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Air Exposure Guidelines for Chemical Warfare Agents

A Brief Review of Occupational Exposure Limits

S.G. Bjarnason

Defence R&D Canada

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Principal Author

Original signed by Stephen Bjarnason

Stephen Bjarnason

Toxicologist

Approved by

Original signed by Dr. T.W. Sawyer

Dr. T.W. Sawyer

Head/Casualty Management Section

Approved for release by

Original signed by Dr. P.A. D'Agostino

Dr. P.A. D'Agostino

Chair/Document Review Panel

Abstract

Chronic exposure guidelines and standards for civilian workers exposed to chemical warfare agents (CWA) have been developed. The Worker Population Limit (WPL) is similar to other occupational guidelines in that it refers to a time-weighted average (TWA) exposure assuming 8 hours/day for 5 days/week while the General Population Limit (GPL) is similar to ambient environmental guidelines (24 hours/day; 7 days/week). In addition, Short-Term Exposure Limits (STEL; 15 minute TWA exposure) have been suggested. The limits that are the most relevant for unprotected workers are the WPL and the STEL.

The specific CWA of interest are those currently used for training purposes (sulphur mustard (HD); sarin (GB); VX). The relevant limits are:

WPL: 4 □ 10^{-4} mg/m^3 for HD; 3 □ 10^{-5} mg/m^3 for GB; 1 □ 10^{-6} mg/m^3 for VX

STEL: 3 □ 10^{-3} mg/m^3 for HD; 1 □ 10^{-4} mg/m^3 for GB; 1 □ 10^{-5} mg/m^3 for VX

The WPL and STEL limits have been developed by the CDC National Institute for Occupational Safety and Health and by the U.S. Army Center for Health Promotion and Preventive Medicine. The evaluation of relevant toxicological studies by panels of experts, in some cases using different risk assessment methodologies, has resulted in a set of exposure limits that represent the best available.

Résumé

Les directives et normes d'exposition concernant les travailleurs civils exposés aux agents de guerre chimiques ont été développées. Les valeurs limites d'exposition professionnelle (VLEP) sont similaires aux directives concernant d'autres occupations en ce qu'elles réfèrent à la moyenne pondérée dans le temps (MPT) de l'exposition, dans l'hypothèse d'une journée de travail de 8 heures, durant une semaine de 5 jours alors que les valeurs limites de la population générale (VLPG) sont similaires à celles des directives environnementales ambiantes, de 24 heures par jour, durant une semaine de 7 jours. Les valeurs limites d'exposition à court terme (VLECT ; 15 min. d'exposition MPT) ont également été suggérées. Les valeurs limites les plus pertinentes au personnel non protégé sont les VLEP et les VLECT.

Les agents de guerre chimiques concernés sont ceux qui sont actuellement utilisés à des fins de formation (le gaz moutarde HD ; le sarin GB ; les VX). Les valeurs limites pertinentes sont :

VLEP : 4 × 10^{-4} mg/m^3 pour HD ; 3 × 10^{-5} mg/m^3 pour GB ; 1 × 10^{-6} mg/m^3 pour VX

VLECT : 3 × 10^{-3} mg/m^3 pour HD ; 1 × 10^{-4} mg/m^3 pour GB ; 1 × 10^{-5} mg/m^3 pour VX

Les valeurs limites VLEP et VLECT ont été développées par CDC National Institute for Occupational Safety and Health et par le the U.S. Army Center for Health Promotion and Preventive Medicine. L'évaluation d'études toxicologiques pertinentes par des panels d'experts, qui ont dans certains cas utilisé des méthodologies différentes d'évaluation des risques, a résulté en un ensemble des valeurs limites d'exposition des meilleures qui soient.

Executive summary

Air Exposure Guidelines for Chemical Warfare Agents: A Brief Review of Occupational Exposure Limits

Stephen G. Bjarnason; DRDC Suffield TM 2008-061; Defence R&D Canada – Suffield; February 2008.

Background: Exposure to low levels of chemical warfare agents (CWA) may continue when a worker is out of personal protective equipment (PPE) and the area has been declared safe. If the worker spends their working week in this environment, exposures would be repeated and chronic. With the storage of various types of CWA munitions awaiting destruction in the USA, significant effort has been expended developing chronic exposure guidelines to protect the civilian worker. The objective of this review is to briefly examine the current chronic exposure guidelines and the relevance of these criteria for workers who may be exposed to repeated, low levels of CWA at DRDC Suffield.

Results: Airborne Exposure Limits established in 1988 by the Centers for Disease Control (CDC) have been reviewed and updated by several panels of experts. The evaluation of relevant toxicological studies by panels of experts, in some cases using different risk assessment methodologies, has resulted in a set of exposure limits that represent the best available. Of these, the Worker Population Limit (WPL), a time-weighted average exposure over the course of a work week and the Short-Term Exposure Limit (STEL) developed by the Centers for Disease Control (CDC) National Institute for Occupational Safety and Health (NIOSH) and by the U.S. Army Center for Health Promotion and Preventive Medicine (CHPPM) are the most relevant to possible exposure of unprotected personnel at DRDC Suffield.

Significance: Given the current level of knowledge, the adoption of the WPL and STEL by DRDC Suffield would be protective of human health for unprotected workers in a low-level CWA environment.

Future plans: Re-evaluations of the WPLs and STELs by the CDC, NIOSH and CHPPM will be monitored on a regular basis to follow developments and changes to the limits.

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Air Exposure Guidelines for Chemical Warfare Agents: A Brief Review of Occupational Exposure Limits

Stephen G. Bjarnason; DRDC Suffield TM 2008-061; R & D pour la défense Canada – Suffield; Février 2008.

Contexte : L'exposition à de faibles niveaux d'agents de guerre chimiques peut continuer après qu'un travailleur ait été sont équipement de protection personnelle (EPP) et que la zone ait été déclarée sécuritaire. Les expositions sont répétées et chroniques si le travailleur passe sa semaine de travail dans un tel environnement. L'entreposage de types variés de munitions de guerre chimiques devant être détruites, a provoqué un effort important aux É-U, visant à développer des directives de protection du personnel civil contre l'exposition chronique. L'objectif de cette étude est d'examiner brièvement les directives actuelles d'exposition chronique et la pertinence de ces critères au personnel pouvant être exposé à des niveaux faibles mais répétés d'agents de guerre chimiques à RDDC Suffield.

Résultats : Les valeurs limites d'exposition aux aérosols établies en 1988 par les Centers for Disease Control (CDC) ont été réexaminées et révisées par plusieurs panels d'experts. L'évaluation d'études toxicologiques pertinentes par des panels d'experts, qui ont dans certains cas utilisé des méthodologies différentes d'évaluation des risques, a résulté en un ensemble des valeurs limites d'exposition des meilleures qui soient. Parmi ces valeurs, les valeurs limites d'exposition professionnelle (VLEP), une moyenne pondérée dans le temps (MPT) durant le cours d'une semaine de travail et les valeurs limites d'exposition à court terme (VLECT) développées par les the Centers for Disease Control (CDC) National Institute for Occupational Safety et Health (NIOSH) et par le U.S. Army Center for Health Promotion and Preventive Medicine (CHPPM) sont, concernant une exposition possible, les valeurs les plus appropriées aux personnel non protégé de RDDC Suffield.

Portée des résultats : Étant donné le niveau actuel de connaissances, l'adoption des VLEP et MPT par RDDC Suffield protégerait la santé de son personnel non protégé placé dans un milieu ayant des niveaux faibles d'agents de guerre chimiques.

Perspectives d'avenir : Les réévaluations concernant les VLEP et VLECT déterminées par CDC, NIOSH et CHPPM seront surveillées régulièrement pour en suivre le développement et y apporter les changements nécessaires.

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Introduction

Acute exposure to Chemical Warfare Agents (CWA) is prevented through the use of Personal Protective Equipment (PPE) approved for the CWA to which an individual is exposed. However, exposure to low levels of CWA may continue when a worker is out of PPE and the area has been declared safe. If the worker spends their working week in this environment, exposures would be repeated and chronic. With the storage of various types of CWA munitions awaiting destruction in the USA, significant effort has been expended developing chronic exposure guidelines to protect the civilian worker. The re-evaluation of existing guidelines has been primarily carried out by Department of Health and Human Services Centers for Disease Control and Prevention (CDC) with significant review and comment from the United States Army and others.

The objective of this review is to briefly examine the current chronic exposure guidelines and the relevance of these criteria for workers that may be exposed to repeated, low levels of CWA at DRDC Suffield.

Exposure Guidelines

Chronic exposure guidelines for civilian workers are the result of the synthesis of a number of civilian [1–4] and military sources [5, 6] that re-evaluated existing Airborne Exposure Limits (AEL) [7]. New Worker Population Limits (WPL) and General Population Limits (GPL) were proposed and levels have been developed for two other limits; Immediately Dangerous to Life and Health (IDLH) and Short-Term Exposure Limit (STEL).

The general definitions for the different limits is as follows:

WPL: Time-weighted average[1] (TWA) exposure for 8 hours/day, 5 days/week[2].

GPL: TWA exposure for 24 hours/day, 7 days/week, lifetime.

STEL: A 15 minute TWA exposure that should not occur more than 4 times per day with at least 60 minutes between successive exposures.

IDLH: An atmospheric concentration of any toxic, corrosive or asphyxiant substance that poses an immediate threat to life or would cause irreversible or delayed adverse health effects or would interfere with an individual's ability to escape

[1] Time-weighted average is the maximum level or concentration of a pollutant, averaged over a specified period of time, generally 8 hours. Most TWA based limits are not intended for use where exposure will be high for a short period (e.g. one hour) and zero for the remaining period.

[2] The U.S. Army applies a 30-year timeframe to their WPL [8] but the CDC argues against this believing that a 30-year exposure assumption will significantly overestimate potential exposures by one or more orders of magnitude [1].

from a dangerous atmosphere. Usually used as part of respirator selection criteria.

The CDC National Institute for Occupational Safety and Health (NIOSH) has brought forward interim airborne exposure limits (WPL, GPL, STEL, IDLH) for sulphur mustard (HD) [1] and final recommendations for these same limits for the nerve agents; tabun (GA), sarin (GB), and VX [2]. NIOSH and the U.S. Department of Labor's Occupational Safety and Health Administration (OSHA) have attached the following notice to the limits with respect to respirators [9]:

> "This product is not a standard or regulation, and it has no effect on employers' legal obligations. The guidance is advisory in nature, informational in content, and is intended only as technical assistance to employers in providing a safe and healthful workplace during emergency response operations. This document does not enhance or diminish any existing obligations under the OSH Act. The information in this document is interim guidance only. It is anticipated that NIOSH CBRN approval for all classes of respirators will be available in the near future. This guidance will change at the time NIOSH CBRN certification standards are available for all respirator classes. OSHA also may update this guidance as additional information becomes available in the future."

The U.S. Army Center for Health Promotion and Preventive Medicine (CHPPM) has published summary information on available exposure guidelines for select CWA [8]. The summary document brings together the military and non-military sources already cited [1–6] and also made use of other reputable references [10, 11].

The following table represents summary information from CHPPM [8] for HD, GB and VX. These limits are in agreement with the CDC recommendations [1, 2].

Table 1: Exposure Limits for HD, GB and VX.

Limit	Exposure Scenario	HD (mg/m^3)	GB (mg/m^3)	VX (mg/m^3)
WPL	TWA; 8hr/day; 5 day/week	4×10^{-4}	3×10^{-5}	1×10^{-6}
STEL	15 minutes[1]	3×10^{-3}	1×10^{-4}	1×10^{-5}
GPL	TWA; 24 hr/day; lifetime	2×10^{-5}	1×10^{-6}	6×10^{-7}
IDLH	1 time exposure	0.7	0.1	0.003

1. The recommendations from the CDC differ with respect to HD/VX vs. GB. For HD and VX, the STEL is an exposure not longer than 15 minutes, limited to once per day [1, 2]. For GB, the STEL is an exposure not longer than 15 minutes and should not occur more than four times per day, with at least 60 minutes between successive exposures in this range [2].

In general, the CDC recommends historic monitoring for WPLs and GPLs and near real-time monitoring for STELs and IDLHs [1, 2]. For HD, the CDC recommends either historic or near real-time monitoring for the WPL. Historic monitoring is when the sample is from an extended time period (*e.g.* 8□12 hours) and the results are not known until laboratory analysis is completed after the sampling event.

The limits that are the most relevant for unprotected workers are the WPL and the STEL.

Justification for HD Worker Limits

Non-Carcinogenic Effects Assessment

Worker Population Limits

The 1988 AELs [7] for HD were based on a 1975 study [12] in animals. Using 5 different species of animals, no detectable adverse effects resulted from exposure to 0.001 mg/m^3 HD for 24 hr/day, 5 days/wk for one year. The 1988 AEL was determined by adjusting the exposure from a 24 hr/day to 8 hr/day exposure (0.001 mg/m^3 □ 24/8 = 0.003 mg/m^3). No other adjustment or uncertainty (e.g. animal to human extrapolation) was applied in the determination of this value.

CHPPM [6] re-examined the AELs for HD in 2000. At this time a reference dose (RfD) methodology utilized by the United States Environmental Protection Agency (USEPA) was used to assess the GPL and WPL for HD. In addition, STEL and IDLH values were proposed. A RfD is derived from the following formula:

$$\mathrm{RfD} = \frac{\mathrm{NOAEL_{ADJ}}}{\mathrm{UF_H} \times \mathrm{UF_A} \times \mathrm{UF_L} \times \mathrm{UF_S} \times \mathrm{UF_D} \times \mathrm{MF}} \quad (1)$$

where:

$\mathrm{NOAEL_{ADJ}}$ = No-observed-adverse-effect level, adjusted for daily exposure.

UF = Uncertainty Factor

$\mathrm{UF_H}$ = To account for human variability in response and for possible sensitive human subpopulations, if such factors can not be evaluated from experimental data.

$\mathrm{UF_A}$ = To extrapolate from animal data to humans using the default assumption that humans may be more sensitive than the test species.

$\mathrm{UF_L}$ = To extrapolate from a Lowest-observed-adverse-effect level (LOAEL) to a NOAEL.

UF_S = To extrapolate from a subchronic to chronic exposure under the assumption that the LOAEL and NOAEL will occur at a lower dose with increasing exposure duration.

UF_D = To account for the possibility that the true NOAEL or LOAEL was not identified because the appropriate toxicity test was not conducted.

MF = Modifying factor to adjust for chemical-specific, or study-specific uncertainties not dealt with by the standard uncertainty factors.

(modified in [6] from [13]). The methodology is similar for determining Reference Concentrations (RfC).

CHPPM [6] used human and animal data to examine the AELs for sulphur mustard; the human data from a 1941 study [14] and the animal data from the same 1975 data used by the CDC in 1988 [7]. The study in humans involved one 8 hr exposure per day for three consecutive days to an HD concentration of 0.06 mg/m^3. The reported effects on the eyes were "scarcely discernable" and this concentration was adjusted to a 5 day work week and used to calculate a new WPL using formula (1). The new WPL was 4×10^{-4} mg/m^3. This value is the same as that recommended by the CDC in 2004 [1]. The WPL calculated from the 1975 animal data was 3×10^{-4} mg/m^3 for ocular effects and 7×10^{-4} mg/m^3 for pulmonary effects. The uncertainty factors were: 3 to extrapolate from a minimal effect LOAEL to a NOAEL (UF_L); 10 to extrapolate from short-term exposures to long-term exposures (UF_S); and 3 to accommodate for additional uncertainties from using acute exposure data and a small number of subjects. CHPPM concluded the assessment of WPLs for HD by recommending the WPL calculated from human data because it is based on human data [6].

The CDC [1] examined the AELs and the development of WPLs using the USEPA's Categorical Regression (CatReg) method and compared the value from the CatReg method (3×10^{-4} mg/m^3) to that from CHPPM (4×10^{-4} mg/m^3) and the Agency for Toxic Substance and Disease Registry (ATSDR) minimum risk level (MRL) of 7×10^{-4} mg/m^3. CatReg performs a regression analyses on toxicity data after assigning effects to ordinal severity categories (e.g. no effect, severe effect) and associating effects with independent variables corresponding to the exposure conditions (e.g. concentration and duration) [15]. The CDC concluded that the value from CHPPM would be protective for noncarcinogenic effects and recommended the value as the new WPL [1]. The difference between the CatReg derived and the RfD/RfC derived values is a factor of 0.75 which is minimal. Considering the amount of available data and the widespread acceptance of the USEPA RfD/RfC methodology, the CHPPM WPL represents the best available limit and CDC recommended this limit be implemented [1].

Short-Term Exposure Limit

In 1988, the CDC did not propose a STEL for HD [7]. CHPPM [6] used human data from the 1941 study in humans [14] to develop a STEL. Three different approaches were used to generate STELs: minimal LOAEL; time-adjusted LOAEL; and probit and logistics. The minimal LOAEL approach was discarded as the STELs derived exceeded the proposed WPL 8 hr TWA of 4×10^{-4} mg/m^3 when averaged over 8 hours. The STELs derived from the other approaches fell in the range of 3×10^{-3} mg/m^3 and this was recommended by CHPPM as the STEL for HD. The

exposure length typically allowed for a STEL is 15 minutes up to 4 times/day with at least 60 minutes between successive exposures [16]. This exposure length and frequency was recommended by CHPPM as the STEL for HD.

Human experimental data [14] indicates a threshold of approximately 0.1 mg/m^3 for ocular effects regardless of the length of exposure. Using the default UF of 10 that was used for the calculation of the STEL, CHPPM argued that the no-effect level would be estimated to be 0.01 mg/m^3 [6]. The CHPPM recommended STEL of 3×10^{-3} mg/m^3 is below this by a factor of approximately 3. Thus, the CHPPM STEL is well below an exposure level where effects would be expected to be seen in an occupational setting. The CDC received comments to proposed limits [3] and incorporated the recommendations from CHPPM in making an interim recommendation for the STEL for HD of 3×10^{-3} mg/m^3 but limited the exposure to 15 minutes, once per day [1]. No explicit reasoning was given for the change but the inference was made that near-real-time monitoring would alert workers to don protective equipment and the level would meet the long-term goal of keeping the carcinogenicity risk below one in one million.

Carcinogenic Effects Assessment

The 1988 AEL recommended by the CDC [7] did not include an estimate for cancer risk as the data did not permit an estimate of carcinogenic potency or risk with confidence. The carcinogenic potential of HD was assessed by CHPPM in 2000 [6] and discussed further by the CDC in 2004 [1]. The issues that surround the numeric estimates for cancer potency of HD were indicated to stem from experimental data from animal studies. The three large uncertainties stated by the CDC [1] were: only a few experiments were conducted; many were in a mouse strain with a genetic susceptibility to spontaneous pulmonary tumours; and the routes of administration tested and duration of observations were not comparable to the human exposures of concern. The examination by CHPPM [6] was well laid out and consistent with the guidance available from the USEPA's risk assessment guidelines for carcinogens as existed in 1991 and 1996. The risk assessment guidelines were finalized in 2005 [17]. Briefly, a method was used to estimate individual increased lifetime cancer by a procedure that estimates a chemical "Unit Risk" and then multiplies the Unit Risk by the air concentration with adjustments for exposure duration. CHPPM used Unit Risk from three sources because of the limited data available. The unit risk estimates were multiplied by the recommended WPL (4×10^{-4} mg/m^3) and adjusted for standard EPA default assumptions (lifetime exposure frequency; duration of scenario). The range of increased lifetime cancer risk associated with potential chronic exposures to the WPL is from 4.2×10^{-3} to 3.0×10^{-6} (10^{-5} = 1 in 100,000). As a specific example from CHPPM [6], an occupational exposure at the WPL for 8 hr/day, 250 days/yr for 25 yr had a range of estimated individual increased cancer risk from 2.8×10^{-3} to 1.5×10^{-5}. The reason for the range is that CHPPM presented three unit risk estimates based on three different evaluations of HD carcinogenicity data. An acceptable cancer risk in Alberta for a risk assessment to exposure to chemical contaminants is 1×10^{-5} [18]. According to Health Canada [18], cancer risks at this level are deemed to be essentially negligible (*de minimis*). The CDC assessed the data on the carcinogenicity of HD, which is classified by the International Agency for Research on Cancer (IARC) as a *Group 1* carcinogen (carcinogenic to human) [6], and determined that enough uncertainty in the risk assessment regarding cancer potency exists that only interim recommendations could be proposed. More data is required to determine the cancer risk from

exposure to HD but from the data available, the CDC interim WPL is reasonable with respect to an increased risk of cancer.

Justification for GB/VX Worker Limits

In 1988, the CDC proposed AELs for GB and VX but not STELs [7]. While the method for deriving these levels was not explicitly described by the CDC in 1988 it has been reported that the AELs for GB were based on a combination of acute human exposure data and animal pharmacokinetic data while the AELs for VX were based on the estimated relative potency of VX and GB [19].

Worker Population Limits

In 2003, the CDC [2] proposed final limits for GB and VX that were not based on a change in, nor a refined understanding of, demonstrated human toxicity of the substances but rather the changes resulted from updated and minimally modified risk assessment assumptions. For GB, an additional uncertainty factor was added to account for individual variation within the work force and this lowered the 1988 value of 1×10^{-4} mg/m^3 by a factor of 3 to 3×10^{-5} mg/m^3. The altered limit for VX was based on a change in the relative potency (from 10 to 12) compared to GB and the application of a modifying factor of three due to a poor toxicity database. The change in the relative potency between GB and VX was based on a 1971 British study that measured pupil constriction (miosis) in rabbits exposed to VX. As the critical effect of exposure to GB was also miosis, the CDC used this as the health effect for determining the relative potency of VX [2]. This approach, using the relative potency and modifying factor, was the same proposed by the National Advisory Committee for Acute Exposure Guideline Levels (NAC/AEGL) [20]. When the CDC applied the relative potency and modifying factor to the proposed GB limit, the VX WPL was calculated to be 1×10^{-6} mg/m^3 [2]. The calculated values are rounded.

Short-Term Exposure Limits

The final CDC recommendations for STELs for GB and VX were 1×10^{-4} mg/m^3 (not longer than 15 minutes, not more than four times per day, at least 60 minutes between successive exposures) and 1×10^{-5} mg/m^3 (not longer than 15 minutes, not more than once per day) [2]. STELs did not exist in the 1988 limits and for GB, the 2003 STEL is the same as the 1988 WPL. The CDC stated that the 1988 WPL for GB protected humans from toxic effects of this agent and it was technically feasible to monitor this concentration using near-real-time monitoring systems. Using the same relative potency of 12 compared to GB and applying a modifying factor of three for an incomplete data set, CDC calculated the STEL for VX to be 4×10^{-6} mg/m^3 [4]. This was subsequently modified to 1×10^{-5} mg/m^3 (not longer than 15 minutes, not more than once per day) based on the technical capabilities of the air monitoring systems available at the time [2].

Conclusion

The limits or guidelines for CWA that are applicable to unprotected workers at DRDC Suffield are the WPL and the STEL. These represent occupational type limits that are similar to other occupational guidelines using a time weighted average concentration over a normal work week (*cf.* Threshold Limit Value (TLV) to WPL) and also the limit for a short-term exposure to a higher concentration (*i.e.* STEL). The American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values[3] (TLV) are guidelines used by professional industrial hygienists [16]. The values are intended for use only as guidelines or recommendations to assist in the evaluation and control of potential workplace health hazards. Further, these values are not fine lines between safe and dangerous conditions and TLVs are not regulatory or consensus standards and if a TLV is exceeded, a potential hazard from that substance is presumed to exist [16]. The TLV□STEL is the concentration to which it is believed that workers can be exposed continuously for a short period of time without suffering from 1) irritation, 2) chronic or irreversible tissue damage, 3) dose-rate-dependent toxic effects, or 4) narcosis of sufficient degree to increase the likelihood of accidental injury, impaired self-rescue, or materially reduced work efficiency. Thus, the WPL and STEL are guidelines that are comparable to other occupational exposure limits in structure and use.

The CDC clearly stated that there has been no indication that the exposure limits set in 1988 have been less than fully protective of human health [4] and the recommended changes are a result of updated and modified risk assessment assumptions [2]. The WPL and STEL values for CWA that have been recommended are the result of information derived from a limited number of studies and the application of regulatory risk assessment strategies. The lack of a sufficient database in some areas, such as VX toxicity, were recognized and strategies were employed to overcome the lack of data. The methods and strategies used to develop the limits have been reviewed and commented on by several expert panels (civilian and military, government and non-government) and there is acceptance of the recommended CDC limits. The issue of carcinogenicity of HD was raised by the CDC but they deferred recommending the incorporation of a cancer potency factor until better data are available [1]. This is the reason that, the values for HD are interim only, and that the CDC believes that for non-cancer effects, the limits set will protect workers and public health. The limits for HD are close to cancer risk levels that are considered acceptable by regulating bodies such as Health Canada and the Alberta Provincial Government. The CDC limits have been put in place by the U.S. Government to protect public health during the destruction of lethal chemical munitions by the U.S. Department of Defense (DoD). Public law in the U.S. mandated the Department of Health and Human Services review DoD plans for disposal of CWA munitions and make recommendations (*i.e.* develop limits) to protect public health [1, 2].

[3] The ACGIH definition [16] of a Threshold Limit Value □Time-Weighted Average (TLV□TWA) is the TWA concentration for a conventional 8-hour workday and a 40-hour workweek, to which it is believed that nearly all workers may be repeatedly exposed, day after day, for a working lifetime without adverse effect. The ACGIH definition of a Threshold Limit Value - Short-Term Exposure Limit (TLV□STEL) is a 15-minute TWA exposure that should not be exceeded at any time during a workday, even if the 8-hour TWA is within the TLV□TWA.

The WPLs and STELs recommended by the CDC for HD, GB and VX represent the best available exposure limits that would be protective of human health given the toxicological information currently known. As stated by the CDC, there has been no indication that the exposure limits have been less than fully protective of human health. While not developed specifically for workers that may be chronically exposed to low levels of CWA at DRDC Suffield, these limits (WPL and STEL) do represent the best available that will be protective of health for long-term exposure.

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List of Acronyms

ACGIH	American Conference of Governmental Industrial Hygienists
AEL	Airborne Exposure Limit
ATSDR	Agency for Toxic Substance and Disease Registry
CatReg	Categorical Regression
CDC	Centers for Disease Control, U.S. Department of Human and Health Services
CHPPM	U.S. Army Center for Health Promotion and Preventive Medicine
CWA	Chemical Warfare Agent
DND	Department of National Defence
DoD	U.S. Department of Defense
DRDC	Defence Research & Development Canada
DRDKIM	Director Research and Development Knowledge and Information Management
GB	Sarin
GPL	General Population Limit
HD	Sulphur Mustard
IARC	International Agency for Research on Cancer
IDLH	Immediately Dangerous to Life and Health
ITA	Indoor Training Arena
LOAEL	Lowest Observed Adverse Effect Level
MF	Modifying Factor
mg/m^3	Milligrams per cubic metre
MRL	Minimum Risk Level
NIOSH	National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention
NOAEL	No Observed Adverse Effect Level
OSHA	Occupational Safety and Health Administration, U.S. Department of Labor
PPE	Personal Protective Equipment
R&D	Research & Development
RfC	Reference Concentration
RfD	Reference Dose
STEL	Short-Term Exposure Limit

TLV	Threshold Limit Value
TWA	Time-Weighted Average
UF	Uncertainty Factor
USEPA	United States Environmental Protection Agency
WPL	Worker Population Limits

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Chronic exposure guidelines and standards for civilian workers exposed to chemical warfare agents (CWA) have been developed. The Worker Population Limit (WPL) is similar to other occupational guidelines in that it refers to a time-weighted average (TWA) exposure assuming 8 hours/day for 5 days/week while the General Population Limit (GPL) is similar to ambient environmental guidelines (24 hours/day; 7 days/week). In addition, Short-Term Exposure Limits (STEL; 15 minute TWA exposure) have been suggested. The limits that are the most relevant for unprotected workers are the WPL and the STEL.

The specific CWA of interest are those currently used for training purposes (sulphur mustard (HD); sarin (GB); VX). The relevant limits are:

WPL: 4 □10-4 mg/m3 for HD; 3 □10-5 mg/m3 for GB; 1 □10-6 mg/m3 for VX

STEL: 3 □10-3 mg/m3 for HD; 1 □10-4 mg/m3 for GB; 1 □10-5 mg/m3 for VX

The WPL and STEL limits have been developed by the CDC National Institute for Occupational Safety and Health and by the U.S. Army Center for Health Promotion and Preventive Medicine. The evaluation of relevant toxicological studies by panels of experts, in some cases using different risk assessment methodologies, has resulted in a set of exposure limits that represent the best available.

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