptable concentration by an additive, multiple pathway (incidental ingestion, inhalation, and dermal absorption) algorithm describing exposure to a solid (soil) matrix. The EPA Region IX soil equations used to determine appropriate HWCLs for solid ( $HWCL_{sol}$ ) carcinogenic and non-carcinogenic compounds are shown below:

**Equation 1.** Multiple Pathway Risk Assessment Model for  $HWCL_{sol}$  – Carcinogens.

$$HWCL_{sol} = \frac{TR \times AT_c \times BW}{EF \times ED \times \left( \frac{(FC \times IRS \times SF_o)}{CF} + \frac{(SA \times AF \times ABS \times SF_o)}{CF} + \frac{(INH \times SF_i)}{VF(orPEF)} \right)}$$

**Equation 2.** Multiple Pathway Risk Assessment Model for  $HWCL_{sol}$  – NonCarcinogens.

$$LDR_{sol} = \frac{THI \times BW \times AT_n}{EF \times ED \times \left( \left( \frac{1}{RfD_o} \times \frac{FC \times IRS}{CF} \right) + \left( \frac{1}{RfD_o} \times \frac{SA \times AF \times ABS}{CF} \right) + \left( \frac{1}{RfD_i} \times \frac{INH}{VF(orPEF)} \right) \right)}$$

where (NOTE: parameters are discussed in more detail in following paragraphs)

<i>TR</i>	= Target Risk (unitless)
<i>THI</i>	= Target Hazard Index (unitless)
<i>SFo</i>	= Slope Factor (oral); chronic toxicity value (mg/kg/day) <sup>-1</sup>
<i>SFi</i>	= Slope Factor (inhalation); chronic toxicity value (mg/kg/day) <sup>-1</sup>
<i>RfDo</i>	= Reference Dose (oral); chronic toxicity value (mg/kg/day)
<i>RfDi</i>	= Reference Dose (inhalation); chronic toxicity value (mg/kg/day)
<i>BW</i>	= Body Weight (kg)
<i>EF</i>	= Exposure Frequency (days/ year)
<i>ED</i>	= Exposure Duration (years)
<i>ATc</i>	= Averaging Time (carcinogenic effects) [70 years x 365days/years]
<i>ATn</i>	= Averaging Time (noncarcinogenic effects) [ED x 365 days/years]
<i>CF</i>	= Conversion Factor (10 <sup>6</sup> mg/kg)
<i>IRS</i>	= Soil Ingestion Rate (mg/day)
<i>FC</i>	= Fraction of contaminated soil ingested (%)
<i>AF</i>	= Soil -to -Skin Adherence Factor (mg/cm <sup>2</sup> )
<i>SA</i>	= Skin Surface Area exposed (cm <sup>2</sup> )
<i>ABS</i>	= Skin Absorption Factor (%)
<i>INH</i>	= Inhalation Rate (m <sup>3</sup> /day)
<i>VF</i>	= Volatilization Factor (m <sup>3</sup> /kg)
<i>PEF</i>	= Particulate Emission Factor (m <sup>3</sup> /kg)

(2) Liquid Matrices. With regards to exposure scenarios concerning agent-related wastewater or liquid nonwastewaters, two exposure pathways were initially considered to be of potential concern; dermal contact with chemicals in an aqueous solution and inhalation of chemicals volatilized from such a solution. The ingestion pathway was not considered a viable process of exposure. Further evaluation concluded, however, that although the exposure pathways of concern include dermal and inhalation, the inhalation pathway is not considered relevant for the nerve agents (G-agents and VX) based on the USEPA guidelines for addressing the inhalation of compounds volatilized from aqueous media. Specifically, the USEPA guidelines state that volatilization from water may be significant for chemical contaminants having a Henry's Law Constant greater than 10<sup>-5</sup> atm·m<sup>3</sup>/mol and a molecular weight less than 200 (USEPA, 1991a).

(a) Although the G agents have molecular weights less than 200, they all have Henry's Law Constants considerably less than  $10^{-5}$  atm·m<sup>3</sup>/mol, as does VX (USACHPPM (HBESL), 1999). Therefore, none of these nerve agents are expected to volatilize from aqueous media.

(b) HD has a molecular weight of 159.08, and an estimated Henry's Law Constant of  $2.4 \times 10^{-5}$  atm·m<sup>3</sup>/mol, indicating that volatilization from water may occur; however, HD undergoes rapid hydrolysis in aqueous solutions. Dilute concentrations of HD ( $\leq 10^{-5}$  M or  $\leq 1.6$  mg/L) hydrolyze almost completely to thiodiglycol and hydrochloric acid. Hydrolysis half-lives of 14.7 min at 20°C and 4 min at 25°C have been reported. With such rapid hydrolysis, volatilization of the agent is unlikely to occur. See USACHPPM, 1999 for additional information.

(c) Lewisite has a molecular weight of 207.32 and a Henry's Law Constant of  $3.2 \times 10^{-4}$  atm·m<sup>3</sup>/mol; therefore, according to the USEPA guidelines this compound would be expected to volatilize from aqueous solutions. However, Lewisite undergoes rapid hydrolysis. The rate of hydrolysis is limited by the low solubility of the parent compound. Lewisite oxide can slowly hydrolyze to 2-chlorovinylarsonous acid (often called CVAA) in aqueous media. While CVAA is only minimally soluble in water, it may be present in the typically caustic decontamination solutions. However, the CVAA will in such cases only be present in the ionized form and therefore not subject to ready volatilization.

(d) Therefore, it is concluded that volatilization from wastewater or liquid nonwastewaters is unlikely to be a significant exposure pathway for the chemical agents related liquid wastes. The resulting equations for modeling the exposure scenario involving a liquid matrix, assuming dermal absorption as the primary exposure pathway, are presented below. This model is adapted from the USEPA Superfund Guidance (USEPA, 19989a and 1991a).

For contaminants having a carcinogenic effect, the equation for HWCL for liquid-based wastes is as follows:

**EQUATION 3 Risk Assessment Model for HWCL<sub>liq</sub> - Carcinogens.**

For contaminants having a noncarcinogenic effect, the equation for HWCL concentration-based standards

$$HWCL_{liq} = \frac{TR \times BW \times AT_c}{ET \times EF \times ED \times (CSF_o \times SA \times PC \times 1L/1000 \text{ cm}^3)}$$

for liquid-based wastes is as follows:

d. Parameters. The specific values and distributions of the individual parameters (for both deterministic and probabilistic analyses) used in Equations 1 through 4 are described below. Tables 1 through 5 summarize these values.

(1) Chronic Toxicity Constants. Table 1 summarizes the chronic toxicity constants used for the chemical agents in this proposed rule. As constants, these values should not be construed as having more certainty associated with them than that with any other parameter used in the risk assessment equations. In fact, the uncertainty associated with these values is a part of their definition which assumes they inherently reflect 'uncertainty of an order of magnitude or more' (USEPA, 1989a). The calculations upon which the toxicity values are based themselves require data extrapolations that must account for use of animal data, limited study subjects, unknown effects of human variability, and dose-

time relationships, to name a few variables. Despite the significant uncertainties built into the chronic toxicity value, and the significance of the impact that this value has on the overall outcome of the risk assessment, the uncertainties are assumed to be conservatively accounted for in the process of establishing the constant. There are two types of toxicity constants: 1) Reference Doses (RfDs) and Reference Concentrations (RfCs) describe *non-cancer* effects caused by a chemical; 2) Slope Factors (SF) and Unit Risk (UR) describe the *carcinogenic potency* associated with compounds shown to cause cancer. Separate toxicity values are established for different modes of toxicity. For example, an RfD reflects the toxicity of the chemical when *ingested*, while the RfC reflects the toxicity of the chemical when *inhaled*. Reference values reflecting dermal toxicity are also sometimes available. The USEPA often uses the oral RfD as a substitute where data are lacking. For most industrial chemicals, the regulatory community has established official/approved toxicity constants. The most common source for these values is the Integrated Risk Information System (IRIS) (USEPA, 1997d). For compounds not in IRIS, EPA allows use of other databases (e.g. Health Effects Summary Tables (HEAST) (USEPA, 1997e)) or other available references, with preference given to those most substantiated. Chronic toxicity constants for the chemical agents and the additional hazardous constituents described in this analysis are not currently listed by the IRIS or HEAST, those that are cite have undergone thorough review and scientific approval processes.

(a) *Chronic Toxicity Constants for Inhalation.* The Centers for Disease Control and Prevention (CDC) has evaluated occupational and general public inhalation exposure limits for the nerve agents GA, GB, VX; the mustard agents H, HD, and HT; and Lewisite (DHHS, 1988). The Army has adopted these inhalation exposure standards (DA, 1990, 1991). Recent technical evaluations have verified the validity of the G-agent air standards but suggests that the VX general population limit should potentially be lowered by a factor of 10 (USACHPPM, 1998). In this analyses, the lowered VX limit ( $3 \times 10^{-7}$ ) was used in place of the existing standard ( $3 \times 10^{-6}$ ) to ensure conservatism should standards be changed. The air standards were used as surrogate RfCs by converting them into Inhalation RfDs (RfDi) using the standard exposure parameters of  $20 \text{ m}^3/\text{day}$  as an adult inhalation rate and 70 kg as an adult body weight.

(b) *Chronic Toxicity Constants for Ingestion.* The US Army Surgeon General recently approved final chronic toxicity values for the primary agents ( i.e. HD, GA, GB, GD, VX, and Lewisite) (USAPPM, 2000). A summary of the review process that these values have gone through is provided in the Annex.

(c) *Dermal chronic toxicity constants.* Dermal chronic toxicity values are not currently available for chemical agents, as is the case with the majority of industrial/agricultural compounds. Using the USEPA Region IX method (which assesses the dermal contact pathway), oral RfDs are converted to (or used as surrogates for) dermal RfDs where no other information is available (USEPA 1992, and USEPA 1998). In this proposed rule, available data on acute dermal effects of the agents were used to evaluate the appropriateness of using the oral RfDs in this manner. Based on this evaluation (USACHPPM,1999) the conversion method was used for all the agents except Lewisite. A derivation of a specific dermal toxicity value for Lewisite was required, because the standard EPA Region XI method for conversion of an oral RfD to a dermal RfD results in a dermal Lewisite RfD of  $7 \mu\text{g}$ , which is above a potential acute dermal effect level of  $3.5 \mu\text{g}$ . Therefore, a dermal RfD for Lewisite of  $1.7 \times 10^{-6} \text{ mg/kg/day}$  was derived from existing acute dermal toxicity data, resulting in a more conservative estimate.

(d) *Cancer Risk from Chemical Agents.* There are no epidemiological or experimental data indicating that chemical agents other than HD are carcinogenic. A variety of data have been evaluated to quantify the carcinogenic potential of HD. Several different approaches have been

evaluated (USACHPPM, 1999). This evaluation yielded HD slope factors of 1.6, 5.0, 2.6, 5.3, 15.6, 9.5, and 95 (mg/kg/day)<sup>-1</sup>, respectively. Since current scientific data were not available to suggest which method/estimate is most accurate, an average of these estimates was selected to represent the cancer toxicity constant. A statistical assessment of the values was used to determine that they presented a log-normal distribution. Therefore, a geometric mean was calculated, resulting in a value of 7.7 (mg/kg/day)<sup>-1</sup>. This is considered to be the best overall measure of the slope factor for HD. It should be noted that the statistical evaluation suggests that the estimate 95 (mg/kg/day)<sup>-1</sup> could be considered an outlier amongst the given data set. If this value is not used in the calculation, the final geometric mean based on the remaining six values would be 5.0 (mg/kg/day)<sup>-1</sup>. By using the value of 7.7 (mg/kg/day)<sup>-1</sup> in the calculations in this analyses, additional conservatism is provided.

<b>Chemical</b>	<b>Oral RfD<sup>a</sup> (mg/kg/d)</b>	<b>Oral Slope Factor (mg/kg/day)<sup>-1</sup></b>	<b>Inhalation Slope Factor (mg/kg/day)<sup>-1</sup></b>	<b>General Public Air Exposure Limit<sup>d</sup> (mg/m<sup>3</sup>)</b>	<b>Inhalation RfD<sup>e</sup> (mg/kg/day)</b>
HD	7 x 10 <sup>-6</sup>	7.7 <sup>b</sup>	300 <sup>c</sup>	1 x 10 <sup>-4</sup>	3 x 10 <sup>-5</sup>
Lewisite	1 x 10 <sup>-4</sup>	-	-	3 x 10 <sup>-3</sup>	8.6 x 10 <sup>-4</sup>
GA	4 x 10 <sup>-5</sup>	-	-	3 x 10 <sup>-6</sup>	9 x 10 <sup>-7</sup>
GB	2 x 10 <sup>-5</sup>	-	-	3 x 10 <sup>-6</sup>	9 x 10 <sup>-7</sup>
GD	4 x 10 <sup>-6</sup>	-	-	1 x 10 <sup>-6</sup> <sup>f</sup>	3 x 10 <sup>-7</sup>
VX	6 x 10 <sup>-7</sup>	-	-	3 x 10 <sup>-7</sup> <sup>g</sup>	9 x 10 <sup>-8</sup>

<sup>a</sup> Source: DA, 1996a and USAPPM,2000.

<sup>b</sup> Geometric mean of estimated slope factors; see Section 1.2.4 of USACHPPM 1999

<sup>c</sup> DA (1996); derived from an inhalation unit risk of 8.5 x 10<sup>-2</sup> per µg/m<sup>3</sup> (see USEPA, 1991a, 1991b and 1994)

<sup>d</sup> DHHS (1988); DA (1990, 1991)

<sup>e</sup> Estimated from the air exposure limits using an inhalation rate of 20 m<sup>3</sup>/day and a body weight of 70 kg

<sup>f</sup> Value estimated by Mioduszewski et al. , ERDEC-TR, April 1998)

<sup>g</sup> From Reutter et al, ECBC-TR February 2000

(2) Target Risk and Target Hazard Index. These unitless parameters describe the accepted risk level for carcinogens and noncarcinogens, respectively.

(a) *Target Risk (TR)*. The TR is the cumulative level of acceptable incremental (additional) risk of an individual developing cancer over a lifetime as a specific result of exposure to the potential carcinogen from all significant pathways for a given medium (USEPA, 1991a). The National Contingency Plan (NCP) (1990) designated remediation goals to represent an excess upperbound lifetime cancer risk to an individual to be between 10<sup>-4</sup> and 10<sup>-6</sup> lifetime cancer risk. The USEPA Office of Solid Waste and Emergency Response (OSWER) Directive entitled "Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions" (USEPA 1991a) indicates that action at a site is generally warranted when the cumulative carcinogenic risk is greater than 10<sup>-4</sup>, whereas no action is required when risks fall below 10<sup>-6</sup>. A TR of 10<sup>-4</sup> is selected as an acceptable carcinogenic risk level for workers at a hazardous waste landfill for this analysis. This is consistent with USEPA guidance and actually is more stringent than the other standards established for worker protection; specifically, the

Occupational Safety and Health Act (OSHA) has identified an acceptable risk level of  $10^{-3}$  for the work force population (refer to USACHPPM, 1999 for more information).

(b) *Target Hazard Index (THI)*. The THI is “the level of exposure to a chemical from all significant exposure pathways in a given medium below which it is unlikely for even sensitive populations to experience adverse health effects. For noncarcinogenic effects, the NCP does not specify a range but it is generally appropriate to assume a THI equal to 1.” (USEPA, 1991a). Therefore, a THI of 1 is used in the calculation of the HWCLs.

(3) *Body Weight (BW)*. A default value of 70 kilograms is used to represent BW. Though more recent national statistics indicate a trend towards slightly higher average adult body weights, the 70 kg default is still used as the current standard EPA default value for adults (USEPA, 1998). In part, use of this value reflects a more conservative assumption; it is also an assumption that is built into the establishment of certain chronic toxicity values.

(4) *Exposure Duration (ED)*. This parameter describes the number of years that an individual in the population may be exposed. In the HW landfill scenario, it describes the number of years that a worker may be expected to work at a HW landfill. The most current USEPA Exposure Factors Handbook (USEPA, 1997c) recommends that the median occupational tenure of the 1987 US working population (109.1 million people, ages 16 years and older) be used for men and women when age cannot be determined. This median value of years working in a given occupation is 6.6 years. The median tenure for the classification of “Operators, Fabricators, and Laborers” from this same population is stated as 5.5 years. This classification most closely fits the landfill worker population of concern. To account for the variability in age and add to the conservatism of the analyses, the ED of 10 years will be used to establish the HWCLs.

(5) *Exposure Frequency (EF)*. This parameter identifies the number of days during a year (days/year) that an individual is exposed. For this parameter, no default standards exist for a landfill scenario. However, since the EF parameter can have a marked influence on the resulting HWCLs, a significant attempt to conservatively yet realistically define this parameter has been accomplished. Since exposure to chemical agents will occur when a variety of conditions exist, in particular the misuse or malfunction of personal protective clothing and equipment (PPE), data concerning the statistics on OSHA safety violations pertaining to PPE was sought by reviewing the OSHA Internet site (OSHA, 1998). Hazardous waste disposal facilities (including transport and processing) fall within the OSHA Standard Industrial Classification (SIC) 4953 - Refuse Systems. Review of individual inspections showed that during the year October 1, 1996 - September 31, 1997, a total of 291 OSHA inspections in the U.S. were performed at facilities falling within the Refuse Systems classification. In the subject inspections, a total of 27 citations regarding the OSHA standards for PPE (OSHA Standards 19100132 - Personal Protective Equipment- General requirements, and 19100134 - Respiratory Protection) were levied. The ratio of citations to inspections is 9 percent. Based on this information, it may be assumed that misuse or malfunction of an HW worker's PPE resulting in exposure occurs 9 percent of the time in any given year. Admittedly, there are many uncertainties associated with these assumptions. For example, many inspections were conducted because of complaints, so the data set cannot be considered a random collection. Also, no detail was given regarding the subclassifications (e.g., HW disposal site, or rubbish collection and disposal) of facilities being inspected, so the percentage of those cited being HW sites is unknown. In addition, PPE citations may involve non- “exposure related” violations, such as documentation requirements. On the other hand, only using data regarding PPE does not consider the contribution of engineering-control-breakdown to exposure frequency. Given these data, an assumed-conservative estimate of 10 percent of the normal 250-day work-year has been proposed as the frequency of exposure at a TSDF landfill. This results in a single value estimate of 25 days.

Considering the circumstances, (the same worker either not wearing PPE or donning faulty equipment, and then contacting chemical agent-contaminated materials on 25 different days throughout the year for 10 years), this is considered an extremely conservative estimate.

(6) Exposure Time (ET). This parameter is used only in the  $HWCL_{liq}$  derivation. This parameter represents the amount of time a contaminated liquid matrix would remain on the skin surface area of an exposed individual. There are no data representing such conditions at the TSDF facility and data regarding half-life and/or degradation of a chemical is not directly (empirically) incorporated in this value. Realistically, a worker who comes into contact with a liquid waste should appropriately wash immediately, thus minimizing overall exposure time to minutes. Many of the liquid matrices may be caustic in nature, maximizing the likelihood of expedited removal and decontamination from the body. However, conditions may prevent immediate washing. For purposes of this rule, a 1 hour duration is used to represent the duration a liquid matrix may remain on the skin of an exposed individual before washing or removal of residual contaminant occurs. This, as with all the other assumptions, assumes that these repeated occurrences and durations of exposure occur to the *same* personnel. Therefore 1 hour is used in the calculations as a reasonable conservative value.

(7) Averaging Time (AT). This parameter is described by an equation which represents the time over which the exposure is averaged (with unit in days). The equations differ for the assessment of carcinogenic compounds vs noncarcinogenic compounds.

(a)  $AT_c$  - For carcinogenic compounds, exposure is averaged over the lifetime of the individual. The current 'standard' default average lifetime designated by EPA is 70 years. The  $AT_c$  is therefore stated as "70 years x 365 days/year" which equals 25550 days. Though more recent statistics show an increase in the longevity of Americans (as of 1993 the average was 75.5 years) some of the chronic toxicity values (such as the cancer slope factor) values incorporate the use of a 70 year lifetime. In addition, the most recent USEPA Region IX PRG guidance continues to use this default of 70 years, in part because this results in a slightly more conservative estimated screening level. Therefore, the 70 year assumption is used in this analyses.

(b)  $AT_n$  - For noncarcinogenic compounds the exposure is averaged over the duration of the exposure itself. Thus,  $AT_n$  equals "ED x 365 days" which equals 3650 days when using the deterministic approach (ED = 10 years).

(8) Soil Ingestion Rate (IRS). The rate at which adults inadvertently ingest soil (including ingestion of dust) is estimated in milligrams of soil per day. The USEPA itself describes available information on adult ingestion rates as "very weak." (USEPA, 1997c) Again, use of these parameters is somewhat complicated by the use of soil as a surrogate for other solid matrices. However, it is assumed that soil would yield the highest soil/dust ingestion rates since incidental ingestion occurs when contaminated material (usually adhered to particulate) is ingested through hand-mouth contact or through airborne particles. These contaminated particles are more likely to be available from a soil matrix as opposed to other solid matrices. The standard USEPA default (USEPA 1989a and 1991a) for ingestion by adults is 100 mg/day. The USEPA Region XI guidance suggests a default for occupational exposures as 50 mg/day while USEPA Region III suggests a default of 480 mg/day for adults engaged in yardwork or physical activity (USEPA 1996 and 1997a). More recent studies (USEPA, 1997c) identify ranges of values typically below the 480 mg/day estimate. For purposes of this evaluation, an IRS of 100 mg/day is used in this analysis.

(9) Fraction Contaminated Soil (FC). This parameter reflects percentage of ingested soil that is actually contaminated with the chemical agent of concern. Again as with other parameters, soil is used to represent all solid waste matrices. As this relates to the fractions of soils/dust available from the matrix for ingestion, this assumption is assumed to add to the conservatism of the HWCLs. Since the IRS reflects the *daily* rate of ingestion, it includes ingestion of soils and dusts from sources outside of the worksite. Though it may be assumed a majority of the landfill workers' ingested soil will come from the worksite itself, the actual portion of that soil and dust that is contaminated with chemical agent is expected to be quite small. An assessment of the percentage of chemical agent wastes from overall hazardous waste received by several waste disposal facilities in Utah from 1994-1997 estimated annual percentages at less than 0.3 %. Even if future chemical agent waste generation was to increase, the anticipated percentage to overall waste received by these facilities is not expected to exceed 1%. Given that the State of Utah has the largest USCWA stockpile, the USACHPPM assumes 1% to be a fairly conservative estimate for any location. However, since this is an unsupported assumption, a FC of 50% is used in the calculations presented in this analysis.

(10) Skin Surface Area exposed (SA). The area of surface skin exposed to a chemical agent or matrices containing residual chemical agent depends on the estimated area of protected clothing that covers an individual worker's body as well as the areas most susceptible to exposure. The USEPA estimate for individuals wearing long-sleeved shirts, pants, and shoes is 2000 cm<sup>2</sup> (i.e., skin surface exposed is head and hands). If skin surface exposed is increased to include forearms and lower legs, the estimated value is 5300 cm<sup>2</sup>. These two examples suggest that with clothes, roughly 10 percent to 25 percent of the skin area may be exposed to soil/other contaminated matrix (25 percent of the adult skin surface area is estimated between 5000 and 5800 cm<sup>2</sup>). One other study in the Exposure Factors Sourcebook (AIHC, 1994) indicates that for adults the total estimated value for the hands, neck, head, and forearms was 3420 cm<sup>2</sup>. The primary areas of concern relative to the TSDF worker are the head, hands and forearms as well as the neck. Data for individual body part areas obtained from the USEPA (USEPA, 1997c) can be added for these areas (not including the neck) resulting in a mean (for men) of 3160 cm<sup>2</sup>. Recently, the USEPA Region IX (USEPA 1998) modified its default SA value to 5700 cm<sup>2</sup> (which could conservatively represent the head, forearms, hands, and neck or other combination of exposed surfaces resulting in a total area equivalent to 25% of the total body surface area). However, use of these estimates assumes that the clothing protects the individual from exposure. Though some studies cited by the USEPA suggest that some contaminants may penetrate clothing or that exposure may occur under loose clothing, it is necessary to note that for the hazardous waste landfill workers, the type of clothing worn is expected to be more substantial than typical clothing. Under more realistic conditions, worker contact and exposure would be eliminated through proper PPE that would include coverage of the entire body (with protection of the face offered by respirator). As stated previously in this proposed rule, the actual potential for this exposure to occur, particularly repeatedly to an individual, is very unlikely. However, for purposes of considering the only plausible exposure to a civilian population, this analysis considers that exposures may occur if gloves or respirators were removed, if clothing was ripped, or if sleeves or pants had unsecured openings. As such, the USEPA Region IX default SA value of 5700 cm<sup>2</sup> is used for calculation of the health-based HWCLs.

(11) Soil-to-Skin Adherence Factor (AF). The previous discussion presented information about the area of skin exposed to soil. These estimates are necessary to estimate the total amount of soil on skin by multiplying the SA to the soil adherence factor (AF) which is given in units of mg/cm<sup>2</sup>. In general, the AF depends on soil properties (e.g., adherence increases with moisture and decreases with particle size), and varies across body parts (i.e. hands highest), and varies with activity. In the absence of site-specific data, the USEPA guidance recommends using the following default values: 1.45 mg/cm<sup>2</sup> for commercial potting soil and 2.77 mg/cm<sup>2</sup> for kaolin clay (USEPA, 1989b). USEPA (USEPA 1992) reported that "a range of values from 0.2 mg/cm<sup>2</sup> to 1.5 mg/cm<sup>2</sup> per event appear

possible. "Based on the most recently developed Dermal Exposure Guidelines, USEPA Region IX now uses a soil adherence value of 0.08 mg/cm<sup>2</sup> for PRG calculations for adults and 0.3 mg/cm<sup>2</sup> for children (USEPA, 1998). The adult default AF value of 0.08 mg/cm<sup>2</sup> was selected for the HWCL calculations.

(12) Skin Absorption Factor (ABS). Once soil (or other solid waste matrices containing chemical residues) has come into contact with and is adhered to the skin, estimating the rate of absorption through the skin is the next step in the risk assessment process. The USEPA default values for ABS for organic compounds include 0.01 (USEPA, 1995a) and 0.1 (USEPA 1998). However, the ABS is highly dependent on a combination of chemical properties as well as soil/matrix properties. While certain chemical properties may be obtained or estimated, the soil/matrix properties are extremely site dependent. This variability of the matrix will result in uncertainty associated with both the estimated ABS values as well as the resulting concentration estimates. The USACHPPM 1999 HBESL report presents a theoretical derivation of specific ABS values (unitless) for the individual chemical agents using assumed *soil* characteristics. The use of soil characteristics to represent any anticipated solid waste matrices may result in under or over conservative estimates – however this matrix was the one with the most available data. A summary of the estimated values is contained in Table 2. These theoretical calculations are based on the assumption of an 8-hour daily exposure.

**Table 2. Dermal absorption (ABS) values for chemical agents**

<u>Agent</u>	<u>ABS</u>
HD	5.6%/8hrday
Lewisite	10%/8hr
GA	2.1%/8hr
GB	2.8%/8hr
GD	6.1%/8hr
VX	2.2%/8 hr

(13) Inhalation Rate (INH). The health risk associated with human exposure to airborne toxins is a function of concentration of air pollutants, chemical species, duration of exposure, and inhalation rate. The inhalation rate represents the rate at which an individual (in this case a landfill worker) inhales a volume of air; it is reflected as m<sup>3</sup>/day. The most significant variables affecting the INH include age (e.g. adult vs child) and the degree of physical activity. The USEPA Region IX default INH value for adults is 20 m<sup>3</sup>/day. This value represents outdoor residential, agricultural, and industrial activities (AIHC, 1994). More recent USEPA guidance suggests 15.2 m<sup>3</sup>/day as the estimate to use (for men; for women the estimate suggested is 11.3 m<sup>3</sup>/day). The default value of 20 m<sup>3</sup>/day exceeds the more recently recommended adult INH value and will be used as the deterministic input parameter.

(14) Volatilization Factor (VF) and Particulate Emission Factor (PEF). To address the soil-to-air pathway, the risk assessment equations incorporate volatilization factors (VF) for volatile contaminants and particulate emission factors (PEF) for nonvolatile contaminants. As with certain other parameters, the use of soil as a surrogate for all anticipated wastestreams adds to the uncertainty of the final estimated HWCLs. These factors relate soil contaminant concentrations to air contaminant concentrations that may be inhaled onsite. The calculation of these two parameters models the emission of the contaminant from the soil as well as the dispersion of the contaminant into the atmosphere. Both parameters are typically represented as a single deterministic estimate even in probabilistic analyses.

(a) *Volatilization Factor (VF)*. Volatilization of chemicals from soil is estimated for those chemicals that have a Henry's Law constant greater than  $10^{-5}$  (atm<sup>3</sup>/mol) and a molecular weight less than 200 g/mole. Of the chemical agents, only sulphur mustard (HD) meets this definition of a volatile compound; all other agents (in soil) are considered as nonvolatile compounds for purposes of the risk assessment process. Therefore, the PEF is used to calculate HWCLs for these compounds. For HD, a chemical specific VF can be derived from the equation provided in the EPA Region IX guidance (USEPA, 1998). Appendix A of the USACHPPM 1999 HBESL report presents these calculations. The VF calculated and used to derive HWCLs for HD is  $5.6 \times 10^4$  m<sup>3</sup>/kg.

(b) *Particulate Emission Factor (PEF)*. For chemicals falling into the nonvolatile category, inhalation of chemicals adsorbed to respirable particles are assessed using a default value of  $1.32 \times 10^9$  m<sup>3</sup>/kg (USEPA, 1998). This value relates the contaminant concentration in soil with the concentration of respirable particles in air due to fugitive dust emissions. This relationship was derived for typical hazardous waste sites where the surface contamination provides relatively continuous and constant potential for emission over an extended time (e.g. years). The default PEF value of  $1.32 \times 10^9$  m<sup>3</sup>/kg is therefore used to calculate the HWCL for the compounds GA, GB, GD, VX, and Lewisite.

(15) Permeability Coefficients (PC). Dermal permeability coefficients are chemical specific values used in the HWCL<sub>liq</sub> equation. Experimentally derived dermal permeability coefficients (PC) were not located in the available literature for any of the chemical warfare agents. In such cases, USEPA (USEPA, 1992) recommends the use of the following algorithm:

#### EQUATION 5. Derivation of Chemical Permeability Coefficients

$$\log K_p = -2.72 + 0.71 \log K_{ow} - 0.0061 MW$$

where:

$K_p$  = Permeability coefficient (PC)

$K_{ow}$  = Octanol/water partition coefficient (chemical-specific)

MW = Molecular weight

The log  $K_{ow}$  values, molecular weights and estimated PC values, and RfD<sub>o</sub> values for the chemical agents are listed in Table 3. A log  $K_{ow}$  value is not available for Lewisite because it undergoes rapid hydrolysis in aqueous solutions; therefore, a PC value cannot be estimated for this compound.

Agent	RfD <sub>o</sub> (mg/kg/day)	Molecular Weight	log K <sub>ow</sub> <sup>a</sup>	PC
HD	7 x 10 <sup>-6</sup>	159.04	1.37	0.00192
VX	6 x 10 <sup>-7</sup>	267.4	2.09	0.00136
GA	4 x 10 <sup>-5</sup>	162.1	1.18	0.00135
GD	4 x 10 <sup>-6</sup>	182.2	1.02	0.00260
GB	2 x 10 <sup>-5</sup>	140.1	0.15	0.00034
Lewisite	1.7 x 10 <sup>-6</sup>	207.32	-	0.000092
CVAA <sup>b</sup>		170.427	-0.07	0.00015

<sup>a</sup> See USACHPPM, 1999 (HBESL) regarding log K<sub>ow</sub>

<sup>b</sup> 2-chlorovinylarsonous acid; hydrolysis product of Lewisite, this is used to provide a surrogate log K<sub>ow</sub> for Lewisite

Parameter	Assumption values
Chronic Toxicity Value	(see Table 1, above)
Risk Index (THI or TR)	THI = 1; TR = 10 <sup>-4</sup>
Body Weight (BW)	70 kg
Exposure Duration (ED)	10 years
Exposure Frequency (EF)	25 days/year
Averaging Time (AT)	[ED x 365 days/yr] (use 70 yrs for ED for carcinogens)=3650days (for nc) or 25550 days (for cancer)
Inhalation Rate (IHR)	20 m <sup>3</sup> /day
Ingestion Rate (IRS)	100 mg/day
Fraction Contaminated (FC)	50%
Skin Area Exposed (SA)	5700 cm <sup>2</sup>
Soil-to-Skin Adherence(AF)	0.08mg/cm <sup>2</sup>
Skin Absorption (ABS)	chemical specific, 8-hr daily exposure; see Table 2
Volatilization/Particulate Emission Factor	VF for HD = 5.6 x 10 <sup>4</sup> m <sup>3</sup> /kg. PEF for other agents =1.32 x 10 <sup>9</sup> m <sup>3</sup> /kg

Parameter	Deterministic Approach- Single values
Chronic Toxicity Value	Chemical specific, see Table 1
Risk Index (THI or TR)	THI = 1; TR = 10 <sup>-4</sup>
Body Weight (BW)	70 kg
Exposure Duration (ED)	10 years
Exposure Frequency (EF)	25 days/year
Exposure Time (ET)	1 hour
Averaging Time (AT)	[ED x 365 days/yr] (use 70 yrs for ED for carcinogens)=3650days (for nc) or 25550 days (for cancer)
Skin Area Exposed (SA)	5700 cm <sup>2</sup>
Skin Absorption (ABS)	chemical specific, 8-hr daily exposure; see Table 2
Permeability Coefficient (PC)	Chemical-specific, see Table 3

e. Calculations. The insertion of the parameters identified in Table 4 and Table 5 above, into the described equations results in the following range of concentrations (Table 6 and Table 7).

Chemical Agent	Proposed HWCL <sub>sol</sub>
HD	6.7
GA	680
GB	320
GD	52
VX	10
Lewisite	37

Chemical Agent	HWCL <sub>liq</sub> criteria
HD	0.7
GA	20
GB	8.3
GD	0.3
VX	0.08
Lewisite	3.3

f. Uncertainties. The concentrations depict a range of concentrations which are considered to offer an adequate level of protection to the population of concern. However, the process of risk assessment cannot provide an *exact* identification of the specific concentration of chemical in a waste that, when exceeded will pose a definitive risk that would result in an adverse health effect. Human variability and sensitivities alone account for some of the uncertainty. However, each assumption in the model is a variable and, depending on the availability and quality of data upon which these variables are

based, there may be greater or less uncertainty in the resulting calculated values. Therefore, the risk calculations described above are derived with assumptions that overall err on the side of conservatism. Despite its limitations and the uncertainties, the process used is consistent with that currently used by the USEPA in assessing potential chronic health effects from chemical exposures. Due to the uncertainties associated with the models and the assumptions themselves, it should be noted that the actual estimated values themselves should not, in accordance with general scientific protocol, be represented by any more than one significant digit. However, since USEPA screening levels (including USEPA Region IX) are represented with two significant digits, two significant digits are also identified here. This should not, however, be assumed to confer added certainty regarding the values. Consideration of the uncertainties in the risk assessment are important to during risk management process. Table 8 presents a summary of some of the key uncertainties associated with the use of the model and the selected parameters in calculating the HWCLs.

<b>Table 8. Uncertainty Summary - Key Areas of Uncertainty and Type of Effect* on "Conservatism" of HWCLs</b>	
<b>Type of Uncertainty</b>	<b>Type of Effect*</b>
Chronic toxicity constants	Assumed overly conservative because of built in safety factors; extreme data limitations associated with Lewisite make this value most questionable though certain modifications have attempted to address; these values have significant impacts on resulting LDR concentration-based standards
Use of additive multiple exposure pathway model for soil	Assumed overly conservative (particularly for vesicants HD and Lewisite)
Exposure duration (ED)	Varied - possible over/under conservatism; primarily effects HD value
Exposure frequency (EF)	Overly conservative; depends on compliance with occupational requirements; this parameter has major impacts on the calculations (i.e the resulting estimate is very sensitive to this input value)
Skin surface area exposed (SA)	Overly conservative; depends on compliance with occupational requirements;
Use of soil as surrogate matrix (affects parameters such as ABS, IRS, FC, and VF, PEF)	Varied - possible over/under conservatism
Fraction ingested from contaminated source (FI)	Overly conservative
Permeability Coefficient	Varied - assumed overconservative

\* Type of effect has been determined by professional judgement

#### 4. ASSUMPTIONS AND DERIVATION OF NHWCLs.

a. Background. Chemical warfare agent environmental screening levels are current documented in the USACHPPM “Derivation of Health-Based Environmental Screening Levels for Chemical Warfare Agents” (USACHPPM, 1999). The report describes scenarios under which there is a potential of exposure to different types of populations from contaminants in soil. The document describes current USEPA methodologies and assumptions commonly used to assess the need for potential remediation/cleanup activities at contaminated sites. USEPA has published screening levels for hundreds of toxic industrial chemicals. The assessment methodology addresses typically two types of current and/or future land use: the 1) residential scenario and 2) the industrial (i.e. “non-residential”) scenario. CWA HBESLs derived from the USEPA Region IX guidance for both residential and industrial are documented. The industrial/non-residential scenario assumes frequent adult exposures in a non-protected environment.

b. Scenario: Management of CWA-related Waste as Non-hazardous. Wastes not identified as hazardous waste are subject to State-implemented Subtitle D requirements. The potential for exposure to such wastes involves a somewhat less protected population of individuals than that managed under Subtitle C requirements. As there are still specific Subtitle D management and manifesting requirements, the general civilian population is not a likely population to be exposed. Under such conditions, the landfill personnel will have the greatest opportunity for exposure to the residual agent from the contaminated matrix. Unlike the waste disposed at a Subtitle C facility, the personnel are not required to maintain the same level of personnel protective equipment and clothing. As a result, their potential for exposure is greater. The concentrations of agent in waste received by such facilities should therefore be reduced to an acceptable level of risk.

c. Assumptions and Derivation. The CWA HBESLs (USACHPPM, 1999) for industrial sites are proposed as appropriate levels for determining whether wastes pose a risk warranting strict management and oversight under RCRA Subtitle C or which can instead be safely managed under the State-implemented RCRA Subtitle D requirements. The calculations used are those previously described for nonwastewater solids. NHWCLs are not established for nonwastewater liquids or wastewaters. Table 9 and 10 summarize the specific parameters and resulting concentration values for use as NHWCLs. Specific discussion these different parameters is contained in USACHPPM, 1999.

**TABLE 9. Description of Selected Exposure Parameters for NHWCLs (for solid nonwastewaters only)**

Parameter	Assumptions
Chronic Toxicity Dose	(see Table 1, above)
Risk Index (THI or TR)	THI = 1; TR = $10^{-4}$
Body Weight (BW)	70 kg
Exposure Duration (ED)	25 years
Exposure Frequency (EF)	250 days/year
Averaging Time (AT)*	9,125 days for noncarcinogens; 25,550 days for carcinogens
Inhalation Rate (IHR)	20 m <sup>3</sup> /day
Ingestion Rate (IRS)	100mg/day
Fraction Contaminated (FC)	50%
Skin Area Exposed (SA)	5700 cm <sup>2</sup>
Soil-to-Skin Adherence (AF)	0.08
Skin Absorption (ABS)	Chemical specific, 8-hr exp/d
Volatilization/Particulate Emission Factor	VF for HD = $5.6 \times 10^4$ m <sup>3</sup> /kg. PEF for other agents = $1.32 \times 10^9$ m <sup>3</sup> /kg

\*AT = [ED x 365 days/yr] (use 70 yrs for ED for carcinogens)

**TABLE 10. NHWCLs \*(for solid nonwastewaters only) (mg/Kg) or ppm**

Chemical Agent	Exemption Levels
HD	0.3
GA	68
GB	32
GD	5.2
VX	1.1
Lewisite	3.7

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## ANNEX

to

**USACHPPM Technical Paper: Chemical Warfare Agent Health-Based Waste Control Limits**Development and Review Process of Chemical Warfare Agent Reference Doses  
General Chronology and POCs

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- 1992 -ORNL Estimated General Population Control Limits document (ORNL TM12035) published; submitted to Army, who transmitted it to CDC for review (POC: ORNL -see below)
- 1993 - New draft document requested (by AEC) review of initial draft by:  
- Dr. Thomas Bucci, Pathology Associates, International, 501-543-7027  
- Dr. I.K. Ho, University of Mississippi Medical Ctr., 601-984-1600
- Dec 93 - CDC comments -- 'concur with methodology but suggest(ed) alternative exposure assumptions rather than standard default which (CDC) considers unrealistic...' (POC - Dr. Harvey Rogers or Dr. Steven Thack, CDC-NCEH 404-488-7070)
- 1993 - Army OTSG (LTC Holly Doyle, 703-756-0133) approves methods - reserves right to review as issue evolves. Points out that control limits are reaching detection limits.
- 1994 - Draft Oak Ridge National Laboratory (ORNL) document ("Estimated Control Limits and Technologies for Use in Remediating Sites Contaminated with NonStockpile Chemical Materiel") containing modified procedures and numbers (as compared to 1992 document) submitted to Army Dec 1994 for review.  
Contract POC- Mr. Joe King, Army Environmental Center 410-671-1535  
Principle Investigators - (ORNL) Dr. Bob Ross/ Dr. Annetta Watson,  
923-574-7797/423-576-2125
- Feb 95 - ORNL outbriefs to the Army (AEC and USACHPPM)
- 95-96 - review by non-DOD 'experts'  
- Dr. Michael Douerson, former EPA Health Risk Assessment Methodology developer; Phone: 513-542-7475 (present employment: Toxicologic Excellence for Risk Assessment (TERA))  
- Dr. William Hartley, former Army researcher, former EPA RA scientist; 504-588-5374
- 95-96 - review of numbers by Army (USACHPPM, AEC, ERDEC); Steve Kistner - Scientific Advisor (USACHPPM), 410-671-2307; modifications made; criteria 'numbers' taken out of AEC report and written up as individual agent health risk assessment documents

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**Interim Army Chronic Toxicological Criteria: Chronology and POCs, *cont'd***

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- Apr 96 - submitted to Strategic Environmental Research and Development Program (SERDP) (includes representation from EPA, DOE, DOD) POC: Dr. Jim Cogliano, EPA and Chair, SERDP - Phone -202-260-2575
- Aug 96 - approval by US Army Office of the Surgeon General - See letter signed by Dr. (COL) Francis O'Donnell, dated 19 August 1996. Cited as Interim pending the National Research Council's (NRC) Commission on Life Sciences- Board on Environmental Studies and Toxicology-Committee on Toxicology (COT) review and approval.
- Sept 96 - final review by SERDP - September 1996. All numbers remain as in OTSG letter except for Lewisite (recommendation was just to use arsenic criteria instead). ORNL is putting together a "White paper" discussing all the issues of concern. SERDP also recommends final review by COT.
- final package submitted to COT; includes support documents for each chemical agent as well as white paper. POC: Dr. Kulbir Bakshi - COT panel chair. 202-334-2613.
- Nov 96 - review by CDC/NCEH: POC: Ms. Linda Anderson/Mr. Joe Paul 770-488-7071
- CDC will review and provide comments; upon COT review the CDC will submit criteria through the Federal Register for public comment
- Feb 97 - COT convenes for initial presentation of documents.
- 1998 - ORNL and AEC - publish RfDs in peer-reviewed journal: *Review of Environmental Contamination and Toxicology*, Opresko et al. Vol 156-1-183, "Chemical Warfare Agents: Estimating Oral Reference Doses"
- 1999 - *National Academy Press* publishes the National Research Council-Committee on Toxicology report "Health Risk Assessments for Oral Exposure to Six Chemical Warfare Agents", 1999
- Dec 99 - Army evaluates NRC/COT report and addresses recommendations
- Feb 00 - Army finalizes position on CWA RfDs - Memorandum, MCHB-CG-PPM, Feb 16 2000.