Reference Document (RD) 230

Chemical Exposure Guidelines for Deployed Military Personnel

A Companion Document to
USACHPPM Technical Guide (TG) 230
Chemical Exposure Guidelines for
Deployed Military Personnel

Version 1.3 –
Updated May 2003

U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM)

This document provides background information relevant to TG 230. The proponent of the TG and RD 230 is USACHPPM. Due to scientific advances and expanding operational needs, these documents will be updated as necessary; therefore, the user should ensure that he/she has the most updated versions.

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These documents and associated information can also be obtained electronically from the following website:

http://chppm-www.apgea.army.mil/desp/

USACHPPM TG 230/RD 230 Acknowledgements

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SECTION 1 - INTRODUCTION

1.1 PURPOSE OF RD 230

Reference Document (RD) 230 provides additional details associated with the scientific rationale and assumptions behind the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) Technical Guide (TG) 230 Version 1.3 – *Chemical Exposure Guidelines for Deployed Military Personnel* (USACHPPM, 2003). As with TG 230, this RD supercedes pervious versions which corresponded to previous TGs (i.e., TG 230A, *Short-Term Chemical Exposure Guidelines for Deployed Military Personnel* (May 1999) and TG 230B, *Draft Long-Term Exposure Guidelines for Deployed Military Personnel* (May 2000)).

TG 230 itself presents chemical concentration levels for various environmental media (referred to as Military Exposure Guidelines (MEGs)), associated health effects information, and procedural guidance to assist with operational risk management (ORM) of chemical hazards. This includes a qualitative risk assessment ranking tool that parallels existing military doctrine. For a description of the specific scope, limitations, intended audience, MEG values, and application scenarios, refer directly to TG 230.

This RD presents specific notes, equations, and sources from which the MEGs were derived. While many users may not need to be familiar with this level of detail, this RD documents the methods used so that one may clearly follow the approach used to develop or select the MEGs.

1.2 PROJECT BACKGROUND

In 1996, USACHPPM identified a broadening scope of preventive medicine concerns relating to chemical exposures during deployments. USACHPPM established a unique working group to provide the necessary input to this growing issue. This group included toxicologists, environmental health risk assessors, physicians, industrial hygienists, chemists, and environmental engineers. As a military support organization functioning as a technical representative to the Army's Office of the Surgeon General, USACHPPM is closely tied to the military community and field-level activities. In addition, USACHPPM utilized existing relationships with Joint Service related efforts to provide multi-service perspectives when developing the TG 230 (see inside back cover for specific acknowledgements).

By 1997, USACHPPM received funding support from the Army Office of the Surgeon General [for Nuclear, Biological, and Chemical (NBC) issues] to address the gap in Army preventive medicine guidance regarding "chemical" threats. Specifically, the term "chemical hazard" had begun to include not only chemical warfare agents (CWA) but also concerns regarding more common toxic industrial chemicals/materials (sometimes referred to as "TICs" or "TIMs"). The concerns were also expanding to include delayed and prolonged health effects that may not be noticeable or might otherwise not have direct and immediate impacts during the deployment. These expanded concerns have been addressed under a variety of topics to include the concept of "NBC-E", where "E" represented environment, and "low-level" exposures (a particular concern in the traditional CWA arena).

Since then, the Department of Defense (DOD) has continued to place more emphasis on the health of its military personnel during deployments under the concept of Force Health Protection (FHP). The need to identify and consider health risks to military personnel from low-level exposures to radiation or chemicals has been cited by both the scientific community as well as the military (HQDA, 2001; Joint Chiefs of Staff (MCM, 2002); DOD, 1999; IoM, 1999; NRC 1999). In fact, the Department of Defense Instruction (DODI) Number 6055.1, *DOD Safety and Occupational Health (SOH) Program*, August, 1998 (DOD, 1998) now specifies that environmental monitoring and risk assessments for DOD personnel in deployments outside the continental United States (OCONUS) be performed using the military ORM Process. It also specifies that "DOD Components shall develop, publish, and follow special military safety and occupational standards, rules, or regulations" that will be used to accommodate military-unique operations, workplaces, equipment and systems. This requirement allows for implementation of other DODIs such as DODI 6050.5, *DOD Hazard Communication Program*, 1990 (DODI, 1997); and DODI 6490.3 *Implementation and Application of Joint Medical Surveillance for Deployments*, 1997 (DODI, 1997).

During that time, USACHPPM attempted to address these expanding responsibilities by developing standard chemical hazard assessment guidance for deployment scenarios. In May 1999, USACHPPM published TG 230A, *Short-Term Chemical Exposure Guidelines for Deployed Military Personnel*, as its first version of this guidance – at that time only addressing short-term exposure scenarios. Later in June 2000, a final review draft TG 230B, *Long-Term Chemical Exposure Guidelines for Deployed Military Personnel*, addressing long-term (e.g. 1-year) exposure scenarios was released. These documents were to provide the military health personnel with a standard tool from which to perform field expedient chemical hazard assessments and assist with the commander's ORM process in the field.

Since that time, the political situation has continued to evolve. This has resulted in several updated and even new policies and procedures. A listing of the some of the key policies, doctrine, procedures, and guiding principles for the management of chemical hazards are listed below (a more complete summary is provided in the back flap):

- DOD Directive 6490.2 (1997) Joint Medical Surveillance
- DOD Instruction (DODI) 6055.1 (1998) DOD Safety and Occupational Health (SOH) Program
- DODI 6050.5 (1990) DOD Hazard Communication Program
- DODI 6490.3 (1997) Implementation and Application of Joint Medical Surveillance for Deployments
- HQDA Letter 1-01-1 (2001) Force Health Protection (FHP): Occupational and Environmental Health (OEH) Threats
- Office of the Chairman of the Joint Chiefs of Staff, MCM-0006-02, Updated Procedures for Deployment Health Surveillance and Readiness, February 2002
- Field Manual 4-02, Force Health Protection in a Global Environment; February 2003
- Joint Publication 3-0, Doctrine for Joint Operations, September 2001
- Joint Publication 3-11, Joint Doctrine for Operations in Nuclear, Biological, and Chemical (NBC) Environments, 11 July 2000
- Joint Publication 4-02, Doctrine for Health Service Support in Joint Operations, 30 July 2001

- Allied Command Europe (ACE) Directive 80-64, ACE Policy for Defensive Measures Against Toxic Industrial Chemical Hazards During Military Operations, 20 December 1996.
- Standardization Agreement (STANAG) 2500 NATO Handbook On The Medical Aspects Of NBC Defensive Operations AMEDP-6(B),(Feb 1996) (FM 8-9).
- USACHPPM TG 248 (Aug 2001) Guide for Deployed Military Personnel on Health Risk Management
- USACHPPM TG 244, The Medical NBC Battlebook, August 2001.
- National Science and Technology Council / Presidential Review Directive 5. (1998). A National Obligation: Planning for Health Preparedness for and Readjustment of the Military, Veterans, and Their Families after Future Deployments. Office of Science and Technology Policy, Executive Office of the President.
- National Research Council, Strategies to Protect the Health of Deployed U.S. Forces, Analytical Framework for Assessing Risks, 1999. National Academy Press, Washington, D.C.

1.3 GENERAL APPROACH

USACHPPM evaluated several different approaches to derive chemical concentration guidelines for a deployed military population. In conclusion, it was determined that use of existing guidelines and peer-reviewed toxicological estimates would the most prudent (primary) basis for the military guidelines. In some cases, source toxicity data were evaluated; however, no toxicological studies were performed by USACHPPM to specifically provide data for this project. This approach allowed for the broadest array of chemicals to be addressed in a time and cost efficient manner. In addition it ensured that the selection of guidelines was consistent with how other Federal guidelines are developed (e.g., for workers and the general population) and had already gone through scientific peer-review. To this extent, the use of previously peer-reviewed guidelines and estimates provided added quality. In all, this approach was scientifically defensible and was the most timely, monetarily feasible approach to provide guidance for already on-going field assessments.

This approach required a significant amount of media-specific, as well as chemical-specific evaluation and assumptions. These details and the specific methodologies used to derive the MEGs are described in the following sections.

1.4 LIMITATIONS OF GUIDANCE

1.4.1 Professional Judgment/Training Requirements

As discussed in TG 230, the presentation of numerical exposure guidelines does not preclude the requirement for sound professional judgment. The end result is a qualitative descriptor of risk. Users of the guidelines are expected to have a basic understanding of the methods and limitations related to the guidelines and some familiarity with potential exposure routes and toxicological effects associated with environmental exposures. USACHPPM is currently performing and developing training and software (see TG 230 Preface) for military health personnel to better accommodate these needs. Recent (FY00 – FY03) preventive medicine training sessions (6AF5 and 6AF6 courses) at the U.S. Army Medical Department (AMEDD) Center and School has demonstrated that individuals in the preventive medicine field personnel are able to learn the application of the TG 230 tool relatively quickly. Specifically, hypothetical case

studies, in Appendix F of TG 230, demonstrate outcomes consistent with the developers at USACHPPM.

1.4.2 Exposure Conditions

The MEGs were developed using several “representative” exposure conditions. This was necessary to accommodate the breadth of military operations. The exposure scenarios were based on reasonably anticipated deployment conditions/durations. However, there is high probability that the true nature of exposure conditions in actual events will *not* correspond exactly to those assumed in development of the MEGs. The limitations associated with use of these exposure assumptions result in varying degrees of certainty with which the guidelines can be said to be protective. The proper use of the guidance requires individuals to find the “ best fitting” guidelines.

1.4.3 Toxicity Data

These guidelines are prospective and were developed to be protective when applied as intended. These guidelines were developed using specific assumptions and are generally based on upper confidence limits of the data and include uncertainty factors (UFs). While exposures below the MEGs (for individual chemicals) would not be expected to result in the specified health effects associated with the chemical, exposures above these levels *may or may not* result in said health effects. The inability to attribute health effects to exposures above these guidelines underscores the fact that these guidelines should not be used for the retrospective assessment of health effects and can not be used to calculate or determine specific numbers of casualties.

1.4.4 Population Assumptions

The MEGs are based on the general assumption that deployed military populations consist of relatively healthy and fit male and non-pregnant female adults. Deployed military personnel are assumed to be 18 to 55 years of age, with an average weight of approximately 70 kilograms (kg) (i.e., approximately 154 pounds). In certain instances, however, the MEGs incorporate an additional level of safety to protect an identifiable sensitive subpopulation that could be anticipated in the deployed military population. While a common assumption is that military personnel will have no predisposing physical or mental factors that could exacerbate exposure to environmental chemicals, such as assumption does not appear to be entirely supported through scientific evidence. While there are basic health and fitness requirements that must be met and maintained by military personnel, an assessment of factors that can lead to chemical specific susceptibilities suggests that many of the predisposing factors such as illness (e.g. asthma), physical and emotional stressors, and life-style choices (e.g., smoking or alcohol use), and genetic traits, exist within the deployed military population (which includes active duty, reserve, and National Guard personnel). For example, the nerve agent guidelines were calculated to address the greater sensitivity of individuals that are genetically predisposed to anti-cholinesterase depression. Even though this represents a minority of the U.S. population, it is not a condition that military personnel are screened for. A specific assessment of this issue is contained in the USACHPPM White Paper entitled *The Role of Susceptibility in Establishing Exposure Standards for Deployed Troops*, C. Weese, MD, November 2001 (see Appendix F of this RD).

Despite the fact that policies dictate that pregnant women will not deploy, it is possible that a woman may not know of her pregnancy until after being placed on deployment status. Since developmental effects are of greatest concern during the first trimester,

when data on developmental (fetal) toxicity and reproductive effects were available, these endpoints were also considered and used in developing these guidelines. However, such data are not available for many chemicals.

1.4.5 Multiple Exposures/Stressors

The MEGs do not consider exposures to multiple chemicals or other non-chemical stressors such as heat stress. The toxicity of a chemical may be increased or decreased by simultaneous or consecutive exposure to another chemical or multiple chemicals, particularly those that affect the same target organ or that alter the pharmacokinetics of one or more chemicals. These issues are not typically addressed by existing federal standards and guidelines. It is noted that the Occupational Health and Safety Administration (OSHA) (29 Code of Federal Regulations (CFR) 1910.1000(d)(2)(i).) does provide a specific algorithm to address exposure to multiple chemicals. However, this quantified approach is not well-suited to the overall qualitative/ranking nature of the TG 230 deployment risk assessment approach.

Therefore, while these issues are not quantitatively addressed by the MEGs themselves, or the specific procedural guidance, the TG 230 provides a general approach to address the potential for additive or even synergistic reactions when there are multiple chemical hazards present. This concept is exemplified through various Hypothetical Case Studies in Appendix F in TG 230 so the user does not ignore these complicating factors. Consideration of other external risk factors (i.e., heavy exercise, physical stresses) are also qualitatively addressed for specific chemicals.

1.4.6 Chemicals Not Listed in TG 230

The list of chemicals addressed by TG 230 is not all inclusive of every chemical to which deployed personnel may be exposed. However, a variety of sources were used to prioritize the chemicals initially addressed by TG 230. TG 230 is a *living* document that will have a growing list of chemicals and MEGs added over time. Users are directed to USACHPPM to obtain MEGs for newly identified chemical hazards. Alternatively, users may choose to research the chemicals themselves (website sources are cited), or address the unavailability of a MEG through added uncertainties in their qualitative assessment.

Some chemical data received from routine laboratory analysis will include certain chemicals/ constituents/compounds that can be readily identified as “non-hazards”. These are primarily identified in soil or water analysis and include essential nutrients, minerals, and related compounds. They are found commonly in nature and are considered, at least at some level, beneficial or even necessary to the proper functioning of the human body. Section 3.4.1.3 describes the basis for determining such constituents in soil as “non-hazards”. Drinking water analysis also often includes constituents that may not cause toxic effects, but which may aesthetically (e.g., color, taste, odor) make the water less palatable. This could lead to reduced consumption that could in turn result in indirect health impacts from dehydration. To ensure the user considers these factors, guidelines and standards (per Technical Bulletin, Medical (TB MED) 577) are specifically identified in TG 230 (Section 1.4.4.1).

SECTION 2 – GUIDELINES FOR SHORT-TERM EXPOSURES

2.1 GENERAL ASSUMPTIONS

2.1.1 Exposure Scenarios

Though deployments tend to span several weeks or months, there are occasions where specific operations will present unique chemical exposure hazards. Although not prolonged exposures, they may last from hours to several days. These exposures could result in significant and immediate impacts to personnel and the mission. Therefore, short-term MEGs have been provided to address these more immediate, acute exposure scenarios. Short-term MEGs should be used in the context of longer deployments (e.g. 1 year) should circumstances define a unique exposure setting of less than 14 days. If multiple short-term exposure scenarios occur consecutively, users should use long-term MEGs. Intermittent short-term exposures may require comparison to both long-term and short-term MEGs. Table RD 2-1 summarizes the durations addressed by short-term MEGs for each environmental media.

Table RD 2-1. Types of Short-term MEGs

<table>
<tr><th rowspan="2"></th><th colspan="6">ENVIRONMENTAL MEDIA</th></tr>
<tr><th colspan="4">Air</th><th colspan="2">Drinking Water</th><th>Soil</th></tr>
<tr><td rowspan="6">MEG Duration and Severity</td><td>1 hour</td><td>Minimal - no effect</td><td>Significant effect</td><td>Severe effect</td><td colspan="2">---</td><td rowspan="6">NONE – not considered to be a notable short-term hazard</td></tr>
<tr><td>8 hour</td><td colspan="3">Minimal - no effect</td><td colspan="2">---</td></tr>
<tr><td>24* hour</td><td colspan="3">Minimal - no effect</td><td colspan="2">---</td></tr>
<tr><td>5 day</td><td colspan="3">---</td><td>5 L/day mild-no effects</td><td>15 L/day mild-no effects</td></tr>
<tr><td>14 day</td><td colspan="3">Minimal - no effect</td><td colspan="2"></td></tr>
</table>

* Only for specific constituents e.g., CWAs and national air criteria pollutants.

2.1.2 Population Assumptions

See Section 1.4.4.

2.1.3 Health Effects and Endpoints

Unlike the long-term MEGs, which are designed to represent a “no effect” level and/or “no significant excess cancer risk”, the short-term MEGs are based on more varied endpoints. Most of the short-term MEGs are designed to represent a minimal to no effect level (see Table RD 2-1). While the process for deriving long-term MEGs tends to incorporate standard extrapolation and factors for uncertainty, the sources used to establish short-term MEGs tend to be based on a more varied interpretation of threshold effects and the degree with which to address uncertainty. Therefore, we acknowledge

the possibility of some mild effects in small portions of the population. In addition, since there is little scientific evidence to prove otherwise, it is generally assumed that short-term exposures that do not result in immediate health effect will not result in long-term health effects. Some of the short-term values have been specifically assessed to ensure that they do not pose significant (greater than 10^{-4}) excess cancer risk (see Sections 2.2.1.2 and 3.1.5). Other, more significant health effects are also represented by a range of 1-hour Air-MEGs. The basis and details for these MEGs are described further in this section.

2.2 AIR HAZARDS – Selection of Chemicals and Guidelines in TG 230 Tables C-1 and C-2, Short-Term Air-MEGs

A list of substances to which deployed military personnel may be exposed was taken from the International Task Force (ITF-25) report of Stuempfle et al. (1998). Chemicals were ranked according to the likelihood of airborne exposures and relative toxicity. Based on continental distribution, physical properties (e.g., vapor pressure) and relative acute toxicity, these substances were categorized into groups of high, medium, and low risk. Additional substances have been added to the air list include CWAs, smokes and obscurants, riot control agents, and some pesticides. It is noted that there is an ongoing ITF initiative (ITF-40) that is re-evaluating the original ITF-25 prioritization list. It is already clear that there will be some additional high-concern constituents identified. As these, and additional, chemical constituents that are not listed are identified, USACHPPM will continue to develop MEGs. A variety of sources were used to identify the actual guidelines for the chemicals. These are described below. Substances for which existing values were not available were excluded from the tables.

2.2.1 1-hour Air-MEGs

2.2.1.1 Health Effect Levels

The 1-hour Air-MEGs were developed to delineate three major levels of health effects: minimum, significant, and severe. These guidelines are defined as follows:

- 1-hour Minimal Effects Air-MEG: The airborne concentration above which continuous exposure for 1 hour could begin to produce mild, non-disabling, transient, reversible effects, if any. Such effects should not impair performance. Increasing concentration and/or duration could result in performance degradation, especially for tasks requiring extreme mental/visual acuity or physical dexterity/strength.

- 1-hour Significant Effects Air-MEG: The airborne concentration above which continuous exposure for 1 hour could begin to produce irreversible, permanent, or serious health effects that may result in performance degradation and incapacitate a small portion of individuals. Increasing concentrations and/or duration of exposure will increase incidence and severity of effects.

- 1-hour Severe Effects Air-MEG: The airborne concentration above which continuous exposure for 1 hour could begin to produce life-threatening or lethal effects in a small portion of individuals. Increasing concentrations and/or duration of exposure will increase incidence of lethality and severity of non-lethal severe effects.

2.2.1.2 Hierarchy of Sources

The 1-hour Air-MEGs were selected from a hierarchy based on evaluation of existing values. The hierarchy and their sources are presented below.

1. AEGLs Levels 1-3 – USEPA
2. ERPGs Levels 1-3 – AIHA
3. TEELs – DOE
4. Other Sources

Each source listed above established values for a specific application. Two criteria were used in determining the priority for use as a MEG: 1) the rigor and quality of the scientific review, and 2) the appropriateness of the intended values with the military application outlined in this document. Descriptions of each guideline listed in the hierarchy are provided below.

Acute Exposure Guideline Levels (AEGLs)

The AEGLs are developed by U.S. Environmental Protection Agency (USEPA) and represent threshold exposure limits for the general public and are applicable to a range of emergency exposure periods. These values are intended to protect the general public, and include consideration of sensitive and susceptible individuals, including sensitive sub-populations but not hypersensitive or hyper-susceptible individuals (NRC 2000). AEGLs are derived for 10-minute, 30-minute, 1-hour, 4-hour, and 8-hour exposures. There are three health effect levels as defined below.

- AEGL-1: The airborne concentration of a substance at or above which it is predicted that the general population, including "susceptible" individuals, could experience notable discomfort, irritation, or certain asymptomatic, non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.

- AEGL-2: The airborne concentration of a substance above which it is predicted that the general population, including "susceptible" individuals, could experience irreversible or other serious, long-lasting health effects or impaired ability to escape.

- AEGL-3: The airborne concentration of a substance at or above which it is predicted that the general population including "susceptible" individuals could experience life-threatening health effects or death.

The AEGL values are protective of susceptible individuals and are derived using a weight-of-evidence (WOE) method that commands a high degree of review. In addition, all AEGL Level 1 and 2 chemicals are evaluated to ensure that they do not pose an excess cancer risk greater than 1×10^{-4} (see Section 3.1.5, Carcinogenicity). Since these values are extensively peer reviewed final, interim, and proposed AEGLs published in the U.S. Federal Registry were selected first when available.

Emergency Response Planning Guidelines (ERPGs)

ERPGs, developed by the American Industrial Hygiene Association (AIHA 2002,

2003), are intended for emergency planning and response operations. They are based on a WOE evaluation and are reviewed at regular intervals as new information becomes available. Definitions of the three levels of ERPG values are as follows:

- ERPG-1: The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing more than mild, transient adverse health effects or without perceiving a clearly defined objectionable odor.

- ERPG-2: The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair an individual's ability to take protective action.

- ERPG-3: The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.

The ERPGs are intended to protect most individuals in the general population but not particularly sensitive individuals (AIHA 2002). All populations have hyper-sensitive individuals who will show adverse effects at concentrations below these guidelines. For the development of the MEGs, ERPG values were applied to a typical deployment population. ERPGs were next in the hierarchy and used if an AEGL was not available.

Temporary Emergency Exposure Limits (TEELs)

The Department of Energy (DOE) Subcommittee on Consequence Assessment and Protective Actions (SCAPA) has published TEELs for about 680 chemicals (Craig et al., 1995, 1998). They are based on the same levels set forth by the AIHA and are designed to be interim ERPGs until final ERPG values can be established. TEELs are based on the correlation between acute data [e.g., lethal concentration, 50% (LC_{50}), lowest lethal concentration (LC_{LO}), etc.] and existing values [e.g., Immediately Dangerous to Life and Health (IDLH)], Short-Term Exposure Limits (STELs), Threshold Limit Values (TLVs®) [TLV] and the various levels of existing ERPGs. Therefore, TEELs were used when ERPGs or AEGLs were not available.

Other Sources

- *Emergency Exposure Guidance Levels (EEGLs)* – The National Research Council (NRC)/ Committee on Toxicology (COT) (NRC, 1986 a, b) has developed EEGLs for emergency situations for deployed military personnel. 1-hour and 24-hour EEGLs have been derived for many substances. The NRC/COT defines EEGLs as:

  "A concentration of a substance in air that may be judged by DOD to be acceptable for the performance of specific tasks during rare emergency conditions."

[TLV] TLV® is a registered trademark of the American Conference of Governmental Industrial Hygienists, Cincinnati, OH. Use of this trademarked name does not imply endorsement by the U.S. Army but is intended only to assist identification of a specific product.

The NRC/COT states that the EEGL is a peak level of exposure and should not be considered as "hygienic" or "safe" (NRC 1986a). The EEGLs were developed for rare emergency conditions and, therefore, represent levels that may cause more substantial effects than the primary levels cited by the preceding sources. This level of protection was equivalent to that of ERPG-2 and AEGL-2. It is for these reasons that EEGLs were considered as Level 2 values only when ERPG or AEGL values were not available since the latter are the more recent and considered the most current available toxicological data.

- *Short-term Public Emergency Guidance Levels (SPEGLs*) – SPEGLs are defined as "suitable concentrations for unpredicted, single, short-term, emergency exposure of the general public" (NRC 1986b). Reproduction and developmental endpoints are considered. The SPEGL values were considered equivalent to minimal effect levels. Few SPEGLs applicable for TG 230 were found.

- *IDLH* – The IDLH values are published by the National Institute for Occupational Safety and Health (NIOSH). These represent 30-minute values that allow for a worker to escape injury or irreversible harm in the event of respiratory protection equipment failure. These values were revised in 1994 (NIOSH, 1994). Not all of these values were revised based on new toxicity information. In the 1994 revision, NIOSH made an *a priori* determination not to publish values higher than the existing values. It is for this and other reasons that IDLH values were used only when ERPG-3 or AEGL-3 values were not available. The IDLH values are often equivalent to TEEL-3 values in most instances (Craig et al. 1995).

- TLVs® - *Ceiling* – For certain chemicals, the American Conference of Governmental Hygienists (ACGIH) TLVs® -Ceiling values (concentrations not to be exceeded during the 8-hr workday by workers) were considered (ACGIH 1991,1999).

- *Other values that were available:* OSHA Permissible Exposure Limits (PELs) and NIOSH Recommended Exposure Limits (RELs) were not generally considered appropriate for inclusion as a criteria. However, in certain cases when toxicity information was extremely limited (particularly if they were irritant-type chemical hazards) these values were used as a basis for a minimal to no-effect level short term Air-MEG. The STELs were considered in the derivation of TEELs. However, STELs are presented for comparison purposes.

Therefore, the overall order of priority was: AEGLs > ERPGs > TEELs. The specific derivation including the criteria most important for value determination was evaluated for each substance. Appendix C of this RD includes the Air-MEGs selected, the source, and pertinent notes, to include listing any other guidelines not incorporated into the Air-MEG. Additional discussion on various exceptions to the stated hierarchy are presented below.

Special considerations were made for the specific selection of 1-hour values when conditions warranted (e.g., values based on dated toxicological information or reviews, unequal consideration of circumstances most applicable to military personnel, etc.). Some values were only applicable to a specific level of severity. For example, EEGLs were generally used to represent significant effect levels, and

the SPEGLs were used to represent minimal effect levels, where appropriate. The TLVs® - Ceiling values (ACGIH) were used to represent minimal to significant effect levels considering the criteria and the logic for which they were based. Similarly, IDLH values were used to represent either significant or severe effects 1-hour Air-MEGs, depending on the endpoints of concern, scientific rigor, and comparison to available animal study or human epidemiological data.

In some instances, the 1-hour minimal effect Air-MEGs were *less* than the 8-hr or 14-day Air-MEGs. This occurred when either: 1) there were slight differences in the professional judgment used in the original determination of the original sources values, 2) one of the original source values was derived for detection purposes (e.g., "objectionable" odor), or 3) one of the original source values was based on studies involving sensitive individuals (e.g., asthmatics).

Further exceptions to the hierarchy were made for special chemicals such as lewisite (a CWA) smokes and obscurants (various Army/DOD technical reports; NRC, Committee on Toxicology, *Toxicity of Military Smokes and Obscurants, Vol. 1*, 1997a, etc.) and other situations where the published value was not consistent with the toxicological literature or with the levels set forth in this document. These exceptions are noted and explained in this RD.

2.2.1.3 CWAs

For the CWAs sulfur mustard (agent HD), the G-series nerve agents (agents GA, GB, GD, and GF) and the nerve agent VX, AEGL values are recommended as health decision criteria for deployed personnel. In addition to 1-hour short-term values there are 10-minute, 8-hour and 24 hour values as well. For completeness and to provide command with sufficient information to make well-informed operational decisions, guidelines characterizing all three AEGL levels of health effect are provided, consistent with the Air-MEGs for other toxic chemicals presented in TG 230. It is noted that other sources of CWA toxicity estimates exist but were not used for developing Air-MEGs (NRC, 1997b). These toxicity estimates include values such as LC_{50}, Incapacitating Concentration 50% (IC_{50}), and "Threshold" first-effects levels, and are specifically derived for war-time operations for casualty estimation on a gross scale. The AEGLs documented in this RD are appropriate for military FHP application since they provide federally-endorsed health criteria. Though designed for general population use (applicable to domestic terrorist/accident scenarios); they are not considered over-conservative for military personnel. They do address potential identifiable groups of susceptible sub-populations, but for nerve agents the identified group was individuals with abnormally low cholinesterase activity – which is a genetically based sensitivity and not screened out in the military. Therefore, the military population is similar to the general population for this particular chemical. Likewise, for HD, the key health effect of concern is on the eyes, to which there is considered to be as much human variation/sensitivity among the military population as the general civilian population. Again, the AEGLs, as conservative as some perceive them, are considered applicable to the military population. Please refer to Appendix F for additional information regarding different types of sensitive subpopulations and individual susceptibility to chemical exposures. The bottom line is that variation among the military versus that of the general population is very similar, indicating that overall physical fitness of our deployed military may not make them uniquely able to sustain greater chemical exposures before demonstrating effects.

2.2.1.4 Health Effects Levels and Hazard Severity

The three levels of health effects in TG 230 Table C-2 are consistent with the three categories presented by the AIHA/ERPG values. This provides the user with a range of concentrations from which to assess the severity of the situation. FM 100-14, *Risk Management*, lists four hazard severity levels: (1) negligible, (2) marginal, (3) critical, and (4) catastrophic. TG 230's minimal effect level delineates to FM 100-14's negligible and marginal hazard severity effect levels in which concentrations below the minimal effect levels may be considered safe for most individuals. Individuals exposed to substance concentrations between TG 230's minimal and significant effect levels correspond to FM 100-14's marginal hazard severity effect levels and may be considered to be in the marginal severity category where individuals may experience mild irritation or transient health effects. Individuals exposed to substance concentrations between TG 230's significant effect levels and the severe effect levels may be considered to be in FM 100-14's critical hazard severity effect levels where individuals may experience irreversible health consequences that would impair their ability to take protective action. Likewise, individuals exposed to air concentrations exceeding TG 230's severe effect levels are in the highest risk severity category of FM 100-14's catastrophic risk hazard severity level. Beyond this point, death may occur. Table 3-1, *Chemical Hazard Severity Ranking Chart for Military Deployments*, in TG 230 presents the relationship between health effects level and hazard severity category.

2.2.2 8-hour and 14-day Air-MEGs

2.2.2.1 General

These values were selected for continuous, 8-hour or up to 14-day exposures, consistent with a brief deployment or a brief exposure given specific information regarding source and ambient air dynamics. The potential variation in the properties and circumstances for both exposure and health effects for many substances can be significant in exposures of this duration (e.g., toxicological disposition, mode of action, environmental factors, etc.). The 8-hour and 14-day Air-MEGs represent exposure levels below which no significant adverse health effects are expected and above which the probability of adverse health effects are increased. Delineation of three levels of concern was not possible for exposures up to 14 days. The 8-hour values provide an intermediate guideline for exposure levels between the minimal effects 1-hour Air-MEG and the 14-day Air-MEG. The user is advised to review the 1-hour values to provide information of toxicity relating to concentration for a qualitative understanding of the potential slope of the dose-response curve for applications where concentrations exceed the 14-day values. The 8-hour and 14-day Air-MEGs are defined as follows:

- 8-hour Air-MEG: The airborne concentration above which continuous exposure for 8 hours could begin to produce mild, non-disabling, transient, reversible effects, if any. Such effects should not impair performance. Increasing concentration and/or duration could result in performance degradation, especially for tasks requiring extreme mental/visual acuity or physical dexterity/strength.

- 14-day Air-MEG: The airborne concentration for a continuous exposure for up to 14 days (24 hours/day) that should not impair performance and is considered protective against any significant, non-cancer effects. Increasing concentration

and/or duration could result in performance degradation or increase the potential for inducing delayed/permanent disease (e.g., kidney disease or cancer).

2.2.2.2 8-hour Air-MEG Hierarchy

The hierarchy used for the selection of 8-hour Air-MEGs was as follows:

1. AEGLs Level 1 – USEPA
2. TLVs® – ACGIH

The basis for the 8-hour Air-MEGs was the 8-hour AEGL-1 values for all chemicals when available. The AEGL concept is described in Section 2.1.1.2 in more detail.

The ACGIH has published TLVs® that are health-based and consider the typical working population who is exposed 8 hrs/day, 5 days/week, 50 weeks/year for 30 years. ACGIH cautions against any other use for the TLVs®. These TLVs® are developed by the ACGIH Committee and are reviewed annually. Epidemiological data, as well as toxicological and toxicokinetic data, are used in the derivation of TLVs®. Since occupational exposures can be chronic (i.e. exceeding 7 years), cancer is considered as an endpoint. Also considered is the 2/3 (16-hour) daily break in exposure that may be important in the disposition of substances to which one is exposed in the workplace. Direct use of TLV® values were deemed suitable for 8-hour exposure and were used for 8-hour Air-MEGs for chemicals with no AEGL values. However, these values were not considered protective for continuous exposure over 24 hours to 14 days.

2.2.2.3 14-day Air-MEG Hierarchy

The hierarchy used for the selection of the 14-day Air-MEGs was as follows:

1. CEGLs – NRC/COT
2. MRLs - ATSDR
3. TLVs® – ACGIH
4. Special Considerations

- Continuous Exposure Guidance Levels (CEGLs) – The NRC/COT has developed values for deployed military personnel for continuous exposures/deployments lasting up to 90 days (e.g., as in a submarine) (NRC 1986). In contrast to EEGLs, CEGLs are not for use during emergencies but rather are intended to provide guidance for persistent exposures that should not cause serious or permanent effects. These values, when available, were the first selected for the 14-day Air-MEGs.

- Minimal Risk Levels (MRLs) – The Agency for Toxic Substances and Disease Registry (ATSDR) has developed acute MRLs that are appropriate for continuous exposures from 1 to 14 days (ATSDR 1996, 1997a-e). However, MRLs are derived using the no-observed adverse effect level (NOAEL) concentration and applying Ufs to extrapolate to the general population (including sensitive sub-populations but not hypersensitive individuals). The methodology used is consistent with that used by the USEPA in the development of Reference Doses (RfDs) (USEPA 1989a, 1991b). Since these values are based on a NOAEL, adverse effects may not occur as a result of exposures to concentrations that slightly exceed the MRL. It should be noted that carcinogenic endpoints were not

considered in the development of MRLs. MRLs were used when CEGLs were not available.

- TLVs® – While there are published methods for mathematically extrapolating TLV®s for variations in work schedules (Paustenbach 1994), none were found that addressed continuous (24-hour) exposures. Moreover, the mathematical extrapolation of values that are effects-based (i.e., a derivation of Haber's Law) may not be appropriate for strong irritants nor is this logic necessarily consistent with the determination of TLVs® (i.e., toxicokinetic data are not always available, yet a threshold was determined). Therefore, as an interim measure, the following approach was used for industrial chemicals to determine TLV® -based 14-day values. The critical endpoints used by the ACGIH in deriving TLVs® are paraphrased in Appendix D. Based on the predominant acute toxicological effects, these endpoints were categorized as "irritation-", "systemic-" or "mixed"-acting substances. Adjustments were made to all TLVs® that are systemic (or mixed) acting substances to account for differences in disposition between the 8-hour work schedule and a continuous exposure. TLVs® were adjusted from intermittent to continuous exposure by a factor of 5 days/7days, from the occupational default inhalation rate to ambient default ventilation rate by a factor of 10 m^3/20 m^3 (per day)* and for the military person's increased ventilation rate (relative to the ambient default) by the ratio of 20 m^3/29.2 m^3. A factor of 10 was applied to account for the uncertainty of extrapolating from intermittent to continuous exposure. [*NOTE: The 10 m^3/day inhalation rate represents the entire inhalation exposure volume over a day - which is assumed to be 8 hours for typical workers- to a specified contaminant. Thus, the conversion to a 20 m^3/day rate considers the full continuous 24 hours that a military person may be exposed. As such, no specific 8-hour to 24-hour conversion is necessary.] This is consistent with the logic used by the COT in CEGL extrapolation (NRC 1986). Special consideration was made for chemicals that either have a steep dose response curve with some differences between doses that cause mild and serious effects (e.g., hydrogen cyanide) or for substances that may bioaccumulate given a constant rate of exposure, though it is recognized that ambient concentrations are unlikely to be consistent. It is important to note that uncertainty has been associated with TLV®s and health effects have been noted for some worker exposures at these levels (Roach 1990). Therefore, the extrapolation using UFs is critical for developing adequately protective guidelines for the exposure scenarios presented here. TLVs® for irritants were not adjusted and, as such, were assumed to be mostly concentration-dependent. Other values, when available, are presented in Appendix D for comparison purposes. Other values developed for occupational scenarios are available (e.g., OSHA PELs and NIOSH RELs). Although these values serve regulatory purposes, TLVs® were preferred given the methods used in their derivation, available documentation, and review that they undergo.

2.2.2.4 Summary

In summary, the order of priority for selection of 8-hour Air-MEGs was AEGLs > TLVs®. The hierarchy for the 14-day MEGs was CEGLs > MRLs > TLVs® > Special Considerations. In instances were AEGL-1 values for 8-hour exposures were more conservative than the values chosen through the hierarchy for the 14-day Air-MEGs, the AEGL-1 values were given precedence.

2.2.3 Special Airborne Chemicals and Associated Risks

2.2.3.1 Concentration-Dependent Chemicals

Effects caused by some substances (e.g., irritants) are primarily concentration-dependent and should not be time-weighted-averages (TWAs) for short-term exposures. These substances often have TLV®-Ceiling values. Since TLV® -Ceiling values denote the threshold of irritant effects, they were also considered as minimal effect values for 1-hour exposures. These TLV® -Ceiling values may be presented as 1-hour, 8-hour, and 14-day Air-MEGs where appropriate. It is noted that particularly for concentration-dependent, threshold-effect chemicals, the Air-MEGs are often the same for several duration periods (e.g., 1-hour minimal, 8-hour, and 14-day Air-MEGs).

2.2.3.2 Chemicals Absorbed Through the Skin

Some substances can be appreciably absorbed through the skin. These substances are noted with an "**s**" in the TG 230 air tables. Caution must be exercised when concentrations of these substances approach the Air-MEG since dermal absorption (to include absorption from the air itself) may contribute to the overall systemic dose and, as such, is not accounted for in these values. Specifically, airborne concentrations may be insufficient indicators of exposure because additional amounts of the chemicals can be introduced to the body via the skin.

2.2.3.3 Military-Unique Chemicals

Guidelines for some military-unique chemicals are addressed in TG 230. Specifically, guidelines were derived for CWA and various smokes and obscurants. Existing values for military-unique substances were not available from the sources previously mentioned. However, comparable values were not always available (exception AEGLs for CWA). Instead other military and NRC publications were identified. The COT has reviewed the data for many military-unique substances (NRC 1997a, and NRC 1997b). Values such as SPEGLs and EEGLs were developed by the COT for some smokes and obscurants (NRC 1997a) and were included in TG 230 using the methods described above.

2.2.3.4 CWAs

Values for many CWAs have been under active review for the development of AEGLs. As of March 2003, the AEGL values for sulfur mustard agent and nerve agents (GA, GB, GD, GF, and VX) have been finalized by the NRC/COT, (Subcommittee on Acute Exposure Guideline Levels) and are available through the National Academy Press (NRC, 2003). The USACHPPM has determined that despite other toxicity estimates for CW agents, the AEGLs are appropriate health exposure guidelines for preventive medicine personnel applications (as is consistently being applied for other toxic industrial chemicals). The reasoning is that susceptible individuals for whom the AEGL values are designed to protect are already present in the deployed forces and are not currently being screened. For example – for nerve agents, susceptible individuals include those with genetically based low levels of cholinesterase as well as those with liver dysfunction, or potentially those who are taking certain common prescription drugs.

Analysis of CWA exposure scenarios indicates that is it very unlikely that deployed personnel would experience a continuous nerve agent or vesicant for a time period greater than 24 hours. Thus, there are not Air-MEGs for any time period in excess of 24 hours. For the CWAs sulfur mustard (agent HD), the G-series nerve agents (agents GA, GB, GD, and GF), and the nerve agent VX, the 24-hour estimates are provided in Table RD 2-2.

The estimation of a "24-hour AEGL equivalent" for each of the CWAs identified above assumes linearity of response from 8 hours to 24 hours of agent exposure, and "flat-lines" the cumulative exposure (Ct) estimate from the 8-hour AEGL estimate. Each "24 hour AEGL equivalent" is thus equal to one-third of the 8-hour AEGL estimate (in mg/m^3; conversion to parts per million (ppm) was performed by calculation, and a rounded estimate is presented). This logic is considered more protective and accurate than assuming that the cumulative exposure Ct, can be applied for both 1-hour and 24-hour exposure periods.

The CWA Air-MEGs are presented in Table C-1 in Appendix C.

2.2.4 Ambient Air Quality

2.2.4.1 Criteria Pollutants

The USEPA uses six "criteria pollutants" as indicators of air quality and has established for each a maximum concentration above which adverse heath effects may occur. These threshold concentrations are called the National Ambient Air Quality Standards (NAAQS). The criteria pollutants are ozone (O_3), particulates [particulate matter (PM_{10}) and ($PM_{2.5}$)], carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and lead (Pb). For most of the criteria pollutants, an allowable 24-hour TWA exposure limit was established, although some have only annual averages and O_3 has 1- and 8-hour standards. Measured concentrations of the various pollutants can be compared to their respective threshold. This generates a descriptive category of air quality called the Pollution Standard Index (PSI). Once the PSI is determined, precautionary statements regarding health effects can be made.

Currently, some sampling efforts during deployments effectively monitor selected criteria pollutants. The following information was considered in preparing guidance on how to evaluate such data and the associated hazards. This information and information from the USEPA (USEPA 1998b, 1999b,c) were summarized in Section 2.2 of the TG 230.

- **O_3 –** O_3 is a photochemical oxidant and the major component of smog. While O_3 in the upper atmosphere is beneficial to life by shielding the earth from harmful ultraviolet radiation from the sun, high concentrations of O_3 at ground level are a major health and environmental concern. O_3 is not emitted directly in the air but is formed through complex chemical reactions between precursor emissions of volatile organic chemicals (VOCs) and oxides of nitrogen (NOx) in the presence of sunlight. Sunlight and temperature stimulate these reactions so that peak O_3 levels occur typically during the warmer times of the year. Transportation and industrial sources emit both VOCs and NOx. VOCs are emitted from sources as diverse as automobiles, chemical manufacturing, dry cleaners, paint shops, and other sources using solvents. The reactivity of O_3 causes health problems

because it damages lung tissue, reduces lung function, and sensitizes the lung to other irritants. Scientific evidence indicates that ambient levels of O_3 not only affect people with impaired respiratory systems such as asthmatics but healthy adults and children as well. Exposure to O_3 for several hours at relatively low concentrations has been found to significantly reduce lung function and induce respiratory inflammation in normal healthy people during exercise. Symptoms including chest pain, coughing, sneezing, and pulmonary congestion generally accompany this decrease in lung function. For this reason, in the past the USEPA has set O_3 standards for 1-hour and 8-hour intervals. The USEPA is transitioning to a more conservative 8-hour standard and revoking the 1-hour standard in those areas of the U.S. which are currently in attainment.

- **PM –** Air pollutants called PM include dust, dirt, soot, smoke, and liquid droplets directly emitted into the air by sources such as factories, power plants, cars, construction activity, fires, and natural windblown dust. Particles formed in the atmosphere by condensation or the transformation of emitted gases such as SO_2 and VOCs are also considered PM.

  Based on studies of human populations exposed to high concentrations of particles and laboratory studies of animals and humans, there are major health effects of concern. These include effects on breathing and respiratory symptoms, aggravation of existing respiratory and cardiovascular disease, alterations in the body's defense systems against foreign materials, damage to lung tissue, carcinogenesis, and premature death. The major subgroups of the population that appear to be the most sensitive to the effects of PM include individuals with chronic obstructive pulmonary disease or cardiovascular disease, influenza and asthmatics, the elderly, and children.

  Annual and 24-hour NAAQS for PM were first set in 1971. Total suspended particulate (TSP) was the first indicator used to represent suspended particulates. However, since July 1987 the USEPA has used the indicator PM_{10} that includes only those particles with an aerodynamic diameter smaller than 10 microns. These particles are small enough to reach the thoracic or lower regions of the respiratory tract. Currently, the USEPA has transitioned into the use of $PM_{2.5}$ as research has supported that particles in this size range are responsible for most of the adverse health effects due to penetration into the lower regions of the respiratory tract.

  Annual and 24-hour NAAQS are available for both PM_{10} and $PM_{2.5}$. An assessment of either level can be used to categorize air quality and define the PSI. It is important to note that particulates measured for ambient air quality are considered "generic" particles in that the concentration of particles is measured, but no assessment of source or composition is made. In sandy environments with high wind, particulate levels will reflect airborne sand particles, while in other settings, particulate levels might be more influenced by industrial emissions. It is also important to note that for various, specific industrial processes which generate particles, specific health-based standards may exist reflecting knowledge of the health effects of specific particles.

- **CO –** CO is a colorless, odorless, and poisonous gas produced by incomplete burning of carbon in fuels. When CO enters the bloodstream, it reduces the delivery of oxygen to the body's organs and tissues. Health threats are most serious for those who suffer from cardiovascular disease, particularly those with

angina or peripheral vascular disease. Exposure to elevated CO levels can cause impairment of visual perception, manual dexterity, learning ability, and the performance of complex tasks. Other major CO sources are wood-burning stoves, incinerators, and industrial sources. The CO standard is an 8-hour standard.

- **SO_2 –** High concentrations of SO_2 affect breathing and may aggravate existing respiratory and cardiovascular disease. Sensitive populations include asthmatics, individuals with bronchitis or emphysema, children, and the elderly. SO_2 is also a primary contributor to acid deposition or acid rain which causes acidification of lakes and streams and can damage trees, crops, and buildings. In addition, sulfur compounds in the air contribute to visibility impairment. Ambient SO_2 results largely from stationary sources such as coal and oil combustion, steel mills, refineries, pulp and paper mills and from nonferrous smelters.

  There are two health-based NAAQS for SO_2. The first is an annual arithmetic mean of 0.03 ppm [80 micrograms per cubic meter ($\mu g/m^3$)]; the 24-hour level is 0.14 ppm (365 $\mu g/m^3$).

- **NO_2 –** NO_2 is a brownish, highly reactive gas that is present in all urban atmospheres. NO_2 can irritate the lungs, cause bronchitis and pneumonia, and lower resistance to respiratory infections. NO_x are an important precursor both to O_3 and acid rain and may affect both terrestrial and aquatic ecosystems. The major mechanism for the formation of NO_2 in the atmosphere is the oxidation of the primary air pollutant NO_2. NO_x, together with VOCs, play a major role in the atmospheric reactions that produce O_3. NO_x form when fuel is burned at high temperatures. The two major emission sources are transportation and stationary fuel combustion sources such as electric utility and industrial boilers. The NAAQS for NO_2 is an annual average. NO_2 can generate a PSI only if measured at levels above 0.65 ppm. A PSI over 200 ppm reflects a very unhealthy category.

2.3 DRINKING WATER HAZARDS – Selection of Chemicals and Guidelines in TG 230 Table D-1, Short-Term Water-MEGS

The chemicals included in Appendix D, Table D-1 of TG 230 were primarily taken from two sources: USEPA Drinking Water Regulations and Health Advisories (HAs) (1996), and DOD TB MED 577 (1996). All the compounds with short-term water standards in TB MED 577 were included in the list as were all the compounds with short-term Health Advisories in the USEPA document. [Note that compounds for which the USEPA has developed Maximum Contaminant Levels (MCLs) but not Health Advisories do not appear in the TG]. Seven compounds were included in Appendix D of TG 230 that were considered to be medium or high priority (Stuempfle et al. 1998). Guidelines for compounds selected from the ITF-25 list that did not have USEPA HAs or TB MED 577 standards were derived from the ATSDR acute oral MRLs.

2.3.1 Prioritization of Chemicals

Chemicals in Appendix D of TG 230 were categorized according to the likelihood of being encountered during deployments. Several sources were used for the

categorization. Sources were investigated which provided prevalence of chemicals in industrial effluents (the USEPA Toxic Release Inventory (TRI)) and in effluents from superfund sites (ATSDR). Pesticides used internationally were identified using sources such as the World Health Organization (WHO) and other United Nations agencies. ITF-25 list was used to identify widely used industrial chemicals.

Compounds identified in the Table in Appendix D of this RD were divided into four categories based on these findings: High Priority, Medium Priority, Low Priority, and Unknown. While prevalence was the major factor used in prioritizing compounds, some weight was given to the toxicity of the compounds. For example, the 5-day or 2-week Water-MEGs that were less than 1 milligram per liter (mg/L) were considered High Priority compounds. Additionally, with the exception of BZ and T-2 toxin, which were not believed to be a substantial threat, all of the compounds with standards in TB MED 577 were ranked as High Priority. High Priority chemicals will vary from area to area depending on the prevalent industries and/or farm crops. Munitions and their by-products were ranked as Medium Priority because, for the most part, exposure to substantial levels of these compounds in water is likely to be confined to the environment surrounding munitions plants.

Compounds placed in the Unknown category were not identified as prevalent compounds in any of the sources used. This does not necessarily reflect the probability of their being encountered in water. For example, there are some pesticides and industrial compounds in this category that are widely used in the U.S. and are likely to be used in industrial and agricultural practices in other areas.

2.3.2 Derivation of Short-Term Water-MEGs

2.3.2.1 General

The 5-day and 14-day Water-MEGs were developed from a selected a hierarchy and evaluation of existing values as described below. The resulting Water-MEGs are defined as follows:

- 5-day Water-MEGs: The drinking water concentration for a continuous daily consumption of either 5 L/day or 15 L/day for up to 5 days that should not impair performance and is considered protective against any significant non-cancer effects. Increasing concentration and/or duration could result in performance degradation, need for medical intervention, or increase the potential for delayed/permanent disease (e.g., kidney disease or cancer).

- 14-day Water-MEGs: The drinking water concentration for a continuous daily consumption of either 5 L/day or 15 L/day for up 14 days that should not impair performance and is considered protective against any significant non-cancer effects. Increasing concentration and/or duration could result in performance degradation, need for medical intervention, or increase the potential for delayed/permanent disease (e.g., kidney disease or cancer).

2.3.2.2 Hierarchy of Sources

Several different guidelines were used as sources for the short-term Water-MEGs. The general hierarchy was as follows:

1. TB MED 577 standards – Department of the Army

2. HAs – USEPA
3. MRLs – ATSDR
4. Other – Unique chemical concerns

Only a few of the MEGs were taken from standards published in TB MED 577. No adjustments were required for these standards, and they were adopted unmodified. For short-term standards, these included six chemicals (arsenic, cyanide, chloride, lindane, magnesium and sulfate) as well as five types of CWAs (sulfur mustard, lewisite, nerve agents, BZ, and T02 toxins). In TG 230, the nerve agents were listed by specific agent (GA, GB, GD, GF, and VX).

The majority of the Water-MEGs were derived from the USEPA 1-day and 10-day HAs. The USEPA derives HAs by dividing the NOAEL [or the lowest-observed adverse effect level (LOAEL) when a NOAEL is not available] from an appropriate human or animal study by standard National Academy of Science (NAS)/Office of Drinking Water UFs and multiplying by body weight over the daily drinking water consumption rate [NOAEL/UF x kg body weight (BW)/L consumed]. The short-term USEPA Health Advisories were derived for a 10 kg child consuming 1 L/day. The Water-MEGs were derived using the same NOAEL and UFs used by the USEPA and a body weight of 70 kg with consumption rates of 5 L/day or 15 L/day. Note that the original source documents for the USEPA HAs were used rather than values in Drinking Water Standards and HAs table because the latter values have been rounded up or down.

A few Water-MEGs were derived from ATSDR acute oral MRLs (see Appendix E). These were adjusted for daily consumption rates in a similar fashion.

One additional chemical was added to the list using yet a separate criteria not listed in the hierarchy. A category of “lead compounds” was added to address the common findings of some level of detected “total lead” in various drinking water sources. Three existing drinking water criterion were identified: the WHO guideline of 0.05 mg/L, USEPA’s MCL of 0.015 mg/L; and the U.S. bottled water criteria standard of 0.005 mg/L established in 21 CFR, Bottled Water Quality Standards, 1 April 1996. The basis for each of these values considered toxicity to children and developing fetuses. In addition, they consider long-term (chronic) exposure (consumption). However, as previously noted, military personnel are believed to consume substantial greater volumes than the 2 L/day assumption used in the derivation of these general population values. While there is limited acute lead toxicity data for adults, a Water-MEG for both short-term (2-weeks) and long-term (1 year) exposure scenarios is necessary. The proposed Water-MEG is based on the WHO 0.05 mg/L as the short-term criteria. These are considered conservative values for military applications, and may be adjusted in the future. Long-term consumption and bottled water guidance is discussed in Section 3.3.5.2.

2.3.3 The Military Adjustment Factor (MAF)

2.3.3.1 Background

The USEPA HAs were developed to protect the civilian population and incorporated UFs of ten to protect the more sensitive constituents (e.g., children, the elderly, and the infirm) of the civilian population. While we had initially considered applying a MAF of ten to the USEPA HAs to account for the more homogeneous population represented by deployed military personnel, USACHPPM decided to use a more

conservative approach in adapting the Health Advisories to guidelines for the military population. Thus, the MAF was limited to three and was only applied in cases where it could be solidly justified. The rationale for using an MAF for each of the compounds to which it has been applied is discussed below.

2.3.3.2 MAF Applications

Examples of when a MAF may (or may not) be applied are as follows:

- A MAF may be used when the USEPA HA was derived from a NOAEL and the effects at the LOAEL are minimal.

- A MAF may be applied to reproductive and developmental toxicants if doing so would not introduce a risk to the developing fetus or to fertility (e.g., if developmental effects are observed only at doses toxic to the dam or at doses higher than the LOAEL of the critical study).

- A MAF may be applied if short-term HAs were derived from minor effects observed at the LOAEL in subchronic and chronic studies.

- An MAF will not be applied to TB MED 577 standards, carcinogens, CWAs, or compounds with steep dose/response curves.

- Ammonium Sulfamate: A MAF is recommended for ammonium sulfamate because the short-term HA was based on a 90-day rat study in which only minimal effects were observed at the LOAEL (500 mg/kg/day). The only significant effect observed at the LOAEL was weight loss with no changes in organ to body weight ratios (Slight fatty degeneration of the liver was observed in one rat at the LOAEL).

  Supporting data –Two other oral rat studies showed no effects at doses equal to or greater than the LOAEL of the critical study. (In the first study, no effects were seen at 500 mg/kg/day after 19 months of exposure; in the second study, no effects were seen after 105 days of exposure to 10 g/kg/day).

  No data were available for mutagenicity, carcinogenicity, or developmental or reproductive effects.

  A MAF of three was applied to the short-term Health Advisories for ammonium sulfamate because the short-term Health Advisory was based on a 90-day rat feeding study in which only mild effects were observed at the LOAEL.

  The 1-day and 10-day Health Advisories of 75 mg/L were adjusted to 50 and 15 L consumption rates to yield Water-MEGs of 30 and 10, respectively. The values were then multiplied by the MAF of three to produce final values of 90 and 30 mg/L for 5 and 15 L consumption rates, respectively. MAFs were applied in the same fashion to the HAs for other chemicals discussed below.

- Hexazinone: A MAF was applied because the short-term HA was based on a 90-day rat feeding study in which only mild effects were observed at the LOAEL.

  - NOAEL = 25 mg/kg/day
  - LOAEL = 125 mg/kg/day

Effects observed at the LOAEL: Weight loss, slightly elevated liver weight, increased alkaline phosphatase, decreased albumin/globulin ratio.

Supporting data – A NOAEL of 375 mg/kg/day was identified in an 8-week rat study (increased absolute and relative liver weights were the only effects observed at the LOAEL of 1500 mg/kg/day).

- Developmental effects (rat): NOAEL = 50 mg/kg/day; LOAEL = 250 mg/kg/day (effects observed: lower pup weight, no malformations).
- Developmental effects (rabbit): NOAEL (highest dose tested) = 125 mg/kg/day.

➢ Diisopropyl methylphosphonate (DIMP)**:** The longer-term (1-year) HA for a 10 kg child was used by the USEPA for the 1-day and 10-day HAs. The critical study was a 90-day feeding study in dogs at doses of 0, 150, 1500, or 3000 ppm DIMP in the diet (equivalent to 0, 3.75, 37.5, or 75 mg/kg/day). No effects were seen at the highest dose (75 mg/kg/day), which was considered to be the NOAEL.

Supporting data – NOAELs of 150 and 315 mg/kg/day, the highest doses tested, were observed in 90-day feeding studies conducted in rats and mice, respectively.

A NOAEL of 135 mg/kg/day (highest dose tested) was observed in a three-generation rat feeding study.

No developmental effects were observed in offspring of rats fed 0, 5, 15, or 150 mg/kg/day on days six through fifteen of gestation.

An MAF of three was applied to account for the shorter exposure duration associated with the Water-MEG. Even with this MAF, the Water-MEG for DIMP is highly conservative.

➢ Isopropyl methylphosphonate (IMP): The longer-term (1-year) HA for a 10 kg child was used for the 1-day and 10-day HAs. The critical study was a 90-day rat-drinking water study at doses of 300, 1000, or 3000 ppm IMP in water. No effects were seen at the highest dose (3,000 ppm), which was considered to be the NOAEL.

An MAF of three was applied to account for the shorter exposure duration associated with the short-term water MEG.

No data were available for carcinogenicity or developmental or reproductive effects. Mutagenicity assays have been negative.

SECTION 3 – GUIDELINES FOR LONG-TERM EXPOSURES

3.1 GENERAL EXPOSURE ASSUMPTIONS

The following sections describe the general exposure assumptions used to calculate the various long-term MEGs presented in TG 230.

3.1.1 Exposure Duration

A continuous 1-year exposure duration was used for developing long-term MEGs. The long-term MEGs are appropriate to use for exposures exceeding 2 weeks up to 1 year. For exposures lasting less than 2 weeks, the user is referred to the short-term MEGs. Long-term MEGs, therefore, represent exposures to ambient environmental conditions such as pollution in the air, use of a continuously contaminated water supply, or persistent soil contamination. Environmental monitoring may indicate fluctuations or variations in the actual concentrations of a chemical over time. These MEGs should be compared with what is considered the most representative and generalized exposure concentration during the >2 week to 1 year period. For peaks at significantly higher concentrations for short durations, the user is referred to the short-term MEGs.

3.1.2 Exposure Frequency

It was assumed that deployed personnel would be exposed daily throughout the course of the year (365 days). Deployments lasting less than 1 year but greater than 2 weeks (it is common to have 60-, 90-, or 120-day deployments) can still be assessed using the guidelines though this provides an additional level of conservatism.

3.1.3 Population Assumptions

See Section 1.4.4.

3.1.4 Toxicological Endpoints

These guidelines address all *known* adverse health effects that could be expected to result from exposure to a given chemical of concern. Above the guideline concentrations, it is possible that a variety of health effects may occur. The types of adverse health effects and target organs associated with exposures exceeding a particular chemical guideline are described in the TG 230 appendices along with the MEGs. Because of the often limited toxicological data, there are potentially additional effects not identified. Due to various data gaps, there are several different levels of uncertainty with determining what specific dose level at which any, some, or all of the effects may actually occur. Due to human variability it is also difficult to quantify the percentage of individuals who would be impacted. For radiation and some specific chemicals (such as CWAs) there have been specific assessments yielding estimates of personnel decrement (i.e., personnel impairment to perform specific assigned tasks and percentage of troops affected) (USACHPPM, 1999b). Specifically, for CWAs, human data are available at various frank effects levels. This is often not true for other chemicals, therefore making such types of assessment extremely uncertain. While several levels of hazard severity are represented by the short-term MEGs, the long-term MEGs hazard the presumption is that the severity of effect is *negligible** if below the

guideline. The significance of the severity of effect once exposures exceeding a 1-year MEGs can be judged on the basis of short-term MEGs, though for several chemicals there is no short-term MEG available (presumably due to lack of acute data/established acute effects).

*Note: With regard to the definition of '*negligible*' effect, the long-term MEGs reflect the assumption that there are concentrations that will not cause any immediate effects or long-term, non-cancer effects, even if exposures are continuous for extended durations (i.e., 1 year). Cancer risks may be increased by any exposure to a carcinogenic chemical, but at some level that increased risk is considered acceptable. See Section 3.1.5 below. Guidelines consider both the carcinogenic and non-carcinogenic effects and ensure protection against both.

3.1.5 Carcinogenicity

Non-carcinogens are presumed to have a threshold dose below which adverse health effects will not occur. Carcinogens, on the other hand, are presumed to have non-threshold effects. Since risk from exposure to cancer-causing chemicals cannot be totally eliminated, health guidelines are traditionally based on a predetermined *de minimis* or "acceptable" risk of cancer from a chemical.

The USEPA often identifies an increased cancer incidence risk of 1-in-10,000 (or 1×10^{-4}) to 1-in-1,000,000 (or 1×10^{-6}) as an acceptable risk range of excess cancer cases over the course of a lifetime from non-voluntary exposures to environmental chemicals (NRC/FR 55 8715, Graham, 1993; Kelly, 1991; Lohner, 1997; Travis, 1987; USEPA, 1991b).). A 1×10^{-6} excess cancer risk is the more conservative end of the range and is most frequently used in decisions regarding protection of larger sectors of the general civilian population in situations where the people do not have a choice in being exposed (e.g., the Food and Drug Administration limits carcinogenic additives in food to levels that present no more than a 1×10^{-6} excess cancer risk). In contrast, many industrial standards for workplace environments offer a protection only to the 1×10^{-3} level or higher risk (e.g., a risk of 1×10^{-2}, or 1 in 100, a 1 percent chance). This higher cancer risk is "accepted" in workplace environments because it is often technologically or financially infeasible to control exposures to even lower levels and the "voluntary" nature of the exposure conditions at the workplace. The U.S. Supreme Court has upheld the industry basis for such standards (Graham, 1993).

For military operations, the level of acceptable risk will vary depending on the mission. Some situations may arise, particularly in adversarial/hostile environments, where high exposures to a relatively potent carcinogen are considered acceptable given the alternative hazards faced. However, this document establishes concentration guidelines that reflect benchmark levels below which there is no unacceptable risk associated with a cancer-causing chemical. As previously indicated, the criteria for delineating acceptable versus unacceptable excess cancer risk level used to establish these military guidelines is 1×10^{-4}. In addition to being within the USEPA acceptable risk range and being more protective than many occupational standards, the selection of this risk level is supported by previous documentation of the DOD risk level determined to be appropriate for the military (NRC, 1986b). For comparison, the background cancer rate in the U.S. is approximately 0.4 or 40% (NCI, 1999). Thus, an excess cancer risk of 1×10^{-4} increases a person's lifetime cancer risk from 0.4000 to 0.4001. Finally, since the information suggesting that a chemical exposure causes cancer is variable, the USEPA WOE classification system (i.e., alphabetical designation from A to E with A qualifying a chemical as a human carcinogen and E as evidence of noncarcinogenicity for humans).

These classifications were, therefore, provided along with MEGs in TG 230. The scheme used by the USEPA for categorizing chemicals according to their carcinogenic potential is provided below in Table RD 3-1.

Table RD 3-1. USEPA Cancer Classes

Cancer Class	Supporting Data Type
Cancer A: Human carcinogen	Sufficient evidence in epidemiological studies to support causal association between exposure and cancer.
Cancer B: Probable human carcinogen	Limited evidence in epidemiological studies (Group B1) and/or sufficient evidence from animal studies (Group B2).
Cancer C: Possible human carcinogen	Limited evidence from animal studies and inadequate or no data in humans.
Cancer D: Not classifiable	Inadequate or no human and animal evidence of carcinogenicity.
Cancer E: No evidence of human carcinogenicity	No evidence of carcinogenicity in at least two adequate animal tests in different species or in adequate epidemiological or animal studies.

3.2 AIR HAZARDS – Selection of Chemicals and Guidelines in TG 230 Table C-3, Long-Term Air-MEGs

Health effects from continuous, low-level, long-term exposures are considered differently than higher, acute (short-term) exposures. Therefore the short-term MEGs presented in Tables C-1 and C-2 of the TG 230 cannot be used to assess longer, continuous exposures. The differences resulting from exposure duration may result from toxicodynamic (specific effects and mechanisms of action) or toxicokinetic (dynamics of absorption, distribution, and elimination) processes. In addition, processes that contribute to development of cancer are more likely to occur with chronic exposure. Therefore, long-term Air-MEGs were specifically developed to address airborne concentrations of chemicals at or below which there would be no expected significant adverse health effects for the assumed maximum deployments of up to 1 year. The 1-year Air-MEG is defined as follows:

- 1-year Air-MEG: The airborne concentration for a continuous exposure up to 1 year (365 days, 24 hours/day) that is considered protective against all known health effects including chronic disease and increased risk to cancer (i.e., cancer risk greater than 1×10^{-4}). No performance degradation or long-term health consequences are expected with exposure at or below this level. Increasing concentration and/or duration could increase the potential for delayed/permanent disease (e.g., kidney disease or cancer).

As previously indicated, the MEGs were developed to be protective and cannot be used to retrospectively assess risk, attribute the occurrence of health effects from a previous exposure, or estimate percentage of casualties.

3.2.1 Chemicals Listed

The initial chemical list was selected to include all contaminants for which the USEPA has developed chronic or subchronic inhalation toxicity values. Additional chemicals were incorporated in the list based on their identification through deployment environmental surveillance (Hutchens and Heller, 1999).

3.2.2 Selection of Methods

The USEPA toxicity values, referred to as RfDs or reference concentrations (RfCs) for noncarcinogenic effects and unit risks or slope factors for carcinogenic effects, are routinely used in human health risk assessment. Toxicity values are available for a number of chemicals for subchronic (defined as 1/10th of the average lifespan, or two weeks to 7 years), and chronic exposures (> 7 years) (USEPA, 1989) through oral and inhalation routes of exposure. For inhalation exposures, these values are referred to as inhalation RfCs, air unit risks (AURs), or inhalation cancer slope factors (CSFi). The primary sources for the inhalation toxicity values used in this section were the Health Effects Assessment Summary Tables (HEAST) (USEPA, 1997a) and the Integrated Risk Information System (IRIS) (USEPA, 1999a). All chemicals for which sub-chronic or chronic inhalation values were available from these sources were included for determination of the preliminary military air guidelines-long term (PMEGs-L).

The USEPA toxicity values were not always available for the compounds identified through deployment environmental surveillance. Therefore, exposure guidelines from other sources, including the ACGIH TLVs® (AGGIH, 1999) and the ATSDR MRLs (ATSDR, 1997a,b, c, d) were considered.

In addition, some of the carcinogenic polycyclic aromatic hydrocarbons (cPAHs) were specifically identified as common contaminants requiring exposure guidelines. As these chemicals lack HEAST or IRIS inhalation toxicity values, TLVs®, and MRLs, the USEPA National Center for Environmental Assessment (USEPA, 1994a) AUR value for benzo(a)pyrene was utilized in conjunction with USEPA provisional guidance for risk assessment of cPAHs (USEPA, 1993) to derive Air-MEGs for four of these compounds. This methodology uses toxicity equivalence factors (TEFs) to quantitatively assess the potency of each cPAH relative to that of benzo(a)pyrene. The TEF values for each of the six cPAHs are included in RD Appendix C, Table C-1. Table RD 3-2 summarizes the TEFs used.

Table RD 3-2. Toxic Equivalence Factors for Selected PAHs (USEPA, 1993)

Compound	Toxic Equivalence Factor
Benzo(a)pyrene	1.0
Benz(a)anthracene	0.1
Benzo(b)fluoranthene	0.1
Benzo(k)fluoranthene	0.01
Chrysene	0.001

The Air-MEGs were derived using the inhalation toxicity values and the guidelines discussed above. These were adjusted to more appropriately suit the conditions and exposures that military personnel might experience during a typical, long-term deployment scenario. Descriptions of the toxicity and health guidelines values, exposure assumption, and final long-term Air-MEG development and selection are described in the following sections.

3.2.3 Toxicity Values and Health Guidelines

PMEGs-L, adjusted TLVs® (TLVs®-Adj), and/or adjusted MRLs (MRLs-Adj), were estimated for all chemicals on a data-available basis (Appendix C Tables C-1 and C-2). The final Air-MEG was then derived from these guidelines.

3.2.3.1 PMEGs

The methods used for estimating the PMEGs-L are based upon those used for developing the USEPA Region III Risk-Based Concentration (RBC) Tables (USEPA, 1997b) and are consistent with the Risk Assessment Guidance for Superfund (USEPA, 1989a) methodology. The toxicity reference values for noncarcinogenic effects developed by USEPA are estimates of a daily exposure level for the human population, including sensitive subpopulations, that are without an appreciable risk of deleterious health effects (USEPA, 1989a). These values are available for a number of chemicals for subchronic and chronic exposures through oral and inhalation routes. These values are based upon animal and/or human toxicity data and critical effects, to which uncertainty and modifying factors are applied.

For the PMEGs-L estimation, RfCs in mg/m^3 were converted to an inhalation RfD in mg/kg/day by multiplying by the standard dose conversion inhalation rate (IR) of 20 m^3/day and dividing by the average weight for adults (70 kg (~160 lbs)). This calculation is shown in Equation 3-1 below. In this conversion, the 20 m^3 USEPA inhalation default is just used for the adjustment to an RfDi. The military-specific inhalation rate is later accounted for (see Section 3.2.4) when adjusting for the specific exposure variables.

Equation 3-1 – Establishing a RfD_i from a RfC

$$RfD_i = \frac{RfC \cdot IR}{BW}$$

The subchronic and chronic Military Risk Concentrations (MRCs) were then estimated using standard USEPA methodology (USEPA, 1989a) and military-specific exposure variables previously described. Since deployments are not expected to exceed 1 year, the subchronic RfCs presented in HEAST were considered most appropriate and used preferentially in developing the MRCs. In cases where subchronic RfCs were not available, chronic values were used.

The CSFs developed by USEPA are plausible upper-bound estimates of the probability of a response per unit intake of a chemical over a lifetime. The WOE classifications are provided along with the slope factors to characterize the extent that the available data suggest the substance is a human carcinogen. In this section, AUR values [risk per $\mu g/m^3$] were converted to inhalation CSFs in $mg/kg/day^{-1}$ by dividing them by the average adult body weight (70 kg (or ~ 160 lbs), multiplying by the default inhalation rate (20 m^3/d), and converting from μg to mg ($\div$ 1000). Military cancer risk concentrations (Appendix C-1) were then calculated as described in Section 3.2.5.

3.2.3.2 *TLVs®* -Adj.

The TLV® - TWA, referred to as the TLV®, is defined as:

"The time-weighted concentration for a conventional 8-hour workday and 40-hour workweek, to which it is believed that nearly all workers may be repeatedly exposed, day after day, without adverse effect" (ACGIH, 1999; ACGIH 1991).

These values are based on available information including occupational experience, and experimental human and/or animal studies. The most recent (ACGIH, 1999) TLV® book was consulted for TLV® values. Where compounds were listed under "Notice of Intended Changes", the proposed new value was used to estimate the TLV®-Adj.

The TLV®s were adjusted from an intermittent to a continuous exposure and to account for the assumed military person's increased respiratory rate, as described in Section 3.2.4. A factor of 10 was then applied to account for the uncertainty of extrapolating from an intermittent to a continuous exposure.

3.2.3.3 MRLs-Adj

ATSDR defines an MRL as "an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse non-cancer health effects over a specified duration of exposure." MRLs are derived using the NOAEL level/UF approach and are below levels that might cause adverse health effects in the people most sensitive to such chemical-induced effects. MRLs are derived for oral and inhalation exposures for acute (1-14 days), intermediate (15-364 days), and chronic (365 days and longer) durations (ATSDR, 1997 a, b, c, d).

For purposes of deriving long-term MEGs, intermediate MRLs were selected over chronic MRLs when available. Acute inhalation MRLs were not considered appropriate for use in a 1-year scenario. The applicable MRL was then adjusted as described later in the next section to account for the increased respiratory rate of a military person.

3.2.4 Exposure Assumptions

3.2.4.1 PMEGs-L

The PMEGs-L were based on a set of assumptions regarding the potentially exposed individual and the defined exposure scenario. Default assumptions (USEPA, 1989a; USEPA, 1989b) were used in developing the PMEGs-L where scenario-specific data were not available.

- *BW* – The BW used to estimate the PMEGs-L was 70 kg (approximately 160 pounds). The USEPA historically uses a 70 kg BW for conducting quantitative Health

Risk Assessments (HRAs). This represents the mean BW of both adult males and females of the U.S. population. Recently, this number was updated by the USEPA's Office of Research and Development (ORD) in the *Exposure Factors Handbook* (USEPA, 1997c). Using data gathered by the National Center for Health Statistics (NCHS), the USEPA now recommends a mean adult BW of 71.8 kg.

However, existing data suggest that the overall BW of the military population is less than that of the general population because of their activity level. Using information from the USEPA *Exposure Factors Handbook* (USEPA, 1989b) it is estimated that the mean BW of adult males ranging from 18-55 years old is 78.2 kg. According to a study by the U.S. Army Research Institute of Environmental Medicine (USARIEM, 1995), the mean BW of men in the Army is 76.7 kg (n=32). Similarly for women, the mean BW for the general population is 64.6 kg for the same age group; for women in the Army, the mean BW is 61.1 kg (n=26).

Taking into account the lower BW of military personnel, a BW of 70 kg was considered reasonable for developing these guidelines and is consistent with BW assumptions used to develop most of the existing toxicity values and guidelines. An analysis also indicated this parameter does not greatly affect the final calculated guidelines (specifically, a 10 kg BW difference would not result in significant changes in final concentration guidelines). [In fact, use of the lower BW (i.e., 70 kg) results in slightly lower, more protective, MEG values]

- *IR* – The IR rate of deployed military personnel is expected to be higher than the general population because of potentially greater activity level. The USEPA has typically used an average adult inhalation rate of 20 m^3/day (USEPA 1989a; USEPA, 1991a). The recently updated USEPA *Exposure Factors Handbook* indicates somewhat lower inhalation rates of 11.3 m^3/day and 15.2 m^3/day for females and males, respectively, for long-term exposures. However, these recommendations would most likely underestimate a military person's inhalation rate (USEPA, 1989b).

  The USARIEM study mentioned above provides useful information on inhalation rates based on soldier-specific activities. The authors evaluated the metabolic rate of soldiers by observing their oxygen uptake. Subjects were attired in mission oriented protective posture (MOPP) and asked to perform tasks of various intensity while their heart rate and oxygen uptake were monitored. Two different classes of MOPP were used: MOPP-0 consisting of the battle dress uniform and MOPP-4 consisting of the battle dress oversuit with gloves, boots, and an M-17 protective mask. Since deployed military personnel are most likely to be in a battle dress uniform in the long run, only data from this experimental group was used.

  To evaluate energy expenditure, soldiers were asked to perform tasks with three different levels of intensity: light (<325 watts), moderate (325-500 watts) and high (>500 watts). In addition, each intensity level was broken down into different tasks. For example, the first task called L-1 involved maintaining a M-16 rifle, and L-2 referred to standing in a foxhole and performing guard duty. A higher numerical designation does not necessarily mean a higher work rate (more watts).

  The USARIEM study and data presented in the USEPA *Exposure Factors Handbook* regarding activity intensity and the associated inhalation rate showed

reasonable similarity. Data from the USARIEM study were used to obtain a soldier-specific inhalation rate because the degree of ventilation can be easily related to a specific activity. The activity categories with the lowest and highest work rate for each intensity level are summarized in Table RD 3-3, below. This information was compiled from male data only.

Table RD 3-3. Estimated Ventilation and Activity Category*

Task	Description	Work rate in Watts
	LIGHT	
L-2	Standing in foxhole/guard duty	135
L-1	Maintain M-16 rifle	304
	MODERATE	
M-1	Load carriage, march 1.11 m/s, combat equipment (LBE only) with no rucksack	325
M-13	Dig defensive position	460
	HEAVY	
H-2	Load carriage, march 1.48 m/s, 20 kg load	505
H-9	Lift and carry, two 13.6 kg, 30 m, 4x/min	1162

*(USAREIM, 1995)

To estimate a daily inhalation rate, it was necessary to determine the probable daily activities of a deployed person. Since the type of activity is mission-dependent, it is not possible to pinpoint the exact number of hours a deployed person would spend on a task. Infantry personnel, however, would be expected to spend more hours performing higher intensity tasks than other personnel. The number of hours spent on some common activities is presented in Table RD 3-4.

Table RD 3-4. Hours Spent On Various Activities

Activity	Hours Spent
Sleep	4-8
Work such as digging foxholes	8
Meals	3
Evening patrol/ambush	2-4
Other light duties	1

This information was provided by a member of the military who was recently deployed to the Middle East and confirmed by another who had been deployed to Bosnia (Blanchard, 1998;Ciesla 1998). Although the number of interviewees is limited, this information is still more realistic than those assumptions used by the USEPA to derive inhalation rates for the general population. It should be noted, however, that while those who had dug foxholes considered it a heavy activity, USARIEM, as well as the USEPA, regard such activities as moderate. Results from the USARIEM report do suggest that digging foxholes is a more strenuous activity than other moderate activities. Activities such as night patrol and waiting in ambush were categorized as light as opposed to moderate.

To estimate an inhalation rate, deployed military personnel were assumed to spend 6 hours sleeping, 4 hours for sedentary activities (e.g. eating meals), 6 hours for light duties (e.g. ambush) and 8 hours for moderate duties (e.g. digging foxholes). Even though military personnel may engage in higher intensity work or obtain less sleep, the assumption that a soldier would be performing activities such as digging foxholes 8 hours a day for 365 days would balance out these conditions. Some of the intense to severely heavy activities, as described by the USEPA, include competitive cycling and long-distance running. It is unlikely that

the deployed military personnel would be engaged in tasks at such intensity levels for prolonged periods of time.

Since the USARIEM study does not include inhalation rates for periods of sleep and rest, data from the USEPA were used to fill this data gap. The recommended values are 0.4 m^3/hr and 0.5 m^3/hr for sleep and sedentary activities, respectively. For light activities, the arithmetic mean of all light intensity tasks from the USARIEM report was used as the representative value (1.2 m^3/hr). The arithmetic mean of moderate activities was computed to be 1.8 m^3/hr. However, this value was not used in the calculation of the chronic inhalation rate because, as indicated above, work such as digging foxholes requires the most energy output of this intensity level. To account for the work performed at similar intensity levels, the inhalation rate of 2.2 m^3/hr for digging defensive positions was used to represent the value for moderate activities. Only data from male subjects were used because the inhalation rate for men was greater than that for women for all tasks. This would result in more conservative soil guidelines. The final (weighted) inhalation rate used to develop the soil guidelines was derived as shown in Equation 3-2.

Equation 3-2 – Weighted Inhalation Rates

$$IR_{daily} = \left(\frac{0.4 m^3}{hr} \cdot \frac{6 hrs}{day}\right) + \left(\frac{0.5 m^3}{hr} \cdot \frac{4 hrs}{day}\right) + \left(\frac{1.2 m^3}{hr} \cdot \frac{6 hrs}{day}\right) + \left(\frac{2.2 m^3}{hr} \cdot \frac{8 hrs}{day}\right)$$

This results in a daily inhalation rate of 29.2 m^3/day. This value is much higher than the USEPA *Exposure Factors Handbook* recommended value of 15.2 m^3/day for long-term exposures for males and is somewhat higher than the average adult USEPA default value of 20 m^3/day (USEPA, 1989b).

- *Exposure Duration (ED)* **–** The duration of deployments can vary but is not expected to exceed 1 year. Therefore, an ED of 1 year was assumed to derive the long-term Air-MEGs. The PMEGs-L may be used to conservatively assess exposures of shorter duration (for exposures of less than 14 days, see USCHPPM TG 230) but were not designed to address continuous exposures exceeding 1 year.

- *Exposure Frequency (EF)* – An exposure frequency of 365 days per year was assumed in developing the PMEGs-L, which address the continuous, daily inhalation of ambient air during a 1 year deployment.

- *Averaging time (AT)* **–** The intakes from longer-term exposure to noncarcinogenic toxicants are evaluated by averaging intakes over the period of exposure (i.e., subchronic or chronic daily intakes). The averaging time for a noncarcinogen (ATn) is ED x 365 days, and is in units of days. The intakes for carcinogens are calculated by prorating the total cumulative dose over a lifetime (i.e., lifetime average daily intake or chronic daily intake). The assumption for carcinogens is that a high dose received over a short period of time is equivalent to a corresponding low dose spread out over a lifetime. The averaging time for a carcinogen (ATc) is 25550 days, based on a 70-year lifetime (70 years x 365 days per year) (USEPA, 1989a).

3.2.4.2 *TLVs®* -Adj

The TLVs®, which are human inhalation values, were adjusted from an intermittent work week schedule (5 days/week) and a default occupational ventilation rate (10 m^3/8 hours) to a continuous exposure (7 days/week) and an ambient default inhalation rate (20 m^3/24 hours). Thus, the TLV® was adjusted by 5 days/7days and 10 m^3/ 20 m^3 (USEPA, 1994b). They were then further adjusted to consider the soldiers increased respiratory rate of 29.2 m^3/day by a factor of 20 m^3/29.2 m^3.

3.2.4.3 MRLs-Adj

Because of the 1-year maximum ED, intermediate (subchronic) inhalation MRLs were used in preference to chronic inhalation MRLs whenever available. The MRL was then adjusted by a factor of 20 m^3/29.2 m^3 to consider the soldiers increased respiratory rate.

3.2.5 Methods for Developing PMEGs-L, Adjusted TLVs® , and Adjusted MRLs

3.2.5.1 PMEGs-L

The methods used to estimate sub-military risk concentrations (MRCs), chronic-MRCs, and military cancer risk concentrations (MCRCs) are based on those used to develop the USEPA Region III Risk-Based Concentration Tables (USEPA, 1997b). Adjustments to the methodology consider the increased INHALATION rate of a soldier, the potential duration and frequency of exposure, and the assumption that the deployed soldier population does not include children. Subchronic RfCs were used preferentially to chronic RfCs when available. The target hazard quotient (THQ) was set to 1.0 and the target cancer risk (TCR) was defined as a 1:10,000 increased incremental risk of developing cancer (1 x 10^{-4}). A TCR of 1 x 10^{-4} is typically used in risk assessment for industrial scenarios and was considered reasonable for subchronic exposures in a healthy military population. The resultant MRCs and MCRCs for each chemical were then compared and the lowest (i.e., the one protective for both carcinogenic and noncarcinogenic effects) was identified as the PMEG. The RfCs, CSFis, MRCs, MCRCs and estimated PMEGs-L are presented in Appendix C.

For Ambient Air – All RfCs were converted to RfDs and all AUR were converted to CSF_i (where CSF_is or RfD_is were not specifically provided) as previously described.

Equation 3-3 – MRCs for Ambient Air

$$MRC = \frac{THQ \cdot RfD_i \cdot BW \cdot AT_n}{EF \cdot ED \cdot IRA}$$

Equation 3-4 – MCRCs for Ambient Air

$$MCRC = \frac{TCR \cdot AT_c}{EF \cdot IFA \cdot CSF_i}$$

Where:

- AT_n = Averaging time noncarcinogens = ED * 365 days/year = 365 days
- AT_c = Averaging time carcinogens = 70 * 365 days/year = 25550 days
- BW = Body weight = 70 kg (see IFA, below)
- CSF_i = carcinogenic slope factor inhalation, compound-specific = $(mg/kg\text{-}day)^{-1}$
- ED = Exposure duration = 1 year (see IFA, below)
- EF = Exposure Frequency = 365 days/year
- IFA = Inhalation factor
  (ED * IRA)/ BW = (1 year * 29.2 m^3/day)/ 70 kg = 0.417 m^3*y/kg*d
  (Modified from USEPA Region III's IFAadj that includes both children and adults)
- IRA = Inhalation rate = 29.2 m^3/day (see IFA, above)
- RfD_i = Reference dose inhalation, compound-specific = mg/kg-day
- TCR = target cancer risk = 1 x 10^{-4}
- THQ = target hazard quotient = 1

3.2.5.2 TLVs®-Adj

The TLV® was adjusted from intermittent to continuous exposure by a factor of 5 days/7 days, from the occupational default inhalation rate to ambient default ventilation rate by a factor of 10 m^3/20 m^3 (per day)* and for the military person's increased ventilation rate (relative to the ambient default) by the ratio of 20 m^3/29.2 m^3. A factor of 10 was applied to account for the uncertainty of extrapolating from intermittent to continuous exposure. [*NOTE: The 10 m^3/day inhalation rate represents the entire inhalation exposure volume over a day - which is assumed to be 8 hours for typical workers- to a specified contaminant. Thus, the conversion to a 20 m^3/day rate considers the full continuous 24 hours that a military person may be exposed. As such, no specific 8 hour to 24 hour conversion is necessary.] The TLVs® for irritants were assumed concentration dependent and were, therefore, not adjusted.

Equation 3-5 – Adjusted TLVs®

$$TLV_{adj} = TLV\left(\frac{5}{7}\cdot\frac{10}{20}\cdot\frac{20}{29.2}\cdot 0.1\right) = TLV \cdot 0.024 \; or \; \frac{TLV}{40.9}$$

3.2.5.3 MRL-Adj

The intermediate MRL was adjusted to account for the military personnel increased inhalation rate by multiplying by the ratio of the general population inhalation rate over the estimated military inhalation rate.

Equation 3-6 – Adjusted MRLs

$$MRL_{adj} = MRL\left(\frac{20}{29.2}\right) = MRL \cdot 0.68$$

3.2.6 Air-MEG Selection

PMEGs-L, TLVs®-Adj and MRLs-Adj were estimated for each chemical for whichever of the identified toxicity values and exposure guidelines were available. The comparison of all three values (where available) gave the most complete picture of existing standard exposure levels (Appendix C, Table C-2). The final Air-MEG selection considered the specific population and exposure scenario and was based on the following general hierarchy: PMEGs-L > TLV® -Adj > MRL-Adj (Appendix C, Table C-3).

The PMEG was selected as the first tier in the hierarchy because the USEPA toxicity values available for many environmental contaminants were developed for continuous exposures, and the toxicity values have undergone significant review. Furthermore, the USEPA exposure assessment methodology is easily adjusted for varying exposure scenarios. The TCR can also be readily adjusted to account for an occupational (healthy worker population) exposure that was considered more appropriate to the scenario under consideration. In addition, the actual duration of exposure, military inhalation rate, and absence of a child population were easily accounted for.

The TLV® -Adj was selected as the second tier of the hierarchy because TLV®s were available for many compounds and were developed for a worker population. Using a UF of 10 to adjust from intermittent to continuous exposure, and adjusting for a military person's inhalation rate, should provide an air concentration level that nearly all military personnel can be exposed to day after day without adverse health effects. It is important to note that uncertainty has been associated with TLV®s and health effects have been noted for some worker exposures at these levels (Roach 1990). Therefore, the extrapolation using UF is critical for developing adequately protective guidelines for the exposure scenarios presented here.

The MRL-Adj was selected as the third tier of the hierarchy for this exposure scenario because MRLs were available for fewer chemicals and were developed to protect the general population, including sensitive subpopulations such as children and the elderly, to whom this guide does not apply. Though the PMEGs-Ls are also based on toxicity parameters which are protective of a general (including sensitive) population, the toxicity parameters are designed to be adjusted for various exposure conditions and have been more widely accepted as "standards." Furthermore, unlike the PMEGs-L and TLVs®, the MRLs do not consider carcinogenic effects.

Whenever more than one preliminary exposure level was estimated, the levels were compared with each other to identify any marked differences. Differences less than an order of magnitude were generally considered insignificant because of the uncertainty involved in the derivation of the numbers and the use of UFs of up to 3000. In such cases, the hierarchy (PMEG > TLV® -Adj > MRL-Adj) was followed. However, if the hierarchy resulted in a MEG that was less protective (such as by less than an order of magnitude) the data were briefly reviewed to determine that a scientifically plausible reason for the difference exists and that the hierarchy-derived MEG would be adequately

protective. If the chemical was an irritant without systemic effects (within a reasonable range of the doses under consideration), and the effects were principally concentration- rather than time-dependent, supporting data were reviewed to assess if one of the higher preliminary exposure levels was more appropriate for selection as the MEG (e.g., ammonia).

If the differences between the PMEG, TLV® -Adj and/or the MRL-Adj were greater than an order of magnitude (either higher or lower) the chemical was marked for further evaluation. Supporting toxicological data were reviewed and the most appropriate value selected as the MEG. The MEGs, their basis, and the rationale for the selection of each MEG is provided in Appendix C-Table C-3.

3.2.7 General Air Quality Standards – Tables C-4 and C-5 in TG 230

As discussed in TG 230, the USEPA identifies six "criteria pollutants" as indicators of basic ambient air quality and has established for each of them a maximum concentration above which adverse health effects may occur. These concentrations are called the NAAQS (USEPA, 1999b). The criteria pollutants include CO, NO_2, SO_2, O_3, particulates (PM_{10} and $PM_{2.5}$) and Pb. The sources of these pollutants include factories, power plants, incinerators, automobiles, construction activity, fires and windblown dusts.

The analyses for these compounds are more routinely being accomplished during deployment missions, and in many environments it has been demonstrated that the ambient concentrations of these pollutants (particularly for particulate matter PM_{10}, $PM_{2.5}$) exceeds the USEPA NAAQ "standards." However, many larger cities/areas in the continental US also frequently, if not routinely, exceed the NAAQS. In CONUS, NAAQS evaluations provide for an overall "index" of air quality that can be used to make location specific advisories to the public in terms of protecting health (USEPA, 1999c). The standards are designated for different averaging durations, for example different pollutants are designated in some cases for a 3-hour average, 8-hour average, 24-hour average, quarterly average and/or annual mean. In attempting to make comparisons to the USEPA criteria standards during deployments, the USACHPPM has noted that these criteria pollutants are of particular concern for sensitive sub-populations such as the elderly, children, or those who have pre-existing health conditions such as cardiovascular or lung disease. However, military personnel are exposed continuously to ambient air concentrations rather than predominately indoor air concentrations as with the general population and will have increased physical activity and resulting higher ventilation rates as compared to the general population. An effort has been made to establish MEGs for pollutants included in the NAAQS that are consistent with the intent of other MEGs derived for the TG. Specifically, the MEGs are desired to be adequately protective of the military population for 24 hours per day, up to 1 full year.

The USEPA has not developed RfCs or RfD_i for these substances. Only the NAAQS (primary), which were developed to protect the general public, are provided by USEPA (see below). However, the NAAQS do provide appropriate estimates of reasonable air concentrations of pollutants. Therefore, they have been considered on a case-by-case basis in choosing an appropriate guideline for military use. Annual mean, quarterly averages, or 24 hour NAAQS were considered when available. Linear extrapolation was used for substances only with standards for 8-hour averages. Since the second tier of the TG 230 hierarchy for deriving MEGs is ACGIH worker TLV® -TWAs, they were also taken into consideration when choosing an appropriate MEG. The TLVs®, as designated in Table RD 3.5, were adjusted for adjusted military IR rate [(and EF/ED as previously

described and were compared to the NAAQS. Table RD 3.6 lists the TLV® -Adj. values and the proposed MEGs for these pollutants.

Table RD 3-5. Non-Adjusted NAAQS and TLV® -TWAs

POLLUTANT	NAAQS (Primary)	ACGIH TLV-TWA*
Carbon Monoxide (CO) 8-hour Average 1-hour Average	 9 ppm (10 mg/m^3)** 35 ppm (40 mg/m^3)**	 25 ppm (29 mg/m^3)**
Nitrogen Dioxide (NO_2) Annual Arithmetic Mean	 0.053 ppm (100 µg/m^3)**	3 ppm (5.6 mg/m^3)**
Ozone (O_3) 8-hour Average	 0.08 ppm (157 µg/m^3)**	0.08 ppm (moderate work) (0.16 mg/m^3)**
Lead Quarterly Average	 1.5 µg/m^3	0.05 mg/m^3*** 0.03 mg/m^3****
Particulate < 10 µm (PM-10) Annual Arithmetic Mean 24-hour[a]	 50 µg/m^3 150 µg/m^3	10 mg/m^3 (inhalable particulate)
Particulate < 2.5 µm (PM-2.5) Annual Arithmetic Mean 24-hour[b]	---- 15 µg/m^3 65 µg/m^3	3 mg/m^3 (respirable particulate)
Sulfur Dioxide (SO_2) Annual Arithmetic Mean 24-hour Average 3-hour Average	 0.03 ppm (80 µg/m^3)** 0.14 ppm (365 µg/m^3)** 0.50 ppm (1300 µg/m^3)**	2 ppm (5.24 mg/m^3)**

* The TWA concentration for a conventional 8-hr workday and a 40-hr workweek, to which it is believed that nearly all workers may be repeatedly exposed, day after day, without adverse effect.
** Parenthetical value is an approximately equivalent concentration.
*** This is also the OSHA 8-hr PEL (29 CFR 1910.1025)
**** OSHA action level (29CFR 1910.1025). For those workers exposed to air concentrations at or above the action level for more than 30 days, OSHA mandates periodic determination of blood lead levels.
[a] 3-year average of the 99th percentile of 24-hour concentrations over a given year.
[b] 3-year average of the 98th percentile of 24-hour concentrations over a given year.

Table RD 3-6. Proposed Long-Term Air-MEGs for NAAQS Pollutants

Criteria Pollutant	TLV®-Adj./TWA-Adj.	Long-Term MEGs*
Carbon Monoxide (CO)	0.61 ppm (0.71 mg/m^3)**	3 ppm (3.3 mg/m^3)**
Nitrogen Dioxide (NO_2)	0.073 ppm (0.14 mg/m^3)**	0.053 ppm (0.1 mg/m^3)**
Ozone (O_3)	0.002 ppm (0.004 mg/m^3)**	0.027 ppm (0.052 mg/m^3)**
Lead (Pb)	0.001 mg/m^3***	0.0015 mg/m^3
Particulate < 10 µm (PM_{10})	0.24 mg/m^3 (inhalable particulate)	0.07 mg/m^3
Particulate < 2.5 µm ($PM_{2.5}$)	0.07 mg/m^3 (respirable particulate)	0.04 mg/m^3
Sulfur Dioxide (SO_2)	0.05 ppm (0.13 mg/m^3)**	0.05 ppm (0.13 mg/m^3)**

* Based on evaluation of NAAQS.
** Parenthetical value is an approximately equivalent concentration.
*** This is also based equivalent to an adjusted OSHA 8-hr PEL (29 CFR 1910.1025)

3.2.8 Uncertainty, Modifying Factors, and Special Considerations

Uncertainties involved in the development of the long-term MEGs are principally those related to exposure parameters and toxicological data. Exposure assumptions include such factors as specified inhalation rates and BW, a continuous exposure of 365 days/year, and an ED of one year maximum. These values may or may not represent those found in the actual deployment scenario. Furthermore, ambient air concentrations of chemicals are highly unlikely to remain constant.

Uncertainty in the toxicological data may result from data gaps, insufficient quality or quantity of data and/or lack of human data. The USEPA addresses these uncertainties in developing their RfDs (for noncancer effects) by applying uncertainty and modifying factors to a critical study NOAEL or LOAEL. The UFs consist of multiples of ten (values less than ten are sometimes used) to account for variation in the general population (including sensitive subpopulations), to extrapolate from animals to humans (interspecies variability), to derive a chronic RfD from a subchronic study, and when a LOAEL is used instead of a NOAEL. A modifying factor of up to ten may also be applied to reflect a qualitative professional assessment of additional uncertainties in the critical study and entire database not specifically addressed by the UFs. ATSDR develops MRLs in a similar manner, using a NOAEL approach and UFs. Thus, the uncertainty associated with a RfD/RfC or a MRL may span an order of magnitude or greater. The USEPA toxicity values and the ATSDR MRLs were developed to protect the general population, including sensitive subpopulations, and their use in developing exposure guidelines for subchronic exposures by healthy military populations may be conservative (overly protective).

As previously discussed (section 3.1.5), the approach to address carcinogenicity followed that of the USEPA. The target cancer rate for deriving the PMEGs-L has been set at 1×10^{-4} as described. This approach involves an upper-bound estimate of the slope of the dose-response curve, the extrapolation model, and various assumptions about carcinogenesis that may or may not be correct for each chemical. For instance, the assumptions historically made by USEPA for carcinogenic risk assessment would not be appropriate for chemicals that have a threshold for response or for substances for which the likelihood of effects is highly dependent on the age of the individual at exposure.

The TLVs® are based on available information including occupational experience, experimental human and/or animal studies. The basis on which these values are established may differ from substance to substance, as the amount and nature of the information considered in establishing the TLV®. Consequently, the precision of the estimated TLV® is also subject to variation (ACGIH, 1999; ACGIH, 1991). The TLVs® do not routinely incorporate all of the standard USEPA/ATSDR-like UFs; however, they typically have some margin of safety and are designed to protect “nearly all workers”. The extrapolation from intermittent to continuous exposure to develop a TLV® -Adj results in additional uncertainty. The extensive number of compounds for which long-term MEGs are required and the data gaps that exist for many chemicals preclude the routine use of a biologically–based model, such as the physiologically-based pharmacokinetic (PBPK) model, in deriving long-term MEGs at this time. The use of a TLV® -Adj for continuous exposure and a soldier’s increased respiratory rate, with the application of a UF, is believed to provide adequate protection for a 1-year military personnel exposure scenario and has precedence in USEPA risk assessment

methodology. However, because of data gaps relative to pharmacokinetics, the health and safety professional in the field should be alert to potential symptoms of exposure when applying any guidelines derived from intermittent exposures to continuous long-term exposures.

3.2.9 Specific Chemicals – Hexachloroethane versus Hexachloroethane Smoke

It is important to note that the MEG for hexachloroethane refers to chemical hexachloroethane (perchloroethane) and *not* hexachloroethane smoke (HC smoke). The inhalation toxicity of hexachlorethane smoke is attributed to the production of zinc chloride ($ZnCl_2$), the major component of the smoke. The NRC has established a military Permissible Exposure Guideline Level (PEGL) of 0.2 mg/m^3 for $ZnCl_2$. This PEGL (NRC, 1997) was established based on an approximation of 50 8-hr exposures during a 2-year tour of duty. It is not appropriate to apply the hexachloroethane MEG levels for evaluating exposures to HC smoke. Exposures to smokes and obscurants are being evaluated as part of a separate initiative.

3.2.10 Specific Chemicals – Selection of the MEGs Outside of Hierarchy

- *Benzene* **–** The MEG for benzene is 0.04 mg/m^3 based on the TLV® -Adj. The PMEG and TLV® were both cancer-based; the MRL was based on neurotoxicity. Review of the data used to establish the MRL suggested that the exposure dose and endpoint used to develop the MRL were overly conservative for development of a MEG, especially considering UFs and that the statistics were not particularly robust. The concentrations evaluated in the study were 0.00, 0.78, 3.13 and 12.52, and a level of 0.78 was used to develop the MRL. The endpoints used to develop the MRL were increased forelimb grip strength and increased frequency of rapid response, as identified by t-tests (an Analyses of Variance (ANOVA) followed by a pair-wise analysis would have been more robust) and U- tests. The number of trials was not specified. It was not felt that these endpoints were indeed adverse effects for the purpose under consideration. Furthermore, removal of all UFs for the MRL would have resulted in a value similar to the PMEG and almost two orders of magnitude higher than the TLV® -adj. The MRL Human Equivalency Concentration (HEC) was 0.33 ppm, to which a UF of 90 was added. The next higher dose level (3.1 ppm) endpoint was increased forelimb grip strength and decreased rapid response frequency and was considered for our purposes a minimal LOAEL, and resulted in a HEC of 1.3 ppm, with an UF of 90 (0.015 ppm). Conversion to mg/m^3 and adjustment for a military person's respiratory rate resulted in an MRL-adj of 0.032 mg/m^3. Considering the UF of 90, this value was considered indistinguishable from the TLV® -adj and the TLV®-Adj, was considered protective of non-cancer and cancer effects. The PMEG was not considered adequately protective for neurological effects.

- *Toluene* – The MEG selected for toluene is 4.6 mg/m³ (1.2 ppm) based on the TLV®-adj. The PMEG was not selected because it was considered too conservative for the exposure being addressed. The PMEG was based on a chronic RfD developed from an 8-hour TWA with a UF of 300 (intended to protect sensitive populations). As the effects of toluene are more concentration- than time-dependent, the conversion from an occupational to chronic exposure likely resulted in additional conservatism.

The unadjusted TLV® (188 mg/kg or 50 ppm) was considered borderline in its protectiveness as it appeared to be a LOAEL in some studies and is actually equivalent to an AIHA ERPG-1. However, because of the greater concentration dependency of the compound and the safety factor of ten used in developing the TLV®-adj (resulting in increased conservatism when converting from a occupational to continuous exposure), the adjusted TLV®-Adj value of 4.6 mg/m³ (1.2 ppm) was considered adequately protective and adopted as the MEG. The new draft ATSDR guidelines for inhalation of toluene are 4 ppm (acute) and 0.4 ppm (chronic), resulting in a chronic MRL of 1.5 mg/m^3 and a MRL-adj of 1.02 mg/m³. The adjusted MRL is within the designated range (one order of magnitude) of the adjusted TLV®, but was not considered as appropriate because it was based on a chronic MRL for protection of sensitive individuals.

- *Ethyl benzene* **-** A MEG of 2.95 mg/m³ was established based on the (intermediate) MRL-adj. for developmental (skeletal) effects. The PMEG and the MRL were both based on the same study and endpoint. However, the PMEG was considered overly conservative due to the incorporation of a UF of 10 related to lack of multigenerational reproductive and chronic studies that did not seem applicable to a shorter-term exposure. The TLV®-adj was based on irritation and was considered less protective for developmental effects. Furthermore, the adjustment used for conversion from occupational to continuous exposure was questionable due to the pharmacokinetics of ethyl benzene.

- *Naphthalene* – The MEG for naphthalene is 0.0071 based on the MRL-adj. There is wide variation between the TLV®-adj, and the MRL-adj and PMEG (which are quite similar). The MRL-adj was selected over the PMEG because the PMEG considered UFs that were more applicable to chronic exposures. There are some data in the ATSDR toxicity profile suggesting that for those with G-6-PD deficiencies neither the TLV® nor the TLV®-adj may be adequately protective. Although the MRL-adj value is considerably more protective than the TLV®-adj., the dose at which G-6-PD deficient persons may develop toxic effects is not known. Based on the ATSDR 1998 toxicological profile for naphthalene, adequate data to develop a dose-effect for hematological and cataract effects in humans is not available, and there are substantial species differences. Considering that G-6-PD deficiencies are not presently screened for prior to deployment (Weese, 2001), and that this deficiency occurs in approximately 10 percent of black males (Italians, Greeks and other people from the Mediterranean basin are also more prone to this disease) the potential seriousness of the effect, and the possibility of potential exposure to compounds with additive effects, a higher (less conservative) MEG cannot be justified without additional data.

- *Polycyclic Aromatic Hydrocarbons (PAHs)* **–** Inhalation toxicity data was lacking for the following PAHs: acenaphthene, acenaphthylene, anthracene, fluoranthene, fluorene, phenanthrene, and pyrene. Oral RfD data were available for acenaphthene, anthracene, fluoranthene, fluorene, and pyrene. Oral to inhalation route extrapolation without additional UFs was used to develop PMEGs for these compounds. For acenaphthylene and phenanthrene, Quantitative Structure-Activity Relationships (QSAR) developed on the TOPKAT[TOPKAT®] system were obtained. RfD estimates were based on TOPKAT estimates of rat chronic LOAEL data and uncertainty factors according to USEPA guidelines.

[TOPKAT] System designed by Health Designs, Inc., Rochester, N.Y. Use of this trademarked name does not imply endorsement by the U.S. Army but is intended only to assist identification of a specific product.

- *Styrene* – The PMEG value of 2.05 mg/m^3, based on neurotoxicity, was selected as the MEG for styrene. This value was in line with the hierarchy and almost identical to the TLV®-adj (2.08 mg/m³) based on neurotoxicity but derived from different data sets. The MRL was considered overly conservative because it was a chronic value based on the same data as the PMEG, differing essentially by a UF of ten that was applied because of different interpretations of a NOAEL vs. a minimal LOAEL (i.e., an UF of 100 versus an UF of ten).

- *N-Hexane* – All three preliminary exposure levels were based on neurotoxicity. The TLV®-adj of 4.31 mg/m^3 (which was not substantively different from the MRL-adj) was selected as the MEG and was considered slightly more appropriate than the MRL-adj (derived from a chronic MRL) for the exposure under consideration. The PMEG was not selected because it was based on the same data as the MRL-adj but was considered overly conservative due to an additional uncertainty factor (100 vs. 300). It is noteworthy that of the hexanes, only the n-hexane isomer appears substantially neurotoxic.

- *Xylene* – The TLV®-adj and the MRL-adj were within an order of magnitude of each other and the hierarchy was followed. TLV®-adj of 10.6 mg/m^3 or 2.44 ppm was selected for the MEG. Although the values were based on different endpoints, the MRL had an UF of 300, and the TLV®-adj was almost two orders of magnitude lower than the less serious LOAEL (developmental) on which the MRL was based.

3.3 DRINKING WATER HAZARDS – Selection of Chemicals and Guidelines in TG 230 Table D-2 – Long-term Water MEGS

Short-term Water-MEGs for deployed military personnel are presented in USACHPPM TG 230. However, health effects from continuous, low-level, long-term exposures may be different than those produced by higher, acute (short-term) exposures to the same chemicals. In addition, health effects from long-term exposures may occur at substantially lower doses than those resulting from acute exposures. The long-term Water-MEGs were specifically developed to address drinking water concentrations for chemicals at or below which no significant adverse health effects would be expected for the average military person during deployments of up to one year. The 1-year Water-MEG is defined as follows:

- 1-year Water-MEG: The drinking water concentration for a continuous daily consumption of either 5 L/day or 15 L/day for up to 1 year that should not impair performance and is considered protective against all health effects including chronic disease and increased risk to cancer (i.e., cancer risk greater than 1 x 10^{-4}). Increasing concentration and/or duration could increase the potential for delayed/permanent disease (e.g., kidney disease or cancer).

The guidelines were developed to be protective and should not be used to retrospectively assess or attribute the occurrence of health effects from a previous exposure.

3.3.1 Sources of Chemicals

Chemicals included in the long-term Water-MEGs table include: (1) those with long-term standards in the TB MED 577 (DA, 1999); (2) compounds that were detected in water by environmental sampling in Bosnia; and (3) compounds that were identified as a high priority in RD 230, Appendix D**.** A number of compounds that have short-term MEGs do not have long-term guidelines. Such compounds include the CWAs and related compounds (GA, GB, GD, VX, BZ, EA 2192, sulfur mustard, lewisite, and T-2 toxin). For these compounds, long-term Water-MEGs have not yet been developed primarily because extended contamination of water with these compounds is considered improbable.

3.3.2 Hierarchy of Sources

The long-term Water-MEGs were derived using a hierarchy process of selecting from existing health-based guidelines and toxicity values. These include the following in descending order of priority:

1. TB MED 577 standards – Department of the Army
2. HAs – USEPA
3. MRLs – ATSDR
4. HEAST RfDs – USEPA
5. Region III (RBC Table oral RfDs – USEPA
6. Other - Unique chemical considerations

With the exception of TB Med 577 water quality standards, all values were adjusted with military exposure assumptions. The TB MED 577 provides field water quality standards for long-term (7-days to 1-year) exposure to six substances (arsenic, cyanide, chloride, lindane, magnesium, and sulfate). These standards were adopted unchanged as the long-term Water-MEGs. If the TB MED 577 standard for any one of these chemicals is exceeded, the water cannot be used as a potable supply. With the exception of the TB MED 577 standards, the long-term MEGs are not standards and should not be used to approve or disapprove field drinking water supplies. For the remaining chemicals, the existing USEPA and ATSDR guidelines were adjusted to address military drinking water consumption rates. Adjustments were also made to better accommodate the specific military population and anticipated deployment scenario exposures. These resulted in adjusted HAs (HA-Adj), MRLs-adj, and adjusted chronic/subchronic RfDs (RfD-Adj).

3.3.3 Toxicity and Health Effect Assumptions

The toxicity information included along with the long-term Water-MEGs was obtained from a variety of toxicity databases. The resulting guidelines and toxicity assumptions used to establish the long-term Water-MEGs have different levels of UF built in and, with the exception of TB MED 577 Field Drinking Water Standards (FDWS), exposure to concentrations somewhat above the long-term Water-MEGs may not cause any adverse health effects. The actual concentration above which one or more of the listed health effects may occur is highly variable due to several factors including the type of chemical, the steepness (slope) of the dose-response curve, the actual quantity of contaminated water consumed, exposure through other sources such as inhaled air, exposure to other chemicals which may cause additive or synergistic effects, and unique individual

susceptibilities. The following sub-sections describe the underlying toxicological basis for each of the toxicity/health guidelines used in the MEG hierarchy.

3.3.3.1 DOD Tri-Service Military FDWS

TB MED 577 provides FDWS for long-term (7-days to 1-year) exposure to six chemicals (arsenic, cyanide, chloride, lindane, magnesium and sulfate). These standards were developed for the soldier consuming either 5 or 15 L of water per day for temperate and arid climates respectively and were adopted unchanged as the long-term Water-MEGs**.** Because they do not include UFs to protect members of the general population who may be unusually sensitive to the effects of chemicals, the DOD Tri-Service standards are less conservative (i.e., less protective) than the long-term MEGs derived from the USEPA Health Advisories or from other sources (e.g., ATSDR MRLs, USEPA RfDs). However, no adverse health effects should be experienced if the concentration of a chemical substance in water is equal to or lower than the concentration indicated by the MEG and if the water is consumed for no more than the specified time period.

The TB MED 577 Standards were derived primarily to prevent performance degradation in the battlefield. As mentioned above, a UF to protect more sensitive members of the population were not incorporated into any of these standards. In some cases, concentrations just slightly higher than the standard may elicit adverse health effects so it is important that the standards not be exceeded. The approach used in their development is described by Daniels J.I. (Daniels, 1988). The basis for each of the six standards is summarized below.

1. Arsenic – The arsenic standard was derived from a NOAEL of 0.32 milligrams per day (mg/day), which was based on the absence of effects in a human population sustained by arsenic-contaminated well water for up to 10 years. No UFs were applied.

2. Chloride – The standard of 600 milligram per liter (mg/L) for chloride was based on the potential for rejection of drinking water due to lack of palatability. It was estimated that, at this level, two percent of the soldiers would refuse to drink the water, risking dehydration, and 12 percent would complain about the bad taste. The fraction of the soldiers refusing to drink the water would increase with the chloride concentration. Because taste was the only health effect considered, the same standard was set for drinking water consumption rates of 5 L and 15 L. No UF was applied.

3. Cyanide (CN) – Toxic levels of cyanide in the drinking water were calculated from the levels of cyanide (CN) in the blood shown to be associated with no adverse health effects in humans. The safe level of blood CN was taken from measured concentrations of cyanide in blood drawn from patients receiving the drug sodium nitroprusside to reduce blood pressure during surgery. From these data, it was estimated that 0.5 mg CN per liter (CN/L) whole blood was the threshold level for changes in blood chemistry and that clinical symptoms of cyanide intoxication were likely above 2 mg/L. Using a pharmacokinetic model, the amount that would have to be ingested in drinking water to reach a level of 0.5 mg CN/L in whole blood was calculated. Because CN is rapidly degraded in the body, the standard was based on the quantity of CN in drinking water that would be consumed during a short time interval rather than by dividing the threshold level by the total quantity of water consumed during a 24-hour period. The Daniels et

al. report concluded from their review of the literature, that protection from the acute effects of CN in drinking water should protect military personnel from suffering from chronic CN toxicity.

4. Lindane – The standard for lindane was based on the lowest dose to cause adverse effects in 3-day human studies. A UF of ten was applied to the LOAEL of 30 mg/day to reduce the concentration to a NOAEL. No other UFs were applied to the human data. This extrapolation was supported by two chronic oral studies in which 50 milligram per kilogram (mg/kg) in the diet was administered to rats. One of these studies identified a NOAEL of 1.25 mg/kg/day and the other identified a LOAEL of 2.5 mg/kg/day based on increased liver weight and slight liver and kidney damage.

5. Magnesium – The standard for magnesium was designed to prevent laxative effects which could cause performance degradation. Such effects can occur at water concentrations just slightly higher than the standard. Since chronic effects from exposure were not identified, the short-term (7 days) and long-term (1 year) standards are identical. No UF was applied.

6. Sulfate – Similar to magnesium, the standard for sulfate was designed to prevent laxative effects. The concentration set by the standard is the lowest dose that will not cause diarrhea. Since chronic effects from exposure were not identified, the short-term (7 days) and long-term (1 year) standards are identical. No UF was applied.

3.3.3.2 USEPA Health Advisories-Adjusted (HA-Adj)

About half of the long-term Water-MEGs were derived from the USEPA longer-term HAs for adults. The USEPA HAs are non-enforceable, recommended drinking water quality guidelines for exposure durations of 1 day, 10 days, longer-term, or a lifetime. The longer-term HA is defined by the USEPA as “the concentration of a chemical in drinking water that is not expected to cause any adverse noncarcinogenic effects up to approximately 7 years (10 percent of an individual's lifetime) of exposure, with a margin of safety”. The USEPA longer-term HAs are based on the weight of a 70-kg adult consuming two liters of water each day, but also incorporate an added tenfold UF to ensure protection of the more sensitive members of the general population including children and the elderly. These assumptions (sensitive populations and moderate drinking water consumption rates) do not accurately reflect the anticipated deployment scenario conditions. Adjustments to account for the maximum military consumption rates described below.

3.3.3.3 ATSDR adjusted MRLs (MRLs-Adj)

The ATSDR has derived short-term/acute (1-14 days), intermediate (15-364 days), and chronic (365 days and longer) oral MRLs. Intermediate oral MRLs, when available, were used for the compounds that were not addressed in TB MED 577 and for which there were no USEPA longer-term HAs. The methodology used for development of the MRLs is based on non-carcinogenic health effects and is similar to that used by the USEPA for development of HAs. As with the USEPA HAs, tenfold UFs (often multiples of them) are incorporated into the MRLs to adjust for (protect) the more sensitive members of the exposed population. Thus, the MRLs also have a built-in margin of safety and exposure to a level up to tenfold greater than the MRL will not necessarily cause adverse health effects. The oral MRLs are

expressed as daily human doses in units of mg/kg/day that are “safe” for the given exposure conditions. These MRLs were adjusted to account for the military exposure scenario using the assumptions discussed in the next section.

3.3.3.4 USEPA RfD-adjusted (RfD-Adj)

For chemicals that have no existing long-term (2-week to 1-year) health guidelines, the USEPA subchronic or chronic RfDs were used to calculate the MEG. About 20 percent of the long-term water MEGs were derived from subchronic and chronic RfDs. Because RfD values are designed to be protective for the general population (like the HAs and MRLs, there are several “UFs” incorporated into them) and they are designed to reflect exposure over 7 years to a lifetime, some of the long-term MEGs derived from these values tend to be quite conservative. Subchronic RfDs were taken from the USEPA HEAST (USEPA, 1997b). Chronic RfDs were taken from IRIS or the Region III RBC Table (USEPA, 1997d). These guidelines also include an UF to provide protection for the more sensitive members of the human population.

3.3.3.5 Cancer Assessment

In line with the logic described in Section 3.1.5, drinking water concentrations associated with a 1×10^{-4} or lower excess risk of developing cancer were considered acceptable for the carcinogenic chemicals included in TG 230. The concentration of the carcinogens that pose a 1×10^{-4} excess risk of cancer with continuous exposure for a 70-year lifetime were obtained from two sources: The USEPA Drinking Water Regulations and HAs (ATSDR, 1996), and from IRIS (USEPA, 1999a). Risk-specific concentrations for five compounds (alachlor, beryllium, chlorothalonil, dibromchloropropane, and TCDD) were present in the HA document but not in IRIS. The risk-specific concentration for benzo(a)pyrene was taken from IRIS where it had been up-dated since its first appearance in the HAs. The risk-specific concentrations for the remainder of the carcinogens were the same in the HA document and IRIS.

To assess whether the long-term Water-MEGs for the carcinogenic compounds are protective against cancer as well as non-carcinogenic effects, the 10^{-4} risk-specific concentrations of those compounds were compared with the long-term Water-MEGs derived from non-cancer endpoints. To do this, the risk-specific concentrations in drinking water (mg/L) were multiplied by 70 years/1 year to estimate the concentrations in water that would pose the same cancer risk for an exposure duration of 1 year as the life-time exposure. An adjusted risk-based concentration was then derived by multiplying this time-adjusted value by 0.4 (2/5) to convert it from a drinking water consumption rate of 2 L/day to 5 L/day (see equation 3-7; (Appendix D, Table D-2). The adjusted drinking water 10^{-4} risk-specific concentration was then compared with the 5 Liter MEG derived from non-carcinogenic endpoints. If the adjusted risk-specific concentration was equal to or greater than the non-cancer-based 5 L MEG, the MEG was considered to be protective against cancer. If the adjusted drinking water, risk-specific concentration was lower than the 5 Liter MEG derived from non-carcinogenic endpoints, then the adjusted drinking water risk-specific concentration was selected as the MEG. This analysis indicated that the long-term Water-MEGs selected on the basis of non-carcinogenic endpoints according to the hierarchy described above for beryllium and hexachlorobenzene were not protective against cancer. The adjusted 10^{-4} risk-specific concentrations was adopted as the long-term Water-MEGs for beryllium and the adjusted MRL was adopted as the long-term Water-MEGs for hexachlorobenzene (see Section 3.3.5.2

for decision logic). These long-term Water-MEGs are protective against both carcinogenic and non-carcinogenic effects. The non-cancer based long-term Water-MEGs were protective for all other carcinogens included in TG 230.

Equation 3-7 – Adjusted CRCs

$$CRC_{adj} = \frac{CRC \cdot AT_c \cdot DWR_{GP}}{DWR_{MP}}$$

Where:

CRC_{adj}	=	Adjusted cancer risk-specific concentration (mg/L)
CRC	=	Cancer risk-specific concentration (mg/L)
DWR_{GP}	=	Drinking water rate (2 L/day) for the general public
DWR_{MP}	=	Drinking water rate (5 L/day) for military personnel
ATc	=	Averaging time for carcinogenic substances (70 years/1 year)

3.3.4 Exposure Assumptions

Depending on the type of toxicity value/health guidelines used to develop a MEG, different exposure assumption adjustments were necessary. These types of adjustments were made to ensure overall consistency with the general military exposure assumptions described in Section 2.1. As previously indicated, an ED of 1 year and EF of 365 days/year were assumed when deriving these guidelines. Similarly, the BW of 70 kg was used to derive the long-term Water-MEGs. Drinking water consumption rates had to be adjusted from those of the general public to those expected for deployed military personnel. Adult members of the general public are considered to drink an average of 2 L water per day. Maximum daily water consumption rates for deployed military personnel vary from 5L /day in temperate climates to 15 L/day in arid climates. To remain combat effective, the maximum individual daily amount of drinking water required by deployed military personnel can range from about 5 to 15 L/day depending on climate, season, intensity of work, and type of battlefield (e.g., conventional, in which chemical, biological, or nuclear attack is not anticipated) (Directorate of Combat Developments, 1983; Headquarters, DA, 1983). These daily maximum consumption rates are consistent with the experiences of the Israeli Defense Forces and observations by U.S. Army Medical Services Officers at National Guard armor battalions training exercises in the Mojave Desert (Henry, 1985). Exposure assumption adjustments made to each toxicity value/health guidelines are summarized below.

3.3.4.1 DOD FDWS

The DOD long-term FDWS were developed assuming a 70 kg adult weight and were designed for exposures of 7 days to 1 year. In addition, they were developed assuming the military-specific consumption rates of 5 L/day (temperate climate) and 15 L/day (arid climate). No exposure adjustments were necessary.

3.3.4.2 Adjusted HAs (HAs-Adj)

The HAs are expressed as water concentrations in units of mg/L. Since the HAs are based on a 2 L/day drinking water consumption rate, the HAs had to be adjusted for the two military drinking water consumption rates of 5 L /day and 15 L/day (See Equation 3-8). Depending on the underlying health effect of concern, further adjustments may be made in the future.

Equation 3-8 – Adjusted Health Advisories

$$HA_{adj} = \frac{HA_{LT} \cdot DWR_{GP}}{DWR_{MP}}$$

Where:

HA_{adj}	=	Adjusted Health Advisory (mg/L)
HA_{LT}	=	Longer-term Health Advisory (mg/L)
DWR_{GP}	=	Drinking water rate (2 L/day) for the general public
DWR_{MP}	=	Drinking water rate (5 or 15 L/day) for military personnel

3.3.4.3 MRL- and RfD- Based Long-term Water-MEGs

The oral MRLs and USEPA RfDs are expressed as daily human doses in units of mg/kg/day. To convert them to military water concentrations, they were multiplied by 70 kg and divided by 5 L or 15 L to produce MRL- or RfD based long-term MEGs for the two rates of drinking water consumption (5 or 15 L/day) (see Equations 3-9 and 3-10). Depending on the underlying health effect of concern, further adjustments may be made in the future.

Equation 3-9 – MRL-based Water-MEGs

$$MRL_{MEG} = \frac{MRL \cdot BW}{DWR_{MP}}$$

Where:

MRL_{MEG}	=	MRL-based MEG (mg/L)
MRL	=	Minimal Risk Level (mg/kg/day)
BW	=	Adult body weight (70 kg)
DWR_{MP}	=	Drinking water rate (5 or 15 L/day) for military personnel

Equation 3-10 – RfD-Based Water-MEGs

$$RfD_{MEG} = \frac{RfD \cdot BW}{DWR_{MP}}$$

Where:

RfD_{MEG} = Adjusted RfD (mg/L)
RfD = Reference dose (mg/kg/day)
BW = Adult body weight (70 kg)
DWR_{MP} = Drinking water rate (5 or 15 L/day) for military personnel

3.3.5 Water-MEG Selection

As previously stated, various methods and guidelines were used to establish the list of long-term water MEGs presented in TG 230. The final long-term water MEG selection considered the specific population and exposure scenario and was based on the following hierarchy: DOD FDWS > USEPA HA-Adj **≥** ATSDR MRL-Adj> USEPA RfD–Adj. With the exception of the FDWS, the hierarchy also considered a cancer assessment and if necessary, a cancer-based value would supercede the stated hierarchy if more protective at the 1 x 10^{-4} risk level. [Note that the FDWS are all protective against unacceptable excess cancer risk according to the criteria discussed in Section 3.1.5.]

3.3.5.1 Uncertainty

The uncertainties described in Section 3.2.8 for the Air-MEGs were developed according to USEPA methodology using the UF/RfD approach. These UFs apply to the derivations for water guidelines as well. With the exception of FDWS, all of the guidelines from which the long-term Water-MEGs were developed were based on the USEPA approach of applying UFs to NOAELs or LOAELs from studies in animals or humans. Additional uncertainty is introduced by the estimation of water consumption rates that may vary considerably from person to person and from day to day. While concentrations of chemicals in water may vary less than those in air, it is probable that considerable variation will occur over a period of a year for chemicals originating in water from sources related to human activities. The TB MED 577 standards were not derived using the UF/RfD approach except that a UF of 10 was incorporated into the standard for lindane that was based on a LOAEL from a short-term human study. Because the FDWS were all were derived from studies in humans, there is no uncertainty associated with extrapolation from the toxic response of animals to those of humans. However, with the exception of arsenic that was based on long-term effects in humans, they were derived from short-term human exposures, and there may be some uncertainty as to the effects from long-term exposures.

3.3.5.2 Unique Chemical Concerns

Special considerations were taken in the derivation of several of the chemicals in this TG. For two chemicals (diazinon and terbufos), errors were found in the source

documents that affected the derivation of the Water-MEGs. The hierarchy described above was not appropriate for four of the chemicals (carbon disulfide, hexachlorobenzene, TCDD, and vanadium) for which long-term Water-MEGs were developed. Finally, for the remaining compound (ethylene dibromide) guidelines based on non-cancer endpoints were not available. Many Polycyclic Aromatic Hydrocarbons (PAHs) have limited toxicity data (cancer and non-cancer), so a relative potency approach was utilized in developing Water-MEGs. In addition, controversial and/or questionable toxicity concerns associated with the metals lead and copper resulted in a unique basis for Water-MEGs. These unique chemical considerations and their resolutions are discussed below:

- *Carbon disulfide*
  The only available long-term guideline for exposure to carbon disulfide is the subchronic HEAST RfD of 0.1 mg/kg/day which equates to 1.4 mg/L for a water consumption rate of 5 L/day. This value was found to be higher than the acute MRL which was based on a l4-day oral (gavage) study in mice (LOAEL = 3 mg/kg/day) while the HEAST subchronic RfD was based on a developmental toxicity inhalation study in rabbits (NOAEL = 11 mg/kg/day). Even though it is tenfold lower than the RfD, the acute MRL was used as the source of the MEG because it was derived from a study that used the more relevant route of exposure.

- *Diazinon*
  The MEG (0.007 mg/L) developed from the longer-term HA was selected even though the adjusted HEAST subchronic RfD (0.0126 mg/L) and the adjusted Region III RBC (0.0126 mg/L) were higher. (The adjusted subchronic or chronic RfDs should theoretically be lower than the longer-term HA since they are targeted for longer exposure periods.) In the HEAST Table, the NOAEL for Diazinon is reported as 0.09 mg/kg/day. This value was taken from a subchronic rat study by Davies and Hollub (NCI, 1999) in which the NOAEL was reported to be 9 microgram per kilogram per day (μg/kg/d) based on depressed cholinesterase levels at higher doses. The NOAEL of 9 μg/kg/day converts to 0.009 mg/kg/day, not 0.09 mg/kg/day as reported in HEAST. Applying the UF of 100 reported in HEAST produces a subchronic RfD of 0.00009 mg/kg/day. This equates to a drinking water value of 0.0013 mg/L for a daily 5 L consumption rate. While lower than the HA-adj, the HA-adj of 0.007 mg/L which is based on a 52-week monkey study was used as the MEG.

- *Ethylene dibromide*
  Exposure guidelines based on non-cancer endpoints have not been developed for ethylene dibromide. While a 1-year adjusted 10^{-4} cancer risk-specific concentration (0.0012 mg/L) is available, further information must be evaluated to ensure that the MEG derived from the adjusted cancer risk specific concentration is protective against health effects other than cancer. Comparison of the unadjusted, lifetime 10^{-4} cancer risk (0.00004 mg/L) with the USEPA MCL of 0.00005 mg/L shows that the two values are virtually identical. The MCL is defined as the maximum permissible level of a contaminant in water which is delivered to any user of a pubic water system and, as such, should be protective against both cancer and non-carcinogenic health effects. Thus, the adjusted cancer risk specific concentration was adopted as the MEG.

- *Hexachlorobenzene*

The adjusted HA (0.08 mg/L) could not be used as the MEG because it is higher than the adjusted cancer risk-specific concentration (0.06 mg/L). Likewise, the MEG could not be derived from the cancer risk because it was not protective against non-carcinogenic health effects. The adjusted intermediate MRL of 0.0042 mg/L was used for the MEG even though it is 2.7 fold lower than the adjusted RfD (0.0112 mg/L). The RfD was based on liver effects in a three-generation rat study conducted in 1985 while the MRL was based on effects on the ovary observed in a 90-day study in monkeys. The study on which the MRL was based was published in 1993 and was not available in 1987 when the HA and RfD were developed (USEPA, 1987a). To be fully protective against reproductive effects, the MEG was derived from the MRL.

- *TCDD*

  Two non-cancer based guidelines, the MRL-adj (2.8×10^{-7} mg/L) and the HA (1.4×10^{-8}), were available for TCDD. Both are lower than the adjusted-cancer-risk-specific concentration (6×10^{-7} mg/L). The intermediate oral MRL was based on a NOAEL of 0.005 μg/kg/day from a 90-day feeding study in guinea pigs in which decreased thymus weight and BW gain occurred at the LOAEL. A UF of 30 was applied. The HA was based on a LOAEL of 0.001 microgram per liter (μg/L) from a three-generation reproduction study in rats. Effects seen at the LOAEL included reduced gestation index, decreased fetal weight, and increased incidence of dilated renal pelvis. The HA was selected as the MEG because of the potential reproductive effects.

- *Terbufos*

  The HA for Terbufos was based on the RfD. This value was reported as 0.00013 mg/kg/day in the Summary Table in the document Drinking Water Regulations and Health Advisories (USEPA, 1996a) but as 0.000025 mg/kg/day in the original HA source document (USEPA, 1987b). The latter value is compatible with the RfD reported in HEAST and was used to derive the MEG.

- *Vanadium*

  The adjusted HEAST subchronic RfD (0.098 mg/L) was two times higher than the adjusted ATSDR intermediate oral MRL (0.042 mg/L). The RfD was based on the absence of renal effects observed at the NOAEL of a lifetime study in which vanadyl sulfate was administered to rats in the drinking water. The MRL was based on the observation of minor renal effects (increased plasma urea, and mild histological changes) in a study in which sodium vanadate was administered to rats in the drinking water for three months. The NOAEL was 0.3 mg/kg/day. The UFs of 100 were used in both studies. Because effects on the kidney were seen in the three-month study at a dose lower than the NOAEL observed in the lifetime rat study, the adjusted ATSDR MRL was adopted as the MEG.

- *Polycyclic Aromatic Hydrocarbons (PAHs)*

  Guidelines based on carcinogenic or non-carcinogenic effects were not available for four carcinogenic PAHs (benzo[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, and chrysene) included in the TG. As discussed, cancer-based guidelines were determined for each of these compounds using toxic equivalence factors (TEFs). In addition, guidelines determined in this manner were compared with guidelines derived from RfDs developed for total petroleum hydrocarbon (TPH) fractions by (Edwards et al.). To err on the conservative side, the lower of the two values was adopted as the MEG. In the TPH method, an RfD of 0.03 mg/kg/day was assigned to the components of the aromatic fraction of

TPH with carbon numbers falling between 17 and 21. This value was based on the established RfD for pyrene which was considered to be a conservative surrogate because it has a lower carbon number than any of the other compounds in the fraction. The values for benzo[k]fluoranthene and chrysene derived from the surrogate RfD were lower than those derived with the TEF method and were selected as the MEG.

- *Lead*
  As described in Section 2.3, a category of "lead compounds" was added to address the common findings of some level of detected "total lead" in various drinking water sources. Three existing drinking water criterion were identified: the WHO guideline of 0.05 mg/L, USEPA's MCL of 0.015 mg/L; and the U.S. bottled water criteria standard of 0.005 mg/L established in 21 CFR, Bottled Water Quality Standards, 1 April 1996. As previously described, despite the fact that military personnel are believed to consume substantial greater volumes than the 2 L/day assumption used in the derivation of these general population values, these criteria are considered conservatively protective since the basis for each of these values considered toxicity to children and developing fetuses. The current proposed long-term MEG in Table D-2 is based on the USEPA action level (MCL) of 0.015 mg/L. Approved bottled water sources should contain less than 0.005 mg/L of lead as a matter of 'regulation', but as long as levels are in accordance with the selected MEGs there is not expected to be a health concern. These are considered conservative values for military applications, and may be adjusted in the future.

- *Copper*
  There is indication that copper, particularly elemental copper, is not a significant toxic constituent. Elemental copper (CAS 7440-50-8) itself is an essential element and therefore *deficiencies* can result in adverse health effects. The major soluble salts (e.g., copper (II) sulfate, copper II chloride) are believed to have greater toxicity, but there are conflicting reports of the overall quantified levels of significance for both acute as well as chronic, long-term ingestion. Some evidence suggests some acute (e.g., abdominal, GI tract) effects at extremely high levels – but it is confounded by presence of other heavy metals. Chronic mice and rat data indicate potential for liver and kidney damage. There are USEPA as well as several State drinking water standards for copper. These range from 1.0 – 1.3 mg/L. These values appear to be quite conservative considering the scientific literature (HSDB, website 2001). A value of 1.0 mg/L was selected for the long-term copper MEG value. It reflects the low-end of the range of existing criteria to somewhat address the increased consumption rate for military. These are considered conservative values for military applications, and may be adjusted in the future.

3.4 Soil Hazards - Selection of Chemicals and Guidelines in TG 230 Table E

The long-term Soil-MEGs were derived using the general USEPA health risk assessment (HRA) guidance used for environmental cleanup efforts (USEPA, 1989a). Specific 'safe' soil concentration levels were established by back-calculating from accepted health target levels (no effect for non-cancer compounds and acceptable cancer risk for cancer-causing compounds as discussed in Section 3.2 and 3.3). Some

chemicals may have both noncancer and carcinogenic effects. For these compounds, soil concentrations determined from both effects were compared and the lower concentration used as the final soil level for that chemical. If a chemical is not suspected to be carcinogenic, then the MEG was based on its noncancer effect. The 1-year Soil-MEG is defined as follows:

- 1-year Soil-MEG: The soil concentration for continuous, daily exposure (from ingestion, dermal absorption, and inhalation) for up to 1 year (365 days) that should not impair performance and is considered protective against all health effects including chronic disease and increased risk to cancer (i.e., cancer risk greater than 1×10^{-4}). Increasing concentration and/or duration could increase the potential for delayed/permanent disease (e.g., kidney disease or cancer).

Subsequent sections discuss the selection of methodology for determining soil levels, toxicity data, and exposure assumptions used to develop the MEGs.

3.4.1 Selection of Chemicals

The chemicals selected for evaluation are consistent with those used to develop drinking water guidelines. This is because health risks from both media involve ingestion of the contaminated media as the primary exposure pathway.

3.4.1.1 Exceptions

Exceptions to this rationale are the CWAs which were not included in the development of water guidelines due to their instability in water (USACHPPM, 1999c). The persistence of chemical agents in soil is dependent on various environmental conditions such as, but not limited to temperature and soil moisture. Studies have shown that CWAs are, in general, not persistent when applied to surface soils. However, since chemical agents do not readily undergo hydrolysis in soil as they do in water, encounters with CWA-contaminated soil is a potential pathway for exposure. In addition, studies have indicated that sulfur mustard (HD) does not undergo natural degradation if buried in soil (USACHPPM, 1999c). Therefore, Soil-MEGs were established for the CWAs.

3.4.1.2 Chemical Exposures From Soil Not Addressed by the Soil-MEGs

Some chemicals, such as dimethyl methylphosphonate, are not expected to adsorb to soil (HSDB, 1999). When available information clearly indicated that a chemical does not bind readily to soil, a Soil-MEG was not established. Other examples include chloride, magnesium, and sulfate which were included in the drinking water list because they have assigned field drinking water standards (DA, 1999). The primary health concern associated with these chemicals is that they can cause dehydration either by military personnel's refusal to drink water due to poor taste or because of the chemical's acute laxative effect. It is unlikely that the military population can be exposed to high enough concentrations of these substances from ingestion of soil alone. Therefore, Soil-MEGs were not developed for these chemicals.

3.4.1.3 Essential Nutrients and Minerals

Some compounds have established recommended daily allowances (RDAs) because they are essential nutrients. The RDAs are not intended to be minimal

requirements nor necessarily optimal levels of intake; they are determined to be safe and adequate levels to ensure proper nutrition (NRC, 1989). Some nutrients do not have RDAs but have what are called "Safe and Adequate Intakes (SAI)". These levels are recommended for those nutrients that do not have sufficient data to derive an RDA but have known upper-level toxicity. Examples include the trace elements manganese, selenium and chromium. Other essential nutrients include minerals (e.g., zinc, calcium, magnesium). Generally, minerals are not chemicals of health concern. Although all chemicals are toxic at some level, these essential nutrients typically do not have recommended toxicity values (e.g. an RfD or an MRL) mostly because health effects are expected only at very high doses for the general population.

At this time, only a Soil-MEG for chromium has been developed since there is an available chronic RfD. Future Soil-MEGs may be derived using SAI for manganese and selenium. USACHPPM considered developing guidelines for calcium and magnesium using RDAs but, due to limited risk associated with these compounds in soil, the current guidance is to consider the presence of either of these compounds in soil as a no risk or "non-hazard".

3.4.2 Selection of Target Levels for Soil-MEGs

The intended application of soil guidelines is to monitor potential health risks from exposure to hazardous chemicals during deployment. For carcinogens, a target excess cancer risk level of 1×10^{-4} was used as the basis to develop the soil guidelines (see Section 3.1.5).

The potential for noncancer effects may be estimated by dividing a chemical's daily intake by its established toxicity value (e.g., RfD) to obtain a hazard quotient (HQ). The USEPA uses an HQ or target ratio of one for noncancer effects. Similarly, an HQ of one was used to develop MEGs based on noncancer effects. An exceedance of one does not imply immediate onset of health effects but rather, a potential for such. In addition, screening values are conservatively derived from toxicity data by utilizing uncertainty/safety factors to ensure protection. However, if an exceedance occurs, precaution should be taken to minimize further exposure. More discussion on the selection of toxicity data is presented in following sections.

Multiple chemicals may interact to result in additive, synergistic, or antagonistic responses. This is acknowledged in the TG as a potential area of concern. The guidance suggests comparing target organs of non-cancer compounds to ascertain whether (at a minimum) additive effects may be assumed. For carcinogens, there is also the assumption that two carcinogens are at least additive, regardless of type/target of carcinogenic action. This concept is consistent with current risk assessment/management approaches used by the USEPA. Recommendations in the TG are, however, to consider the carcinogenic WOE classification when determining potential strength of additive or synergistic cancer effects.

3.4.3 Method Selection

Several alternatives for estimating soil concentration are available: the USEPA's method for estimating Soil Screening Levels (SSL) (USEPA, 1996b), USEPA Region III's RBC, (USEPA, 1999d) and USEPA Region IX's Preliminary Remediation Goals (PRG) (USEPA, 1998). The theoretical approach is the same for all three, but the assumptions

vary. Region IX's method was used because it results in the most conservative soil concentrations since it includes more exposure pathways than either the SSL or the RBC methodology. The pathways include incidental soil ingestion, dermal contact, and inhalation of volatiles or fugitive dusts.

Region IX provides screening levels for both residential and industrial land uses; the major differences between the two are the exposure parameters such as inhalation rate and soil ingestion rate. Since the military personnel scenario is most similar to the industrial scenario, the equations for the industrial scenario were used. They are as follows:

Equation 3-11 – Soil-MEGs for Carcinogens

$$MEG_c = \frac{TR \cdot BW \cdot AT_c}{EF \cdot ED\left(\frac{IR_s \cdot FC \cdot CSF_o}{10^6} + \frac{SA \cdot AF \cdot ABS \cdot CSF_o}{10^6} + \frac{IR_a \cdot CSF_i}{PEF}\right)}$$

Equation 3-12 – Soil-MEGs for Noncarcinogens

$$MEG_{nc} = \frac{THQ \cdot BW \cdot AT_n}{ED \cdot EF\left(\frac{IR_s \cdot FC}{RfD_o \cdot 10^6} + \frac{SA \cdot AF \cdot ABS}{RfD_o \cdot 10^6} + \frac{IR_a}{RfD_i \cdot PEF*}\right)}$$

Where:

MEG_c	=	military soil guideline based on carcinogenicity (mg/kg)
MEG_{nc}	=	military soil guideline based on noncarcinogenicity (mg/kg)
TR	=	target risk
BW	=	adult body weight (kg)
AT_c	=	averaging time for carcinogenic substances (days)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
IR_s	=	soil ingestion rate
FC	=	fraction contaminated (assumed 100%)
CSF_o	=	oral cancer slope factor $(mg/kg/day)^{-1}$
10^6	=	units conversion (mg/kg)
SA	=	skin surface area (cm^2/day)
AF	=	adherence factor (mg/cm^2)
ABS	=	skin absorption
IR_a	=	air inhalation rate (m^3/day)
CSF_i	=	inhalation cancer slop factor $(mg/kg/day)^{-1}$
PEF	=	particulate emission factor *(or volatilization factor for volatiles)
THQ	=	target hazard quotient
RfD_o	=	oral reference dose (mg/kg/day)

3.4.3.1 Inhalation of Volatiles and Fugitive Dust in Surface Soils

Some chemicals can volatilize from the soil and be inhaled as vapor while others tend to adhere to soil particles that can then be inhaled as fugitive dust during such activities as foxhole digging. Whether or not a chemical will volatilize from the soil depends on the chemical's physicochemical characteristics. In the USEPA Region IX PRG equations, inhalation of volatile compounds is included by means of the soil-to-air volatilization factor (VF); the VF replaces the soil particulate emission factor (PEF) which is used for semi volatile organics and metals.

The same criteria used by USEPA Region IX were used to determine whether or not a chemical is volatile. They are based on chemical properties and depend on the two following conditions:

- Henry's Law constant ≥ to 10^{-5} atm-m^3/mole; and,
- Molecular weight < 200 g/mole.

When a chemical was identified as a VOC, its MEG was developed without the inhalation pathway because field sampling of air concentrations would capture these soil-to-air vapor concentrations. Therefore, military air guidelines (see Section 4) would be most applicable in addressing inhalation exposure for these chemicals.

Inhalation of nonvolatile in fugitive dust as a result of surface soil agitation was estimated using the PEF model. This factor is predominantly affected by wind erosion. The general PEF equation is shown in Equation 3-13:

Equation 3-13 – Particulate Emission Factor

$$PEF = \frac{Q}{C} \cdot \left(\frac{3600}{0.036 \cdot (1 - V) \cdot \left(\frac{U_m}{U_t} \right)^3 \cdot F(x)} \right)$$

Where:

PEF = particulate emission factor (m^3/kg)
3600 = units conversion (seconds per hour)
Q/C = simplified dispersion term, 90.80 (g/m^2-s per kg/m^3)
V = vegetative cover, 0.5 (50%)
U_m = mean annual wind speed, 4.69 m/s
U_t = equivalent wind speed threshold at 7 meters, 11.32 m/s
F(x) = function dependent on U_m/U_t, 0.194

USEPA recommended default values were used for all parameters. It should be noted, however, that these parameters are based on data obtained from the continental U.S. and may not be representative of other geographical regions. But without actual field data, these parameters cannot be accurately predicted.

For the dispersion term, which depends both on meteorological conditions and source size, the USEPA assumes a 0.5-acre square source area and uses the 90th

percentile Q/C as the default value when site-specific information is not available (USEPA 1996b). While the 0.5-acre square source area may not be the average size of a contaminated area during deployment, it is noted that only *decreases* in this value will result in more conservative MEGs and specifically will impact only those chemicals that are more toxic via inhalation). In most cases, increasing the source size did not impact final MEGs. It should be noted that using a source area of 0.5-acres to develop the MEGs does not mean that samples need to be obtained every 2 acres.

Applying the given parameters to Equation 3 results in a single PEF value of 1.32 x 10^9 m^3/kg. This value is applicable for all chemicals since the PEF is used to estimate the dust emission from the surface soil given various environmental conditions.

3.4.4 Soil Saturation Consideration

Certain factors such as a substance's physical chemical characteristics must be taken into account to ensure that the estimated soil concentrations are meaningful. For chemicals that were classified as volatiles using the criteria above, they were compared with a chemical-specific soil saturation concentration (C_{sat}) calculated using Equation 3-14:

Equation 3-14 – Soil Saturation Concentration

$$C_{sat} = \frac{s}{\rho_b} \cdot \left(\kappa_d \cdot \rho_b + \theta_w + H' \cdot \theta_a \right)$$

Where:

C_{sat} = soil saturation concentration (mg/kg)
S = water solubility (mg/L water)
ρ_b = dry soil bulk density, 1.5 g/cm^3
θ_w = water-filled soil porosity, 0.15
H' = dimensionless Henry's Law constant
θ_a = air-filled soil porosity, 0.28
K_d = soil-water partition coefficient (L/kg)

As described by the USEPA Region IX guidance, the soil saturation limit determines the concentration at which the soil pore air and water volumes are saturated with the chemical. Above this level, the chemical may be a non-aqueous phase liquid (NAPL) if it is a liquid at ambient temperature, or a pure solid if it is a solid at ambient temperature. Therefore, it is not possible for the chemical to be present in the soil at a concentration higher than what the soil can physically hold. Subsequently, for liquid contamination, if a chemical's C_{sat} was lower than its health-based value, the C_{sat} was used as the final MEG.

Similarly, for inorganics and semi-volatiles, a maximum soil concentration is attained when the estimated soil concentration reaches 10^6 mg/kg. In the event where the estimated soil concentration exceeded this value of 10^6 mg/kg, the value itself was used as the MEG for that chemical.

3.4.5 Toxicity Data

3.4.6.1 Inhalation Toxicity

To be consistent with the air and drinking water guidelines, the hierarchies of toxicity values used to derive those guidelines were used to derive the soil guidelines. To estimate soil concentrations from chemicals that are carcinogenic via inhalation, CSF_is published by the USEPA in IRIS and HEAST were used. For the PAHs that have a USEPA WOE of B2, TEFs as recommended by the USEPA (USEPA, 1993) were applied to the CSF of benzo(a)pyrene as previously described in Section 4.3.

For non-carcinogenic effects, similar to the development of the PMEGs, subchronic RfCs were used followed by chronic RfCs and then by TLV®s. Since some TLVs® are based on a chemical's carcinogenicity, all TLV®s derived RfCs were checked with the background TLV® documentation to ensure that the TLVs® are based on noncarcinogenic effects. Currently, five chemicals within this document have TLV®-derived RfCs. These are: cadmium, chromium (III), chromium (VI), nickel, and xylene (mixture). Of the TLVs® used to derive the long-term MEGs, only that of cadmium is based on cancer (of the lungs). Upon closer evaluation, it was determined that the TLVs® of 0.002 mg/m^3 is for the respirable fraction. A different TLV® is available for the inhalable particulate fraction, which in this case, is more appropriate for the long-term MEGs because inhalation of metals from the soil is calculated using a particulate emission factor (see Equation 3-13). Therefore, the TLV® of 0.01 mg/m^3 as inhalable particulates was used to obtain a TLV®-derived RfC for cadmium. This TLV® is based on effects on the kidney.

Unlike the adjustment factors used for the PMEGs-L, the TLVs® were converted to RfCs as follows in Equation 3-15.

Equation 3-15 – Conversion of TLVs® to RfCs

$$RfC_{TLV} = TLV\left(\frac{5\,days}{7\,days}\cdot\frac{10\,m^3}{20\,m^3}\cdot 0.1\right)=\frac{TLV}{28}$$

As previously discussed, these adjustments are necessary to account for differences in exposure conditions. The higher inhalation rate of 29.2 m^3/day is omitted from this conversion because this factor is accounted for in Equation 3-2. Currently, no inhalation MRLs were used to derive the MEGs for the present list of chemicals.

3.4.6.2 Ingestion Toxicity

Oral CSFs from IRIS or HEAST were used for chemicals that are carcinogenic via ingestion. The TEFs from Table RD 3-2 were used to derive CSFs for carcinogenic PAHs. If a chemical was not carcinogenic, then an MEG based on carcinogenicity was not developed.

Oral reference doses (RfD_o) were used to estimate a chemical's MEG for noncancer effects. Although IRIS and HEAST provide RfD_os, these values were not used

because they are intended for longer-term exposures. Instead, the same rationale used to develop the MEGs was implemented. As a first step, the MEGs that are based on noncancer effects were used to back-calculate for an RfD_o as follows:

Equation 3-16 – Oral Reference Doses

$$RfD_o\ (mg/kg/day) = \frac{MEG \cdot 5\,L/day}{70\,kg}$$

If an MEG is based on a chemical's carcinogenicity, the hierarchy of toxicity data compiled during the development of the MEGs was assessed to determine the most appropriate noncancer toxicity value to use for that chemical. Based on this evaluation, it was determined that the MEGs of beryllium, ethylene dibromide and 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) could not be used to establish the RfD_os. Therefore, USEPA's longer-term HA was used as the RfD_o for beryllium and the ATSDR's MRL was used for RfD_o of 2,3,7,8-TCDD. Since no other noncarcinogenic data are available for ethylene dibromide, the MCL was used as the surrogate RfD_o for this compound. The same water ingestion rate and body weight factors as shown above, were used to convert these values to the appropriate units of mg/kg/day.

3.4.6.3 Dermal Toxicity

Currently, no dermal toxicity data is presented in either the USEPA's IRIS (USEPA, 1999a) database or HEAST database (USEPA, 1997a). These are the two most commonly used databases for oral and inhalation toxicity data for HRA purposes. The USEPA does, however, provide guidance on the use of surrogate information to develop dermal toxicity data when the need arises (USEPA 1989a). This involves using oral toxicity values and applying appropriate gastrointestinal (GI) absorption rates when they are available. If a chemical-specific GI ABS is not available, then a default value of 100 percent is recommended (i.e., dermal toxicity value is the same as the oral toxicity value). Using a 100 percent absorption may be less conservative in some instances. However, in light of the data gaps, this may be the best means to estimate dermal toxicity. For CSF the dermal toxicity value is obtained by dividing the oral CSF by the GI absorption rate. For non-cancer effects, the RfD_o is multiplied by the GI absorption rate to obtain a dermal RfD.

Not all chemicals are hazardous via dermal exposure. Therefore, information from the ACGIH was used to screen out substances that have no known dermal toxicity. Typically, when the ACGIH reports TLVs® for a substance, a chemical with a potential for dermal absorption is assigned a skin notation. This skin notation was used as a screening method for a chemical's potential to cause health effects from dermal exposure. Therefore, when a chemical is designated a skin notation, the dermal exposure pathway was included in Equations 3-11 and/or 3-12. For a chemical that is listed, but does not have a skin notation, the dermal exposure pathway was excluded. If a chemical is not listed by the ACGIH, the dermal exposure pathway was conservatively included to develop the MEG.

3.4.6.4 Derivation of a Soil-MEG for Pb

Pb has a USEPA WOE of B2 (probable human carcinogen based on evidence in animals and inadequate or no evidence in humans) and has known systemic toxicity

(refer to Section 4.8 for more discussion on lead toxicity). However, there are no recommended toxicity values to quantify lead exposure in soil. The USEPA recommends a soil-lead screening level of 400 ppm (mg/kg), which was derived using the Integrated Exposure Uptake Biokinetic Model (USEPA, 1994c,d), for residential exposures. This value is aimed at protecting the health of children who are more susceptible to lead poisoning. Since the military population does not include children, this soil-lead screening level would not be appropriate as the lead MEG.

Although USEPA Region IX recommends a soil screening level of 1000 ppm for industrial exposures, this value is based on USEPA default assumptions for industrial workers (e.g., soil ingestion rate of 50 mg/day). Since these assumptions are different from those used to derive the MEGs in this document, the 1000 ppm is not applicable as an MEG. In addition, it is unclear how 1000 ppm was derived using the Adult Lead Model (ALM) (TRW 1996). The Technical Review Workgroup (TRW) for lead suggests that a soil screening level of 750 ppm at industrial sites is a reasonable value (TRW 1999).

Using USEPA recommended lead exposure models is also problematic since these models generally use child-specific data. Therefore, the open literature was consulted for other models that can be used for adult lead exposure. During a telephone discussion with the USEPA's TRW for Lead, it was suggested that the Stern Model (Stern, 1996) might be more applicable for the purposes of the guidelines described in this document (Follansbee, 2000). The Stern Model is based on a relationship between blood pressure elevation and low-level lead exposure. During the last ten years, numerous studies have indicated a possible correlation between lead exposure and blood pressure, particularly in adult men (Harlan, 1988; Schwartz, 1995). However, as the ATSDR (ATSDR, 1999) points out, this relationship is still being debated in the scientific community. Other studies have shown weak or no correlation between blood pressure and blood lead (Elwood, 1988; Pocock, 1988). Since the relationship between blood pressure and low-level lead exposure is still a debatable issue, the Stern Model was not used.

A different model that does not depend on the blood lead-blood pressure relationship was also evaluated to establish a soil-lead concentration. The Bowers et al. (Bowers, 1994) model (herein referred to as the Bowers model) allows for the estimation of blood lead levels in adults exposed to environmental levels of lead. Since Bowers et al. considered blood-lead concentration from lead exposure to various media (primarily, soil, water, and air), for the purposes of the MEGs, the model was modified to exclude the other pathways. A comparison of the modified model with the ALM indicates that it is a component of the ALM.

A soil-lead concentration can be estimated using the Bowers model by back calculating from a target blood lead level. Equation 3-17 shows the modified relationship between soil-lead and blood lead concentration:

Equation 3-17 – Soil-Pb Concentration Estimate Using Stern Model

$$C_{lead} = \frac{PbB_2 - PbB_1}{BKSF \cdot AF_{s/d} \cdot IR_s}$$

Where:

MEG_{lead} = soil lead concentration (mg/kg)
PbB_1 = background blood lead concentration in adult male (µg/dL)
PbB_2 = target blood lead level (µg/dL)
BKSF = relationship between Pb soil ingestion and PbB (µg/dL)/(µg/day)
$AF_{s/d}$ = soil/dust absorption (unit less)
IR_s = soil ingestion rate (g/day)

Table RD 3-7 contains the parameters that were used to derive a MEG for lead. Those parameters recommended by the TRW for use in the ALM were used whenever possible.

Table RD 3-7. Input Parameters for the Modified Bowers Model

Parameter	Value	Rationale
PbB_2	30 µg/dL	See text for more discussion
PbB_1	2.0 µg/dL	Mid-range of 1.7 to 2.2 µg/dL as recommended by the TRW when demographic-specific information is not available
BKSF	0.4 µg/dL per µg/day	TRW's recommended default
$AF_{s/d}$	0.12	TRW's recommended default [based on absorption factor for soluble lead of 0.20 and a relative bioavailability of 0.6 (soil/soluble)]
IR_s	0.265 g/day	See Section 3.2.4

Various standards for lead exposure have been established to protect the health of workers. OSHA states that if a worker's blood lead exceeds 40 micrograms per deciliter (µg/dL), the worker must be temporarily removed for medical examinations (29 CFR). The OSHA also recommends that the blood lead of workers who intend to have children not exceed 30 µg/dL. This value is also the recommended ACGIH biological exposure index (BEI) for lead exposure in the workplace. In addition, almost all the studies reviewed by ATSDR (Table 2-1 of ATSDR 1999) show that no adverse health effects were observed in occupational populations where the blood-lead level was below 40 µg/dL. Therefore, 30 µg/dL was used as the target blood-lead level in Equation 3-17. Applying the parameters in Table RD 3-8 to Equation 3-12 results in a soil lead level of 2200 ppm.

3.4.6 Exposure Factors

Equations 3-11 and 3-12 require various exposure factors before soil concentrations can be calculated. Although USEPA Region IX provides default exposure factors for the residential and industrial scenarios, they may not all reflect the exposure factors typical of deployed situations. A discussion of each factor is presented in the following sections.

3.4.6.1 Exposure Duration and Frequency

As previously discussed (see Section 3.1) an ED of 1 year and EF of 365 days was assumed when deriving the guidelines in TG 230.

3.4.6.2 BW

As indicated in Section 3.1, a BW of 70 kg is used as the representative weight for deployed personnel.

3.4.6.3 Soil Ingestion

Currently, no information is available to estimate incidental soil ingestion for the military population either during training at continental U.S. facilities or during deployment. Although the USEPA provides adult-specific soil ingestion rates, the uncertainty associated with these recommendations is rather high because of the lack of adult-specific studies. Since soil ingestion is a function of age, studies have typically focused on children because of their behavioral patterns.

At present, the USEPA suggests a mean soil ingestion rate of 50 mg/day for adults (USEPA, 1997). However, an adult soil ingestion rate of 100 mg/day is still commonly used for residential or agricultural settings (USEPA, 1989a; USEPA, 1991a). For commercial and industrial scenarios, the soil ingestion rate is 50 mg/day (USEPA, 1991a). For certain activities such as construction or landscaping which involve a greater soil contact rate, a soil ingestion rate of 480 mg/day is recommended. This value is based on the assumption that the ingested soil comes from a 50 µm layer of soil adhered to the insides of the thumb and the fingers of one hand (USEPA, 1997c). All the ingestion rates presented above include ingestion of both soil and dust particles.

The activity of deployed military personnel is probably more similar to those of a construction worker than a resident. Activities may include digging or crawling on the ground leading to a higher soil exposure than the general U.S. population. However, the ingestion rate of 480 mg/day is not supported by measured data and thus contains a high degree of uncertainty (USEPA, 1997c). In addition, the USEPA advises that this value should only be used for short-term exposures (USEPA, 1991a). Despite this uncertainty, this value cannot be wholly discounted. Therefore, to estimate a soil ingestion rate for deployed scenarios, it was assumed that the deployed military personnel would be exposed at both the high ingestion rate and a mean ingestion rate throughout the year. The two ingestion rates were averaged to obtain a weighted daily ingestion rate as follows in Equation 3-18.

Equation 3-18 – Weighted Daily Soil Ingestion Rate

$$IR_{soil} = \frac{(480\,mg/day)\cdot(182.5\,days) + (50\,mg/days)\cdot(182.5\,days)}{365\,days} = 265\,mg/days$$

3.4.6.4 Inhalation Rate

As described in Section 3.2.4, a specific estimate of a deployed military person's inhalation rate was calculated assuming different activities rates throughout daily activities. This daily inhalation rate of 29.2 m^3/day was used to calculate the Soil-MEGs.

3.4.6.5 Dermal Exposure

Three parameters are needed to evaluate dermal uptake of chemicals from the soil. These include the skin surface area (SA) available for contact, the skin-to-surface adherence factor (AF) and the skin absorption factor (ABS). These parameters are either scenario-specific or chemical-specific. Although there are no known studies on soldier exposure to soil, the USEPA's *Exposure Factors Handbook* (USEPA, 1989b) provides sufficient data to estimate chemical uptake via the dermal route for deployment situations.

- Skin Surface Area (SA) – The average amount of surface area available for contact depends on the type of clothing that is worn during deployment. While there may be instances where tops will be removed or sleeves will be rolled up during work, in general, military persons under deployment are expected to be clad in uniforms at all times. This ensures that they are camouflaged and protects them from injury or insect bites.

  When a soldier is properly attired in the field, only the soldier's hands, head, and neck would be exposed. Also, to account for the likely instance of soldiers rolling up their sleeves, the SA from the forearm was also included to account for dermal exposure from soil. Using this assumption, the total exposed skin SA was derived from the USEPA's *Exposure Factors Handbook* (USEPA, 1997c) which contains SA for various body parts and for different percentiles. For the soil guidelines, the 90^{th} percentile SA of each exposed area of adult males was used since the USEPA believes that high end is conceptually above the 90^{th} percentile of a distribution (USEPA, 1992a). This ensures that the soil guidelines would be protective of the high end individuals. Therefore, a final SA of 4090 cm^2 was used to derive the soil guidelines for deployed situations. This number is based on SAs of 0.112 m^2 , 0.140 m^2, and 0.157 m^2 for the hands, head, and forearms, respectively.

- Skin-To-Surface AF – The AF is primarily dependent on soil property, the part of the body that is exposed, and the type of activity. Since little is known about the extent of soil adherence to the skin for military-specific activities, AFs developed from other activities were reviewed as a possible source of surrogate data. Various activity factors of deployment scenarios must be considered to select a representative AF.

  Based on activity pattern, it can be concluded that a deployed personnel's activities most resemble those of outdoor workers such as farmers. This group of people tends to have a high soil contact rate. However, the AFs presented in the USEPA's *Exposure Factors Handbook* do not appear to fit those of deployed personnel. Part of this is due to the difference in the body coverage by clothing. Since outdoor work tends to be performed during warmer months, subjects from the studies used in the *Exposure Factors Handbook* have more exposed SA for soil contact. Other factors to consider include the fact that a deployed personnel may not have the opportunity to shower daily. Therefore, the amount of soil that adheres to the skin can accumulate in between washing. In addition, for high intensity tasks, more soil can stick to the skin because of sweating (USEPA, 1989b).

Based on the lack of information, a default upper tendency value of 1.0 mg/cm^2 per event (USEPA, 1992b) was used for the deployment scenario. Selection of a higher AF can also account for some of the soil and dust particles getting beneath the clothing layer. This parameter may be adjusted in the future as more representative AFs become available.

- Skin Absorption Factor (ABS) – The ABS is a chemical-specific parameter used to estimate the amount of chemical that travels across the skin barrier. This parameter is used in conjunction with the AF discussed above. The AF determines how much soil is available for contact while the ABS determines how much of the chemical bound to the soil particle actually gets absorbed dermally.

  Very few chemical-specific ABS have been developed. The USEPA lists only about 10 chemicals with suggested chemical-specific ABS values, all of which are less than 10 percent. For chemicals with no ABS, USEPA Region IX suggests using default values of 1 percent for inorganics and 10 percent for organics, respectively. This is similar to Region III's recommended defaults of 1 percent for metals, 3 percent for volatiles, and 10 percent for semi volatiles and pesticides. Using these same recommendations, values of 1 percent and 10 percent for inorganics and organics were used to develop MEGs when chemical-specific data were not available.

  Chemical-specific ABS values have been proposed for some of the chemical warfare agents (Major, 1998). These ABS values are based on an hourly soil absorption rate. To account for the situation where military personnel under deployment may not shower everyday, thereby, prolonging the adherence of contaminated soil to the skin, a 24-hour exposure was assumed to develop the MEGs. Since no chemical-specific ABS has been developed for lewisite, the USEPA's default of 10 percent for organics was used for lewisite.

Table RD 3-8. Skin Absorption Factors Used for the Development of Soil-MEGs

Chemical	ABS
Inorganics	1% per day
Organics	10% per day
GA	0.35% per hour
GB	0.26 % per hour
GD	0.78% per hour
HD	0.70% per hour
VX	0.27% per hour

3.4.7 Consideration of Acute Toxicity

It is often assumed that when using sub-chronic or chronic toxicity criteria as the underlying basis for a risk assessment, that the resulting health-based levels (e.g. the MEGs) will be protective against all adverse health effects, including immediate or acute effects associated with single or short-term exposures. Since the specific scenario used to calculate MEGs assumes much shorter duration of exposure than that typically used in USEPA risk assessment, it was necessary to evaluate whether the resulting guidelines could pose immediate/acute health effects after short-term exposures. To ensure that the MEGs do not exceed acutely toxic levels, they were compared with USEPA's short-term one-day drinking water Health Advisories (HA) (USEPA, 1996a).

As noted in TG 230, these HAs are protective for up to 5 days of consecutive exposure. Henceforth, they are referred to as 5-day HAs for the purpose of this document.

To compare the MEGs and the 5-day drinking water HAs, all concentrations were converted to an intake or a dose (i.e., mg/kg/day). Therefore, the HAs were adjusted by the amount of water typically consumed in the field (5 L) and the average adult BW as follows:

Equation 3-19 – Equivalent Acute RfDs

$$RfD_{acute} = \frac{HA_{5days} \cdot IR_w}{BW}$$

Where:

RfD_{acute} = equivalent acute reference dose (mg/kg/day)
$HA_{5\ days}$ = 5-day health advisory (mg/L)
IR_w = water ingestion rate, 5L/day
BW = average body weight, 70 kg

Similarly, the MEGs were converted from a soil concentration to an intake as follows:

Equation 3-20 – Daily Intake from Soil

$$I_{soil} = \frac{MSG \cdot FC \cdot IR_s}{BW \cdot 10^{6}}$$

Where:

I_{soil} = daily intake of chemical from soil (mg/kg/day)
MEG = military soil guideline, long-term (mg/kg)
FC = fraction of soil contaminated, 100% (unit less)
IR_s = soil ingestion rate, 265 mg/day
BW = body weight, 70 kg
10^6 = conversion from mg to kg

While the objective here was to ensure that the MEGs do not exceed acute health concerns, it should be noted that unique 'short-term exposure scenarios' (such as where the ingestion rate might be exceedingly higher than the average rates assumed in MEG calculations) were not specifically evaluated.

As noted in Equation 3-20, only the ingestion route of exposure was used to estimate an intake using the MEG. This is mainly because the HAs are intended for ingestion only and currently, little information is available to evaluate health effects from dermal contact for acute exposures. In addition, the soil ingestion pathway generally dominates as the major pathway of concern when compared with the inhalation of fugitive dust.

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APPENDIX A
REFERENCES

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APPENDIX B
ACRONYMS

APPENDIX B - Acronyms

ABS	Skin Absorption Factor
ACGIH	American Conference of Governmental Industrial Hygienists
Adj	Adjusted
AEGL	Acute Exposure Guideline Level
AF	Adherence Factor
AIHA	American Industrial Hygiene Association
ALM	Adult Lead Model
AMEDD	Army Medical Department
ANOVA	Analyses of Variance
AQI	Air Quality Index
AT	Averaging Time
ATSDR	Agency for Toxic Substances and Disease Registry
AUR	Air Unit Risk
BEI	Biological Exposure Index
BW	Body Weight
CAS	Chemical Abstract Service
CAWG	Chemical Agent Working Group
CEGLs	Continuous Exposure Guidance Levels
CFR	Code of Federal Regulation
cm^2	square centimeter
CN	Cyanide
CN/L	Cyanide/ L
CNS	Central Nervous System

CO	Carbon Monoxide
CONUS	Continental United States
COT	Committee on Toxicology
cPAHs	Carcinogen Polycyclic Aromatic Hydrocarbons
C_{sat}	Soil Saturation Concentration
CSF	Cancer Slope Factor
CSFi	Inhalation Cancer Slope Factor
CSFo	Oral Carcer Slope Factor
CWA	Chemical Warfare Agents
CVS	Cardiovascular System
DIMP	Diisopropyl methylphosphate
DNBI	Disease and Non-Battle Injury
DOD	Department of Defense
DODI	Department of Defense Instruction
DOE	Department of Energy
DODI	Department of Defense Instruction
ED	Exposure Duration
EEGLs	Emergency Exposure Guidance Levels
EF	Exposure Frequency
ERPG	Emergency Response Planning Guideline
FDWS	Field Drinking Water Standards
FHP	Force Health Protection
FM	Field Manual
gm	Gram
g/kg	Gram per kilogram

GI	Gastrointestinal
gm/L	Gram per Liter
HAs	Health Advisories
HAs-Adj	Health Advisories-Adjusted
HC	Hexachloroethane
HEAST	Health Effects Assessment Summary Tables
HEC	Human Equivalency Concentration
HRA	Health Risk Assessment
HSDB	Hazardous Substance Databank
HQ	Hazard Quotient
IC_{50}	Incapacitating Concentration for 50 percent exposed population
IDLH	Immediately Dangerous to Life and Health
IMP	Isopropyl methylphosphonate
IR	Inhalation Rate
IRIS	Integrated Risk Information System
ITF	International Task Force
Kg	kilogram
L	Liter
LC_{50}	Lethal Concentration for 50 percent of the exposed population
LC_{LO}	Lowest Lethal Concentration
LD	Lethal Dose
LD_{50}	Lethal Dose 50%
L/day	Liter per day
LOAEL	Lowest Observed Adverse Effects Level
MAF	Military Adjustment Factor

MEG	Military Exposure Guideline
MCLGs	Maximum Contaminant Level Goals
MCL	Maximum Contaminant Level
MCRC	Military Cancer Risk Concentration
MRC	Military Risk Concentration
MRLs	Minimal Risk Levels
m	meter
m^3/day	cubic meter per day
m^3/hr	cubic meter per hour
µg/dl	microgram per deciliter
µg/kg/day	Microgram per kilogram per day
µg/kg	microgram per kilogram
µg/L	microgram per liter
µg/m^3	microgram per cubic meter
mg/cm^2	milligram per square centimeter
mg/day	milligram per day
mg/kg	milligram per kilogram
mg/kg/day	milligram per kilogram per day
mg/L	milligram per Liter
mg/m^3	milligram per cubic meter
MOPP	Mission-Oriented Protective Posture
NA	Not applicable
NAAQS	National Ambient Air Quality Standards
NAC	National Advisory Committee
NAPL	Non-aqueous phase liquid

NAS	National Academy of Science
NATO	North Atlantic Treaty Organization
NBC	Nuclear, Biological, and Chemical
NBC-E	Nuclear, Biological, and Chemical Environment
NCHS	National Center for Health Statistics
ND	Not determined
NIOSH	National Institute of Safety and Occupational Health
NO_2	Nitrogen Dioxide
NO_x	Oxides of Nitrogen
NOAEL	No-Observed Adverse Effect Level
NRC	National Research Council
O_3	Ozone
OCONUS	Outside the continental United States
ORD	Office of Research and Development
ORM	Operational Risk Management
OSHA	Occupational Safety and Health Administration
PAHs	Polycyclic Aromatic Hydrocarbons
Pb	Lead
PBPK	Physiologically-Based Pharmacokinetic Model
PEF	Particulate Emission Factor
PEGL	Permissible Exposure Guidelines Level
PEL	Permissible Exposure Limit
PM	Particulate Matter
PMEGs	Preliminary Military Air Guidelines
Ppm	parts per million

PRG	Preliminary Remediation Goals
PSI	Pollution Standard Index
QSTAG	Quadripartite Standardization Agreement
RBC	Risk Based Concentration
RD	Reference Document
RDA	Recommended Daily Allowance
RfC	Reference Concentration
RfD	Reference Dose
RfD-Adj	Adjusted Chronic/ Sub-chronic Reference Dose
RfD_i	Inhalation Reference Dose
RfD_o	Oral Reference Dose
ROWPU	Reverse Osmosis Water Purification Unit
SA	Surface Area
SAI	Safe and Adequate Intake
SCAPA	Subcommittee on Consequence Assessment and Protective Actions
SO^2	Sulfur Dioxide
SOH	Safety and Occupational Health
SPEGLs	Short-term Public Guidance Levels
SSL	Soil Screening Level
SST	Soil Screening Level
STANAG	Standardization Agreement
STEL	Short-term Exposure Level
TB MED	Technical Bulletin, Medical
TCR	Target Cancer Risk
TEELs	Temporary Emergency Exposure Limits

TEFs	Toxic Equivalent Factors
TG	Technical Guide
THQ	Target Hazard Quotient
TICs	Toxic Industrial Chemicals
TIMs	Toxic Industrial Materials
TLVs®	Threshold Limit Values
TLVs®-Adj	Threshold Limit Values-Adjusted
TPH	Total Petroleum Hydrocarbons
TRI	Toxic Release Inventory
TRW	Technical Review Workgroup
TT	Treatment Technique
TWA	Time-Weighted Average
UF	Uncertainty Factor
USACHPPM	U.S. Army Center for Health Promotion and Preventive Medicine
USARIEM	U.S. Army Research Institute of Environmental Medicine
USEPA	U.S. Environmental Protection Agency
VF	Volatilization Factor
VOC	Volatile Organic Compounds
WOE	Weight-of-Evidence
WQAS-PM	Water Quality Analysis Set-Preventive Medicine
$ZnCl_2$	Zinc Chloride

APPENDIX C
DERIVATION OF MILITARY EXPOSURE GUIDELINES FOR AIR

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Table C-1: Air Military Exposure Guidelines for Chemical Warfare Agents

Chemical CAS No.	Air-MEG Health Effect Level	10-Minute mg/m^3 [ppm]	1-Hour mg/m^3 [ppm]	8-Hour mg/m^3 [ppm]	24-Hour mg/m^3 [ppm]	Potential Symptoms and Target Organs/Systems	Notes
GA (Tabun) 77-81-6	MINIMAL	0.0069 [0.0010]	0.0028 [0.00042]	0.0010 [0.00015]	0.0003 [0.00005]	Running nose; tightness of chest; miosis and dim vision; difficulty breathing; drooling and excessive sweating; nausea, vomiting; CNS effects.	Based on relative potency from GB (see NRC 2003) 24-hour MEG estimate derived from 8-hour AEGL by straight-line extrapolation of 8-hour AEGL Ct IDLH = 0.1 mg/m^3 (per DA Pam 40-173, 2003)
	SIGNIFICANT	0.087 [0.013]	0.035 [0.0053]	0.013 [0.0020]	0.004 [0.00067]		
	SEVERE	0.76 [0.11]	0.26 [0.039]	0.10 [0.015]	0.03 [0.005]	Local effects to pupil of the eye; Respiratory system, CNS	
GB (Sarin) 107-44-8	MINIMAL	0.0069 [0.0012]	0.0028 [0.00048]	0.0010 [0.00017]	0.0003 [0.000057]	Running nose; tightness of chest; dimness of vision and miosis; difficulty in breathing; drooling and excessive sweating; nausea, vomiting; cramps and involuntary defecation or urination; twitching, jerking and staggering; headache, confusion, drowsiness; at high exposures, coma and convulsion, leading to cessation of breathing and	Minimal Level: Reversible miosis, headache, eye pain, rhinorrhea, tightness in chest, cramps, nausea, malaise, miosis in human volunteers; may limit performance for night operations, aircrews, and tasks involving distance or spatial judgment Significant Level:

Table C-1: Air Military Exposure Guidelines for Chemical Warfare Agents

Chemical CAS No.	Air-MEG Health Effect Level	10-Minute mg/m^3 [ppm]	1-Hour mg/m^3 [ppm]	8-Hour mg/m^3 [ppm]	24-Hour mg/m^3 [ppm]	Potential Symptoms and Target Organs/Systems	Notes
						death --- Local effects to pupil of the eye; Respiratory system, CNS, gastrointestinal system	Reversible miosis, dyspnea, Red blood cell(RBC)-ChE inhibition, single fibre electromyography (SFEMG) changes in human volunteers; may limit performance for night operations, aircrews, and tasks involving distance or spatial judgment Severe Level: Based on GB vapor experimental Sprague-Dawley rat lethality data (LC_{01}, LC_{50}) IDLH = 0.1 mg/m^3 (per DA Pam 40-173, 2003)
	SIGNIFICANT	0.087 [0.015]	0.035 [0.0060]	0.013 [0.0022]	0.004 [0.00073]		
	SEVERE	0.38 [0.064]	0.13 [0.022]	0.051 [0.0087]	0.02 [0.0029]		
GD (Soman) 96-64-0	MINIMAL	0.0035 [0.00046]	0.0014 [0.00018]	0.00050 [0.000065]	0.0002 [0.000022]	See GB for Symptoms. --- Local effects to pupil of the eye; Respiratory system, CNS, gastrointestinal system	Based on relative potency from GB (NRC 2003) 24-Hour MEG derived from 8-hour AEGL by straight-line extrapolation of 8-hour AEGL Ct IDLH = 0.05 mg/m^3 (per DA Pam 40-173, 2003)
	SIGNIFICANT	0.044 [0.0057]	0.018 [0.0022]	0.0065 [0.00085]	0.002 [0.00028]		

Table C-1: Air Military Exposure Guidelines for Chemical Warfare Agents

Chemical CAS No.	Air-MEG Health Effect Level	10-Minute mg/m^3 [ppm]	1-Hour mg/m^3 [ppm]	8-Hour mg/m^3 [ppm]	24-Hour mg/m^3 [ppm]	Potential Symptoms and Target Organs/Systems	Notes
	SEVERE	0.38 [0.049]	0.13 [0.017]	0.051 [0.0066]	0.02 [0.0022]		
GF 329-99-7	MINIMAL	0.0035 [0.00049]	0.0014 [0.00020]	0.00050 [0.000070]	0.0002 [0.000023]	See GB for Symptoms. Local effects to pupil of the eye; respiratory system, CNS, gastrointestinal system	Based on relative potency from GB (NRC 2003) 24-Hour MEG derived from 8-hour AEGL by straight-line extrapolation of 8-hour AEGL Ct IDLH = 0.05 mg/m³ (per DA Pam 40-173, 2003)
	SIGNIFICANT	0.044 [0.0062]	0.018 [0.0024]	0.0065 [0.00091]	0.002 [0.00030]		
	SEVERE	0.38 [0.053]	0.13 [0.018]	0.051 [0.0071]	0.02 [0.0024]		
Sulfur mustard [HD]	MINIMAL	0.40 [0.06]	0.067 [0.01]	0.008 0.001	0.003 [0.00033]	Delayed development of irritation to eyes, mucous membranes; potent alkylating agent; mutagenic.	24-Hour MEG estimate derived from 8-hour AEGL by straight-line extrapolation of 8-hour AEGL Ct

Table C-1: Air Military Exposure Guidelines for Chemical Warfare Agents

Chemical CAS No.	Air-MEG Health Effect Level	10-Minute mg/m^3 [ppm]	1-Hour mg/m^3 [ppm]	8-Hour mg/m^3 [ppm]	24-Hour mg/m^3 [ppm]	Potential Symptoms and Target Organs/Systems	Notes
505-60-2	SIGNIFICANT	0.60 [0.09]	0.10 [0.02]	0.013 [0.002]	0.004 [0.00067]	Conjunctivitis, blindness, edema of eyelids; necrosis of respiratory tract and exposed skin; nausea, vomiting. Eyes, respiratory system, skin	IDLH = 2 mg/m^3 (per DA Pam 40-8, 2003)
	SEVERE	3.9 [0.59]	2.1 [0.32]	0.27 [0.04]	0.09 [0.013]		
VX 50782-69-9	MINIMAL	0.00057 [0.000052]	0.00017 [0.000016]	0.000071 [0.0000065]	0.000024 [0.0000022]	AChE inhibitor; CNS effects: headache, runny nose and nasal congestion, nausea, vomiting, giddiness, anxiety, difficulty in sleeping/thinking, muscle twitching, weakness, abdominal cramps	Minimal and Significant Levels: Derived by relative potency from study of multiple minimal (1) or transient (2) effects in human volunteers exposed to agent GB;

Table C-1: Air Military Exposure Guidelines for Chemical Warfare Agents

Chemical CAS No.	Air-MEG Health Effect Level	10-Minute mg/m^3 [ppm]	1-Hour mg/m^3 [ppm]	8-Hour mg/m^3 [ppm]	24-Hour mg/m^3 [ppm]	Potential Symptoms and Target Organs/Systems	Notes
						abdominal cramps.	exposed to agent GB; may limit performance for night operations, aircrews, and tasks involving distance or spatial judgment
	SIGNIFICANT	0.0072 [0.00065]	0.0029 [0.00027]	0.0010 [0.000095]	0.00033 [0.000032]	Local effects to pupil of the eye; Respiratory system, CNS, gastrointestinal system	Severe Level: Derived by relative potency from study of GB vapor experimental Sprague-Dawley rat lethality data (LC_{01}, LC_{50}) (NRC 2003).
	SEVERE	0.029 [0.0027]	0.010 [0.00091]	0.0038 [0.00035]	0.0013 [0.00012]		Hour MEG estimate derived 8-hour AEGL by straight-line apolation of 8-hour AEGL Ct IDLH = 0.01 mg/m³ (per DA Pam 40-173, 2003)

Table C-1: Air Military Exposure Guidelines for Chemical Warfare Agents

FOOTNOTES FOR TABLE RD 2-2 – AIR-MEGS FOR CHEMICAL WARFARE AGENTS

AchE: Acetylcholinesterase
AEGL: Acute Exposure Guideline Level
CNS: Central nervous system
Ct: Concentration $\times$ time
GPL: General population limit
IDLH: Immediately dangerous to life and health
WPL: Worker population limit
RBC: Red blood cell
ppm: part per million
$mg/m^{3:}$ milligrams per cubic meter

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DA Pam 40-8, *Occupational Health Guidelines for the Evaluation and Control of Exposure to Mustard Agents*, Medical Services, revised staffing version, Jan 2003.

Table C-2: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
Acetone cyanohydrin 75-86-5	16.4[C] [4.7]	ND	ND	Dermal exposures can contribute to systemic dose. Ceiling value derived as CN.	Only acute value available.
Acrolein 107-02-8	0.07 [0.03] (AEGL-1*)	0.23 [0.1] (AEGL-2*)	3.2 [1.4] (AEGL-3*)	Concentrations of 0.06 ppm for 5 min caused irritation in humans.	*Proposed AEGL's published in Fed. Reg. ERPG (1-3): 0.1, 0.5, 3 ppm; EEGL – 0.05 ppm; Ceiling value – 0.1 ppm, IDLH – 2 ppm.
Acrylic acid 79-10-7	3 [1.0] (AEGL-1)	136 [46] (AEGL-2)	531 [180] (AEGL-3)	Irritation eyes, skin, respiratory system; skin burns and skin sensitivity.	NIOSH TWA = 6 [2]
Acrylonitrile 107-13-1	22 [10] (ERPG-1)	76 [35] (ERPG-2)	163 [75] (ERPG-3)	Lethality was observed in dogs after exposure to 65 ppm for 4 hrs.	IDLH – 85 ppm.
Aldrin 309-00-2	ND	ND	25 (IDLH)	Based on oral data; 18 mg/m^3/day caused no effects in man; ingestion of 25.6 mg/kg caused convulsions in 20 min (extrapolated: 1200 mg/m^3 for 30 min) (NIOSH 1994).	No other acute values available.
Allyl alcohol 107-18-6	5 [2.1] (AEGL-1)	10 [4.2] (AEGL-2)	159 [67] (AEGL-3)	NIOSH (1994) notes that inferences from animal experiments suggest that single 1-hour exposures of 150 ppm may be fatal, yet exposures to 100 ppm would probably allow survival.	TEEL (1-3): 4, 15, 20 ppm; STEL - 4 ppm; IDLH - 20 ppm.
Ammonia 7664-41-7	17 [25] (AEGL-1*)	77 [110] (AEGL-2*)	766 [1100] (AEGL-3*)	Minimal effect levels based on eye and respiratory irritation; significant to severe irritation in subjects exposed to 500 ppm for 0.5 hrs (NIOSH 1994).	*Proposed AEGL's published in Fed. Reg. ERPG (1-3): 25, 150, 750 ppm; STEL - 35 ppm; EEGL – 100 ppm; IDLH – 300 ppm.

Table C-2: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
Aniline 62-53-3	30 [8] (AEGL-1)	46 [12] (AEGL-2)	76 [20] (AEGL-3)	Weakness, dizziness, ataxia, irritated eyes, liver cirrohsis; bladder cancer.	OSHA 8 hr TWA 19 [5]
Arsine 7784-42-1	NA	0.54 [0.17] (AEGL-2)	1.6 [0.5] (AEGL-3)	Levels based on methemoglobin synthesis and hemolysis (and subsequent renal effects); NIOSH (1994) states that 6 – 30 ppm is maximum concentration for 1 hr without serious consequences.	ERPG (1-3): NA, 0.5, 1.5 ppm; EEGL – 1 ppm; IDLH – 3 ppm.
Benzene 71-43-2	160 [50] (ERPG-1)	479 [150] (ERPG-2)	3195 [1000] (ERPG-3)	Exposure at 1500 ppm for 1 hr induces serious symptoms; exposure at 500 ppm for 1 hr leads to symptoms of illness; exposure at 150 ppm for 5 hrs produces headache, lassitude, and weakness (NIOSH 1994).	STEL - 2.5 ppm; EEGL – 50 ppm; IDLH – 500 ppm.
Boron tribromide 10294-33-4	10 [1^C]	ND	ND	Considered primary irritant (see Appendix D). Minimal effect levels based on NOAEL in rats; rats exposed for 6 hrs/day, 5 days/wk for 3 months produced transient signs of irritation; rounded up to be consistent with the 1-14 day value.	Ceiling value – 10 mg/m^3.
Boron trifluoride 7637-07-2	0.6 [0.22] (AEGL-1)	16 [5.8] (AEGL-2)	39 [14] (AEGL-3)	Considered primary irritant (see Appendix D).	ACGIH ceiling value – 3 mg/m^3. ERPG (1-3): 2, 30, 100 mg/m^3.
Bromine 7726-95-6	0.16 [0.024] (AEGL-1*)	1.6 [0.24] (AEGL-2*)	56 [8.5] (AEGL-3*)	Concentrations above 10 ppm cause severe upper respiratory irritation; 1.7 – 3.5 ppm produces severe choking; 30 ppm would be	*Proposed AEGL's published in Fed. Reg. ERPG (1-3): 0.2, 0.5, 5 ppm; STEL - 0.2 ppm; IDLH – 3 ppm.

Table C-2: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
				fatal in a short duration (NIOSH 1994).	
Butyl isocyanate (n-) 111-36-4	0.04 [0.01] (ERPG-1)	0.2 [0.05] (ERPG-2)	4.1 [1] (ERPG-3)	A 4-hr LC_{01} for rats was 6.8 ppm. Concentrations of 0.1 – 1 ppm produce irritation to the respiratory tract and mucous membranes (AIHA 2002).	No other acute values available.
Carbon disulfide 75-15-0	3 [1] (ERPG-1)	156 [50] (ERPG-2)	1557 [500] (ERPG-3)	Exposures to 4800 ppm for 30 min cause coma and is fatal; severe symptoms and unconsciousness may occur within 30 min at 1100 ppm; 760 ppm causes an immediate headache that lasts for hrs (NIOSH 1994).	EEGL – 50 ppm; IDLH – 500 ppm.
Carbon monoxide 630-08-0	NA	95 [83] (AEGL-2)	380 [330] (AEGL-3)	1-hr exposures to 1000 – 1200 ppm will cause unpleasant but no dangerous symptoms; 1500 – 2000 may be dangerous after 1 hr.	IDLH – 1200 ppm; EEGL – 400 ppm. ERPG (1-3): 200, 350, 500 ppm.
Carbon tetrachloride 56-23-5	75 [12] (AEGL-1)	352 [56] (AEGL-2)	1070 [170] (AEGL-3)	Exposures to 1000 – 2000 ppm for 0.5 – 1.0 hrs have caused human fatalities and kidney damage; 30-min exposure to 300 ppm causes symptoms of intoxication (NIOSH 94).	ERPG (1-3): 20, 100, 750 ppm; Above odor threshold; STEL – 10 ppm; IDLH – 200 ppm.
Chlorine 7782-50-5	1.5 [0.5] (AEGL-1)	5.8 [2] (AEGL-2)	58 [20] (AEGL-3)	Exposures of 30 min cause intense coughing fits; a concentration of 34 – 51 ppm has been reported to be fatal in 1 – 1.5 hrs.	ERPG (1-3): 1, 3, 20 ppm; STEL – 1 ppm; EEGL – 3 ppm; IDLH – 10 ppm

Table C-2: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
Chlorine dioxide 10049-04-4	0.4 [0.15] (AEGL-1)	3 [1.1] (AEGL-2)	6.6 [2.4] (AEGL-3)	Irritating to eyes, nose, and throat, coughing, pulmonary edema, chronic bronchitis	ERPG (2-3): 1.4, 8.4 mg/m³. NIOSH 8 hr TWA: 0.3 mg/m³ [0.1 ppm]. STEL 0.9 mg/m³ [0.3 ppm].
Chlorine trifluoride 7790-91-2	0.5 [0.12] (AEGL-1)	11.7 [3.1] (AEGL-2)	53 [14] (AEGL-3)	Exposures of 50 ppm for 0.5 – 2 hrs may be fatal.	ERPG (1-3): 0.1, 1, 10 ppm; EEGL – 1 ppm; Ceiling value – 0.1 ppm; IDLH – 20 ppm.
Chloroacetaldehyde 107-20-0	3.2 [1^C]	71 [22] (TEEL-2)	144 [45] (TEEL-3)	Volunteers found that concentrations of 45 ppm were very disagreeable, and conjuctival irritation was noted (NIOSH 1994).	IDLH – 45 ppm.
Chloroacetone 78-95-5	3.8 [1^C]	ND	ND	Concentration of 605 ppm is lethal after a 10-min exposure and 26 ppm is intolerable after a 1-min exposure (ACGIH 1991).	No other acute values available.
Chloroacetophenone [CN] 532-27-4	ND	ND	15 IDLH	Concentration of 31 mg/m^3 is intolerable after 3 min (NIOSH 1994).	IDLH – 15 mg/m^3.
Chloroacetyl chloride 79-04-9	0.23 [0.05] (ERPG-1)	2.3 [0.5] (ERPG-2)	46 [10] (ERPG-3)	Exposures exceeding 0.14 ppm may cause slight eye irritation and respiratory irritation.	STEL – 0.15 ppm.
Chlorobenzylidene malonitrile o- [CS] 2698-41-1	0.39 [0.05^C]	ND	2 [0.26] (IDLH)	Incapacitating concentration range from 12 – 20 mg/m^3 after 20 seconds of exposure (NIOSH 1994).	No other acute values available.
Chloroform 67-66-3	NA	430 [88] (AEGL-2*)	3174 [650] (AEGL-3*)	Disorientation occurs at concentrations exceeding 1000 ppm (NIOSH 1994).	*Proposed AEGL's published in Fed. Reg. ERPG (1-3): NA, 50, 5000 ppm; REL 1 – 0.74 ppm; EEGL – 1000 ppm; IDLH 500 ppm.

Table C-2: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
Chloromethane (methyl chloride) 74-87-3	NA	828 [400] (ERPG-2)	2070 [1000] (ERPG-3)	Dizziness, vomiting, visual ditortion; staggering slurred speech; convulsions; liver and kidney damage, repro effects; liquid contact: frostbite;	OSHA 8 hr: 1900 mg/m³ [350 ppm] IDLH = 700 ppm
Crotonaldehyde 4170-30-3	0.54 [0.19] (AEGL-1)	12.6 [4.4] (AEGL-2)	40 [14] (AEGL-3)	Exposure to 4.1 ppm for 15 min was reported to be highly irritating to the nose and upper respiratory tract (NIOSH 1994).	ERPG (1-3): 2, 10, 50 ppm; IDLH – 50 ppm.
Cyanogen 460-19-5	22 [20] (*)	78 [71] (*)	166 [150] (*)	*Based on 10 x Hydrogen Cyanide AEGLs according to ACGIH Documentation of the Threshold Limit Values and Biological Exposure Indices. 6th ed. Volumes I,II, III. Cincinnati, OH: ACGIH, 1991 cyanogen is “10 times less acutely toxic).	TEEL (1-3): 64 [30], 107[50], 107 [50].
Diborane 19287-45-7	0.34 [0.3] (TEEL-1)	1.13 [1] (AEGL-2)	4.2 [3.7] (AEGL-3)	Dogs experienced minor irritation at 1 ppm for 1 hr (AIHA 2002). AIHA determined odor threshold insufficient to derive a minimal effect levels.	ERPG (2-3): 1, 3 ppm, IDLH – 15 ppm.
Dichloroethane (1,1-) 75-34-3	ND	ND	12,144 [3000] (IDLH)	Rats survived 4-hr exposures of 4000 ppm but not 16000 ppm; may cause narcosis at lower concentrations (NIOSH 1994).	No other acute values available.
Dichloroethylene (trans-1,1-) 156-60-5	1112 [280] (AEGL-1)	3970 [1000] (AEGL-2)	6749 [1700] (AEGL-3)	Irritating to eyes, skin, respiratory system; CNS depressant.	For 1,2 Dichloroethylene 540-59-0: IDLH [1000 ppm], 8hr TWA OSHA = 790 mg/m³ [200 ppm].

Table C-2: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
Dichloroethylene (cis-1,1-) 156-59-2	556 [140] (AEGL-1)	1985 [500] (AEGL-2)	3375 [850] (AEGL-3)	Irritating to eyes, skin, respiratory system; CNS depressant.	
Dieldrin 75-34-3	0.75 (TEEL-1)	1.25 (TEEL-2)	50 (IDLH)	Lethal oral dose = 5 g (equivalent to 3300 mg/m^3 for 30 min); (NIOSH 1994).	No other acute values available.
Diesel fuel smoke	8 (SPEGL)	80 (EEGL)	ND	No irritant effects in humans; pulmonary inflammation in rats (NRC[a]).	No other acute values available.
Diketene 674-82-8	3.4 [1] (ERPG 1)	17 [5] (ERPG 2)	69 [20] (ERPG 3)	Serious signs of toxicity observed in rats at 250 ppm surviving a 1-hr exposure (AIHA 2002).	No other acute values available.
Dimethyl hydrazine (1,1-) 57-14-7	NA	7.4 [3] (AEGL-2)	27 [11] (AEGL-3)	Irritating to eyes, nose, mucous membranes; pulmonary edema; hemolytic agent. Can cause nausea, vomiting, anorexia, hypoglycemia, CNS stimulation, seizures, and coma. Liquid: skin burns.	No other acute values available.
Dimethyl hydrazine (1,2-) 540-73-8	NA	7.4 [3] (AEGL-2)	27 [11] (AEGL-3)	Irritating to eyes, nose, mucous membranes; pulmonary edema; hemolytic agent. Can cause nausea, vomiting, anorexia, hypoglycemia, CNS stimulation, seizures, and coma. Liquid: skin burns.	No other acute values available.
Dimethyl sulfate 77-78-1	1.5 [0.3] (TEEL-1)	5.2 [1] (TEEL-2)	36 [7] (IDLH)	20-min exposures to 13 ppm caused severe symptoms in monkeys; death (LC_{50}) in guinea pigs at 75 ppm (NIOSH 1994).	No other acute values available.

Table C-2: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
Endrin 72-20-8	0.1^S [0.008] TWA 8-hr	0.3 [0.024] **	2.0 (IDLH, TEEL 2)	Oral dose of 171 mg/kg is lethal; 0.2 mg/kg may cause convulsions (equivalent to 8000 ppm and 9 ppm, respectively); (NIOSH 1994).	**TEEL-1 = 0.3; **ACGIH 3 x Excursion Limit -0.3 mg/m³ TEEL 2 = 2.0
Ethyl benzene 100-41-4	542 [125] (TEEL-1)	4342 [1000]	8684 [2000]	Dizziness may occur after 5 min of exposure to 2000 ppm (NIOSH 1994). IDLH based on 1/10th lower explosive limit.	STEL – 125 ppm; Significant (strong eye irritation/tear/with tolerance developing) and Severe (intolerable eye irritation and lacrimation) levels based on Grant, W.M, "Tox of the Eye, 1986, peer reviewed; 542 [125] =TEEL-2; IDLH = 800 ppm
Ethylenimine 151-56-4	2.64 [1.5] (TEEL-1)	8.1 [4.6] (AEGL-2)	17.4 [9.9] (AEGL-3)	Powerful lacrimator and emetic; exposures exceeding 100 ppm have caused respirator irritation and inflammation, yet symptoms may be delayed several hours (NIOSH 1994).	TEEL (1-2): 1.5, 2.3 ppm, IDHL- 100 ppm.
Ethylene glycol 107-21-1	202 [50] (AEGL-1)	810 [200] (AEGL-2)	1210 [300] (AEGL-3)	Irritation eyes, skin, nose, throat; nausea, vomiting; headache, dizziness; abdominal pain, stupor; CNS depression, skin sensitization.	ACGIH Ceiling: 100 mg/m³
Ethylene oxide 75-21-8	14 [7.5] (TEEL-1)	81 [45] (AEGL-2)	360 [200] (AEGL-3)	Exposures above 2000 ppm have caused headache, nausea, vomiting, dyspnea, and respiratory irritation; concentrations > 1 hr at 2000 ppm may be fatal (NIOSH 1994). AIHA determined insufficient data to derive a minimal effect level.	ERPG (2-3): 50, 500 ppm; IDLH – 800 ppm.

Table C-2: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
Fluorine 7782-41-4	2.6 [1.7] (AEGL-1)	7.8 [5] (AEGL-2)	20.2 [13] (AEGL-3)	Concentrations of 25 ppm have been tolerated briefly, yet both volunteers developed sore throats and chest pains that lasted 6 hrs; 50 ppm could not be tolerated (NIOSH 1994). Minimal effect levels based on objectionable odor threshold, yet repeated exposures to workers of 10 ppm has been reported to be well tolerated (AIHA 2002).	ERPG (1-3): 0.5, 5, 20 ppm; EEGL – 7.5 ppm; STEL – 2 ppm; IDLH – 25 ppm; ERPG-1 – 0.5 ppm.
Fog oil smoke	9 (SPEGL)	90 (EEGL)	ND	Based on Shoshkes, et al. (1950). Haber's law applied based on the similarity of fog-oil and diesel-fuel smokes (in NRC[a]).	No other acute values available.

Table C-2: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
Formaldehyde 50-00-0	1.2 [1] (ERPG-1)	12.3 [10] (ERPG-2)	31 [25] (ERPG-3)	5 to 10 min exposures to 50 – 100 ppm may cause serious injury to the lower respiratory tract; many volunteers could not tolerate prolonged exposures to 4 - 5 ppm (NIOSH 1994).	ACGIH ceiling – 0.3 ppm; IDLH – 20 ppm.
GA (Tabun) 77-81-6	0.00042 (0.0028) (AEGL-1)	0.0053 (0.035) (AEGL-2)	0.039 (0.26) (AEGL-3)	Based on relative potency from GB (NRC 2003).	IDLH = 0.1 mg/m³
GB (Sarin) 107-44-8	0.00048 (0.0028) (AEGL-1)	0.0060 (0.035) (AEGL-2)	0.022 (0.13) (AEGL-3)	Level-1: Reversible miosis, headache, eye pain, rhinorrhea, tightness in chest, cramps, nausea, malaise, miosis in human volunteers; may limit performance for night operations, aircrews, and tasks involving distance or spatial judgement Level-2: Reversible miosis, dyspnea, RBC-ChE inhibition, single fibre electromyography (SFEMG) changes in human volunteers; may limit performance for night operations, aircrews, and tasks involving distance or spatial judgement Level-3: Based on GB vapor experimental Sprague-Dawley rat lethality data (LC_{01}, LC_{50}) NRC	IDLH = 0.1 mg/m³

Table C-2: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
				2003.	
GD (Soman) 96-64-0	0.00018 (0.0014) (AEGL-1)	0.0022 (0.018) (AEGL-2)	0.017 (0.13) (AEGL-3)	Based on relative potency from GB (see text for more information); (NRC 2003).	IDLH = 0.05mg/m³
GF 329-99-7	0.00020 (0.0014) (AEGL-1)	0.0024 (0.018) (AEGL-2)	0.018 (0.13) (AEGL-3)	Based on relative potency from GB (NRC 2003).	IDLH =0.05 mg/m³
Hexachlorobutadiene 87-68-3	32 [3] (ERPG-1)	107 [10] (ERPG-2)	320 [30] (ERPG-3)	Less than odor threshold; concentrations of 23 ppm (245 mg/m^3) produced strong odors; 1 ppm (10 mg/m^3), faint.	No other acute values available.
Hexachlorocyclo-pentadiene 77-47-4	0.1 [0.01] 8-hr TLVs® –	0.35 [0.03] ACGIH excur limt – 3xTWA	1.6 [0.15] (*)	Rabbit lethality at 1.5 PPM (15.9 mg/m³) for 7 hr; mice- 1.4 ppm (15.2 mg/m³) for three 7-hr periods; rats- 1.0 ppm (10.9 mg/cu m) for five 7-hr periods or 3.2 ppm (35.1 mg/m³) for two 7-hr periods; American Conference of Governmental Industrial Hygienists. Documentation of the Threshold Limit Values and Biological Exposure Indices. 5th ed. Cincinnati, OH:American Conference of Governmental Industrial Hygienists, 1986. 300]**PEER REVIEWED**	Rabbit lethality at 1.5 PPM (15.9 mg/m³) for 7 hr was divided by an uncertainty factor (animal to human) of 10. This and the additional conservatism of usng a 7-hr exposure is considered to be a reason crude Severe effects/thrshold fatality estimate. Significant is based on ACGIH “Excursion Limit” which is 3 times the TWA TEEL 1 – 3 values identical 0.22 [0.02] based on limited data;

Table C-2: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
Hexachloroethane smoke 67-72-1	0.3 (SPEGL)	3 (EEGL)	ND	Based on reports from acute human inhalation exposures (NRC[a]).	IDLH – 300 ppm (based on oral toxicity); deemed not appropriate for use.
Hexane 110-54-3	528 [150] (TEEL-1)	880 [250] (TEEL-2)	3872 [1100] (TEEL-3)	Exposures of 10 min to 5000 ppm caused dizziness and a feeling of giddiness (NIOSH 1994).	IDLH – 1100 ppm; STEL – 1000 ppm.
Hydrazine 302-01-2	0.13 [0.1] (AEGL-1)	17 [13] (AEGL-2)	46 [35] (AEGL-3)	Exposures of 4 hr to 80 – 300 ppm were lethal to rats (NIOSH 1994).	TEEL (1-3): 0.3, 0.8, 10 ppm; IDLH – 50 ppm; SPEGL – 0.12 ppm. ERPG (1-3): 0.7, 6.6, 40 mg/m³.
Hydrogen bromide 10035-10-6	9.9 [3] (TEEL-1) (ACGIH Ceiling)	19.8 [6] (*)	99 [30] (TEEL-3)	Exposures of 1300 – 2000 ppm may be lethal in exposures lasting a few minutes; 2 – 6 ppm has been reported to cause nose and throat irritation (NIOSH 1994).	IDLH – 30 ppm; ACGIH Ceiling – 3 ppm. 9.9 [3] =TEEL-2 *For Significant Level – use “6” ppm, based on ACGIH – ref. Clayton; G.D., Pattys IH and Tox; Vol 2, 1994; significant eye and nasal irritation
Hydrogen chloride 1333-74-0	2.7 [1.8] (AEGL-1)	33 [22] (AEGL-2)	149 [100] (AEGL-3)	Concentrations of 35 ppm caused throat irritation; 50 – 100 ppm are barely tolerable (NIOSH 1994). Concentrations exceeding 3 ppm may produce discomfort in asthmatics.	ERPG (1-3): 3, 20, 150 ppm; IDLH - 50 ppm; ACGIH Ceiling – 5 ppm; EEGL – 20 ppm.
Hydrogen cyanide 74-90-8	2.2 [2] (AEGL-1)	7.8 [7.1] (AEGL-2)	16.6 [15] (AEGL-3)	Concentrations of 45 – 54 ppm may be tolerable for 0.5 – 1.0 hr; 110 – 135 ppm may be fatal after 0.5 – 1.0 hr or later (NIOSH 1994).	TEEL 1 - 4.7; ERPG (2-3): 10, 25 ppm; IDLH – 50 ppm; ACGIH Ceiling – 4.7 ppm.
Hydrogen fluoride 7664-39-3	0.82 [1] (AEGL-1)	19.7 [24] (AEGL-2)	36 [44] (AEGL-3)	Concentrations of 50 ppm for 30 – 60 min may be fatal; volunteers tolerated 4.7 ppm for 6 hrs/day for 10 – 50 days (NIOSH 1994).	ERPG (1-3): 2, 20, 50 ppm; IDLH – 30 ppm; ACGIH Ceiling – 3 ppm; EEL – 8 ppm; ERPG-1 – 0.1 ppm.

Table C-2: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
Hydrogen selenide 7783-07-5	NA	0.66 [0.2] (ERPG-2)	6.6 [2] (ERPG-3)	IDLH based on Se; human data used.	IDLH: 3.3 mg/m³ (1 ppm).
Hydrogen sulfide 7783-06-4	0.71 [0.51] (AEGL-1)	38 [27] (AEGL-2)	70 [50] (AEGL-3)	Concentrations of 170 to 300 ppm are the maximum tolerated concentrations for 1-hr without serious consequences; olfactory fatigue occurs at 100 ppm (NIOSH 1994). Minimal effect levels based on objectionable odor at 0.3 ppm.	ERPG (1-3): 0.1, 30, 100 ppm; IDLH – 100 ppm; STEL – 15 ppm, EEGL (10 min) – 50 ppm; ERPG-1 – 0.1 ppm.
Iron pentacarbonyl 13463-40-6	NA	0.5 [0.20] (AEGL-2)	1.4 [0.60] (AEGL-3)	Respiratory irritation, lack of data at lower concentrations, occup. max. permissible conc. 0.1 ppm.	STEL – 0.2 ppm.
Lewisite 541-25-3	0.003[C]	ND	ND	Irritation: eye and mucous membrane.	No other acute values available.
Lindane 58-89-9	1.5 (TEEL-1)	50 (TEEL-2)	50 (IDLH)	IDLH value based on acute oral data; oral doses of 150 mg/kg have been associated with grand-mal seizures (equivalent to 7000 mg/m^3 for 30 min) (NIOSH 1994).	No other acute values available.
Mercury vapor (inorganic) 7439-97-6	NA	2 [0.25] (ERPG-2)	4.1 [0.5] (ERPG-3)	Irritating to eyes, cough, chest pain, dypsnea, bronchitis; tremor, insomnia, irritability; headache, weakness; GI distress; salivation, anorexia.	8 hr TWA NIOSH : 0.05 mg/m³ OSHA ceiling : 0.1 mg/m³ Skin
Methylacrylonitrile 126-98-7	NA	3 [1.1] (AEGL-2)	9.3 [3.4] (AEGL-3)	Irritating to eyes, skin; convulsions, (animal: loss of motor control in hind limbs).	NIOSH 8 hr: 3 mg/m³ [1 ppm] Skin

Table C-2: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
Methyl bromide 74-83-9	58.3 [15] (TEEL-1)	195 [50] (ERPG-2)	777 [200] (ERPG-3)	AIHA determined ERPG-1 was NA based on the lack of detectable odor at low concentrations (poor warning properties). NIOSH (1994) reports that concentrations of 200 ppm may be endured for several hours without serious effects; data mixed.	IDLH – 250 ppm.
Methylene chloride 75-09-2	695 [200] (ERPG-1)	2600 [750] (ERPG-2)	13,880 [4000] (ERPG-3)	Data variable: vertigo, dizziness, nausea may occur at concentrations above 2300 ppm (NIOSH 1994).	IDLH – 2300 ppm.
Methylene diphenyl isocyanate (4,4-) 101-68-8	0.2 [0.02] (ERPG-1)	2 [0.2] (ERPG-2)	25 [2.4] (ERPG-3)	Irritating to eyes, throat; RS, cough, pulmonary secretions; chest pain, dypsnea; asthma.	8 hr TWA OSHA: 0.05 mg/m³ [0.005 ppm] OSHA ceiling 10 min: 0.2 mg/m³ [0.02 ppm].
Methyl hydrazine 60-34-4	ND	1.9 [1] (AEGL-2)	5.7 [3] (AEGL-3)	Known human carcinogen, dermal exposures may contribute to total dose.	PEL – 0.2 ppm, IDLH – 20 ppm.
Methyl isocyanate 624-83-9	0.06 [0.025] (ERPG-1)	0.16 [0.067] (AEGL-2)	0.47 [0.2] (AEGL-3)	Mild, transient eye irritation possible above Minimal effects level. Eye irritation and lacrimation at 5 ppm in less than 50 seconds; unbearable at 21 ppm (NIOSH 1994).	ERPG (2-3): 0.5, 5 ppm; IDLH – 3 ppm.

Table C-2: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
Methyl mercaptan 74-93-1	1 [0.5] (AEGL-1*)	9.8 [5] (AEGL-2*)	45 [23] (AEGL-3*)	Exposures to 4 ppm for several hours have caused headaches and nausea (NIOSH 1994). Minimal effect levels based on low odor threshold that may be perceived as objectionable. ERPG-1 based on low odor threshold.	*Proposed AEGL's published in Fed. Reg. ERPG (1-3): 0.005, 25, 100 ppm, IDLH – 150 ppm; ERPG-1 – 0.005 ppm.
Nickel carbonyl 13463-39-3	NA	0.2 [0.028] (AEGL-2)	1.1 [0.16] (AEGL-3)	Headache, vertigo, vomiting , epigastric pain; cough; cyanotic; weakness; delirium; convulsions; reproductions and teratogenic effects.	NIOSH 8 hr: 0.007 mg/m^3 [0.001 ppm] IDLH: 2 ppm
Nitric acid 7697-37-2	1.3 [0.5] (AEGL-1)	10 [4] (AEGL-2)	57 [22] (AEGL-3)	Animals exhibited no adverse effects to concentrations of 24 ppm; maximum allowable workplace value proposed – 10 ppm (NIOSH 1994).	IDLH – 25 ppm; STEL – 4 ppm. ERPG (1-3): 1, 15, 30 ppm.
Nitric oxide 10102-43-9	0.61 [0.5*] (AEGL-1*)	15 [12] (AEGL-2*)	25 [20] (AEGL-3*)	Oxides dangerous for exposures between 100 and 150 ppm from 30 – 60 min (NIOSH 1994).	TEEL (1-2): 25, 25 ppm; IDHL – 100 ppm. *Values for nitrogen dioxide adopted due to conversion in atmosphere. No hazard assoc. with short-term exp. to 80 ppm.
Nitrogen dioxide 10102-44-0	0.94 [0.5] (AEGL-1*)	23 [12] (AEGL-2*)	38 [20] (AEGL-3*)	TEELs most appropriate and consistent with other values. Exposure to 10 – 20 ppm mildly irritating; exposure > 150 ppm can cause death from pulmonary edema (NIOSH 1994).	*Proposed AEGL's published in Fed. Reg. TEEL-2 – 15 ppm; IDLH – 20 ppm, EEL – 10 ppm; SPEGL – 1 ppm; STEL – 5 ppm; TEEL-1 – 2 ppm. ERPG (1-3): 1, 15, 30 ppm.

Table C-2: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
Paraquat 4685-14-7	0.15 [0.024] (NIOSH 8-hr PEL)	1.0 [0.16] (IDLH)	***	Toxicity: particle size dependant (< 5 μ) 5-6 times more toxic; under spraying conditions particle sizes are nonrespirable) (NIOSH 1994).	Toxicity based on particle size (see RD 230). 1.5 mg/m³ = IDLH; 0.5 = PEL for TOTAL DUST; 0.1 =PEL for RESPIRABLE FRACTION; excursion limit = 3x TWA; 0.15; [0.024] = TEEL 1-2 *** This chemical must be aerosolilized to inhale – general resulting in relatively brief exposures; severe effects toxicity data is limited to primary route of INGESTION.
Parathion 56-38-2	0.3 [0.0024] (TEEL-1)	2 [0.16] (TEEL-2)	10 [0.8] (IDLH)	Workers regularly exposed to 2 to 15 mg/m^3 exhibited only a 25% decrease in cholinesterase; 69 mg/m^3 (extrapolated from an oral dose) may be lethal (NIOSH 1994).	No other acute values available.

Table C-2: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
Perchloromethyl mercaptan 594-42-3	0.09 [0.012] (AEGL-1)	0.27 [0.035] (AEGL-2)	2.3 [0.3] (AEGL-3)	Data show exposures to 25 ppm may be appropriate (NIOSH 1994).	IDLH – 10 ppm.
Phenol 108-95-2	17 [4.5] (AEGL-1)	58 [15] (AEGL-2)	181 [47] (AEGL-3)	Irritating to eyes, nose, throat; anorexia; weakness, muscle aches; dark urine; liver/kidney damage; tremor/twitching, cyanosis, convulsions.	ERPG (1-3): 10, 50, 200 ppm. IDLH: 250 ppm. OSHA 8 hr TWA: 19 mg/m³ [5ppm] Ceiling 15 min: 60 mg/m³ [15.6 ppm] Skin.
Phosgene 75-44-5	0.4 [0.1] (TEEL-1)	1.2 [0.3] (AEGL-2)	3.0 [0.75] (AEGL-3)	Lethal dose to humans for a 30-min exposure was calculated to about 17 ppm; lethality may be evident at lower (5 ppm) concentrations due to pulmonary edema (NIOSH 1994).	ERPG (2-3): 0.2, 1 ppm; IDLH – 2 ppm; EEGL – 0.2 ppm.
Phosphine 7803-51-2	NA	2.8 [2.0] (AEGL-2)	5.1 [3.6] (AEGL-3)	Concentrations up to 35 ppm have caused diarrhea, nausea, vomiting, cough, headache, and dizziness; 100 – 200 ppm may be maximum for a duration of 0.5 – 1.0 hrs (NIOSH 1994).	ERPG (2-3): 0.5, 5 ppm; STEL – 1 ppm; IDLH – 50 ppm.
Phosphorus (yellow) 7723-14-0	0.3 (TEEL-1)	3 (TEEL-2)	5 (IDLH)	Single lethal oral doses of 1 mg/kg have been reported; severe symptoms have been reported following a single 15 mg dose (equivalent to 10 mg/m^3 for 30 min); (NIOSH 1994).	No other acute values available.
Phosphorous oxychloride 10025-87-3	NA	NA	5.3 [0.85] (AEGL-3)	Chronic asthmatic-like bronchitis may develop after acute inhalations.	*Proposed AEGL's published in Fed. Reg. STEL – 0.5 ppm.

Table C-2: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
Phosphorus trichloride 7719-12-2	ND	ND	4.9 [0.88] (AEGL-3)	Concentrations of 1.8 – 27 ppm have been reported to produce burning of the eyes and throat, and mild bronchitis within 2 – 6 hours after exposure (NIOSH 1994).	*Proposed AEGL's published in Fed. Reg. IDLH – 25 ppm, STEL – 0.5 ppm.
Propylene oxide 75-56-9	143 [60] (AEGL-1)	690 [290] (AEGL-2)	1452 [610] (AEGL-3)	Irritation eyes, respiratory tract; skin burns; blisters carcinogen.	ERPG (1-3): 50, 250, 750 ppm. IDLH: 400 ppm. OSHA 8 hr: 5 mg/m³ [2 ppm] Skin
Red phosphorus smoke	1 (SPEGL)	10 (EEGL)	1000 (NRC[a])	Lethality, respiratory distress and irritation, pulmonary lesions; severe effects value based on "intolerable" concentration (Mitchell and Burrows 1990); (NRC[a]).	No other acute values available.
Selenium hexafluoride 7783-79-1	1.2 [0.15] (TEEL-1)	2 [0.25] (TEEL-2)	16 [2] (IDLH)	Rabbits, mice, rats, and guinea pigs exposed to 5 ppm for 4 hrs developed pulmonary edema of which all survived (NIOSH 1994).	No other acute values available.
Stibine 7803-52-3	ND	2.6 [0.5] (ERPG-2)	7.7 [1.5] (ERPG-3)	Exposures to 40 – 45 ppm for 1 hr in dogs and cats have been reported to be dangerous (NIOSH 1994).	IDLH – 5 ppm.
Styrene 100-42-5	213 [50] (ERPG-1)	1065 [250] (ERPG-2)	4260 [1000] (ERPG-3)	Irritation eyes, nose, respiratory tract; dizziness, headache, weak, unsteady gait, narcolepsy; defatting of derm; liver and reproductive effects.	IDLH: 700 ppm. STEL 425 mg/m³. OSHA Ceiling: 200 ppm; 5 min 600 ppm NIOSH 8 hr TWA: 215 mg/m³ [[500 ppm].

Table C-2: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
Sulfur dioxide 7446-09-5	0.8 [0.3] (ERPG-1)	8 [3] (ERPG-2)	39 [15] (ERPG-3)	Maximum concentration for 0.5 – 1.0 hrs was reported to be 50 to 100 ppm (NIOSH, 1994). Minimal effect levels based on increased airway resistance in asthmatics exposed to concentrations above 0.4 ppm.	IDLH – 100 ppm; EEGL – 10 ppm.
Sulfur mustard [HD] 505-60-2	0.067 [0.01] (AEGL-1)	0.10 [0.02] (AEGL-2)	2.1 [0.32] (AEGL-3)	Delayed development of irritation to eyes, mucous membranes; potent alkylating agent; mutagenic. Based on AEGL analysis by NRC (see text for more information); (NRC in press).	IDLH = 2.0 mg/m³
Sulfuric acid 7664-93-9	2 [0.5] (ERPG-1)	10 [2.5] (ERPG-2)	30 [7.5] (ERPG-3)	Variable human responses; 5- to 15-min exposures of 5 mg/m^3 reported to be very objectionable (NIOSH 1994).	IDLH – 15 mg/m^3; STEL – 3 mg/m^3; EEGL – 1 mg/m^3.
Sulfuryl fluoride 2699-79-8	ND	ND	835 [200] (IDLH)	Based on animal data. Less than 5% mortality resulted from 3-hr exposures of 1000 ppm in animals (NIOSH 1998).	STEL – 10 ppm.
Tellurium hexafluoride 7783-80-4	0.6 [0.06] (TEEL-1)	10 [1] (TEEL-2 and IDLH)	**	IDLH = TEEL-2 value; in animals, 1 ppm for 4 hrs caused increased rate of breathing but no mortality levels at 5 ppm and above for 4 hours did resulting animal death (NIOSH 1994).	** Limited data. Suggestion of tolerance – mild effects may dissipate after prolonged exposure. Not clear at what level human fatlities or trult severe effect swould occur (just greater than 1 ppm).
Tetrachloroethane (1,1,2,2-) 79-34-5	20.6 [3] (TEEL-1)	3.4 [5] (TEEL-2)	686 [100] (IDLH)	A 30-min exposure to 146 ppm has caused vertigo, irritation, fatigue, head pressure; same effects were	No other acute values available.

Table C-2: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
				noted after a 10-minute exposure to 335 ppm (NIOSH 1994).	
Tetrachloroethylene (Perchloroethylene) 127-18-4	237 [35] (AEGL-1)	1559 [230] (AEGL-2)	8136 [1200] (AEGL-3)	95-min exposures exceeding 1000 ppm produces slight drunkenness, yet no narcosis; 30 min exposures to > 206 ppm may cause dizziness and irritation.	ERPG (1-3): 100, 200, 1000 ppm; IDLH – 150 ppm; STEL – 100 ppm.
Tetraethyl lead 78-00-2	0.13 (TEEL-1)	0.75 (TEEL-2)	40 (IDLH)	NIOSH reports that a value of 100 mg/m^3 would have been appropriate for IDLH but not being currently reviewed.	IDLH – 40 mg/m^3.
Tetrafluoroethane (1,1,1,2-) 811-97-2	33,360 [8000] (AEGL-1)	54,210 [13,000] (AEGL-2)	112,590 [27,000] (AEGL-3)	Irritation eyes, skin, nose, throat, respiratory system; dizziness, headache, hypoxia; pulmonary and cerebral edema	No other acute values available.
Tetramethyl lead 75-74-1	ND	ND	40 (IDLH)	NIOSH reports a value of 150 mg Pb/m^3 may be appropriate.	No other acute values available.
Titanium tetrachloride 7550-45-0	5 (ERPG-1)	20 (ERPG-2)	100 (ERPG-3)	At higher concentrations irritation of the respiratory tract and exposed tissue may result. Based on theoretical extrapolation of hydrochloric acid release (AIHA 2002).	No other acute values available.
Toluene 108-88-3	754 [200] (AEGL-1)	1923 [510] (AEGL-2)	10,933 [2900] (AEGL-3)	Eye and respiratory irritation and symptoms of dizziness, fatigue, drowsiness, headache, and feelings of intoxication at the minimal effects level; loss of consciousness to	ERPG (1-3): 50, 300, 1000 ppm, IDLH – 500 ppm; EEGL – 200 ppm.

Table C-2: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m³ [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
				humans at concentrations > 5000 ppm within minutes.	
Toluene 2,4-diisocyanate 584-84-9	0.14 [0.02] (AEGL-1)	0.59 [0.083] (AEGL-2)	3.6 [0.51] (AEGL-3)	Strong sensitizer; repeated exposures may lower concentration at which effects are experienced.	TEEL (1-2): 0.02, 1 ppm; IDLH – 2.5 ppm; STEL – 0.02 ppm. ERPG (1-3): 0.01, 0.15, 0.6 ppm.
Trichloroethane (1,1,1-) 71-55-6	1256 [230] (AEGL-1)	3276 [600] (AEGL-2)	20,748 [3800] (AEGL-3)	Irritation eyes, nose, CNS depression; liver kidney damage, dermal effects.	ERPG (1-3): 350, 700, 3500 ppm. IDLH: 100 ppm. OSHA 8 hr: 45 mg/m³ [10 ppm].
Trichloroethylene 79-01-6	537 [100] (ERPG-1)	2687 [500] (ERPG-2)	26,870 [5000] (ERPG-3	Exposures of 1000 ppm for 2 hrs caused decrements in perception and motor skills (NIOSH 1994).	IDLH – 1000 ppm; STEL – 100 ppm.
Trichloropropane (1,2,3-) 96-18-4	181 [30] (TEEL-1)	302 [50] (TEEL-2)	603 [100] (IDLH)	Exposures exceeding 100 ppm causes objectionable ocular and mucosal irritation after 15 min.	No other acute values available.
Vinyl acetate 108-05-4	17.6 [5] (ERPG-1)	264 [75] (ERPG-2)	1760 [500] (ERPG-3)	**Irritation to eyes, skin, nose, throat; hoarseness, cough; loss of smell; eye burns; skin blisters**	NIOSH ceiling 15 mg/m³ [4 ppm].
VX 50782-69-9	0.00017 [0.000016] (AEGL-1)	0.0029 [0.00027] (AEGL-2)	0.01 [0.00091] (AEGL-3)	Levels 1 and 2: Derived by relative potency from study of multiple minimal (1) or transient (2) effects in human volunteers exposed to agent GB; may limit performance for night operations, aircrews, and tasks involving distance or spatial judgement Level 3: Derived by relative potency from study of GB vapor	IDLH = 0.01 mg/m³

Table C-2: Basis for 1-hour Short-Term Air-MEGs

Chemical CAS No.	1-hour Air-MEGs mg/m^3 [ppm]			Notes	Other Values
	Minimal effect level	Significant effect level	Severe effect level		
				experimental Sprague-Dawley rat lethality data (LC_{01}, LC_{50}) (NRC 2003)	
Xylene (mixed) 1330-20-7	650 [150] (TEEL-1)	868 [200] (EEGL)	3906 [900] (IDLH)	Exposures of 1000 ppm for 5 min may allow for self-rescue; reaction time not affected in 23 volunteers exposed to 100 or 200 ppm from 3 to 7 hrs (NIOSH 1994).	STEL – 150 ppm.

Notes:
CAW – Chemical Agent Warfare Technical Report: *Information for Combat Developers on Performance Effects from Exposure to Chemical Warfare Agents,* March 1999.
NRC[a] – National Research Council. 1997. *Toxicity of Military Smokes and Obscurants, Vol. 1*. Committee on Toxicology, National Academy Press, Washington, DC.
NRC—National Research Council, in press. *Acute Exposure Guideline Levels for Selected Airborne Chemicals, Vols. 1-3*, Committee on Toxicology. National Academy Press, Washington, D.C. (2001) (2002) (2003).
AIHA – American Industrial Hygiene Association. *Emergency Response Planning Guidelines*, AIHA Press, Fairfax, VA. 2003.
EPA – Environmental Protection Agency. 2001. "National Advisory Committee for Acute Exposure Guideline Levels (AEGLs) for Hazardous Substances; Proposed AEGL Values" *Federal Register* 66 (85): 21940-21964 (2 May 2001).ACGIH – American Conference of Governmental Industrial Hygienists. 1998, *Threshold Limit Values for Chemical Substances and Physical Agents*, ACGIH Press, OH.
♦ - Indicates values less than 1-14 day value, based on objectionable odor, differences in professional judgment between organizations in value derivation, or derived based on applications to sensitive subpopulations (e.g., asthmatics).
CAS No. – Chemcial Abstract Service number
c – Ceiling value.
NA – Not applicable; value determined not appropriate.
ND – Not determined; data not yet evaluated.
Mitchell, W. R., Burows, E. P. 1990. *Assessment of Red Phosphorus in the Environment*. AD-A221704. U.S. Army Biomedical Research & Development Laboratory, Fort Detrick, Frederick, MD 21701-5010.
Shoshkes, M., Banfield, Jr., W.G., and Rosenbaum, S.J. 1950. "Distribution, effect, and fate of oil aerosol particles retained in the lungs of mice." Arch. Ind. Hyg. Occup. Med. 1:20-35 (*in* NRC, 1997a).

Table C-3: Basis for 8 and 24-hour or 14-day Short-term Air-MEGs

Chemical CAS No.	8-hour Air-MEG mg/m^3 [ppm]	14-day Air-MEG mg/m^3 [ppm]	Source	Critical Study Endpoint	Notes
Acetone cyanohydrin 75-86-5	8 [2]	0.4 [0.1]	AIHA ACGIH	CNS effects, anoxia.	WEEL / TLVs® -Adj. OSHA permissible exposure limit - 5 mg/m^3 (1.3 ppm). NIOSH recommended exposure limit; ceiling value – 1 ppm. Ceiling value derived as CN.
Acrolein 107-02-8	0.07 [0.03]	0.023 [0.01]	AEGL-1 NRC[1]	Irritant; dermal and eye irritation in humans.	ATSDR/MRL - 0.00011 mg/m^3; ACGIH/ TLVs® CS – 0.23 mg/m^3.
Acrylic acid 79-10-7	3 [1.0]	ND	AEGL-1	Irritation eyes, skin, respiratory system; skin burns and skin sensitivity	NIOSH TWA = 6 [2]
Acrylonitrile 75-05-8	4.4 [2]	0.22 [0.10]	ACGIH ATSDR	Based on human NOAEL.	ACGIH/ TLVs® – 4.4 mg/m^3.
Idrin 309-00-2	0.25 [0.02]	0.006^S [0.0004]	ACGIH ACGIH	Based on an exposure designed to prevent liver effects (limited data).	CNS and liver effects may be possible during prolonged exposures; dermal exposure may contribute to overall dose; deposits in subcutaneous fat; carcinogen. TLVs® / TLVs® - Adj.
Allyl alcohol 107-18-6	5 [2.1]	0.012^S [0.05]	AEGL-1 ACGIH	Mixed; eye irritation, corneal necrosis, lacrimation; visceral congestion, hematuria, nephritis.	Dermal exposures may contribute to overall dose. TLV-Adj.
Ammonia 7664-41-7	17 [25]	0.35 [0.13]	AEGL-1 ATSDR	No effect on pulmonary function.	Based on chronic occupational exposures. ACGIH/TLV – 1.7 mg/m^3.
Aniline 62-53-3	3.8 [1]	ND	AEGL-1	Weakness, dizziness, ataxia, irritated eyes, liver cirrohsis; bladder cancer	OSHA 8 hr TWA 19 [5]

Table C-3: Basis for 8 and 24-hour or 14-day Short-term Air-MEGs

Chemical CAS No.	8-hour Air-MEG mg/m^3 [ppm]	14-day Air-MEG mg/m^3 [ppm]	Source	Critical Study Endpoint	Notes
Arsenic trichloride 7784-34-1	0.01* [0.003]	0.01* [0.003]	ACGIH ACGIH	Irritation of mucous membranes, dermatitis, perforation of nasal septum, pharyngitis and conjunctivitis; value based on industrial concentrations where no effects were found.	Based on arsenic as an inorganic compound; soluble arsenic acutely toxic form; chlorides may induce irritation effects at lower concentrations; data to substantiate this is lacking; carcinogen. *Measured as arsenic.
Arsine 7784-42-1	0.17 [0.05]	0.004 [0.0012]	ACGIH ACGIH	Red blood cell and kidney effects.	Carcinogen. TLV / TLV-Adj.
Benzene 71-43-2	1.6 [0.5]	0.16 [0.05]	ACGIH ATSDR	Based on lymphocyte apoptosis in mice.	TLV: Based on chronic studies where cancer was primary endpoint; TLV approaches odds for those not exposed in the development of cancer.
Boron tribromide 10294-33-4	10^C [1]	10^C [1]	ACGIH ACGIH	Irritation; primary irritant with no known chronic effects.	TLV.
Boron trifluoride 7637-07-2	0.6 [0.2]	0.6 [0.2]	AEGL-1 ERPG-1	Irritation; pulmonary irritant leading to pneumonia after repeated exposure; no pathological changes in rats exposed to 6 ppm or 6 hrs/day, 5 day/wk, for 13 wks.	ACGIH ceiling value – 3 mg/m^3.
Bromine 7726-95-6	0.063 [0.095]	0.063 [0.095]	AEGL-1 AEGL-1	Irritant; respiratory passage irritation and lung injury.	ACGIH (TLV) - 0.1 ppm (0.65 mg/m^3)
Bromine pentafluoride 7789-30-2	0.7 [0.1]	0.7 [0.1]	ACGIH ACGIH	Irritant; irritation to upper respiratory passages and eyes.	TLV.

Table C-3: Basis for 8 and 24-hour or 14-day Short-term Air-MEGs

Chemical CAS No.	8-hour Air-MEG mg/m^3 [ppm]	14-day Air-MEG mg/m^3 [ppm]	Source	Critical Study Endpoint	Notes
Carbon disulfide 75-15-0	3^S [1]	0.76^S [0.24]	ERPG-1 ACGIH	Systemic; headaches.	Dermal exposures may contribute to overall dose; carcinogen. TLV-Adj.
Carbon monoxide 630-08-0	28 [25]	0.70 [0.61]	ACGIH ACGIH	Systemic; based on blood carboxyhemoglobin levels < 3.5%.	May not be protective of sensitive individuals under conditions of heavy labor, high temperatures, or in elevation >5,000ft. TLV / TLV-Adj.
Carbon tetrachloride 56-23-5	32.5 [5.2]	1.3 [0.2]	AEGL-1 ATSDR	Systemic; liver toxicity; alcohol potentiation may occur.	ACGIH/TLV - 31 mg/m^3; carcinogen.
Carbonyl fluoride 353-50-4	5 [2]	0.13 [0.05]	ACGIH ACGIH	Mixed; pulmonary edema; kidney injury; fluorosis.	TLV / TLV-Adj.
Chlorine 7782-50-5	1.5 [0.5]	0.29 [0.1]	AEGL-1 NRC[1]	Irritation; eyes and mucous membrane irritation.	ACGIH/TLV – 1.5 mg/m^3.
Chlorine dioxide 10049-04-4	0.4 [0.15]	ND	AEGL-1	Irritating to eyes, nose, and throat, coughing, pulmonary edema, chronic bronchitis	ERPG (2-3): 1.4, 8.4 mg/m³. NIOSH 8 hr TWA: 0.3 mg/m³ [0.1ppm]. STEL 0.9 mg/m³ [0.3].
Chlorine trifluoride 7790-91-2	0.45 [0.12]	0.45 [0.12]	AEGL-1 AEGL-1	Irritant; lung and mucous membrane injury.	ACGIH ceiling value - 0.1 ppm (0.4 mg/m^3)
Chloroacetaldehyde 107-20-0	3.2^C [1]	3.2^C [1]	ACGIH ACGIH	Irritant; pneumonitis, bronchitis; tumor initiator.	ACGIH ceiling value and OSHA Permissible exposure limit. Carcinogen.
Chloroacetone 78-95-5	3.8^C [1]	3.8^C [1]	ACGIH ACGIH	Irritation; lacrimation, upper respiratory tract, skin effects.	ACGIH ceiling value.
Chloroacetophenone [CN] 532-27-4	0.32 [0.05]	0.32 [0.05]	ACGIH ACGIH	Irritation, eyes, respiratory tract.	TLV.

Table C-3: Basis for 8 and 24-hour or 14-day Short-term Air-MEGs

Chemical CAS No.	8-hour Air-MEG mg/m^3 [ppm]	14-day Air-MEG mg/m^3 [ppm]	Source	Critical Study Endpoint	Notes
Chloroacetyl chloride 79-04-9	0.23 [0.05^S]	0.23 [0.05^S]	ACGIH ACGIH	Irritant; eye and respiratory passage irritation.	TLV. Dermal exposures may contribute to overall dose.
Chlorobenzylidene malonitrile (o-) [CS] 2698-41-1	0.39^C [0.05]	0.39^C [0.05]	ACGIH ACGIH	Irritation, eye, conjunctiva, nose and throat.	ACGIH ceiling value and OSHA Permissible exposure limit. Potential sensitizer.
Chloroform 67-66-3	48 [10]	0.5 [0.1]	ACGIH ATSDR	Systemic; liver effects; embryotoxic.	TLV; carcinogen.
Crotonaldehyde 4170-30-3	0.54^S [0.19]	0.54^S [0.19]	AEGL-1 AEGL-1	Irritation; eyes and respiratory passages, lacrimation.	ACGIH ceiling value - 0.3 pmm, Probable carcinogen. Dermal exposures may contribute to overall dose.
Cyanogen 460-19-5	20 [10]	0.51 [0.24]	ACGIH ACGIH	Mixed; by analogy with hydrogen cyanide to prevent irritation and systemic effects.	TLV / TLV-Adj.
Diborane 19287-45-7	0.1 [0.1]	0.0024 [0.0024]	ACGIH ACGIH	Mixed; neurological effects, respiratory irritant; pulmonary function.	TLV / TLV-Adj.
Dichloroethane (1,1-) 75-34-3	400 [100]	9.8 [2.4]	ACGIH ACGIH	Systemic; liver toxicity.	TLV / TLV-Adj.
Dichloroethylene (trans-1,1-) 156-60-5	1112 [280]	ND	AEGL-1	Irritating to eyes, skin, respiratory system; CNS depressant	For 1,2 Dichloroethylene 540-59-0: IDLH [1000 ppm] 8hr TWA OSHA = 790 mg/m³ [200 ppm]
Dichloroethylene (cis-1,2-) 156-59-2	556 [140]	ND	AEGL-1	Irritating to eyes, skin, respiratory system; CNS depressant	For 1,2 Dichloroethylene 540-59-0: IDLH [1000 ppm] 8hr TWA OSHA = 790 mg/m³ [200 ppm]

Table C-3: Basis for 8 and 24-hour or 14-day Short-term Air-MEGs

Chemical CAS No.	8-hour Air-MEG mg/m^3 [ppm]	14-day Air-MEG mg/m^3 [ppm]	Source	Critical Study Endpoint	Notes
Dieldrin 60-57-1	0.25^S [0.02]	0.006^S [0.0004]	ACGIH ACGIH	Based on systemic toxicity; liver effects.	Dermal exposures may contribute to overall dose; ACGIH suggests that the greatest pathway for exposure in an industrial exposure is through the skin; toxic metabolite of aldrin; TLV / TLV-Adj.
Diesel fuel smoke	5	5	NRC[a] NRC[a]	Weight losses and reduced weight gain in rats, focal pneumonitis in rats.	Value based on two 8-hour exposures per week. Critical study endpoint data obtained from Lock et al. (1984) and Dalbey et al. (1982) (*in* NRC[a]).
Dimethyl sulfate 77-78-1	0.5^S [0.1]	0.0012^S [0.0024]	ACGIH ACGIH	Mixed; irritation of eyes and skin; liver and CNS effects.	Dermal exposures may contribute to overall dose. TLV / TLV-Adj.
Endrin 72-20-8	0.1^S [0.008]	0.002^S [0.00016]	ACGIH ACGIH	Based on extrapolation of acute animal data and limited evidence in humans.	Stereoisomer of dieldrin; dermal exposures may contribute to overall dose. TLV / TLV-Adj.
Ethyl benzene 100-41-4	435 [100]	10.5 [2.4]	ACGIH ACGIH	Mixed effects; hepatic, renal, pulmonary, cardiac, and neurological toxicity; narcosis and respiratory irritation; skin notation.	TLV / TLV-Adj.
Ethylenimine 151-56-4	0.92^S [0.5]	0.022^S [0.012]	ACGIH ACGIH	Mixed; CNS effects; liver and kidney effects; respiratory irritation, eye and nose irritation, skin notation.	Dermal exposures may contribute to overall dose. TLV / TLV-Adj.
Ethylene oxide 75-21-8	1.8 [1]	0.04 [0.02]	ACGIH ACGIH	Systemic; mutagen, neurotoxin; liver, kidney and blood effects.	Carcinogen. TLV / TLV-Adj.
Fluorine 7782-41-4	2.6 [1.7]	1.6 [1]	AEGL-1 ACGIH	Irritant; eye, mucous membrane, and skin irritation.	TLV.

Table C-3: Basis for 8 and 24-hour or 14-day Short-term Air-MEGs

Chemical CAS No.	8-hour Air-MEG mg/m^3 [ppm]	14-day Air-MEG mg/m^3 [ppm]	Source	Critical Study Endpoint	Notes
Fog oil smoke	5	5	NRC[a] NRC[a]	Discomfort threshold.	Based on Hendricks et al. (1962) (*in* NRC[a]).
Formaldehyde 50-00-0	0.37[C] [0.3]	0.37[C] [0.3]	ACGIH ACGIH	Irritation; eye, nose, throat, and upper respiratory tract irritation; dermatitis; rhinitis; conjunctivitis, and asthma.	ACGIH ceiling value. Carcinogen.
GA (Tabun) 77-81-6	0.001 [0.00015]	24 hours only: 0.0003 [0.00005] (Level-1) 0.004 [0.00067] (Level-2) 0.03 [0.005] (Level - 3)	AEGL –1 8-hr; NRC 2003, see Table 2-2 this RD	Based on relative potency from GB. Derived from 8-hr AEGL	24-hour MAGs estimate derived from 8-hour AEGL by straightline extrapolation of 8-hour AEGL Ct (see EPA 2001 and document text) For reference: ExiGPL = 0.000003 (0.000003) mg/m³ WPL = 0.0001 (0.0001) mg/m³

Table C-3: Basis for 8 and 24-hour or 14-day Short-term Air-MEGs

Chemical CAS No.	8-hour Air-MEG mg/m^3 [ppm]	14-day Air-MEG mg/m^3 [ppm]	Source	Critical Study Endpoint	Notes
GB (Sarin) 107-44-8	0.001 [0.00017]	24 hrs only: 0.0003 [0.000057] (Level-1) 0.004 [0.00073] (Level-2) 0.02 [0.0029] (Level-3)	AEGL –1 8-hr; NRC 2003, see Table 2-2 this RD	Level-1: Reversible miosis, headache, eye pain, rhinorrhea, tightness in chest, cramps, nausea, malaise, miosis in human volunteers; may limit performance for night operations, aircrews, and tasks involving distance or spatial judgement Level-2: Reversible miosis, dyspnea, RBC-ChE inhibition, single fibre electromyography (SFEMG) changes in human volunteers; may limit performance for night operations, aircrews, and tasks involving distance or spatial judgement Level-3: Based on experimental Sprague-Dawley rat lethality data (LC_{01}, LC_{50}) Derived from 8-hr AEGL	24-hour MEGs estimate derived from 8-hour AEGL by straightline extrapolation of 8-hour AEGL Ct (see RD Table 2-2) For Reference GPL = 0.000003 (0.000003) mg/m^3 WPL = 0.0001 (0.0001) mg/m^3
GD (Soman) 96-64-0	0.0005 [0.000065]	24 hours only: 0.000022 (0.0002) (Level-1) 0.00028 (0.002) (Level-2) 0.0022 (0.02) (Level-3)	AEGL –1 8-hr; NRC 2003, see Table 2-2 this RD	Based on relative potency from GB. Derived from 8-hr AEGL	**24-hour MEGs estimate** derived from 8-hour AEGL by straightline extrapolation of 8-hour AEGL Ct (see RD Table 2-2) For Reference: GPL = 0.000003 (0.000001) mg/m^3 WPL = 0.00003 (0.00003) mg/m^3

Table C-3: Basis for 8 and 24-hour or 14-day Short-term Air-MEGs

Chemical CAS No.	8-hour Air-MEG mg/m^3 [ppm]	14-day Air-MEG mg/m^3 [ppm]	Source	Critical Study Endpoint	Notes
GF 329-99-7		24 hours only: 0.0002 [0.000023] (Level-1) 0.002 [0.00030] (Level-2) 0.02 [0.0024] (Level-3)	AEGL –1 8-hr; NRC 2003, see Table 2-2 this RD	Based on relative potency from GB. Derived from 8-hr AEGL	**24-hour MEGs estimate** derived from 8-hour AEGL by straightline extrapolation of 8-hour AEGL Ct (see RD Table 2-2) For Reference: GPL = 0.000003 (0.000001) mg/m^3 WPL = 0.00003 (0.00003) mg/m^3
Hexachlorobutadiene 87-68-3	0.24 [0.02]	0.005[S] [0.0005]	ACGIH ACGIH	Systemic; kidney effects; no human data; based on a NOEL of 0.2 mg/kg/day after continuous ingestion by rats for 2 yrs.	Dermal exposures may contribute to overall dose; carcinogen. TLV / TLV-Adj.
Hexachlorocyclopentadiene 77-47-4	0.1 [0.01]	0.1 [0.01]	ACGIH ACGIH	Irritant; skin and mucous membrane irritation, lacrimation, sneezing, and salivation; higher concentrations cause pulmonary hyperemia and edema.	TLV.
Hexachloroethane smoke 67-72-1	0.2	0.2	NRC[a] NRC[a]	In mice; respiratory distress, edema of the lungs, destructive alveolitis, and macrophage infiltration, followed by development of fibrosis.	Based on data for $ZnCl_2$, Marrs et al. (1988) (*in* NRC[a]).
Hexane 110-54-3	180[S] [50]	4.3[S] [1.2]	ACGIH ACGIH	Systemic; polyneuropathy; based on the conclusion that solvents contain 50% to 70% n-hexane.	Dermal exposures may contribute to overall dose. TLV / TLV-Adj.
Hydrazine 302-01-2	0.13[S] [0.1]	0.013[S] [0.01]	AEGL-1 ACGIH	Based on a slightly higher incidence of nasal tumors in rats exposed to 0.05 ppm.	Given the application of the given exposure period (equivalent to $1/70^{th}$ of the exposure period); no UF was applied.

Table C-3: Basis for 8 and 24-hour or 14-day Short-term Air-MEGs

Chemical CAS No.	8-hour Air-MEG mg/m^3 [ppm]	14-day Air-MEG mg/m^3 [ppm]	Source	Critical Study Endpoint	Notes
Hydrogen bromide 10035-10-6	9.9^C [3]	9.9^C [3]	ACGIH ACGIH	Irritant; nose, throat, and eye irritation.	ACGIH ceiling value and OSHA Permissible exposure limit.
Hydrogen chloride 1333-74-0	2.7 [1.8]	2.7 [1.8]	AEGL-1 AEGL-1	Irritant; eye, mucous membrane, and skin irritation.	5 ppm ACGIH ^{C}
Hydrogen cyanide 74-90-8	1.1^S [1]	0.11^S [0.11]	AEGL-1 ACGIH	Mixed; CNS, headache, tachycardia, nausea; nasal irritation.	Given the possibility of bioaccumulation from continuous exposures and the magnitude of effect, TLV-Adj. Dermal exposures may contribute to overall dose.
Hydrogen fluoride 7664-39-3	0.82 [1.0]	0.82 [1.0]	AEGL-1 AEGL-1	Irritant; respiratory irritation; in solution, burns to the skin and eyes.	3 ppm ACGIH ^{C}
Hydrogen selenide 7783-07-5	0.2 [0.05]	0.2 [0.05]	ACGIH ACGIH	Irritation; eye and mucous membrane.	*Measured as selenium. TLV.
Hydrogen sulfide 7783-06-4	0.46 [0.33]	0.46 [0.33]	AEGL-1 AEGL-1	Mixed; eye irritation; neuroasthenic symptoms such as headache, dizziness, and irritability; CNS effects.	TLV (ACGIH) – 10 ppm; TLV-Adj. – 0.12 ppm.
Iron pentacarbonyl 13462-40-6	NA	0.02 [0.0024]	ACGIH	Mixed; respiratory distress, cyanosis, tremors, and paralysis of the extremities in animals.	* Measured as Fe. TLV / TLV-Adj.
Lewisite 541-25-3	0.003^C	0.003^C	DA PAM 50-6	Irritation: eye and mucous membrane.	Value represents a technologically feasible “real-time” detection limits. Based on inference from available toxicity information.
Lindane 58-89-9	0.5^S [0.04]	0.012^S [0.001]	ACGIH ACGIH	Based on a LOAEL of 0.19 – 0.7 mg/m^3 for CNS effects.	TLV / TLV-Adj.; dermal exposures may contribute to overall dose.

Table C-3: Basis for 8 and 24-hour or 14-day Short-term Air-MEGs

Chemical CAS No.	8-hour Air-MEG mg/m^3 [ppm]	14-day Air-MEG mg/m^3 [ppm]	Source	Critical Study Endpoint	Notes
Methyl bromide 74-83-9	4^S [1]	0.09^S [0.024]	ACGIH ACGIH	Systemic; pulmonary edema, neurotoxic effects.	TLV / TLV-Adj.; dermal exposures may contribute to overall dose; carcinogen.
Methylene chloride 75-09-02	175 [50]	2.1 [0.6]	ACGIH *PMAG	Based on human behavioral data.	ACGIH/TLV - 175 mg/m^3; carcinogen. *See TG230B for description.
Methyl hydrazine 60-34-4	0.02^S [0.01]	0.0005^S [0.00024]	ACGIH ACGIH	Systemic; hemolytic anemia.	TLV / TLV-Adj.; dermal exposures may contribute to overall dose; carcinogen.
Methyl isocyanate 624-83-9	0.05^S [0.02]	0.05^S [0.02]	ACGIH ACGIH	Irritant; corrosive and irritating to the mucous membranes; sensitization of the pulmonary tract.	TLV. Dermal exposures may contribute to overall dose.
Methyl mercaptan 74-93-1	1 [0.5]	0.024 [0.012]	AEGL-1 ACGIH	Mixed; eye and mucous membrane irritation; CNS depression.	TLV-Adj.
Nitric acid 7697-37-2	1.3 [0.5]	1.3 [0.5]	AEGL-1 AEGL-1	Irritant; eye and mucous membrane irritant, corrosion of the teeth and skin; pulmonary edema.	ACGIH TLV – 2 ppm.
Nitric oxide 10102-43-9	0.61 [0.5]	0.61 [0.5]	AEGL-1* AEGL-1*	Systemic; methemoglobinemia, CNS effects.	* Proposed AEGL, based on value for nitrogen dioxide due to conversion in atmosphere. TLV-Adj. – 0.6 ppm (ACGIH).
Nitrogen dioxide 10102-44-0	0.94 [0.5]	0.94 [0.5]	AEGL-1* AEGL-1*	Irritant; mildly irritating to the eyes, nose, and upper respiratory tract; bronchitis and emphysema.	*Proposed AEGL, TLV – 3 ppm (ACGIH).
Paraquat 4685-14-7	0.1 [0.016]	0.01 [0.0016]	ACGIH ACGIH	Based on systemic toxicity of respirable fraction (<5 μm) TLV = 0.5 mg/m^3.	TLV / TLV-Adj.; toxicity dependant on particle size, particles <5 μm.
Parathion 56-38-2	0.1^S [0.008]	0.0024^S [0.0002]	ACGIH ACGIH	Systemic; anticholinesterase activity.	TLV / TLV-Adj.; dermal exposures may contribute to overall dose.

Table C-3: Basis for 8 and 24-hour or 14-day Short-term Air-MEGs

Chemical CAS No.	8-hour Air-MEG mg/m^3 [ppm]	14-day Air-MEG mg/m^3 [ppm]	Source	Critical Study Endpoint	Notes
Perchloromethyl mercaptan 594-42-3	0.04 [0.0049]	0.04 [0.0049]	AEGL-1 AEGL-1	Irritant; eye, nose, and throat irritation; at higher concentrations may cause coughing, dyspnea, lacrimation, pallor, vomiting, tachycardia, cyanosis.	TLV- 0.1 ppm (ACGIH).
Phenol 108-95-2	7.3 [1.9]	ND	AEGL-1	Irritating to eyes, nose, throat; anorexia; weakness, muscle aches; dark urine; liver/kidney damage; tremor/twitching, cyanosis, convulsions	ERPG (1-3): 10, 50, 200 ppm. IDLH: 250 ppm. OSHA 8 hr TWA: 19 mg/m^3 [5 ppm]. Ceiling 15 min: 60 mg/m^3 [15.6 ppm]. Skin
Phosgene 75-44-5	0.4 [0.1]	0.04 [0.01]	ACGIH NRC[1]	Mixed; pulmonary edema, anoxia.	ACGIH/TLV – 0.10 ppm.
Phosphine 7803-51-2	0.4 [0.3]	0.01 [0.0073]	ACGIH ACGIH	Mixed; severe respiratory irritant; gastrointestinal, respiratory, and CNS effects noted at concentrations < 10 ppm (14 mg/m^3).	TLV / TLV-Adj.; does not account for chronic phosphorus poisoning.
Phosphorus (yellow) 7723-14-0	0.1 [0.02]	0.0024 [0.0005]	ACGIH ACGIH	Acute effects; respiratory irritation, nausea, hepatic and renal necrosis.	TLV / TLV-Adj.; severe symptoms in man at relatively low, single doses (15 mg); chronic effects not well characterized.
Phosphorus oxychloride 10025-87-3	0.6 [0.1]	0.015 [0.002]	ACGIH ACGIH	Mixed; eyes, mucous membrane, and skin irritation; kidney effects.	TLV / TLV-Adj..
Phosphorus trichloride 7719-12-2	1.5 [0.2]	1.5 [0.2]	ACGIH ACGIH	Irritant; severe irritation of the eyes, mucous membranes, and skin.	TLV.
Propylene oxide 75-56-9	26.2 [11]	ND	AEGL-1	Irritation eyes, respiratory tract; skin burns; blisters carcinogen	ERPG (1-3): 50, 250, 750 ppm. IDLH: [400 ppm] OSHA 8 hr: 5 mg/m^3 [2 ppm]. Skin

Table C-3: Basis for 8 and 24-hour or 14-day Short-term Air-MEGs

Chemical CAS No.	8-hour Air-MEG mg/m^3 [ppm]	14-day Air-MEG mg/m^3 [ppm]	Source	Critical Study Endpoint	Notes
Red phosphorus smoke	1	1	NRC[a] NRC[a]	Eye and skin irritation, pulmonary effects.	Based on the ACGIH TLV-TWA for phosphoric acid, the main combustion product of concern.
Selenium hexafluoride 7783-79-1	0.4 [0.05]	0.4 [0.05]	ACGIH ACGIH	Irritation; based on acute toxicity, pulmonary edema.	* Measured as Se. TLV.
Stibine 7803-52-3	0.5 [0.1]	0.5 [0.1]	ACGIH ACGIH	Irritant; pulmonary irritation; kidney and liver damage at higher concentrations.	TLV.
Sulfur dioxide 7446-09-5	0.8 [0.3]	0.8 [0.3]	ERPG-1 ERPG-1	Irritant; mild respiratory irritation and human bronchoconstriction.	ACGIH/TLV – 5.2 mg/m^3. NRC – 1 ppm.
Sulfur mustard [HD] 505-60-2	0.0083 [0.0012]	0.003 [0.00033] (Level-1) 0.004 [0.00067] (Level-2) 0.09 [0.013] (Level-3)	AEGL 1 8 hr, NRC 2003	Level 1: **Delayed development** (hours post-exposure) of conjunctival injection and minor discomfort with no functional decrement in human volunteers in hot-weather conditions; greater concentrations tolerated in cold-weather conditions. Level 2: **Delayed development** (hours post-exposure) of well-marked, generalized conjunctivitis, edema, photophobia, and eye irritation in human volunteers in hot-weather conditions; greater concentrations tolerated in cold-weather conditions Level 3: Based on experimental lethality data for Swiss mice Derived from 8-hr AEGL	**24-hour MEGs estimate** derived from 8-hour AEGL by straightline extrapolation of 8-hour AEGL Ct (see RD Table 2-2) For reference: GPL = 0.0001 (0.00002) mg/m^3 WPL = 0.003 (0.0004) mg/m^3 Known human carcinogen.

Table C-3: Basis for 8 and 24-hour or 14-day Short-term Air-MEGs

Chemical CAS No.	8-hour Air-MEG mg/m^3 [ppm]	14-day Air-MEG mg/m^3 [ppm]	Source	Critical Study Endpoint	Notes
Sulfuric acid 7664-93-9	1 [0.25]	1 [0.25]	ACGIH ACGIH	Irritant; pulmonary irritation.	TLV. Carcinogen.
Sulfuryl fluoride 2699-79-8	20 [5]	0.5 [0.12]	ACGIH ACGIH	CNS depressant and pulmonary irritant in animals.	TLV / TLV-Adj.
Tellurium hexafluoride 7783-80-4	0.2 [0.02]	0.2 [0.02]	ACGIH ACGIH	Irritant; pulmonary irritation in animals; in humans, respiratory tract irritation and intoxication.	*Measured as tellurium. TLV.
Tetrachloroethane (1,1,2,2-) 79-34-5	7^S [1]	0.2^S [0.024]	ACGIH ACGIH	Systemic; nervous, hepatic, and gastrointestinal effects.	TLV / TLV-Adj.; dermal exposures may contribute to overall dose.
Tetrachloroethylene (Perchloroethylene) 127-18-4	237 [35]	4.2 [0.61]	AEGL-1 ACGIH	Systemic; liver injury.	TLV-Adj.
Tetraethyl lead* 78-00-2	0.1^S [0.013]	0.0024^S [0.0003]	ACGIH ACGIH	Tinnitus, ataxia, tremors, insomnia, psychosis, mania, and convulsions.	*Measured as total Pb (no speciation); guideline based on most toxic Pb species. TLV / TLV-Adj.; dermal exposures may contribute to overall dose.
Tetrafluoroethane (1,1,1,2-) 811-97-2	33,360 [8000]	ND	AEGL-1	Irritation eyes, skin, nose, throat, respiratory system; dizziness, headache, hypoxia; pulmonary and cerebral edema	NA
Tetramethyl lead* 75-74-1	0.1^S [0.013]	0.0024^S [0.0003]	ACGIH ACGIH	Headache, nausea, and convulsions.	*Measured as total Pb (no speciation); guideline based on most toxic Pb species. TLV / TLV-Adj. - 0.0004 ppm.
Titanium tetrachloride 7550-45-0	0.5	0.012	AIHA AIHA	Respiratory tract, skin, and eye irritation. (AIHA 2002).	AIHA WEEL / WEEL-Adj.

Table C-3: Basis for 8 and 24-hour or 14-day Short-term Air-MEGs

Chemical CAS No.	8-hour Air-MEG mg/m^3 [ppm]	14-day Air-MEG mg/m^3 [ppm]	Source	Critical Study Endpoint	Notes
Toluene 108-88-3	754 [200]	11 [3]	AEGL-1 ATSDR	Mixed; skin irritation and CNS effects.	ACGIH/TLV - 190 mg/m^3.
Toluene 2,4-diisocyanate 584-84-9	0.07 [0.01]	0.036 [0.005]	AEGL-1 ACGIH	Irritant; cough, phlegm production, breathlessness, and wheezing, bronchitis.	Potential sensitizer.
Trichloroethylene 79-01-6	270 [50]	6.6 [1.2]	ACGIH ACGIH	Headache, fatigue, and irritability.	TLV / TLV-Adj.
Trichloropropane (1,2,3-) 96-18-4	60^S [10]	1.5^S [0.24]	ACGIH ACGIH	Systemic; hepatic and renal injury.	TLV / TLV-Adj.; dermal exposures may contribute to overall dose; carcinogen.
Tungsten hexafluoride 7783-82-6	1 [0.125]	0.024 [0.003]	ACGIH ACGIH	Mixed; anorexia, colic, incoordination of movement, trembling, and dyspnea (CNS).	TLV / TLV-Adj., TLV based on soluble tungsten.
VX 50782-69-9	0.000071 [0.00000265]	24 hr only: 0.000024 [0.0000022] (Level-1) 0.00033 [0.000032] (Level-2) 0.0013 [0.00012] (Level-3)	AEGL 1, 8-hr, NRC 2003	Levels 1 and 2: Derived by relative potency from study of multiple minimal (1) or transient (2) effects in human volunteers exposed to agent GB; may limit performance for night operations, aircrews, and tasks involving distance or spatial judgement Level 3: Derived by relative potency from study of experimental Sprague-Dawley rat lethality data (LC_{01}, LC_{50}) Derived from 8-hr AEGL	24-hour estimate derived from 8-hour AEGL by straightline extrapolation of 8-hour AEGL Ct (see) GPL = 0.000003 (0.0000003) mg/m^3 WPL = 0.00001 mg/m^3
Xylene (mixed) 1330-20-7	435 [100]	10.6 [2.4]	ACGIH ACGIH	Mixed; eye, skin, and mucous membrane irritation; hepatic and renal; neurological impairments.	TLV / TLV-Adj.

Table C-3: Basis for 8 and 24-hour or 14-day Short-term Air-MEGs

Chemical CAS No.	8-hour Air-MEG mg/m^3 [ppm]	14-day Air-MEG mg/m^3 [ppm]	Source	Critical Study Endpoint	Notes

Notes:

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EPA – Environmental Protection Agency. 2001. "National Advisory Committee for Acute Exposure Guideline Levels (AEGLs) for Hazardous Substances; Proposed AEGL Values" *Federal Register* 66 (85): 21940-21964 (2 May 2001).

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C – Ceiling value (ACGIH, 1998).

CAS No. – Chemical Abstract Service number

s – Skin notation; dermal exposures have the potential for significant contribution to overall dose.

CNS – Central Nervous System.

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Table C-4: Data Sheet and Risk Calculations for PMEGs-L

Chemical	CAS No.	Sub RfC (mg/m^3)	Source	UF	Chronic RfC (mg/m^3)	Source	UF	Carc Class	INH Risk ($rsk/ug/m^3$)	Source	CSFi $1/(kg/mg-d)$	Sub-MRC mg/m^3	Chronic-MRC mg/m^3	MCRC mg/m^3	PMEG-L mg/m^3
acenaphthene	83-32-9				2.10E-01	I[O]	3000						1.44E-01		1.44E-01
acenaphthylene	208-96-8				2.80E-02	Q	3000	D					2.80E-02		2.80E-02
acetaldehyde	75-07-0				9.00E-03	I	1000	B2	2.20E-06	I	7.70E-03		6.16E-03	2.18E+00	6.16E-03
acetone	67-64-1							D							
acetone cyanohydrin	75-86-5	1.00E-01	H	100								6.85E-02			6.85E-02
acetonitrile	75-05-8	5.00E-01	H	300				D				3.42E-01			3.42E-01
acrolein	107-02-8				2.00E-05	I	1000	C					1.37E-05		1.37E-05
acrylamide	79-06-1							B2	1.30E-03	I	4.55E+00			3.69E-03	3.69E-03
acrylic acid	79-10-7	3.00E-03	H	100								2.05E-03			2.05E-03
acrylonitrile	107-13-1				2.00E-03	I	1000	B1	6.80E-05	I	2.38E-01		1.37E-03	7.05E-02	1.37E-03
aldrin	309-00-2							B2	4.90E-03	I	1.72E+01			9.78E-04	9.78E-04
allyl chloride	107-05-1	1.00E-02	H	300				C				6.85E-03			6.85E-03
ammonia	7664-41-7	1.00E-01	H	30								6.85E-02			6.85E-02
aniline	62-53-3	1.00E-02	H	300				B2				6.85E-03			6.85E-03
antimony trioxide	1309-64-4	2.00E-04	H	30								1.37E-04			1.37E-04
anthracene	120-12-7				1.05E+00	I[O]	3000	D					1.05E+00		1.05E+00
arsenic	7440-38-2							A	4.30E-03	I	1.51E+01			1.11E-03	1.11E-03
arsine	7784-42-1				5.00E-05	I	300						3.42E-05		3.42E-05
azobenzene	103-33-3							B2	3.10E-05	I	1.09E-01			1.55E-01	1.55E-01
barium	7440-39-3	5.00E-03	H	100								3.42E-03			3.42E-03
benzene	71-43-2							A	7.80E-06	I	2.73E-02			6.15E-01	6.15E-01
benzidine	92-87-5							A	6.70E-02	I	2.35E+02			7.16E-05	7.16E-05
benzo(a)anthracene	56-55-3							B2	8.80E-05	E	3.08E-01			5.45E-02	5.45E-02
benzo(a)pyrene	50-32-8							B2	8.80E-04	N	3.08E+00			5.45E-03	5.45E-03
benzo(b)fluoranthene	205-99-2							B2	8.80E-05	E	3.08E-01			5.45E-02	5.45E-02
benzo(k)fluoranthene	207-08-9							B2	8.80E-06	E	3.08E-02			5.45E-01	5.45E-01
beryllium	7440-41-7				2.00E-05	I	10	B1	2.40E-03	I	8.40E+00		1.37E-05	2.00E-03	1.37E-05
bis(2-chloroethyl)ether	111-44-4							B2	3.30E-04	I	1.16E+00			1.45E-02	1.45E-02
bis(2-chloro-1-methylethyl)ether	108-60-1							C	1.00E-05	H	3.50E-02			4.79E-01	4.79E-01
bis (2-ethylhexyl) phthalate	117-81-7							B2	2.08E-06	R	7.28E-03			2.30E+00	2.30E+00
boron	7440-42-8	2.00E-02	H	100								1.37E-02			1.37E-02
boron trifluoride	7637-07-2	7.00E-03	H	300								4.79E-03			4.79E-03
bromoform	75-25-2							B2	1.10E-06	I	3.85E-03			4.36E+00	4.36E+00
1,3-butadiene	106-99-0							B2	2.80E-04	I	9.80E-01			1.71E-02	1.71E-02
sec-Butylbenzene	135-98-8				3.70E-02	R	1000						2.53E-02		2.53E-02
cadmium (elemental)	7440-43-9							B1	1.80E-03	I	6.30E+00			2.66E-03	2.66E-03
carbon disulfide	75-15-0	7.00E-01	H	30								4.79E-01			4.79E-01
carbon monoxide	630-08-0														
carbon tetrachloride	56-23-5							B2	1.50E-05	I	5.25E-02			3.20E-01	3.20E-01
chlordane	57-74-9				7.00E-04	I	1000	B2	1.00E-04	I	3.50E-01		4.79E-04	4.79E-02	4.79E-04
chlorine dioxide	10049-04-4				2.00E-04	I	3000						1.37E-04		1.37E-04
2-chloroacetophenone	532-27-4				3.00E-05	I	1000						2.05E-05		2.05E-05
chlorobenzilate	510-15-6							B2	7.80E-05	H	2.73E-01			6.15E-02	6.15E-02
2-chloro-1,3-butadiene	126-99-8	7.00E-02	H	30								4.79E-02			4.79E-02
1-chloro-1,1-difluoroethane	75-68-3				5.00E+01	I	300						3.42E+01		3.42E+01
chlorodifluoromethane	75-45-6				5.00E+01	I	100						3.42E+01		3.42E+01
chloroethane	75-00-3				1.00E+01	I	300						6.85E+00		6.85E+00
chloroform	67-66-3							B2	2.30E-05	I	8.05E-02			2.08E-01	2.08E-01

Table C-4: Data Sheet and Risk Calculations for PMEGs-L

Chemical	CAS No.	Sub RfC (mg/m^3)	Source	UF	Chronic RfC (mg/m^3)	Source	UF	Carc Class	INH Risk ($rsk/ug/m^3$)	Source	CSFi $1/(kg/mg-d)$	Sub-MRC mg/m^3	Chronic-MRC mg/m^3	MCRC mg/m^3	PMEG-L mg/m^3
chloromethane	74-87-3							C	1.80E-06	H	6.30E-03			2.66E+00	2.66E+00
2-chloropropane	75-29-6	1.00E+00	H	100								6.85E-01			6.85E-01
chromium VI (particulate)	18540-29-9				1.00E-04	I	300	A	1.20E-02	I	4.20E+01		6.85E-05	4.00E-04	6.85E-05
chromium VI (soluble)	18540-29-9				8.00E-06	I	90						5.48E-06		5.48E-06
chrysene	218-01-9							B2	8.80E-07	E	3.08E-03			5.45E+00	5.45E+00
cumene	98-82-8	9.00E-02	H	1000	4.00E-01	I	1000	D				6.16E-02	2.74E-01		2.74E-01
cyclopentadiene	542-92-7	3.00E+00	H	100								2.05E+00			2.05E+00
DDT	50-29-3							B2	9.70E-05	I	3.40E-01			4.94E-02	4.94E-02
dibenzo(a,h)anthracene	53-70-3							B2	8.80E-04	E	3.08E+00			5.45E-03	5.45E-03
1,2-dibromo-3-chloropropane	96-12-8				2.00E-04	I	1000	B2	6.70E-07	H	2.35E-03		1.37E-04	7.16E+00	1.37E-04
1,2-dibromoethane	106-93-4	2.00E-03	H	100				B2	2.20E-04	I	7.70E-01	1.37E-03		2.18E-02	1.37E-03
1,2-dichlorobenzene	95-50-1	2.00E+00	H	100				D				1.37E+00			1.37E+00
1,4-dichlorobenzene	106-46-7	2.50E+00	H	30								1.71E+00			1.71E+00
1,4-dichloro-2-butene	764-41-0							B2	2.60E-03	H	9.10E+00			1.84E-03	1.84E-03
dichlorodifluoromethane	75-71-8	2.00E+00	H	1000								1.37E+00			1.37E+00
1,1-dichloroethane	75-34-3	5.00E+00	H	100				C				3.42E+00			3.42E+00
1,2-dichloroethane	107-06-2							B2	2.65E-05	I	9.28E-02			1.81E-01	1.81E-01
1,1-dichloroethylene	75-35-4							C	5.00E-05	I	1.75E-01			9.59E-02	9.59E-02
1,2-dichloropropane	78-87-5	1.30E-02	H	100								8.90E-03			8.90E-03
1,3-dichloropropene	542-75-6	2.00E-02	H	30				B2	3.70E-05	I	1.30E-01	1.37E-02		1.30E-01	1.37E-02
dichlorvos	62-73-7				5.00E-04	I	100	B2					3.42E-04		3.42E-04
dicyclopentadiene	77-73-6	2.00E-03	H	1000								1.37E-03			1.37E-03
dieldrin	60-57-1							B2	4.60E-03	I	1.61E+01			1.04E-03	1.04E-03
diesel engine emissions	none				5.00E-03	I	30						3.42E-03		3.42E-03
1,1-difluoroethane	75-37-6				4.00E+01	I	300						2.74E+01		2.74E+01
N,N-dimethylformamide	68-12-2	3.00E-02	H	300								2.05E-02			2.05E-02
1,2-diphenylhydrazine	122-66-7							B2	2.20E-04	I	7.70E-01			2.18E-02	2.18E-02
epichlorohydrin	106-89-8	1.00E-02	H	100				B2	1.20E-06	I	4.20E-03	6.85E-03		4.00E+00	6.85E-03
1,2-epoxybutane	106-88-7				2.00E-02	I	300						1.37E-02		1.37E-02
2-ethoxyethanol	110-80-5	2.00E+00	H	30								1.37E+00			1.37E+00
ethyl benzene	100-41-4				1.00E+00	I	300	D		I			6.85E-01		6.85E-01
ethyl chloride	75-00-3	1.00E+01	H	300								6.85E+00			6.85E+00
ethylene glycol monobutyl ether	111-76-2	2.00E-01	H	100								1.37E-01			1.37E-01
ethylene oxide	75-21-8							B1	1.00E-04	H	3.50E-01			4.79E-02	4.79E-02
fluoranthene	206-44-0				1.40E-01	I[o]	3000	D					1.40E-01		1.40E-01
fluorene	86-73-7				1.40E-01	I[o]	3000	D					1.40E-01		1.40E-01
formaldehyde	50-00-0							B1	1.30E-05	I	4.55E-02			3.69E-01	3.69E-01
furfural	98-01-1	5.00E-01	H	100								3.42E-01			3.42E-01
glycidaldehyde	765-34-4	1.00E-02	H	300				B2				6.85E-03			6.85E-03
heptachlor	76-44-8							B2	1.30E-03	I	4.55E+00			3.69E-03	3.69E-03
heptachlor epoxide	1024-57-3							B2	2.60E-03	I	9.10E+00			1.84E-03	1.84E-03
hexachlorobenzene	118-74-1							B2	4.60E-04	I	1.61E+00			1.04E-02	1.04E-02
hexachlorobutadiene	87-68-3							C	2.22E-05	I	7.77E-02			2.16E-01	2.16E-01
alpha-HCH	319-84-6							B2	1.80E-03	I	6.30E+00			2.66E-03	2.66E-03
beta-HCH	319-85-7							C	5.30E-04	I	1.86E+00			9.05E-03	9.05E-03
technical HCH	608-73-1							B2	5.10E-04	I	1.79E+00			9.40E-03	9.40E-03
hexachlorocyclopentadiene	77-47-4	7.00E-04	H	100				D				4.79E-04			4.79E-04

Table C-4: Data Sheet and Risk Calculations for PMEGs-L

Chemical	CAS No.	Sub RfC (mg/m^3)	Source	UF	Chronic RfC (mg/m^3)	Source	UF	Carc Class	INH Risk ($rsk/ug/m^3$)	Source	CSFi $1/(kg/mg-d)$	Sub-MRC mg/m^3	Chronic-MRC mg/m^3	MCRC mg/m^3	PMEG-L mg/m^3
hexachlorodibenzodioxin mix	19408-74-3							B2	1.30E+00	I	4.55E+03			3.69E-06	3.69E-06
hexachloroethane	67-72-1							C	4.00E-06	I	1.40E-02			1.20E+00	1.20E+00
1,6-hexamethylene diisocyanate	822-06-0				1.00E-05	I	100						6.85E-06		6.85E-06
N-hexane	110-54-3	2.00E-01	H	300								1.37E-01			1.37E-01
hydrazine	302-01-2							B2	4.90E-03	I	1.72E+01			9.78E-04	9.78E-04
hydrogen chloride	7647-01-0				2.00E-02	I	300						1.37E-02		1.37E-02
hydrogen cyanide	74-90-8				3.00E-03	I	1000						2.05E-03		2.05E-03
hydrogen sulfide	7783-06-4	1.00E-02	H	100								6.85E-03			6.85E-03
indeno(1,2,3-c,d)pyrene	193-39-5							B2	8.80E-05	E	3.08E-01			5.45E-02	5.45E-02
manganese	7439-96-5				5.00E-05	I	1000	D					3.42E-05		3.42E-05
mercury (inorganic)	7439-97-6	3.00E-04	H	30								2.05E-04			2.05E-04
2-methoxyethanol	109-86-4	2.00E-01	H	100								1.37E-01			1.37E-01
methylacrylonitrile	126-98-7	7.00E-03	H	300								4.79E-03			4.79E-03
methyl bromide	74-83-9				5.00E-03	I	100						3.42E-03		3.42E-03
methylcyclohexane	108-87-2	3.00E+00	H	100								2.05E+00			2.05E+00
4,4-methylene bis(2-chloroaniline)	101-14-4							B2	3.75E-05	H	1.31E-01			1.28E-01	1.28E-01
methylene chloride	75-09-2	3.00E+00	H	100				B2	4.70E-07	I	1.65E-03	2.05E+00		1.02E+01	2.05E+00
4,4-methylenediphenyl isocyanate	101-68-8	2.00E-05	H	300								1.37E-05			1.37E-05
methyl ethyl ketone	78-93-3	1.00E+00	H	3000				D				6.85E-01			6.85E-01
methyl isobutyl ketone	108-10-1	8.00E-01	H	100								5.48E-01			5.48E-01
methyl styrene (mixture)	25013-15-4	4.00E-02	H	1000								2.74E-02			2.74E-02
methyl tert-butyl ether	1634-04-4				3.00E+00	I	100						2.05E+00		2.05E+00
napthalene	91-20-3				3.00E-03	I	3000	C					2.05E-03		2.05E-03
nickel refinery dust	none							A	2.40E-04	I	8.40E-01			2.00E-02	2.00E-02
nickel subsulfide	12035-72-2							A	4.80E-04	I	1.68E+00			9.99E-03	9.99E-03
2-nitroaniline	88-74-4	2.00E-03	H	1000								1.37E-03			1.37E-03
nitrobenzene	98-95-3	2.00E-02	H	1000				D		I		1.37E-02			1.37E-02
2-nitropropane	79-46-9	2.00E-02	H	1000				B2	2.70E-03	H	9.45E+00	1.37E-02		1.78E-03	1.78E-03
N-nitroso-di-n-butylamine	924-16-3							B2	1.60E-03	I	5.60E+00			3.00E-03	3.00E-03
N-nitrosodiethylamine	55-18-5							B2	4.30E-02	I	1.51E+02			1.11E-04	1.11E-04
N-nitrosodimethylamine	62-75-9							B2	1.40E-02	I	4.90E+01			3.42E-04	3.42E-04
N-nitrosopyrrolidine	930-55-2							B2	6.10E-04	I	2.14E+00			7.86E-03	7.86E-03
phenanthrene	85-01-8				4.20E-02	Q	10,000	D					4.20E-02		4.20E-02
phosphine	7803-51-2	3.00E-03	H	100				D		I		2.05E-03			2.05E-03
phosphoric acid	7664-38-2				1.00E-02	I	300						6.85E-03		6.85E-03
phthalic anhydride	85-44-9	1.20E-01	H	300								8.22E-02			8.22E-02
polychlorinated biphenyls	1336-36-3							B2	5.71E-04	I	2.00E+00			8.40E-03	8.40E-03
propylene glycol monomethyl ether	107-98-2	2.00E+01	H	30								1.37E+01			1.37E+01
n-propylbenzene	103-65-1			1000	3.70E-02	R	1000	D					2.53E-02		2.53E-02
propylene oxide	75-56-9	3.00E-02	H	100				B2	3.70E-06	I	1.30E-02	2.05E-02		1.30E+00	2.05E-02
pyrene	129-00-0				1.05E-01	I[O]	3000	D					1.05E-01		1.05E-01
strontium	7440-24-6				2.20E+00	R							1.51E+00		1.51E+00
styrene	100-42-5	3.00E+00	H	10								2.05E+00			2.05E+00
2,3,7,8-tetrachlorodibenzodioxin	1746-01-6							B2	3.30E+01	H	1.50E+05			1.12E-07	1.12E-07
1,1,1,2-tetrachloroethane	630-20-6							C	7.40E-06	I	2.59E-02			6.48E-01	6.48E-01

Table C-4: Data Sheet and Risk Calculations for PMEGs-L

Chemical	CAS No.	Sub RfC (mg/m^3)	Source	UF	Chronic RfC (mg/m^3)	Source	UF	Carc Class	INH Risk ($rsk/ug/m^3$)	Source	CSFi $1/(kg/mg-d)$	Sub-MRC mg/m^3	Chronic-MRC mg/m^3	MCRC mg/m^3	PMEG-L mg/m^3
1,1,2,2-tetrachloroethane	79-34-5							C	5.80E-05	I	2.03E-01			8.27E-02	8.27E-02
1,1,1,2-tetrafluoroethane	811-97-2				8.00E+01	I	100						5.48E+01		5.48E+01
toluene	108-88-3				4.00E-01	I	300	D					2.74E-01		2.74E-01
toxaphene	8001-35-2							B2	3.20E-04	I	1.12E+00			1.50E-02	1.50E-02
1,2,4-trichlorobenzene	120-82-1	2.00E+00	H	100				D		I		1.37E+00			1.37E+00
1,1,2-trichloroethane	79-00-5							C	1.60E-05	I	5.60E-02			3.00E-01	3.00E-01
trichlorofluoromethane	75-69-4	7.00E+00	H	1000								4.79E+00			4.79E+00
1,1,2-trichloro-1,2,2-trifluoroethane	76-13-1	3.00E+01	H	100								2.05E+01			2.05E+01
2,4,6-trichlorophenol	88-06-2							B2	3.10E-06	I	1.09E-02			1.55E+00	1.55E+00
1,2,4-trimethylbenzene	95-63-6				5.95E-03	N							4.08E-03		4.08E-03
1,3,5-trimethylbenzene	108-67-8				5.95E-03	N							4.08E-03		4.08E-03
triethylamine	121-44-8				7.00E-03	I	3000						4.79E-03		4.79E-03
vinyl acetate	108-05-4	2.00E-01	H	30								1.37E-01			1.37E-01
vinyl bromide	593-60-2	3.00E-03	H	3000				B2	3.20E-05	H	1.12E-01	2.05E-03		1.50E-01	2.05E-03
vinyl chloride	75-01-4							A	8.40E-05	H	2.94E-01			5.71E-02	5.71E-02

Notes

Sub RfC	subchronic reference dose
UF	uncertainty factor
Chronic RfC	chronic reference concentration
Carc. Class	carcinogen class
INH Risk	inhalation risk
CSFi	cancer slope factor-inhalation
Sub-MRC	estimated subchronic military risk concentration
Chronic-MRC	estimated chronic military risk concentration
MCRC	estimated military cancer risk concentration
MAG-L	estimated military air guidelines – long-term
I	Integrated Risk Information System (IRIS), EPA, 1999
I^O	Integrated Risk Information System (IRIS), EPA, 1999, using oral to inhalation extrapolation
H	Health Effects Summary Tables (HEAST), EPA, 1997
N	NCEA – National Center for Environmental Assessment, EPA, 1994
E	estimated based on air unit risk for benzo(a)pyrene and toxicity equivalence factors (EPA, 1993)
R	estimated based on US EPA Region 3 or Region 9 ambient air guidelines, 2000
Q	estimated based on Quantitative Structure Activity Relationship (QSAR) data

Table C-5: Data Sheet and Relative Concentration Estimates for Long-Term Air-MEGs

Chemical	CAS No.	MW	PMEG-L mg/m³	MRL mg/m³	MRL Adj mg/m³	TLV mg/m³	TLV Adj mg/m³	MRL Adj/ PMEG	TLV Adj/ PMEG	TLV Adj/ MRL Adj	TLV critical effect(s)	MRL1 critical effect(s)	PMEG-L2 critical effect(s)	RfD UF (PMEG-L)
acetaldehyde	75-07-0	44.05	6.16E-03								Irritation			1000
acetone cyanohydrin	75-86-5	85.1	6.85E-02								CNS, anoxia			100
acenaphthene	83-32-9	154.2	1.44E-01	2.10E+00	2.10E+00			14.60				Eyes, skin, respir. sys.	Eyes, skin, respir. sys., kidney and liver effects possible	
acenaphthylene	208-96-8	152.2	2.80E-02										No data, LOAEL estimated from LD50 and QSAR	
acetone	67-64-1	58.08		3.09E+01	2.10E+01	1.19E+03	2.90E+01			1.383	Eyes, skin, respir. sys., CNS		Eye irritation, nose, throat, headache, dizziness, CNS depression, dermatitis	
acetonitrile	75-05-8	41.05	3.42E-01			6.72E+01	1.64E+00		4.795		lung; anoxia		Increased liver weight; kidney damage; CNS	300
acrolein	107-02-8	56.06	1.37E-05	2.06E-05	1.40E-05			1.02			Irritation; pulmonary edema	Respiratory effects (metaplasia); LOAEL; rat; UF=1000	Squamous metaplasia nasal epith; irrit eyes; decreased pulmonary function	1000 S
acrylamide	79-06-1	71.08	3.69E-03			3.00E-02	7.33E-04		0.199		Cancer; CNS; dermatitis		C--CNS, mammary, thyroid (B2)	S
acrylic acid	79-10-7	72.06	2.05E-03			5.89E+00	1.44E-01		70.138		Irritation; reproductive		Nasal mucosa lesions; CNS; PNS; Repro; liver; kidney	100 S
acrylonitrile	107-13-1	53.05	1.37E-03			4.34E+00	1.06E-01		77.453		Cancer		Degeneration & inflammation nasal epithelium/hyperplasia mucus secreting cells; CNS; CVS; liver kidneys; Cancer (B1)	1000 S
aldrin	309-00-2	364.93	9.78E-04			2.50E-01	6.11E-03		6.247		Liver		C--liver; CNS; kidneys (B2)	S
allyl chloride	107-05-1	76.5	6.85E-03			3.13E+00	7.65E-02		11.169		liver		Neurotoxicity; irrit eyes, resp. system; liver; kidneys	300
ammonia	7664-41-7	17.03	6.85E-02	2.09E-01	1.42E-01	1.74E+01	4.26E-01	2.07	6.216	2.996	Irritation	Chronic MRL; respiratory effects; human; NOAEL; UF=10; no effects on pulmonary function long-term	Rhinitis/ pneumonia/ lung lesions; irritant; bronchospasms, pulmonary edema	30
aniline	62-53-3	93.12	6.85E-03			7.62E+00	1.86E-01		27.191		Anoxia		Spleen; blood; CVS; CNS; liver; kidney; resp. system	300 S
antimony trioxide	1309-64-4	171.5	1.37E-04								Cancer (lung); pneumoconiosis			30
anthracene	120-12-7	178.23	1.05E+00	3.50E+01	3.50E+01			33.33			Skin, Eyes, Resp. Sys.		Skin, nose, throat, and eye irritation, itching and burning, coughing, and wheezing	
arsenic	7440-38-2	74.92	1.11E-03			1.00E-02	2.44E-04		0.219		Cancer (lung, skin); lung		C--Lung/lymphatics (A); CNS; respiratory system; liver; kidneys; skin; GI	
arsine*	7784-42-1	77.95	3.42E-05			1.59E-01	3.90E-03		113.806		Blood; kidney		Hemolysis/abnormal RBC morphology/increased spleen weight/; CNS; liver; kidneys; lung	300
azobenzene	103-33-3	182.22	1.55E-01										C	
barium	7440-39-3	137.3	3.42E-03			5.00E-01	1.22E-02		3.570		Irritation; GI; muscle toxin		Fetotoxicity; irrit. eyes, resp. tract; lung; GI; baritosis	100
benzene	71-43-2	78.11	6.15E-01	1.28E-02	8.69E-03	1.60E+00	3.91E-02	0.01	0.064	4.494	Cancer	Neuro (increased rapid response time); mouse; LOAEL; UF=90	Cancer	
benzidine	92-87-5	184.23	7.16E-05	no inhalation mrl							Cancer (bladder)		C	
benzo(a)anthracene	56-55-3	228.3	5.45E-02	no inhalation mrl							Cancer		C	
benzo(a)pyrene	50-32-8	252.3	5.45E-03	no inhalation mrl							Cancer		C	
benzo(b)fluoranthene	205-99-2	252.3	5.45E-02								Cancer		C	
benzo(k)fluoranthene	207-08-9	252.32	5.45E-01										C	
beryllium*	7440-41-7	9.01	1.37E-05			2.00E-04	4.89E-06		0.357		Cancer (lung); berylliosis		Beryllium sensitization/chronic beryllium disease; CNS; eyes; skin; cancer (B1)	10
bis(2-chloroethyl)ether	111-44-4	143.02	1.45E-02	1.17E-01	7.96E-02			5.48				Decreased body weight; LOAEL; rat; UF=1000	C--Hepatomas (from gavage study)(B2)	
bis(2-chloro-1-methylethyl)ether	108-60-1	171.07	4.79E-01	2.10E-03	1.43E-03			0.003				Resp and other systemic effects; NOAEL; rat; UF=100	C--liver tumors (gavage study) (C)	

Table C-5: Data Sheet and Relative Concentration Estimates for Long-Term Air-MEGs

Chemical	CAS No.	MW	PMEG-L mg/m³	MRL mg/m³	MRL Adj mg/m³	TLV mg/m³	TLV Adj mg/m³	MRL Adj/ PMEG	TLV Adj/ PMEG	TLV Adj/ MRL Adj	TLV critical effect(s)	MRL1 critical effect(s)	PMEG-L2 critical effect(s)	RfD UF (PMEG-L)
boron	7440-42-8	10.81	1.37E-02	no inhalation mrl										100
boron trifluoride	7637-07-2	67.82	4.79E-03								Irritation			300
bromoethane	593-60-2	106.96	2.05E-03										Liver damage; CNS; irrit. eyes/skin; Cancer (B2)	
bis (2-ethylhexyl) phthalate	117-81-7	390.56	2.30E+00	1.40E+00	9.52E-01	5.00E+00	1.22E-01	0.413	0.053	0.128	Eyes, skin, respir. sys., CNS, liver, reprod. Sys., GI		Eye irritation, liver damage, possible teratogenic and carcinogenic effects	
bromoform	75-25-2	252.8	4.36E+00			5.17E+00	1.26E-01		0.029		Irritation; liver		C--Neoplastic lesions liver; decreased body weight (B2)	
1,3-butadiene	106-99-0	54.09	1.71E-02			4.42E+00	1.08E-01		6.318		Cancer		C--tumors throughout body; irrit. ent; CNS; repro	
sec-Butylbenzene	135-98-8	134.24	2.53E-02								Irritation, eyes, nose, throat , skin		Irritation eyes, nose, throat, skin, CNS depression, incoordination, nausea, general anesthetic effects;	
cadmium (elemental)	7440-43-9	112.4	2.66E-03			1.00E-02	2.44E-04		0.092		Kidney; cancer; metal fume fever		C--Lung, trachea, bronchus; pulmonary edema; kidneys; blood	
cadmium (compounds)						2.00E-03	4.89E-05				Cancer; kidney; metal fume fever		C-Tumors of lung, trachea, bronchus (cancer deaths) in human occupational epidemiology study; B1	
carbon disulfide	75-15-0	76.14	4.79E-01	9.34E-01	6.35E-01	3.11E+01	7.61E-01	1.33	1.588	1.199	CVS; CNS; neuropathy	Chronic MRL; motor conduction velocity; human; LOAEL; UF=30	PNS dysfunction; CNS; CVS; eyes; kidneys; liver ; repro	30
carbon monoxide	630-08-0	28.01				2.86E+01	7.00E-01							
carbon tetrachloride	56-23-5	153.84	3.20E-01	3.15E-01	2.14E-01	3.15E+01	7.69E-01	0.67	2.407	3.596	Liver; cancer	Liver effects; rat; NOAEL; UF=100	C--Carcinomas/hepatomas; irrit eyes/skin; CNS; liver; kidney (B2)	S
chlordane	57-74-9	409.8	4.79E-04	2.00E-04	1.36E-04	5.00E-01	1.22E-02	0.28	25.498	89.889	Seizure; liver	Hepatic effects; rat; NOAEL; UF=100	Hepatic effects; CNS; blurred vision; liver; thyroid; thymus (B2)	1000 S
chlorine dioxide	10049-04-4	67.46	1.37E-04			2.76E-01	6.75E-03		49.246		Irritation; bronchitis		Vascular congestion/peribronchiolar edema; irrit ent	3000
2-chloroacetophenone	532-27-4	154.59	2.05E-05			3.16E-01	7.73E-03		376.167		Irritation; sensitization		Squamous hyperplasia nasal resp epithelium; lacrimation; irritation rashes	1000
chlorobenzilate	510-15-6	325.2	6.15E-02										C	
2-chloro-1,3-butadiene	126-99-8	88.54	4.79E-02			3.62E+01	8.85E-01		18.467		Irritation, CNS; liver; blood		Degeneration of olfactory epithelium; CNS; blood liver	30 S
1-chloro-1,1-difluoroethane	75-68-3	100.47	3.42E+01											300
chlorodifluoromethane	75-45-6	86.47	3.42E+01			3.54E+03	8.65E+01		2.525		CVS		Increased kidney/ adrenal/pituitary weights; CVS; CNS liver	100
chloroethane	75-00-3	64.52	6.85E+00	acute inhalation only										300
chloroform	67-66-3	119.38	2.08E-01	2.44E-01	1.66E-01	4.88E+01	1.19E+00	0.80	5.727	7.191	CVS; liver; kidney; CNS; repro	Hepatic effects; LOAEL; human; UF=100	C--kidney tumors; Irrit eyes/skin; CNS; liver; kidneys; heart (B20	
chloromethane	74-87-3	50.49	2.66E+00	4.13E-01	2.81E-01			0.11				Hepatic effects; LOAEL; rat UF=300	C--kidney tumors (C)	
2-chloropropane	75-29-6	78.54	6.85E-01											100
chrysene	218-01-9	228.3	5.45E+00	no inhalation mrl							Skin		C	
chromium metal and Cr III compounds	7440-47-3/ 16065-83-1	varies				5.00E-01	1.22E-02				Irritation; dermatitis			
Cr VI compounds (water-soluble)	18540-29-9	varies	5.48E-06	1.00E-04	6.80E-05	5.00E-02	1.22E-03	12.41	223.083	17.978	Cancer; liver; kidney	Intermediate & chronic MRL; nasal irrit., mucosal atrophy and ulceration, decreased pulmonary function; human; NOAEL; UF=10; chromic acid (chromium trioxide mist)	Nasal septum atrophy in humans	90

Table C-5: Data Sheet and Relative Concentration Estimates for Long-Term Air-MEGs

Chemical	CAS No.	MW	PMEG-L mg/m³	MRL mg/m³	MRL Adj mg/m³	TLV mg/m³	TLV Adj mg/m³	MRL Adj/ PMEG	TLV Adj/ PMEG	TLV Adj/ MRL Adj	TLV critical effect(s)	MRL1 critical effect(s)	PMEG-L2 critical effect(s)	RfD UF (PMEG-L)
Cr VI compounds (insoluble)	18540-29-9	varies	6.85E-05	5.00E-04	3.40E-04	1.00E-02	2.44E-04	4.96	3.570	0.719	Cancer; irritation	Effects on alveolar macrophages and immune function; rat; LOAEL; UF=90; hexavalent chromium particulate (sodium dichromate)	Lactate dehydrogenase in bronchialveolar fluid; irrit eyes; dermal sens; lung, liver kidney; lung cancer humans (A)	300
cumene	98-82-8	120.19	2.74E-01			2.46E+02	6.01E+00		21.935		Irritation; CNS		CNS effects and nasal irritation; CNS; irrit eyes resp, skin	1000
cyclopentadiene	542-92-7	66.1	2.05E+00			2.03E+02	4.96E+00		2.413		Irritation		Liver and kidney lesions; irrit eyes, nose	100
DDT	50-29-3	354.5	4.94E-02			1.00E+00	2.44E-02		0.495		Seizures; liver		C--liver tumors (diet study) (B2); CNS; PNS	
dibenzo(a,h)anthracene	53-70-3	278.33	5.45E-03										C	
1,2-dibromo-3-chloropropane	96-12-8	236.36	1.37E-04	1.93E-03	1.31E-03			9.60				Sperm abnormalities; rabbit; NOAEL; UF=100	Testicular effects; irrit ent; CNS; liver; kidney; spleen; cancer (B2)	1000
1,2-dibromoethane	106-93-4	187.88	1.37E-03	no inhalation mrl										100
1,2-dichlorobenzene	95-50-1	147	1.37E+00											100
1,4-dichlorobenzene	106-46-7	147.01	1.71E+00	1.20E+00	8.18E-01	6.01E+01	1.47E+00	0.48				Hepatic effects; NOAEL; rat; UF=100	Increased liver weights; eye irrit, profuse rhinitis; headaches; kidneys	30
1,4-dichloro-2-butene	764-41-0	125	1.84E-03										C	
dichlorodifluoromethane	75-71-8	98.97	1.37E+00			4.05E+03	9.90E+01		72.248		CVS		Liver lesions; CVS, PNS, CNS	1000
1,1-dichloroethane	75-34-3	98.97	3.42E+00			4.05E+02	9.90E+00		2.890		Liver; kidney; irritation		Kidney damage; CNS; liver; lungs; skin irrit (C)	100
1,2-dichloroethane	107-06-2	98.96	1.81E-01	8.09E-01	5.50E-01	4.05E+01	9.90E-01	3.04	5.470	1.799	Liver; narcosis	Chronic MRL; Hepatic effects; rat; NOAEL; UF=90	C--Hemangiosarcomas (oral study); liver; CNS (B2)	
1,1-dichloroethylene	75-35-4	96.95	9.59E-02	7.93E-02	5.39E-02	1.98E+01	4.85E-01	0.56	5.055	8.989	CNS; liver; kidney	Altered liver function; guinea pig; NOAEL; UF=300	C--Kidney adenosarcomas; liver; CNS	
1,2-dichloropropane	78-87-5	112.99	8.90E-03	3.23E-02	2.20E-02	3.47E+02	8.47E+00	2.47	951.719	385.240	Irritation; CNS; liver; kidney	Respiratory lesions; rat; LOAEL; UF=1000	Nasal mucosa hyperplasia; upper resp system; CNS; liver; kidney	100
1,3-dichloropropene	542-75-6	110.98	1.37E-02	1.36E-02	9.26E-03	4.54E+00	1.11E-01	0.68	8.101	11.985	Irritation	Nasal epithelial changes; rat; NOAEL; UF=100	Nasal mucosa hypertrophy and hyperplasia; cancer (lung) (B2); irrit eyes, skin, resp syst; CNS; liver; kidneys	30
dichlorvos	62-73-7	220.98	3.42E-04	2.71E-03	1.84E-03	9.00E-01	2.20E-02	5.38	64.254	11.935	Cholinergic	Ache inhibition; rat; NOAEL; UF=100	Decreased brain cholinesterase; CNS; CVS; resp. syst.; eyes	100 S
dicyclopentadiene	77-73-6	132.21	1.37E-03			2.70E+01	6.61E-01		482.564		Irritation		Kidney dysfunction; CNS; resp syst; irrit ent	1000 S
dieldrin	60-57-1	380.93	1.04E-03			2.50E-01	6.11E-03		5.865		Liver; CNS		C--Liver carcinomas; CNS; kidneys	S
diesel engine emissions*	none		3.42E-03			5.00E-02	1.22E-03		0.357		Cancer		Histological changes in lung; eye irrit.; pulmonary function changes	30
1,1-difluoroethane	75-37-6	66.1	2.74E+01											300
N,N-dimethylformamide	68-12-2	73.09	2.05E-02			2.99E+01	7.31E-01		35.570		Liver		Liver and Gi effects; irrit eyes, skin resp syst.; CVS	300 S
1,2-diphenylhydrazine	122-66-7	184.24	2.18E-02										C	
epichlorohydrin	106-89-8	92.53	6.85E-03			1.89E+00	4.63E-02		6.755		Irritation; liver; kidney		Lesions nasal epithelium; irrit eyes/skin; resp distress; kidneys; liver; repro syst.; cancer (nasal) (B2)	100 S
1,2-epoxybutane	106-88-7	72.12	1.37E-02											300
2-ethoxyethanol	110-80-5	90.12	1.37E+00			1.84E+01	4.51E-01		0.329		Reproductive		Hematological changes; irrit eyes, resp syst.; liver, kidney lung damage, repro effects	30 S
ethyl benzene*	100-41-4	106.12	6.85E-01	4.34E+00	2.95E+00	4.34E+02	1.06E+01	4.31	15.493	3.596	Irritation; CNS	Skeletal anomalies; NOAEL; rat; UF=100	Developmental toxicity; irrit ent, CNS; liver; kidneys; resp syst.	300
ethyl chloride	75-00-3	64.52	6.85E+00			2.64E+02	6.45E+00		0.942		Liver; CNS		Developmental toxicity; CNS; liver; kidneys, resp syst.	300 S
ethylene glycol monobutyl ether	111-76-2	118.2	1.37E-01											100
ethylene oxide	75-21-8	44.05	4.79E-02			1.80E+00	4.40E-02		0.919		Lung; liver; kidney; blood; CNS; cancer		C--Leukemia and gliomas; irrit ent; CNS; resp syst.; liver; kidneys; repro (B1)	
fluoranthene	206-44-0	202.3	1.40E-01	1.40E+00	1.40E+00			10.00				No data	No data	
fluorene	86-73-7	166.2	1.40E-01	1.40E+00	1.40E+00			10.00				No data	Skin and eye irritation	

Table C-5: Data Sheet and Relative Concentration Estimates for Long-Term Air-MEGs

Chemical	CAS No.	MW	PMEG-L mg/m³	MRL mg/m³	MRL Adj mg/m³	TLV mg/m³	TLV Adj mg/m³	MRL Adj/ PMEG	TLV Adj/ PMEG	TLV Adj/ MRL Adj	TLV critical effect(s)	MRL1 critical effect(s)	PMEG-L2 critical effect(s)	RfD UF (PMEG-L)
formaldehyde	50-00-0	30.03	3.69E-01	3.68E-02	2.51E-02			0.07			Irritation; cancer (nasal)	Nasopharyngeal irritation and lesions of nasal epithelium; monkey; NOAEL; UF=30; conc.-dep.	C--Squamous cell carcinoma nasal cavity (B1); irrit ent, resp syst; lacrimation; bronchospasm, cough	
furfural	98-01-1	96.08	3.42E-01			7.86E+00	1.92E-01		0.561		Irritation		Olfactory degeneration; irrit. en resp tract; headaches; dermatitis	100 S
glycidaldehyde	765-34-4	72.07	6.85E-03											300
heptachlor	76-44-8	373.32	3.69E-03			5.00E-02	1.22E-03		0.331		CNS; liver; blood		C--Hepatocellular carcinomas; CNS (B2)	S
heptachlor epoxide	1024-57-3	389.4	1.84E-03			5.00E-02	1.22E-03		0.663		CNS; liver; blood		C--Hepatocellular carcinomas (B2)	
hexachlorobenzene	118-74-1	284.78	1.04E-02			2.00E-03	4.89E-05		0.005		Liver; metabolic disorders		C--Hepatocellular carcinomas (B2); metabolic disorders; thyroid; kidneys	S
hexachlorobutadiene	87-68-3	260.76	2.16E-01			2.13E-01	5.22E-03		0.024		Irritation; kidney		kidneys; irrit ent; renal tubular adenomas (C)	S
alpha-HCH	319-84-6	290.83	2.66E-03	no inhalation mrl									C	
beta-HCH	319-85-7	290.83	9.05E-03	no inhalation mrl									C	
technical HCH	608-73-1	290.8	9.40E-03	no inhalation mrl									C	
hexachlorocyclopentadiene	77-47-4	272.75	4.79E-04	1.12E-01	7.59E-02	1.12E-01	2.73E-03	158.22	5.689	0.036	Irritation; pulmonary edema	Effects on Clara cells in lungs; rat; NOAEL; UF=30 (adaptive?)	Squamous metaplasia nasal cavity; irrit eyes, skin, resp syst.; lacrimation; pulmonary edema; liver; kidneys	100
hexachlorodibenzodioxin mix	19408-74-3		3.69E-06										C	
hexachloroethane	67-72-1	236.74	1.20E+00	5.81E+01	3.95E+01	9.68E+00	2.37E-01	32.96	0.198	0.006	Irritation; liver; kidney	Multiple effects at high dose (tremors, reduced body weight and resistance to infection); rat; NOAEL; UF=30	C--Hepatocellular carcinoma (C); irrit eyes, skin, mucous membranes; CNS; kidney; hexachloroethane NOT HC Smoke	S
1,6-hexamethylene diisocyanate	822-06-0	168.22	6.85E-06	2.06E-04	1.40E-04	3.44E-02	8.41E-04	20.49	122.800	5.993	Irritation; sensitization	Nasal epithelial changes; rat; NOAEL; UF=30; decreased liver and kidney weights at higher doses	Degeneration olfactory epithelium; irrit eyes, skin, resp syst.; bronchitis, pulmonary edema, asthma	100
N-hexane	110-54-3	86.18	1.37E-01	2.11E+00	1.44E+00	1.76E+02	4.31E+00	10.50	31.456	2.996	Neuropathy; CNS; irritation	Chronic MRL; Increased latency and decreased motor nerve conduction velocity; human; LOAEL; UF=100	Neurotoxicity; irrit eyes, skin, resp syst.	300 S
hexane (other isomers)		86.18				1.76E+03	4.30E+01				CNS; Irritation			
hydrazine	302-01-2	32.05	9.78E-04	5.24E-03	3.57E-03	1.31E-02	3.20E-04	3.64	0.328	0.090	Irritation; liver; kidney	Moderate to severe fatty liver changes; mouse; LOAEL; UF=300	C--Nasal cavity adenomas/adenocarcinomas (B2); irrit eyes, skin resp syst.; CNS; kidney; liver	S
hydrogen chloride	7647-01-0	36.47	1.37E-02								Irritation; corrosion			300
hydrogen cyanide	74-90-8	27.03	2.05E-03								CNS; irritation; anoxia; lung; thyroid			1000
hydrogen sulfide*	7783-06-4	34.08	6.85E-03	4.18E-02	2.84E-02	6.97E+00	1.70E-01	4.15	24.878	5.993	Sudden death; irritation; CNS	Inflammation of nasal mucosa; mouse; NOAEL; UF=30; repro effects in rats at dose lower than resp. NOAEL	Inflammation of nasal mucosa; irrit eyes, resp syst; CNS (to death); lacrimation; photophobia; GI; Above 0.03 mg/m3 olfactory fatigue	100
indeno(1,2,3-c,d)pyrene	193-39-5	276.34	5.45E-02										C-	

Table C-5: Data Sheet and Relative Concentration Estimates for Long-Term Air-MEGs

Chemical	CAS No.	MW	PMEG-L mg/m³	MRL mg/m³	MRL Adj mg/m³	TLV mg/m³	TLV Adj mg/m³	MRL Adj/ PMEG	TLV Adj/ PMEG	TLV Adj/ MRL Adj	TLV critical effect(s)	MRL1 critical effect(s)	PMEG-L2 critical effect(s)	RfD UF (PMEG-L)
manganese	7439-96-5	54.94	3.42E-05	4.00E-05	2.72E-05	2.00E-01	4.89E-03	0.79	142.787	179.779	CNS (manganism); lung; reproduction	Chronic MRL; Neurological effects; humans; LOAEL; UF=900	Neurobehavioral; CNS/PNS, resp syt.; blood; kidneys	1000
mercury (inorganic)	7439-97-6	200.59	2.05E-04	2.00E-04	1.36E-04	2.50E-02	6.11E-04	0.66	2.975	4.494	CNS; kidney; neuropathy; vision; reproductive; GI	Chronic MRL; Neurological effects (tremors); human; LOAEL; 30	CNS effects ; irrit eyes, skin, resp. syst; kidneys; GI	30 S
2-methoxyethanol	109-86-4	76.09	1.37E-01			1.56E+01	3.80E-01		2.777		Blood; reproductive; CNS		Testicular effects; blood, CNS	100 S
methylacrylonitrile	126-98-7	67.09	4.79E-03			2.74E+00	6.71E-02		14.006		Irritation; CNS		Altered liver function; irrit eyes, skin; lacrimation; CNS	300
methyl bromide	74-83-9	94.95	3.42E-03	1.94E-01	1.32E-01	3.88E+00	9.49E-02	38.55	27.701	0.718		Decreased neurotransmitters in brain; rat; NOAEL; UF=100	Nasal cavity degeneration and lesions; heart; esophagus; CNS; blood	100
methylcyclohexane	108-87-2	98.19	2.05E+00			1.61E+03	3.93E+01		19.114		Narcosis; irritation		Mineralization and papillary hyperplasia of kidney; CNS; irrit eyes, skin, resp syst.	100
4,4-methylene bis(2-chloroaniline)	101-14-4	267.17	1.28E-01			1.09E-01	2.67E-03		0.021		Anoxia; kidney; cancer (bladder)		C--Lung tumors (B2)	
methylene chloride	75-09-2	84.93	2.05E+00	1.04E+00	7.09E-01	1.74E+02	4.25E+00	0.35	2.067	5.989	CNS; anoxia	Hepatic effects; rat; LOAEL; UF=90; same mrl for chronic	Liver toxicity; CNS; CVS; irrit eyes, skin; cancer (B2) (lung, salivary and mammary gland)	100
4,4-methylenediphenyl isocyanate	101-68-8	250.26	1.37E-05			5.12E-02	1.25E-03		91.344		Irritation; pulmonary edema; sensitization		Lesions of the nasal cavity; irrit ent; resp sensit.; pulmonary secretions; asthma	300
methyl ethyl ketone	78-93-3	72.1	6.85E-01			5.90E+02	1.44E+01		21.053		Irritation; CNS		Decreased birth weights (repro); CNS; irritation	3000
methyl isobutyl ketone	108-10-1	100.16	5.48E-01			2.05E+02	5.01E+00		9.140		Irritation; narcosis; liver; kidney		Increased liver weight and kidney effects; CNS, irritation	100
methyl styrene (mixture)	25013-15-4	118.18	2.74E-02										Lesions of nasal cavity; resp. effects	1000
methyl tert-butyl ether	1634-04-4	88.15	2.05E+00	2.52E+00	1.72E+00	1.44E+02	3.53E+00	0.84	1.716	2.055	Irritation; kidney; reproductive	CNS sedation; rat; NOAEL; UF=100; same MRL for chronic (nephropathy)	Increased liver/kidney weights; spontaneous renal lesions; prostration; swollen periocular tissues	100
naphthalene	91-20-3	128.19	2.05E-03	1.05E-02	7.13E-03	5.24E+01	1.28E+00	3.47	623.855	179.779	Irritation; ocular; blood	Chronic MRL; Inflammation of nose and lung; mouse; LOAEL; UF=1000	Hyperplasia/metaplasia resp/olfactory epithelium; resp sensit.; ocular irritation, cataracts; acute hemolysis	3000 S
nickel (elemental/metal)	7440-02-0	58.71				1.50E+00	3.67E-02				Dermatitis, pneumoconiosis, kidney			
nickel (soluble compounds)				2.00E-04	1.36E-04	1.00E-01	2.44E-03			17.978	CNS; irritation; dermatitis	Chronic MRL; Chronic active inflammation & lung fibrosis; rat; NOAEL; UF=30; nickel sulfate hexahydrate		
nickel (insoluble compounds)						2.00E-01	4.89E-03				Cancer (lung); irritation; dermatitis			
nickel carbonyl	13463-39-3	170.73				3.49E-01	8.54E-03				Irritation; CNS			
nickel subsulfide	12035-72-2	240.19	9.99E-03			1.00E-01	2.44E-03		0.245		Cancer (lung); irritation; dermatitis		Cancer (lung) in humans	
nickel refinery dust	none		2.00E-02				0.00E+00						C--Lung cancer (A); sensit. Dermatitis; allergic asthma; pneumonitis	
2-nitroaniline	88-74-4	138.14	1.37E-03										Hematological effects	1000
nitrobenzene	98-95-3	123.11	1.37E-02			5.04E+00	1.23E-01		8.987		Cyanosis; anoxia; liver; neurotoxicity; irritation; dermatitis		Hematological effects and adrenal, kidney and liver lesions; irrit eyes/skin; CVS; repro	1000 S

Table C-5: Data Sheet and Relative Concentration Estimates for Long-Term Air-MEGs

Chemical	CAS No.	MW	PMEG-L mg/m³	MRL mg/m³	MRL Adj mg/m³	TLV mg/m³	TLV Adj mg/m³	MRL Adj/ PMEG	TLV Adj/ PMEG	TLV Adj/ MRL Adj	TLV critical effect(s)	MRL1 critical effect(s)	PMEG-L2 critical effect(s)	RfD UF (PMEG-L)
2-nitropropane	79-46-9	89.09	1.78E-03										C	1000
N-nitroso-di-n-butylamine	924-16-3		3.00E-03										C	
N-nitrosodiethylamine	55-18-5	102.14	1.11E-04										C	
N-nitrosodimethylamine	62-75-9	74.08	3.42E-04								Liver		C	
N-nitrosopyrrolidine	930-55-2	100.12	7.86E-03										C	
phenanthrene	85-01-8	178.24	4.20E-02										Skin, eye, nose, throat irritation, blistering, respiratory effects, skin photosensitization.	
phosphine	7803-51-2	34	2.05E-03			4.17E-01	1.02E-02		4.964		Irritation; CNS; GI		Decreased body weights; CNS; resp. syst.; GI	100
phosphoric acid	7664-38-2	98	6.85E-03			1.00E+00	2.44E-02		3.570		Irritation		Bronchiolar fibrosis; irrit eyes, skin, resp. syst.	300
phthalic anhydride*	85-44-9	148.11	8.22E-02			6.06E+00	1.48E-01		1.802		Irritation; sensitization		Rhinitis and bronchitis; irrit eyes, skin resp syst.; bronchial asthma; liver; kidney	300
polychlorinated biphenyls	1336-36-3		8.40E-03										C	
propylene glycol monomethyl ether	107-98-2	90.12	1.37E+01			3.69E+02	9.01E+00		0.658		Irritation; CNS		Nervous syst. effects; irrit ent, skin; GI	30
n-propylbenzene	103-65-1	120.2	2.53E-02								Irritation, eyes, nose, throat , skin		Irritation eyes, nose, throat, skin, CNS depression, incoordination, nausea, general anesthetic effects; *Using n-butylbenzene as surrogate	*Using n-butylbenzene as surrogate
propylene oxide*	75-56-9	58.08	2.05E-02			1.19E+01	2.90E-01		14.133		Irritation; CNS; dermatitis		Effects nasal epithelium; irrit eyes, skin, resp syst,; CNS; liver; cancer (nasal) (B2)	100
pyrene	129-00-0	202.3	1.05E-01										Skin irritation	
stronium	7440-24-6	87.62	1.51E+00								Bone, heart, skin, eyes		Skin and eye irritation, altered heart function, bone abnormalities	
styrene	100-42-5	104.16	2.05E+00	2.56E-01	1.74E-01	8.52E+01	2.08E+00	0.08	1.014	11.985	Neurotoxicity; irritation; CNS	Chronic; Neurotoxicity; human; LOAEL; UF=100	CNS effects; irrit eyes, nose, resp syst; liver; repro	10
2,3,7,8-tetrachlorodibenzodioxin	1746-01-6		1.12E-07										C	
1,1,1,2-tetrachloroethane	630-20-6	167.85	6.48E-01										C	
1,1,2,2-tetrachloroethane	79-34-5	167.86	8.27E-02	2.75E+00	1.87E+00	6.87E+00	1.68E-01	22.59	2.031	0.090	Liver; CNS; GI	Hepatic effects; rat; LOAEL; UF=300	C--Hepatocellular carcinoma (oral (C)); kidneys; CNS; Gi; dermatitis	S
1,1,1,2-tetrafluoroethane	811-97-2	102.03	5.48E+01											100
toluene	108-88-3	92.13	2.74E-01	1.51E+00	1.03E+00	1.88E+02	4.61E+00	3.75	16.814	4.486	CNS	Chronic MRL; Neurological effects; human; LOAEL; UF=30	Neurological effects; irrit eyes,nose; resp syst; liver; kidneys	300 S
toxaphene	8001-35-2	414	1.50E-02			5.00E-01	1.22E-02		0.816		Seizures; liver		C--hepatocellular carcinomas/neoplastic nodules (oral)(C); CNS; skin	S
1,2,4-trichlorobenzene	120-82-1	181.46	1.37E+00											100
1,1,2-trichloroethane	79-00-5	133.41	3.00E-01			5.46E+01	1.33E+00		4.452		CNS; liver		C--Hepatocellular carcinomas; CNS; irrit eyes, resp syst; kidneys	
trichlorofluoromethane	75-69-4	137.88	4.79E+00								CVS; CNS			1000
1,1,2-trichloro-1,2,2-trifluoroethane	76-13-1	187.4	2.05E+01			7.66E+03	1.87E+02		9.120		Narcosis; CVS; asphyxiation		Decreased body weight; CNS; CVS; resp syst; dermatitis	100
2,4,6-trichlorophenol	88-06-2	197.45	1.55E+00										C	
1,2,4-trimethylbenzene	95-63-6	120.19	4.08E-03			1.25E+02	3.06E+00		749.933		Eyes, Skin, Respiratory Sys., CNS, Blood		Skin, eye, nose, throat irritation, bronchitis, anemia, drowsiness, fatigue, nausea	
1,3,5-trimethylbenzene	108-67-8	120.19	4.08E-03			1.25E+02	3.06E+00		749.933		Eyes, Skin, Respiratory Sys., CNS, Blood		Skin, eye, nose, throat irritation, bronchitis, anemia, drowsiness, fatigue, nausea	
triethylamine	121-44-8	101.19	4.79E-03			4.14E+00	1.01E-01		21.105		Irritation; vision		Irrit eyes, skin resp syst; myocardial, kidney, liver damage; thymic atrophy; lung effects; (frank effects may occur at 4x NOAEL)	3000 S
vinyl acetate	108-05-4	86.09	1.37E-01	3.52E-02	2.39E-02	3.52E+01	8.61E-01	0.17	6.285	35.956	Irritation	Nasal inflammation, bronchitis; mouse; NOAEL; UF=100	Nasal cavity lesions; irrit ent, skin; loss of smell	30
vinyl chloride	75-01-4	62.5	5.71E-02	7.67E-02	5.21E-02	2.56E+00	6.25E-02	0.91	1.095	1.199	CNS; cancer; liver; Raynaud's syndrome	Increased liver, heart, spleen weights; rat; LOAEL; UF=300	C--Liver tumors (A); CNS; blood; resp. syst; lymphatics.; GI	

Table C-5: Data Sheet and Relative Concentration Estimates for Long-Term Air-MEGs

Chemical	CAS No.	MW	PMEG-L mg/m³	MRL mg/m³	MRL Adj mg/m³	TLV mg/m³	TLV Adj mg/m³	MRL Adj/ PMEG	TLV Adj/ PMEG	TLV Adj/ MRL Adj	TLV critical effect(s)	MRL1 critical effect(s)	PMEG-L2 critical effect(s)	RfD UF (PMEG-L)
xylene (mixed, o, m, p)	1330-20-7	106.16		3.03E+00	2.06E+00	434.00	1.06E+01			5.150	Irritation	Developmental effects (decreased rotorod performance of pups); UF=300		

Notes

* - Chemicals listed under "Notice of Intended Changes (1999) for TLVs
MRL – Minimal Risk Level, intermediate used over chronic when available (ATSDR)
TLV – Threshold Limit Value (ACGIH, 1999)
PMAG-L – Preliminary Military Air Guideline-Long-term (calculated, see Appendix 4-1)
Adj – adjusted (TLV Adj = TLV/40.9; MRL Adj = MRL*0.68; See text for detailed explanation)
RfD - Reference dose
UF - uncertainty factor; included for RfDs and MRLs
ent – ear, nose, throat
S – dermal exposures have the potential for significant contribution to overall dose (ACGIH, 1999)
C – PMAG-L based on carcinogenic effect
resp – respiratory
irrit – irritation
syst – system
CNS – central nervous system

Table C-6: Long-Term Air- MEGs and Basis

Chemical	CAS No.	MW	PMEG-L mg/m³	MRL Adj mg/m³	TLV Adj mg/m³	Air-MEG mg/m³	Air-MEG ppm	Long-Term Air-MEG Basis	Rationale
acenaphthene	83-32-9	154.2	1.44E-01	2.10E+00		1.44E-01	2.28E-02	PMEG-L	PMEG is more conservative and deemed more appropriate given uncertainty concerning the carcinogenicity of the compound.
acenaphthylene	208-96-8	152.2	2.80E-02			2.80E-02	4.50E-03	PMEG-L	Data very limited. Classified as D carcinogen; PAH's are considered possible carcinogens. LOAEL and QSAR estimate provided a more conservative level than using a surrogate and more appropriate given limitations.
acetaldehyde	75-07-0	44.05	6.16E-03			6.16E-03	3.42E-03	PMEG-L	Hierarchy-based; no TLV or MRL
acetone	67-64-1	58.08		2.10E+01	2.90E+01	2.90E+01	1.22E+01	TLV Adj	Hierarchy-based; No PMEG.
acetone cyanohydrin	75-86-5	85.1	6.85E-02			6.85E-02	1.97E-02	PMEG-L	Hierarchy-based; no TLV or MRL
acetonitrile	75-05-8	41.05	3.42E-01		1.64E+00	3.42E-01	2.04E-01	PMEG-L	Hierarchy-based; no MRL
acrolein	107-02-8	56.06	1.37E-05	1.40E-05		1.37E-05	5.97E-06	PMEG-L	Hierarchy-based; no TLV
acrylamide	79-06-1	71.08	3.69E-03		7.33E-04	3.69E-03	1.27E-03	PMEG-L	Hierarchy-based; no MRL
acrylic acid	79-10-7	72.06	2.05E-03		1.44E-01	1.44E-01	4.89E-02	TLV-Adj	The PMEG and TLV were based on the same studies. Considering a healthy worker population and agent as an irritant at relavent dose levels, TLV-Adj was deemed more appropriate.
acrylonitrile	107-13-1	53.05	1.37E-03		1.06E-01	1.06E-01	4.89E-02	TLV-Adj	PMEG based on chronic RfC with UF=1000 was deemed overly conservative. TLV-Adj is cancer risk based and should be protective against any non-cancer risks.
aldrin	309-00-2	364.93	9.78E-04		6.11E-03	9.78E-04	6.56E-05	PMEG-L	Hierarchy-based; no MRL
allyl chloride	107-05-1	76.5	6.85E-03		7.65E-02	7.65E-02	2.44E-02	TLV-Adj	PMEG was basd on subchronic study in rabbits using an UF for chronic extrapolation. The TLV was based on sub-chronic study in 4 species and is protective against neurotoxic and hepatic effects.
ammonia	7664-41-7	17.03	6.85E-02	1.42E-01	4.26E-01	3.50E-01	5.00E-01	TLV Adj	At exposure levels within more than an order of magnitude of those under consideration, ammonia is a simple irritant with no systemic effects or effects on pulmonary function. The RfC was chronic (UF=30), and only a chronic MRL was available. The un-adjusted MRL was selected as being adequately protective and most applicable to a 1-year exposure since it falls between that of the TLV-Adj and the MRL-Adj.
aniline	62-53-3	93.12	6.85E-03		1.86E-01	1.86E-01	4.89E-02	TLV-Adj	PMEG and TLV based on same study. PMEG has UF=300 including subchronic to chronic extrapolation. TLV-adj deemed adequately protective.
antimony trioxide	1309-64-4	171.5	1.37E-04			1.37E-04	1.95E-05	PMEG-L	Hierarchy-based; no TLV or MRL

Table C-6: Long-Term Air- MEGs and Basis

Chemical	CAS No.	MW	PMEG-L mg/m³	MRL Adj mg/m³	TLV Adj mg/m³	Air-MEG mg/m³	Air-MEG ppm	Long-Term Air-MEG Basis	Rationale
anthracene	120-12-7	178.23	1.05E+00	3.500E+01		3.50E+01	4.80E+00	MRL Adj	PMEG was based on NOAEL of subchronic study with UF for extrapolation to chronic. MRL is close to the PMEG otherwise.
arsenic	7440-38-2	74.92	1.11E-03		2.44E-04	1.11E-03	3.64E-04	PMEG-L	Hierarchy-based; no MRL
arsine	7784-42-1	77.95	3.42E-05		3.90E-03	3.42E-05	1.07E-05	PMEG-L	Hierarchy-based; no MRL
azobenzene	103-33-3	182.22	1.55E-01			1.55E-01	2.08E-02	PMEG-L	Hierarchy-based; no TLV or MRL
barium	7440-39-3	137.3	3.42E-03		1.22E-02	3.42E-03	6.10E-04	PMEG-L	Hierarchy-based; no MRL
benzene	71-43-2	78.11	6.15E-01	8.69E-03	3.91E-02	3.91E-02	1.22E-02	TLV Adj	TLV-based. The PMEG and the TLV-adj were both cancer based. The MRL adj was based on neurotoxicity. The PMEG was not considered adequately protective for neurological effects. The MRL-adj was considered overly protective because of the endpoint selected and non-robust statistics.
benzidine	92-87-5	184.23	7.16E-05			7.16E-05	9.50E-06	PMEG-L	Hierarchy-based; no TLV or MRL
benzo(a)anthracene	56-55-3	228.3	5.45E-02			5.45E-02	5.83E-03	PMEG-L	Hierarchy-based; no TLV or MRL
benzo(a)pyrene	50-32-8	252.3	5.45E-03			5.45E-03	5.28E-04	PMEG-L	Hierarchy-based; no TLV or MRL
benzo(b)fluoranthene	205-99-2	252.3	5.45E-02			5.45E-02	5.28E-03	PMEG-L	Hierarchy-based; no TLV or MRL
benzo(k)fluoranthene	207-08-9	252.32	5.45E-01			5.45E-01	5.28E-02	PMEG-L	Hierarchy-based; no TLV or MRL
beryllium	7440-41-7	9.01	1.37E-05		4.89E-06	1.37E-05	3.72E-05	PMEG-L	Hierarchy-based; no MRL
bis(2-chloroethyl)ether	111-44-4	143.02	1.45E-02	7.96E-02		1.45E-02	2.48E-03	PMEG-L	Hierarchy-based; no TLV
bis(2-chloro-1-methylethyl)ether	108-60-1	171.07	4.79E-01	1.43E-03		1.43E-03	2.04E-04	MRL Adj	PMEG was cancer-based and not necessarily against systemic effects. The MRL-adj considered to be protective against cancer and systemic effects.
bis (2-ethylhexyl) phthalate	117-81-7	390.56	2.30E+00	9.52E-01	1.22E-01	1.22E-01	7.65E-03	TLV Adj	Uncertainty in route to route extrapolation in PMEG
boron	7440-42-8	10.81	1.37E-02			1.37E-02	3.10E-02	PMEG-L	Hierarchy-based; no TLV or MRL
boron trifluoride	7637-07-2	67.82	4.79E-03			4.79E-03	1.73E-03	PMEG-L	Hierarchy-based; no TLV or MRL
bromoform	75-25-2	252.8	4.36E+00		1.26E-01	1.26E-01	1.22E-02	TLV-Adj	PMEG was cancer-based and may not be adequately protective for systemic effects and and significant irritation.
1,3-butadiene	106-99-0	54.09	1.71E-02		1.08E-01	1.71E-02	7.74E-03	PMEG-L	Hierarchy-based; no MRL

Table C-6: Long-Term Air- MEGs and Basis

Chemical	CAS No.	MW	PMEG-L mg/m³	MRL Adj mg/m³	TLV Adj mg/m³	Air-MEG mg/m³	Air-MEG ppm	Long-Term Air-MEG Basis	Rationale
sec-Butylbenzene	135-98-8	134.24	2.53E-02			3.50E-02	6.37E-03	PMEG-L	Hierarchy-based; no MRL or TLV, RfC obtained from ncea/EPA IX extrapolation
cadmium (elemental)	7440-43-9	112.4	2.66E-03		2.44E-04	2.44E-04	5.32E-05	TLV Adj	PMEG is cancer-based while TLV-adj is lower and protective for cancer and kidney effects.
cadmium (compounds)					4.89E-05	4.89E-05		TLV Adj	Hierarchy-based; no PMEG-L or MRL
carbon disulfide	75-15-0	76.14	4.79E-01	6.35E-01	7.61E-01	4.79E-01	1.54E-01	PMEG-L	Hierarchy-based
carbon monoxide	630-08-0	28.01			7.00E-01	3.30E+00	3.00E+00	NAAQS	See reference document.
carbon tetrachloride	56-23-5	153.84	3.20E-01	2.14E-01	7.69E-01	3.20E-01	5.08E-02	PMEG-L	Hierarchy-based
chlordane	57-74-9	409.8	4.79E-04	1.36E-04	1.22E-02	4.79E-04	2.86E-05	PMEG-L	PMEG was based on a study different from TLV. TLV study was from 1951, and a recent study shows that neurological effects may occur below this level.
chlorine dioxide	10049-04-4	67.46	1.37E-04		6.75E-03	6.75E-03	2.44E-03	TLV Adj	PMEG was based on sub-chronic inhalation study; TLV was based on NOAEL of 0.1 ppm in rat and human occupational studies. Low dose effects are generally irritation and PMEG considered overly conservative.
2-chloroacetophenone	532-27-4	154.59	2.05E-05		7.73E-03	2.10E-04	3.32E-05	PMEG-L / TLV Adj	TLV was not selected due to LOAEL misinterpretation and lack of clarity in exposure limit. PMEG UF=1000 was overly conservative and was reduced to 100.
chlorobenzilate	510-15-6	325.2	6.15E-02			6.15E-02	4.62E-03	PMEG-L	Hierarchy-based
2-chloro-1,3-butadiene	126-99-8	88.54	4.79E-02		8.85E-01	4.79E-02	1.32E-02	PMEG-L	Conflicting data on toxicity of compound and MAG conservatively based on PMEG until further data is available.
1-chloro-1,1-difluoroethane	75-68-3	100.47	3.42E+01			3.42E+01	8.33E+00	PMEG-L	Hierarchy-based
chlorodifluoromethane	75-45-6	86.47	3.42E+01		8.65E+01	3.42E+01	9.68E+00	PMEG-L	Hierarchy-based; no MRL
chloroethane	75-00-3	64.52	6.85E+00			6.85E+00	2.60E+00	PMEG-L	Hierarchy-based
chloroform	67-66-3	119.38	2.08E-01	1.66E-01	1.19E+00	2.08E-01	4.27E-02	PMEG-L	Hierarchy-based
chloromethane	74-87-3	50.49	2.66E+00	2.81E-01		2.66E+00	1.29E+00	PMEG-L	Hierarchy-based
2-chloropropane	75-29-6	78.54	6.85E-01			6.85E-01	4.66E-01	PMEG-L	Hierarchy-based
chromium metal and Cr III compounds	7440-47-3/ 16065-83-1	varies			1.22E-02	1.22E-02		TLV Adj	Hierarchy-based; no PMEG-L or MRL

Table C-6: Long-Term Air- MEGs and Basis

Chemical	CAS No.	MW	PMEG-L mg/m³	MRL Adj mg/m³	TLV Adj mg/m³	Air-MEG mg/m³	Air-MEG ppm	Long-Term Air-MEG Basis	Rationale
Cr VI compounds (water-soluble)	18540-29-9	varies	5.48E-06	6.80E-05	1.22E-03	6.80E-05		MRL Adj	PMEG and MRL based on same human studies. UF excessive since based on human data. TLV not adequately protective since it was between LOAEL and NOAEL.
Cr VI compounds (insoluble)	18540-29-9	varies	6.85E-05	3.40E-04	2.44E-04	6.85E-05		PMEG-L	Hierarchy-based
chrysene	218-01-9	228.3	5.45E+00			5.45E+00	5.84E-01	PMEG-L	Hierarchy-based; no TLV or MRL
cumene	98-82-8	120.19	2.74E-01		6.01E+00	2.74E-01	5.57E-02	PMEG-L	Hierarchy-based; no MRL, may be overly conservative due to large uncertainty factor.
cyclopentadiene	542-92-7	66.1	2.05E+00		4.96E+00	2.05E+00	7.60E-01	PMEG-L	Hierarchy-based; no MRL
DDT	50-29-3	354.5	4.94E-02		2.44E-02	4.94E-02	3.41E-03	PMEG-L	Hierarchy-based; no MRL
dibenzo(a,h)anthracene	53-70-3	278.33	5.45E-03			5.45E-03	4.79E-04	PMEG-L	Hierarchy-based; no TLV or MRL
1,2-dibromo-3-chloropropane	96-12-8	236.36	1.37E-04	1.31E-03		1.37E-04	1.42E-05	PMEG-L	Hierarchy-based; no TLV
1,2-dibromoethane	106-93-4	187.88	1.37E-03			1.37E-03	1.78E-04	PMEG-L	Hierarchy-based; no TLV or MRL
1,2-dichlorobenzene	95-50-1	147	1.37E+00			1.37E+00	2.28E-01	PMEG-L	Hierarchy-based; noTLV or MRL
1,4-dichlorobenzene	106-46-7	147.01	1.71E+00	8.18E-01	1.47E+00	1.71E+00	2.85E-01	PMEG-L	Hierarchy-based; no MRL
1,4-dichloro-2-butene	764-41-0	125	1.84E-03			1.84E-03	3.61E-04	PMEG-L	Hierarchy-based; no TLV or MRL
dichlorodifluoromethane	75-71-8	98.97	1.37E+00		9.90E+01	9.90E+01	2.44E+01	TLV Adj	Excessive UF of 1000 used in RfC and no effects observed at much higher doses. TLV was deemed more appropriate.
1,1-dichloroethane	75-34-3	98.97	3.42E+00		9.90E+00	3.42E+00	8.46E-01	PMEG-L	Hierarchy-based; no MRL
1,2-dichloroethane	107-06-2	98.96	1.81E-01	5.50E-01	9.90E-01	1.81E-01	4.47E-02	PMEG-L	Hierarchy-based
1,1-dichloroethylene	75-35-4	96.95	9.59E-02	5.39E-02	4.85E-01	9.59E-02	2.42E-02	PMEG-L	Hierarchy-based
1,2-dichloropropane	78-87-5	112.99	8.90E-03	2.20E-02	8.47E+00	2.20E-02	4.76E-03	MRL Adj	MRL and PMEG based on same study but have different UF's applied. MRL deemed more appropriate due to healthy worker population and minor effects. TLV is currently under review.
1,3-dichloropropene	542-75-6	110.98	1.37E-02	9.26E-03	1.11E-01	1.37E-02	3.02E-03	PMEG-L	Hierarchy-based

Table C-6: Long-Term Air- MEGs and Basis

Chemical	CAS No.	MW	PMEG-L mg/m³	MRL Adj mg/m³	TLV Adj mg/m³	Air-MEG mg/m³	Air-MEG ppm	Long-Term Air-MEG Basis	Rationale
dichlorvos	62-73-7	220.98	3.42E-04	1.84E-03	2.20E-02	1.84E-03	2.04E-04	MRL Adj	PMEG based on chronic exposure, where as MRL based on intermediate exposure. Significant ChE depression observed at TLV level and value was deemed questionable.
dicyclopentadiene	77-73-6	132.21	1.37E-03		6.61E-01	1.37E-02	2.53E-03	PMEG-L	PMEG UF=1000 was deemed excessive, however, effects observed below the TLV value. PMEG was chosen, changing UF to 100.
dieldrin	60-57-1	380.93	1.04E-03		6.11E-03	1.04E-03	6.69E-05	PMEG-L	Hierarchy-based; no MRL
diesel engine emissions	none		3.42E-03		1.22E-03	3.42E-03		PMEG-L	Hierarchy-based; no MRL
1,1-difluoroethane	75-37-6	66.1	2.74E+01			2.74E+01	1.01E+01	PMEG-L	Hierarchy-based; no TLV or MRL
N,N-dimethylformamide	68-12-2	73.09	2.05E-02		7.31E-01	6.16E-02	2.06E-02	PMEG-Adj	PMEG was adjusted using UF=100 instead of 300 based on less than chronic exposure and population. TLV was above effect levels in human studies.
1,2-diphenylhydrazine	122-66-7	184.24	2.18E-02			2.18E-02	2.89E-03	PMEG-L	Hierarchy-based; no TLV or MRL
epichlorohydrin	106-89-8	92.53	6.85E-03		4.63E-02	6.85E-03	1.81E-03	PMEG-L	Hierarchy-based; no MRL
1,2-epoxybutane	106-88-7	72.12	1.37E-02			1.37E-02	4.64E-03	PMEG-L	Hierarchy-based; no TLV or MRL
2-ethoxyethanol	110-80-5	90.12	1.37E+00		4.51E-01	1.37E+00	3.72E-01	PMEG-L	Hierarchy-based; no MRL
ethyl benzene	100-41-4	106.12	6.85E-01	2.95E+00	1.06E+01	2.95E+00	6.80E-01	MRL Adj	MRL-based. The MRL-adj and the PMEG were based on developmental endpoints and the TLV was based on irritation. The PMEG was considered overly conservative due to an UF for missing chronic studies; the TLV-adj was considered less protective for developmental effects than the MRL-adj.
ethyl chloride	75-00-3	64.52	6.85E+00		6.45E+00	6.85E+00	2.60E+00	PMEG-L	Hierarchy-based; no MRL
ethylene glycol monobutyl ether	111-76-2	118.2	1.37E-01			1.37E-01	2.83E-02	PMEG-L	Hierarchy-based; no TLV or MRL
ethylene oxide	75-21-8	44.05	4.79E-02		4.40E-02	4.79E-02	2.66E-02	PMEG-L	Hierarchy-based; no MRL
fluoranthene	206-44-0	202.3	1.40E-01	1.40E+00		1.40E+00	1.69E-01	MRL Adj	PMEG was based on NOAEL of subchronic study with UF for extrapolation to chronic. MRL is the same as PMEG otherwise.
fluorene	86-73-7	166.2	1.40E-01	1.40E+00		1.40E+00	2.06E-01	MRL Adj	PMEG was based on NOAEL of subchronic study with UF for extrapolation to chronic. MRL is the same as PMEG otherwise.

Table C-6: Long-Term Air- MEGs and Basis

Chemical	CAS No.	MW	PMEG-L mg/m³	MRL Adj mg/m³	TLV Adj mg/m³	Air-MEG mg/m³	Air-MEG ppm	Long-Term Air-MEG Basis	Rationale
formaldehyde	50-00-0	30.03	3.69E-01	2.51E-02		2.51E-01	2.04E-01	MRL Adj	The MRL UF+10 accounting for sensitive populations was removed. This level should be protective against cancer (below PMEG) while still protecting against significant irritation (below TLV ceiling).
furfural	98-01-1	96.08	3.42E-01		1.92E-01	3.42E-01	8.71E-02	PMEG-L	Hierarchy-based; no MRL
glycidaldehyde	765-34-4	72.07	6.85E-03			6.85E-03	2.32E-03	PMEG-L	Hierarchy-based; no TLV or MRL
heptachlor	76-44-8	373.32	3.69E-03		1.22E-03	3.69E-03	2.42E-04	PMEG-L	Hierarchy-based; no MRL
heptachlor epoxide	1024-57-3	389.4	1.84E-03		1.22E-03	1.84E-03	1.16E-04	PMEG-L	Hierarchy-based; no MRL
hexachlorobenzene	118-74-1	284.78	1.04E-02		4.89E-05	4.89E-05	4.20E-06	TLV Adj	PMEG was not selected because it may not be protective against non-cancer effects and was above workplace limits.
hexachlorobutadiene	87-68-3	260.76	2.16E-01		5.22E-03	5.22E-03	4.89E-04	TLV Adj	PMEG was based on cancer risk and may not be adequately protective against non-cancer effects.
alpha-HCH	319-84-6	290.83	2.66E-03			2.66E-03	2.24E-04	PMEG-L	Hierarchy-based; no TLV or MRL
beta-HCH	319-85-7	290.83	9.05E-03			9.05E-03	7.60E-04	PMEG-L	Hierarchy-based; no TLV or MRL
technical HCH	608-73-1	290.8	9.40E-03			9.40E-03	7.90E-04	PMEG-L	Hierarchy-based; no TLV or MRL
hexachlorocyclopentadiene	77-47-4	272.75	4.79E-04	7.59E-02	2.73E-03	7.59E-02	6.80E-03	MRL Adj	PMEG was excessive based on exposure scenario. TLV was based on much older data than the MRL and PMEG.
hexachlorodibenzodioxin mix	19408-74-3		3.69E-06			3.69E-06		PMEG-L	Hierarchy-based; no TLV or MRL
hexachloroethane	67-72-1	236.74	1.20E+00	3.95E+01	2.37E-01	1.20E+00	1.24E-01	PMEG-L	TLV and MRL based on same data with different UF applied. PMEG is adequately protective against carcinogenic and non-carcinogenic effects.
1,6-hexamethylene diisocyanate	822-06-0	168.22	6.85E-06	1.40E-04	8.41E-04	1.40E-04	2.04E-05	MRL Adj	PMEG and MRL are based on same data with different UF. TLV is not protective for adverse effects in more responsive individuals. Compound is a sensitizer and the MRL was deem more appropriate.
N-hexane	110-54-3	86.18	1.37E-01	1.44E+00	4.31E+00	4.31E+00	1.22E+00	TLV Adj	TLV-based. All endpoints were based on neurotoxicity. The TLV-adj was considered more appropriate for this exposure scenario than the "chronic" MRL-adj. The PMEG was based on the same data as the MRL but was considered overly conservative because it was derived from a chronic RfD with an additional UF (300 vs. 100).
hexane (other isomers)		86.18			4.30E+01	4.30E+01	1.22E+01	TLV Adj	Hierarchy-based

Table C-6: Long-Term Air- MEGs and Basis

Chemical	CAS No.	MW	PMEG-L mg/m³	MRL Adj mg/m³	TLV Adj mg/m³	Air-MEG mg/m³	Air-MEG ppm	Long-Term Air-MEG Basis	Rationale
hydrazine	302-01-2	32.05	9.78E-04	3.57E-03	3.20E-04	9.78E-04	7.46E-04	PMEG-L	Hierarchy-based
hydrogen chloride	7647-01-0	36.47	1.37E-02			1.37E-02	9.18E-03	PMEG-L	Hierarchy-based; no TLV or MRL
hydrogen cyanide	74-90-8	27.03	2.05E-03			2.05E-03	1.86E-03	PMEG-L	Hierarchy-based; no TLV or MRL
hydrogen sulfide	7783-06-4	34.08	6.85E-03	2.84E-02	1.70E-01	1.50E-01	1.08E-01	TLV Adj	RfC, MRL, and TLV were all based on same data with the TLV considering occupational exposures. No adverse effects were observed at doses higher than TLV-Adj. A slightly lower TLV-Adj. was chosen to be consistent with AEGL and ERPG guidelines.
indeno(1,2,3-c,d)pyrene	193-39-5	276.34	5.45E-02			5.45E-02	4.82E-03	PMEG-L	Hierarchy-based; no TLV or MRL
manganese	7439-96-5	54.94	3.42E-05	2.72E-05	4.89E-03	3.42E-05	1.52E-05	PMEG-L	RfC, MRL, and TLV were all based on neurobehavioral data with different UF. UF for chronic exposure not deemed necessary and removed from PMEG. Effects have been observed above TLV level..
mercury (inorganic)	7439-97-6	200.59	2.05E-04	1.36E-04	6.11E-04	2.05E-04	2.50E-05	PMEG-L	Hierarchy-based
2-methoxyethanol	109-86-4	76.09	1.37E-01		3.80E-01	1.37E-01	4.40E-02	PMEG-L	Hierarchy-based; no MRL
methylacrylonitrile	126-98-7	67.09	4.79E-03		6.71E-02	6.71E-02	2.44E-02	TLV Adj	RfC and TLV based on same data. RfC had an additional UF factor for use of inhalation study, otherwise was close to the TLV.
methyl bromide	74-83-9	94.95	3.42E-03	1.32E-01	9.49E-02	9.49E-02	2.44E-02	TLV-Adj	Based on TLV-adj. MRL from chronic MRL from human occupational study. Neurological effects may be irreversible and conservative estimate is prudent. PMEG was based on chronic rat study with UF=100 and overly conservative based on exposure scenario.
methylcyclohexane	108-87-2	98.19	2.05E+00		3.93E+01	3.93E+01	9.78E+00	TLV Adj	Both PMEG and TLV are both based on NOAEL, and no systemic effects have been reported in humans. TLV should be adequately protective.
4,4-methylene bis(2-chloroaniline)	101-14-4	267.17	1.28E-01		2.67E-03	2.67E-03	2.44E-04	TLV Adj	PMEG based only on lung cancer. TLV was designed to be protective against other cancers and effects.
methylene chloride	75-09-2	84.93	2.05E+00	7.09E-01	4.25E+00	2.05E+00	5.92E-01	PMEG-L	Hierarchy-based
4,4-methylenediphenyl isocyanate	101-68-8	250.26	1.37E-05		1.25E-03	1.25E-03	1.22E-04	TLV Adj	PMEG must be corrected to new EPA values and includes UF for sub-chronic to chronic exposure. TLV considered sufficiently protective.

Table C-6: Long-Term Air- MEGs and Basis

Chemical	CAS No.	MW	PMEG-L mg/m³	MRL Adj mg/m³	TLV Adj mg/m³	Air-MEG mg/m³	Air-MEG ppm	Long-Term Air-MEG Basis	Rationale
methyl ethyl ketone	78-93-3	72.1	6.85E-01		1.44E+01	1.44E+01	4.89E+00	TLV Adj	PMEG has UF of 3000 and NOAEL was 2978 mg/m3. TLV should be protective against systemic, reproductive, and irritation effects.
methyl isobutyl ketone	108-10-1	100.16	5.48E-01		5.01E+00	5.48E-01	1.34E-01	PMEG-L	Hierarchy-based; noTLV
methyl styrene (mixture)	25013-15-4	118.18	2.74E-02			2.74E-02	5.67E-03	PMEG-L	Hierarchy-based; no TLV or MRL
methyl tert-butyl ether	1634-04-4	88.15	2.05E+00	1.72E+00	3.53E+00	2.05E+00	5.70E-01	PMEG-L	Hierarchy-based
naphthalene	91-20-3	128.19	2.05E-03	7.13E-03	1.28E+00	7.13E-03	1.36E-03	MRL Adj	MRL-based. Despite large differences, all values were based on irritation. The PMEG was not selected because it included an uncertainty factor related to chronic exposure. The TLV-adj was not selected because it was not considered adequately protective for those with G-6-PD deficiencies.
nickel (elemental/metal)	7440-02-0	58.71			3.67E-02	3.67E-02	1.53E-02	TLV Adj	Hierarchy-based; no PMEG-L or MRL
nickel (soluble compounds)				1.36E-04	2.44E-03	1.36E-04		MRL Adj	Narrow range between NOAEL and LOAEL. MRL judged more prudent.
nickel (insoluble compounds)					4.89E-03	4.89E-03		TLV Adj	Hierarchy-based; no PMEG-L or MRL
nickel carbonyl	13463-39-3	170.73			8.54E-03	8.54E-03	1.22E-03	TLV Adj	Hierarchy-based; no PMEG-L or MRL
nickel subsulfide	12035-72-2	240.19	9.99E-03		2.44E-03	9.99E-03	1.02E-03	PMEG-L	Hierarchy-based; no MRL
nickel refinery dust	none		2.00E-02			2.00E-02		PMEG-L	Hierarchy-based; no TLV or MRL
2-nitroaniline	88-74-4	138.12	1.37E-03			1.37E-03	2.42E-04	PMEG-L	Hierarchy-based; no TLV or MRL
nitrobenzene	98-95-3	123.11	1.37E-02		1.23E-01	1.37E-02	2.72E-03	PMEG-L	Hierarchy-based; no MRL
2-nitropropane	79-46-9	89.09	1.78E-03			1.78E-03	4.87E-04	PMEG-L	Hierarchy-based; no TLV or MRL
N-nitroso-di-n-butylamine	924-16-3		3.00E-03			3.00E-03		PMEG-L	Hierarchy-based; no TLV or MRL
N-nitrosodiethylamine	55-18-5	102.14	1.11E-04			1.11E-04	2.67E-05	PMEG-L	Hierarchy-based; no TLV or MRL
N-nitrosodimethylamine	62-75-9	74.08	3.42E-04			3.42E-04	1.13E-04	PMEG-L	Hierarchy-based; no TLV or MRL
N-nitrosopyrrolidine	930-55-2	100.12	7.86E-03			7.86E-03	1.92E-03	PMEG-L	Hierarchy-based; no TLV or MRL
phenanthrene	85-01-8	178.24	4.20E-02			4.20E-02	5.76E-03	PMEG-L	Limited toxicity data available.

Table C-6: Long-Term Air- MEGs and Basis

Chemical	CAS No.	MW	PMEG-L mg/m³	MRL Adj mg/m³	TLV Adj mg/m³	Air-MEG mg/m³	Air-MEG ppm	Long-Term Air-MEG Basis	Rationale
phosphine	7803-51-2	34	2.05E-03		1.02E-02	2.05E-03	1.48E-03	PMEG-L	Hierarchy-based; no MRL
phosphoric acid	7664-38-2	98	6.85E-03		2.44E-02	2.44E-02	6.10E-03	TLV Adj	PMEG had additional UF over TLV for interspecies extrapolation and use of a sub-chronic study. TLV based on human data.
phthalic anhydride	85-44-9	148.11	8.22E-02		1.48E-01	8.22E-02	1.36E-02	PMEG-L	Hierarchy-based; no MRL
polychlorinated biphenyls	1336-36-3		8.40E-03			8.40E-03		PMEG-L	Hierarchy-based; no TLV or MRL
propylene glycol monomethyl ether	107-98-2	90.12	1.37E+01		9.01E+00	1.37E+01	3.72E+00	PMEG-L	Hierarchy-based; no MRL
n-propylbenzene	103-65-1	120.2	2.53E-02			3.50E-02	7.12E-03	PMEG-L	Hierarchy-based; no MRL or TLV, RfC obtained from ncea/EPA IX extrapolation. Using n-butylbenzene as surrogate
propylene oxide	75-56-9	58.08	2.05E-02		2.90E-01	2.90E-01	1.22E-01	TLV Adj	TLV based on human data. PMEG based on mild endpoint and conservative due to UF and chronic animal study data.
pyrene	129-00-0	202.3	1.05E-01			1.05E-01	1.27E-02	PMEG-L	Limited toxicity data available.
strontium	7440-24-6	87.62	1.51E+00			1.51E+00	4.20E-01	PMEG-L	Hierarchy-based; no RfC, MRL, or TLV. Based on Region 3 risk-based concentrations
styrene	100-42-5	104.16	2.05E+00	1.74E-01	2.08E+00	2.05E+00	4.81E-01	PMEG-L	Hierarchy-based. All values were based on neurotoxicity. The PMEG and TLV-adj were very close despite considering different studies. The MRL-adj was considered overly conservative because of its chronic basis and differing interpretation of a NOAEL vs minimal LOAEL.
2,3,7,8-tetrachlorodibenzodioxin	1746-01-6		1.12E-07			1.12E-07		PMEG-L	Hierarchy-based; no TLV or MRL
1,1,1,2-tetrachloroethane	630-20-6	167.85	6.48E-01			6.48E-01	9.44E-02	PMEG-L	Hierarchy-based; no TLV or MRL
1,1,2,2-tetrachloroethane	79-34-5	167.86	8.27E-02	1.87E+00	1.68E-01	8.27E-02	1.20E-02	PMEG-L	PMEG is lower than the TLV and MRL and is protective against carcinogenic effects.
1,1,1,2-tetrafluoroethane	811-97-2	102.03	5.48E+01			5.48E+01	1.31E+01	PMEG-L	Hierarchy-based; no TLV or MRL
toluene	108-88-3	92.13	2.74E-01	1.02E+00	4.61E+00	4.61E+00	1.22E+00	TLV Adj	TLV-based. All endpoints were CNS-based. The PMEG was considered overly conservative because it was derived from a chronic RfD with a UF of 300. The TLV-adj was considered more appropriate for this exposure scenario than the "chronic" MRL-adj.
toxaphene	8001-35-2	414	1.50E-02		1.22E-02	1.50E-02	8.85E-04	PMEG-L	Hierarchy-based; no MRL

Table C-6: Long-Term Air- MEGs and Basis

Chemical	CAS No.	MW	PMEG-L mg/m³	MRL Adj mg/m³	TLV Adj mg/m³	Air-MEG mg/m³	Air-MEG ppm	Long-Term Air-MEG Basis	Rationale
1,2,4-trichlorobenzene	120-82-1	181.46	1.37E+00			1.37E+00	1.85E-01	PMEG-L	Hierarchy-based; no TLV or MRL
1,1,2-trichloroethane	79-00-5	133.41	3.00E-01		1.33E+00	3.00E-01	5.49E-02	PMEG-L	Hierarchy-based; no MRL
trichlorofluoromethane	75-69-4	137.88	4.79E+00			4.79E+00	8.50E-01	PMEG-L	Hierarchy-based; no TLV or MRL
1,1,2-trichloro-1,2,2-trifluoroethane	76-13-1	187.4	2.05E+01		1.87E+02	2.05E+01	2.68E+00	PMEG-L	Hierarchy-based; no MRL
2,4,6-trichlorophenol	88-06-2	197.45	1.55E+00			1.55E+00	1.92E-01	PMEG-L	Hierarchy-based; no MRL
1,2,4-trimethylbenzene	95-63-6	120.19	4.08E-03		3.06E+00	3.06E+00	6.22E-01	PMEG-L	TLV-based; no subchronic RfC or MRL. PMEG overly conservative due to chronic RfD.
1,3,5-trimethylbenzene	108-67-8	120.19	4.08E-03		3.06E+00	3.06E+00	6.22E-01	PMEG-L	TLV-based; no subchronic RfC or MRL. PMEG overly conservative due to chronic RfD.
triethylamine	121-44-8	101.19	4.79E-03		1.01E-01	1.01E-01	2.44E-02	TLV Adj	PMEG has overly conservative UF=3000 for exposure scenario. TLV is below level where any systemic effects have been observed.
vinyl acetate	108-05-4	86.09	1.37E-01	2.39E-02	8.61E-01	1.37E-01	3.89E-02	PMEG-L	Hierarchy-based
vinyl bromide	593-60-2	106.96	2.05E-03			2.05E-03	4.69E-04	PMEG-L	Hierarchy-based; no TLV or MRL
vinyl chloride	75-01-4	62.5	5.71E-02	5.21E-02	6.25E-02	5.71E-02	2.23E-02	PMEG-L	Hierarchy-based
xylene (mixed, o, m, p)	1330-20-7	106.16		2.06E+00	1.06E+01	1.06E+01	2.44E+00	TLV Adj	Hierarchy-based; No PMEG. Although the TLV and MRL were based on different endpoints, the MRL had an UF of 300, and the TLV-adj was almost two orders of magnitude lower than the less seriour LOAEL.

Notes
MRL – Minimal Risk Level, intermediate used over chronic when available (ATSDR)
TLV – Threshold Limit Value (ACGIH, 1999)
PMAG-L – Preliminary Military Air Guideline-Long-term (calculated, see Appendix 4-1)
Adj – adjusted (TLV Adj = TLV/40.9; MRL Adj = MRL*0.68; See text for detailed explanation)
MW - molecular weight

APPENDIX D

DERIVATION OF MILITARY EXPOSURE GUIDELINES FOR WATER

Table D-1: Selecting Chemicals Of Concern In Drinking Water – An Assessment of "Lists"

Chemical CAS No.	ITF 25	TB MED 577	EPA/ Army	TRI	PIC	POP	LL	WHO	ATSDR gw/sw	Short-Term Water-MEG (mg/L)
Alachlor 15972-60-8								X		0.14
Aldrin 309-00-2				Low	X	X		X	8/2	0.0004
Benzene 71-43-2				Top 75					115/41	0.1
Carbofuran 1553-66-2							X	X		0.07
Carbon disulfide 75-15-0	X			Top 75				X		0.14**
Chlordane 57-74-9				Low	X	X		X		0.09
Chloride 16887-00-6	As chlorine	X		Top 21 as chlorine						600
Chloromethane [Methyl chloride)] 74-87-3				Top 34						0.5
Chromium (total) 7440-47-3				Top 21 as Cr cpds					93/55	2
Cyanide 21725-46-2	As HCN	X		Top 34					13/9	6
2,4-D 94-75-7								X		0.4

Table D-1: Selecting Chemicals of Concern in Drinking Water – An Assessment of "Lists"

Chemical CAS No.	ITF 25	TB MED 577	EPA/ Army	TRI	PIC	POP	LL	WHO	ATSDR gw/sw	Short-Term Water-MEG (mg/L)
Diazinon 333-41-5										**0.03**
Dibromochloropropane 96-12-8								**X**		**0.28**
Dieldrin 60-57-1					**X**	**X**		**X**	**8/2**	**0.007**
Dinitrobenzene (1,3-) 99-65-0			**X**	**Top 34**						**0.06**
Dinoseb 88-85-7					**X**					**0.42**
Dioxane (1,4-) 123-91-1				**Top 21**						**0.56**
Disulfoton 298-04-4								**X**		**0.014**
Ethylene dibromide 106-93-4					**X**			**X**		**0.01**
Endrin 72-20-8						**X**		**X**		**0.02**
Fenamiphos 22224-92-6								**X**		**0.013**
Fonofos 944-22-9								**X**		**0.03**

Table D-1: Selecting Chemicals of Concern in Drinking Water – An Assessment of "Lists"

Chemical CAS No.	ITF 25	TB MED 577	EPA/ Army	TRI	PIC	POP	LL	WHO	ATSDR gw/sw	Short-Term Water-MEG (mg/L)
GA [Tabun[77-81-6		**X**								**0.14***
GB [Sarin[107-44-8		**X**								**0.028***
GD [Soman[96-64-0		**X**								**0.012***
Heptachlor 76-44-8				**Low**	**X**	**X**		*X*	**2/0**	**0.014**
Heptachlor epoxide 1024-57-3						**X**			**2/0**	**0.014***
Hexachlorobenzene 118-74-1				**Top 145**	**X**			**X**		**0.08**
Lewisite 542-25-3		**X**			**X**					**0.027***
Lindane 58-89-9		**X**		**None**				**X**		**0.6**
Magnesium 7439-95-4		**X**								**100**
Malathion 121-75-5										**0.3**
Methylparathion 298-00-0								**X**		**0.4**

Table D-1: Selecting Chemicals of Concern in Drinking Water – An Assessment of "Lists"

Chemical CAS No.	ITF 25	TB MED 577	EPA/ Army	TRI	PIC	POP	LL	WHO	ATSDR gw/sw	Short-Term Water-MEG (mg/L)
Molybdenum trioxide 7439-98-7				**Top 34**						**0.03**
Oxamyl [Vydate] 23135-22-0										**0.35**
Paraquat 1910-42-5								**X**		**0.14**
Simazine 122-34-9								**X**		**0.03**
Sulfate 14808-79-8	**As H_2SO_4**	**X**		**Top 21 as H_2SO_4**						**300**
Sulfur mustard [HD] 505-60-2		**X**								**0.14***
TCDD (2,3,7,8-) 1746-01-6						**X**			**5/3**	**1**
Terbufos 13071-79-9								**X**		**0.007**
Trifluralin 1582-09-8								**X**		**0.1**
VX 50782-69-9		**X**								**0.015***

Table D-2: Long-Term Water-MEGs and Basis

Compound	TB MED 577 Longer-term (mg/L)(5L)	HA Longer-term MWGL (mg/L)(5L)	ATSDR Intermed. MRL MWGL (mg/L)(5L)	HEAST subchronic RfD MWGL (mg/L) (5L)	RfD Water-MEG (mg/L)(5L)	10-4 Cancer risk MWGL (mg/L)(5L)	Cancer Class	MCL (mg/l)	Water-MEG (mg/L)(5L)	Water-MEG source B	Critical Study Endpoint
Acenapthene 83-32-9			8.4	8.4	0.84				8.4	ATSDR	NOAEL= 175 mg/kg/day based on hepatotoxicity in a mouse oral subchronic study UF= 300
Acenapthylene 208-96-8					0.14		D		0.14	HEAST[C]	Based on the TPH fraction specific RfDs using an RfD of 0.01 mg/kg/d for aromatic fractions between C_{10} and C_{12}.
Acetone 67-64-1			28	14			D		14	HEAST	NOEL = 100 mg/kg/d, LOAL = 500 mg/kg/d based on increased kidney and liver weights and nephrotoxicity.
Alaclor 15972-60-8				0.14	0.14	1	B2	0.002	0.14	HEAST	NOEL = 1 mg/kg/d from a 1-yr oral dog study; based on absence of anemia and hemosiderosis. UF=100
Aldrin 309-00-2		0.0004	0.0004[D]	0.0004	0.0004	0.006	B2	-	0.0004	HA/RfD	LOAEL = 1 mg/kg/d from a 2-yr rat feeding study (Fitzhugh, 1964) based on liver lesions and increased relative liver weight. UF=1000
Anthracene 120-12-7			140	42	4.2		D		140	ATSDR	NOEL=1000 mg/kg/day based on no observed effects in a subchronic mouse study. UF=100
Aroclor-1016 12674-11-2					0.001				0.001	Reg3/RfD	
Aroclor-1254 11097-69-1				0.0007	0.0003				0.0007	HEAST	LOAEL=0.005 mg/kg/d based on effects on the immune system observed in a >5-yr oral monkey study. UF=100
Arsenic 7440-38-2	0.06			0.004	0.004	0.06	A		0.06	TBMED	NOAEL=0.32 mg/d based on no effects in humans sustained by arsenic-contaminated well water for up to 10 years. UF=0
Benzene 71-43-2					0.042	3	A	0.005	0.042	Reg3/RfD	
Benzo[a]anthracene 56-55-3						0.14	B2		0.14	CANCER RISK[C]	Based on risk-specific concentration for benzo(a)pyrene and a TEF of 0.1
Benzo(a)pyrene 50-32-8					102.2	0.014	B2		0.014	CANCER RISK	Based on cancer bioassays in multiple species.
Benzo[b]fluoranthene 205-99-2						0.14	B2		0.14	CANCER RISK[C]	Based on risk-specific concentration for benzo(a)pyrene and a TEF of 0.1
Benzo[k]fluoranthene 207-08-9						1.4	B2		1.4	CANCER RISK[C]	Based on risk-specific concentration for benzo(a)pyrene and a TEF of 0.01
Beryllium 7440-41-7		6		0.07	0.07		B2	0.004	0.02	CANCER RISK	

Table D-2: Long-Term Water-MEGs and Basis

Compound	TB MED 577 Longer-term (mg/L)(5L)	HA Longer-term MWGL (mg/L)(5L)	ATSDR Intermed. MRL MWGL (mg/L)(5L)	HEAST subchronic RfD MWGL (mg/L) (5L)	RfD Water-MEG (mg/L)(5L)	10-4 Cancer risk MWGL (mg/L)(5L)	Cancer Class	MCL (mg/l)	Water-MEG (mg/L)(5L)	Water-MEG source B	Critical Study Endpoint
Bis (2-ethylhexyl) phthalate 117-81-7	0.006	0.28	5.6	0.28	0.28	0.3	B2	0.006	0.28	CANCER RISK	LOAEL=19 mg/kg/d based on increased liver weight in guinea pig subchronic study.
Boron 7440-42-8		1.3			1.3		D		1.3	HA	NOAEL= 8.8 mg/kg/day based on testicular lesions in a 90-day dog feeding study.
Bromodichloromethane 75-27-4		5	0.3[D]	0.3	0.3	1.7	B2	0.08	0.3	HEAST	LOAEL= 17.9 mg/kg/day based on kidney lesions (cytomegaly) in a 2-year rat gavage study. UF=1000
Sec-Butylbenzene 135-98-8					0.148				0.148	ncea/EPA IX	Based on EPA chronic water ingestion guidelines.
Cadmium 7440-43-9		0.007			0.007			0.005	0.007	HA/RfD	LOAEL=0.005 mg/kg/d based on renal dysfunction in humans. UF=10
Carbon disulfide 75-15-0			0.14	1.4	1.4				0.14	ATSDR[C]	LOAEL=3 mg/kg/day, based on minimal effects in the liver (decrease in P-450 and drug metabolizing enzymes) in mice gavaged with carbon disulfide for 1-14 days. (A UF of 3 was used for a minimum LOAEL.) UF=300
Chlordane 57-74-9			0.008	0.0008	0.007	0.08	B2	0.002	0.008	ATSDR	NOAEL=0.055 mg/kg/day, based on absence of effects on the liver in a 30-month feeding study in rats. UF=100
Chloride	600				1.4				600	TBMED	Based on inpalatability and possibility of dehydration at concentrations higher than 600 mg/L. UF = 0
Chloroform 67-66-3		0.16	1.4	0.14	0.14	16.8	B2	0.08	1.4	ATSDR	NOAEL = 15 mg/kg/day based on increased SGPT activity in a 6 week study in dogs. UF=100
Chloromethane (Methyl chloride) 74-87-3		0.5			0.05		C		0.5	HA	LOAEL=70 mg/m^3 based on mild neurological signs in humans occupationally exposed to chloromethane for 1 to 26 years. UF=100
Chlorothalonil 1897-45-6		0.2		0.2	0.2	4	B2		0.2	HA	NOAEL=1.5 mg/kg/d, based on absence of kidney effects in rats exposed to chlorothalonil in the diet for 13 weeks. UF=100
Chromium III 16065-83-1					21				21	RfD	NOAEL = 1468 mg/kg/d, based on a rat chronic feeding study (LOAEL not observed) UF=1000

Table D-2: Long-Term Water-MEGs and Basis

Compound	TB MED 577 Longer-term (mg/L)(5L)	HA Longer-term MWGL (mg/L)(5L)	ATSDR Intermed. MRL MWGL (mg/L)(5L)	HEAST subchronic RfD MWGL (mg/L) (5L)	RfD Water-MEG (mg/L)(5L)	10-4 Cancer risk MWGL (mg/L)(5L)	Cancer Class	MCL (mg/l)	Water-MEG (mg/L)(5L)	Water-MEG source B	Critical Study Endpoint
Chromium (total) 7440-47-3		0.3			0.08		D		0.3	HA	NOAEL = 2.41 mg/kg/d, based on the absence of adverse effects in rats exposed to chromium in drinking water. UF=100
Chromium VI 18540-29-9				0.3	0.04		D		0.3	HEAST	NOAEL=0.003 mg/kg/day, based on a drinking water study in rats. UF=300,MF=3.
Chrysene 218-01-9				4.2	0.42	14	B2		4.2	HEAST[C]	Based on TPH fraction specific RfDs using the RfD of 0.03 mg/kg/d for pyrene as a surrogate. (The cancer risk is based on a risk-specific concentration for benzo(a)pyrene and a TEF of 0.001.)
Copper 7440-50-8				0.5	0.5		D		0.5	HEAST	LOAEL = 5.3 mg, based on single oral dose which caused gastrointestinal irritation in humans.
Cumene 98-82-8		1.4		5.6	1.4		D		1.4	HA/RfD	Hierarchy based, chronic value.
Cyanide 57-12-5	6	0.3	0.7	0.3	0.3				6	TBMED	Based on estimates that 0.5 mg CN/L blood is not associated with clinical or subclinical effects. UF=1
2,4-D 94-75-7		0.14		0.14	0.14		D	0.07	0.14	HA/RfD	NOAEL=1 mg/kg/d, based on the absence of blood, liver and kidney effects in rats given 2,4-D orally for 2 years. UF=100
P,p'-DDT 50-29-3			0.007	0.007	0.007				0.007	ATSDR	NOAEL= 0.05 mg/kg/d, based on absence of effects on the liver (cellular hypertrophy, cytoplasmic eosinophilia) in rats fed DDT for 15-27 wk. UF=100
Diazinon 333-41-5		0.007	0.003	0.0013	0.0013		E		0.007	HA[C]	NOAEL=0.05 mg/kg/d, based on the absence of ChE inhibition in monkeys given diazinon orally for 52 weeks. UF=100
Dibromochloromethane 594-18-3				2.8	0.28				2.8	HEAST	NOAEL = 21.4 mg/kg/day based on liver lesions in a 13 week gavage study in rats. UF=100
Dibromochloropropane 96-12-8			0.03			0.08	B2	0.0002	0.03	ATSDR	LOAEL= 1.88 mg/kg/d based on reproductive effects (abnormal sperm morphology, decreased spermatogenesis) in rabbits given DDT in the drinking water 5 d/wk for 10 wk. UF=1000

Table D-2: Long-Term Water-MEGs and Basis

Compound	TB MED 577 Longer-term (mg/L)(5L)	HA Longer-term MWGL (mg/L)(5L)	ATSDR Intermed. MRL MWGL (mg/L)(5L)	HEAST subchronic RfD MWGL (mg/L) (5L)	RfD Water-MEG (mg/L)(5L)	10-4 Cancer risk MWGL (mg/L)(5L)	Cancer Class	MCL (mg/l)	Water-MEG (mg/L)(5L)	Water-MEG source B	Critical Study Endpoint
Dieldrin 60-57-1		0.0007	0.0007[D]	0.0007	0.0007	0.006	B2		0.0007	HA/RfD	NOAEL=0.4 mg/kg/d, based on the absence of effects on spleen and liver weights with no changes in spermatogeneis or histological changes in the testes in rats given dieldrin in the drinking water for 16 weeks. UF=100
Dinitrobenzene (1,3-) 99-65-0		0.06	0.007	0.014	0.0014		D		0.06	HA	NOAEL=0.005 mg/kg/d, based on the absence of hepatic effects in rats fed dieldrin in the diet for 2 years. UF=100
Dinoseb 88-85-7		0.014		0.014	0.014		D	0.007	0.014	HA	LOAEL=1 mg/kg/d, based on decreased pup weight in a 2-generation reproduction study in rats. UF=1000
Disulfoton 298-04-4		0.004	0.001	0.0006	0.0006		E		0.004	HA	NOAEL=0.025 mg/kg/d, based on absence of ChE effects in dogs exposed to di+M32sulfoton in the diet for up to 2 years. ChE effects were observed at higher doses during the first 40 to 69 weeks of exposure and thereafter. UF=100
Endrin 72-20-8		0.006	0.004	0.004	0.006		D	0.002	0.006	HA/RfD	NOAEL=0.045 mg/kg/d, based on absence of kidney and heart weight changes in dogs exposed to endrin in the diet for up to 18.7 months. UF=100
Ethylbenzene 100-41-4		1.4			1.4		D	0.7	1.4	HA/RfD	NOEL=100 mg/kg/d, based on liver and kidney toxicity in oral rat study. UF=1000.
Ethylene dibromide 106-93-4						0.0012	B2	0.00005	0.0012	CANCER RISK[C]	
Fenamiphos 22224-92-6		0.007			0.0036		D	-	0.007	HA	NOAEL=0.05 mg/kg/d, based on absence of significant ChE inhibition in dogs exposed to Fenamiphos in the diet for 3 months. UF=100
Fluoranthene 206-44-0				5.6	0.56		D		5.6	HEAST	NOAEL = 125 mg/kg/day based on nephropathy, and weight and hematological changes in a 90 day gavage study in mice. UF=300
Fluorene 86-73-7				5.6	0.56		D		5.6	HEAST	NOAEL = 125 mg/kg/day based on decreased erythrocyte counts in a 13 wk gavage study in mice. UF=300

Table D-2: Long-Term Water-MEGs and Basis

Compound	TB MED 577 Longer-term (mg/L)(5L)	HA Longer-term MWGL (mg/L)(5L)	ATSDR Intermed. MRL MWGL (mg/L)(5L)	HEAST subchronic RfD MWGL (mg/L) (5L)	RfD Water-MEG (mg/L)(5L)	10-4 Cancer risk MWGL (mg/L)(5L)	Cancer Class	MCL (mg/l)	Water-MEG (mg/L)(5L)	Water-MEG source B	Critical Study Endpoint
Fonofos 944-22-9		0.03			0.028		D	-	0.03	HA	NOAEL=0.2 mg/kg/d, based on absence of systemic toxicity or ChE inhibition in dogs exposed to Fonofos in the diet for 2 years. UF=100
Heptachlor 76-44-8		0.007		0.007	0.007	0.02	B2	0.0004	0.007	HA/RfD	NOAEL=0.15 mg/kg/d, based on absence of increased liver to body weight in rats exposed to Heptachlor in the diet for 2 years. UF=300
Heptachlor epoxide 1024-57-3		0.0002		0.0002	0.0002	0.01	B2	0.0002	0.0002	HA/RfD	LOEL=0.0125 mg/kg/d, based on increased liver to body weights in dogs exposed to Heptachlor epoxide in the diet for 60 weeks. UF=1000
Hexachlorobenzene 118-74-1		0.08	0.004		0.01	0.06	B2	0.001	0.004	MRL[C]	LOAEL=0.1 mg/kg/d based on decreased number of oocytes and ultrastructural ovarian epithelial damage from a 90 day monkey study. UF=300
Lead tetraethyl 78-00-2					0.0000014				0.0000014	RfD	Based on liver and neuronal damage in rats. UF=1000
Lindane 58-89-9	0.6	0.05					C		0.6	TBMED	LOAEL = 30 mg/day, based on the lowest dose to cause adverse effects in 3-day human studies. UF = 10
Magnesium 7439-95-4	100								100	TBMED	Based on performance degrading laxative effects in humans at concentrations higher than 600 mg/L. UF = 1
Malathion 121-75-5		0.3		0.3	0.3		D		0.3	HA/RfD	NOAEL=0.23 mg/kg/d, based on absence of cholinesterase depression in humans exposed to Malathion orally for 32 to 56 days. UF=10
Mercury (inorganic) 7439-97-6		0.002					D	0.002	0.002	HA	NOAEL=0.05 mg/kg/d, based on absence of renal effects in rats injected sq 3 times/week for up to 12 weeks. UF=1000
Methyl ethyl ketone 78-93-3		8.4			8.4		D		8.4	IRIS	NOAEL=1771 mg/kg-d. UF=3000
Methyl mercury 22967-92-6			0.0042[D]	0.0014	0.0014				0.0042	ATSDR	NOAEL=0.005 mg/kg/d, based on adverse neurodevelopmental outcomes in human children exposed in utero to mercury. UF=1

Table D-2: Long-Term Water-MEGs and Basis

Compound	TB MED 577 Longer-term (mg/L)(5L)	HA Longer-term MWGL (mg/L)(5L)	ATSDR Intermed. MRL MWGL (mg/L)(5L)	HEAST subchronic RfD MWGL (mg/L) (5L)	RfD Water-MEG (mg/L)(5L)	10-4 Cancer risk MWGL (mg/L)(5L)	Cancer Class	MCL (mg/l)	Water-MEG (mg/L)(5L)	Water-MEG source B	Critical Study Endpoint
Methylparathion 298-00-0		0.04	0.004[D]	0.03	0.004		D		0.04	HA	NOAEL=0.3 mg/kg/d, based on absence of effects on body and organ weights, clinical chemistry, hematology, gross pathology, and ChE activity in dogs fed methyl parathion for 90 days. UF=100
Molybdenum 7439-98-7		0.07		0.07	0.07				0.07	HEAST	LOAEL=0.14 mg/kg/d from a human drinking water study based on increased uric acid and painful swollen joints. UF=30
Napthalene		0.5	0.3		0.05		D		0.5	HA	NOAEL=35.7 mg/kg/d, based on absence of decreased body weight gain in rats exposed by gavage for 13 wks. UF=1000
Oxamyl [Vydate] 23135-22-0		0.35			0.4		E	0.2	0.35	HA/RfD	NOAEL=2.5 mg/kg/d, based on absence of depression of weight gain in a 2-yr feeding study in rats. UF=100
Paraquat 1910-42-5		0.06			0.06		E		0.06	HA/RfD	NOAEL=0.45 mg ion/kg/d, based on absence of biochemical, hematological, gross and histopathological changes in a 1-yr feeding study in dogs. UF=100
Phenanthrene 85-01-8				4.2	0.42		D		4.2	HEAST[C]	Based on the TPH fraction specific RfDs using the RfD of 0.03 mg/kg/d and the subchronic RfD of 0.3 mg/kg/d for pyrene as a surrogate.
N-propylbenzene 103-65-1					0.148		D		0.148	Reg9/RfD	Based on EPA chronic water ingestion guidelines.
Pyrene 129-00-0				4.2	0.42		D		4.2	HEAST	NOAEL = 75 mg/kg/d based on kidney changes in a 13 wk gavage study in mice. UF=300
Simazine 122-34-9		0.07		0.07	0.07		C	0.004	0.07	HA/RfD	NOAEL=0.52 mg/kg/d from a 2-yr rat study based on hematological effects. UF=100
Strontium 7440-24-6		8.4		8.4	8.4				8.4	HEAST	NOAEL=190 mg/kg/d based on subchronic rat study and rachitic bone. UF=300
Sulfate (As H2SO4)	300							500	300	TBMED	Based on performance degrading laxative effects in humans at concentrations higher than 600 mg/L. UF = 0

Table D-2: Long-Term Water-MEGs and Basis

Compound	TB MED 577 Longer-term (mg/L)(5L)	HA Longer-term MWGL (mg/L)(5L)	ATSDR Intermed. MRL MWGL (mg/L)(5L)	HEAST subchronic RfD MWGL (mg/L) (5L)	RfD Water-MEG (mg/L)(5L)	10-4 Cancer risk MWGL (mg/L)(5L)	Cancer Class	MCL (mg/l)	Water-MEG (mg/L)(5L)	Water-MEG source B	Critical Study Endpoint
TCDD (2,3,7,8-) 1746-01-6		0.000000014	2.80E-07			6.00E-07	B2	3E-08	1.40E-08	HA[C]	LOAEL=0.001 ug/kg/day from a 3-generation reproduction study in rats. UF=1000
Terbufos 13071-79-9		0.00035		0.00035			D		0.00035	HA/RfD[C]	NOAEL=0.0025 mg/kg/d, based on absence of inhibition of cholinesterase from a 6-month feeding study in dogs. UF=100
Toluene 108-88-3		2.8	0.28	28	2.8		D	1	2.8	HEAST	NOAEL= 223 mg/kg/d, based on changes in liver and kidney weights in a 13-Week rat Gavage study; UF=100
Toxaphene 8001-35-2			0.014			0.08	B2	0.003	0.014	ATSDR	NOAEL=0.35 mg/kg/day, based on absence of hepatic toxicity in rats exposed to Toxaphene in the diet for 3 months. UF=300.
Trifluralin 1582-09-8		0.1		0.1	0.1	14	C		0.1	HA/RfD	LOAEL=2.5 mg/kg/d, based on increased unrinary globulins in rats consuming a trifluralin diet for 3 months. UF=1000
1,2,4-Trimethylbenzene					0.7				0.7	Reg3/RfD	Based on EPA chronic water ingestion guidelines.
1,3,5-Trimethylbenzene					0.7				0.7	Reg3/RfD	Based on EPA chronic water ingestion guidelines.
Vanadium 7440-62-2			0.04	0.1	0.1				0.1	HEAST[C]	NOAEL=0.003 mg/kg/day, based on the absence of renal effects (increased plasma urea, and mild histological changes) in rats treated with sodium vanadate in the drinking water for 3 months. UF=100.
Xylene (total) 1330-20-7		40	2.8		28		D	10	40	HA	NOAEL= 250 mg/kg/d, based on hyperactivity, changes in body weight in a 103-Week rat Gavage study; UF=100
Zinc 7440-66-6		4	4	4	4				4	HA	LOAEL = 1 mg/kg/d, based on changes in the blood (decreased superoxide dismutase activity, hematocrit, and serum ferritin) observed in a 10 week dietary supplement study in humans. UF = 3

A. To enable a direct comparison of values, the ATSDR MRLs, HEAST subchronic RfDs, and Region 3 RfDs were adjusted from mg/kg/day to mg/L water for a daily 5 L consumption rate and the HAs were converted from mg/L for a consumption rate of 2 L water to mg/L for a consumption rate of 5 L water . The 10^{-4} cancer risk-specific concentration was adjusted from a lifetime exposure to a 1-year exposure.

B. This column shows the sources from which the MWGs-L were chosen. HA/RfD indicates that the longer-term HA was derived from the RfD. Reg3(9)/RfD indicates the source was Region 3 or 9. All other RfDs used as MWG-Ls were obtained from IRIS.

Table D-2: Long-Term Water-MEGs and Basis

Compound	TB MED 577 Longer-term (mg/L)(5L)	HA Longer-term MWGL (mg/L)(5L)	ATSDR Intermed. MRL MWGL (mg/L)(5L)	HEAST subchronic RfD MWGL (mg/L) (5L)	RfD Water-MEG (mg/L)(5L)	10-4 Cancer risk MWGL (mg/L)(5L)	Cancer Class	MCL (mg/l)	Water-MEG (mg/L)(5L)	Water-MEG source B	Critical Study Endpoint

Region 3 or 9. All other RfDs used as MWG-Ls were obtained from IRIS.

C. Reason for deviation from the selection hierarchy is explained in Section 5.6 of the text.

D. Value was derived from a chronic MRL.

APPENDIX E
DERIVATION OF MILITARY EXPOSURE GUIDELINES FOR SOIL

Table E-1: Estimated Soil Concentrations for Carcinogens

							Endpoint: Cancer						
Chemical	**H** atm-m^3/mole	**MW** (g/mole)	**VOC?***	**DA** (cm^2/s)	**VFs or PEF** (m^3/kg)	**ABS**	**CSF_{oral}** $(mg/kg/day)^{-1}$	**CSF_{inh}** $(mg/kg/day)^{-1}$	**CSF_{dermal}** $(mg/kg/day)^{-1}$	**Ingestion** (kg-kg)/mg	**Inhalation** (kg-kg)/mg	**Dermal** (kg-kg)/mg	**Sc** (mg/kg)
Acenapthene	1.55E-04	154.21	1	4.71E-07	3.32E+04	10%							NA
Acenapthylene	1.13E-05	152.2	1	1.28E-07	6.38E+04	10%							NA
Acetone	3.88E-05	58.08	1	1.00E-04	1.30E+04	10%							N/A
Alachlor	3.20E-08	269.8	0	NA	1.32E+09	10%	8.00E-02		8.00E-02	2.12E-05		3.27E-05	9.09E+03
Aldrin	1.27E-05	364.9	0	NA	1.32E+09	10%	1.70E+01	1.72E+01	1.70E+01	4.51E-03	3.81E-07	6.95E-03	4.28E+01
Anthracene	6.50E-05	178.23	1	3.20E-08	1.28E+05	10%							NA
Aroclor-1016	3.43E-04	257.9	0	NA	1.32E+09	10%							NA
Aroclor-1254	2.83E-04	327	0	NA	1.32E+09	10%							NA
Arsenic	0.00E+00	75	0	NA	1.32E+09	1%	1.50E+00	1.51E+01		3.98E-04	3.34E-07		1.23E+03
Benzene	5.55E-03	78.1	1	2.02E-03	5.08E+02	10%	2.90E-02	2.73E-02	2.90E-02	7.69E-06		1.19E-05	2.51E+04
Benz(a)anthracene	8.00E-06	228.3	0	NA	1.32E+09	10%	7.30E-01	3.08E-01		1.93E-04	6.83E-09		2.53E+03
Benzo(a)pyrene	1.13E-06	252.3	0	NA	1.32E+09	10%	7.30E+00	3.08E+00		1.93E-03	6.83E-08		2.53E+02
Benzo(b)fluoranthene	1.11E-04	252.3	0	NA	1.32E+09	10%	7.30E-01	3.08E-01		1.93E-04	6.83E-09		2.53E+03
Benzo(k)fluoranthene	8.29E-07	252.3	0	NA	1.32E+09	10%	7.30E-02	3.08E-02	7.30E-02	1.93E-05	6.83E-10	2.99E-05	9.96E+03
Beryllium	0.00E+00	9	0	NA	1.32E+09	1%		8.40E+00			1.86E-07		2.63E+06
bis (2-ethylhexyl) phthalate	1.02E-07	390.56	0	NA	1.32E+09	1%	1.40E-02	7.28E-03	7.37E-02	3.71E-06	1.62E-10	3.01E-05	1.45E+04
sec-Butylbenzene	1.90E-02	134.24	1	2.26E-04	1.52E+03	10%							NA
Cadmium	0.00E+00	112	0	NA	1.32E+09	1%		6.30E+00			1.40E-07		3.51E+06
Carbon disulfide	3.00E-02	76.1	1	1.06E-02	2.21E+02	10%							NA
Chlordane	4.86E-05	409.8	0	NA	1.32E+09	10%	3.50E-01	3.50E-01	3.50E-01	9.28E-05	7.77E-09	1.43E-04	2.08E+03
Chloromethane	2.40E-02	51	1	1.14E-02	2.14E+02	10%	1.30E-02	6.30E-03	1.30E-02	3.45E-06		5.32E-06	5.59E+04
Chlorothalonil	2.00E-07	265.9	0	NA	1.32E+09	10%	1.10E-02		1.10E-02	2.92E-06		4.50E-06	6.61E+04
Chromium (total)	0.00E+00	52	0	NA	1.32E+09	1%							NA
Chromium III	0.00E+00	52	0	NA	1.32E+09	1%							NA
Chromium VI	0.00E+00	52	0	NA	1.32E+09	1%		4.20E+01			9.32E-07		5.26E+05
Chrysene	9.46E-05	228.3	0	NA	1.32E+09	10%	7.30E-03	3.08E-03	7.30E-03	1.93E-06	6.83E-11	2.99E-06	9.96E+04
Cumene	1.20E+00	120.19	1	4.33E-03	3.47E+02	10%							NA
Cyanide (TBMED)	4.22E-04	26.02	1	4.91E-05	3.26E+03	1%							NA
2,4-D (2,4-dichlorophenoxy acetic acid)	1.02E-08	221	0	NA	1.32E+09	10%							NA
p,p'-DDT	8.10E-06	354.5	0	NA	1.32E+09	10%	3.40E-01	3.40E-01	3.40E-01	9.01E-05	7.53E-09	1.39E-04	2.14E+03
Diazinon	1.17E-07	304.4	0	NA	1.32E+09	10%							NA
Dibromochloropropane	1.50E-04	236.4	0	NA	1.32E+09	10%	1.40E+00	2.35E-03	1.40E+00	3.71E-04	5.20E-11	5.73E-04	5.19E+02
Dieldrin	5.80E-05	381	0	NA	1.32E+09	10%	1.60E+01	1.61E+01	1.60E+01	4.24E-03	3.57E-07	6.54E-03	4.54E+01
1,3-Dinitrobenzene	2.33E-06	168.1	0	NA	1.32E+09	10%							NA
Dinoseb	5.04E-04	240.2	0	NA	1.32E+09	10%							NA
Disulfoton	1.10E-04	274.4	0	NA	1.32E+09	10%							NA
Endrin	4.00E-07	381	0	NA	1.32E+09	10%							NA
Ethyl benzene	7.88E-03	106.2	1	9.06E-04	7.58E+02	10%							NA

Table E-1: Estimated Soil Concentrations for Carcinogens

							Endpoint: Cancer						
Chemical	**H** atm-m^3/mole	**MW** (g/mole)	**VOC?***	**DA** (cm^2/s)	**VFs or PEF** (m^3/kg)	**ABS**	**CSF_{oral}** $(mg/kg/day)^{-1}$	**CSF_{inh}** $(mg/kg/day)^{-1}$	**CSF_{dermal}** $(mg/kg/day)^{-1}$	**Ingestion** (kg-kg)/mg	**Inhalation** (kg-kg)/mg	**Dermal** (kg-kg)/mg	**Sc** (mg/kg)
Ethylene dibromide (EDB)	4.47E-04	187.9	1	4.79E-05	3.30E+03	10%	8.50E+01	7.70E-01	8.50E+01	2.25E-02		3.48E-02	8.55E+00
Fenamiphos	1.20E-09	303.4	0	NA	1.32E+09	10%							NA
Fluoranthene	1.61E-05	202.3	0	NA	1.32E+09	10%							NA
Fluorene	7.70E-05	166.2	1	2.10E-07	4.98E+04	10%							NA
Fonofos	5.40E-06	246.3	0	NA	1.32E+09	10%							NA
Heptachlor	1.48E-03	373.3	0	NA	1.32E+09	10%	4.50E+00	4.55E+00	4.50E+00	1.19E-03	1.01E-07	1.84E-03	1.62E+02
Heptachlor epoxide	3.20E-05	389.3	0	NA	1.32E+09	10%	9.10E+00	9.10E+00	9.10E+00	2.41E-03	2.02E-07	3.72E-03	7.99E+01
Hexachlorobenzene	5.00E-02	284.8	0	NA	1.32E+09	10%	1.60E+00	1.61E+00	1.60E+00	4.24E-04	3.57E-08	6.54E-04	4.54E+02
Lead	0.00E+00	207.2	0	NA	1.32E+09	1%							NA
Lead (Tetraethyl)	5.68E-01	323.45	0	NA	1.32E+09	1%							NA
Lindane (TriServ)	3.82E-06	290.85	0	NA	1.32E+09	10%	1.30E+00		1.30E+00	3.45E-04		5.32E-04	5.59E+02
Malathion	1.20E-07	330.4	0	NA	1.32E+09	10%							NA
Mercury (inorganic)	7.10E-03	201	0	NA	1.32E+09	1%							NA
Methyl ethyl ketone	2.70E-05	72.11	1	4.08E-05	3.57E+03	10%							NA
Methylmercury	4.70E-07	215.63	0	NA	1.32E+09	10%							NA
Methylparathion	8.40E-08	263.21	0	NA	1.32E+09	10%							NA
Molybdenum trioxide	0.00E+00	143.95	0	NA	1.32E+09	10%							NA
Napthalene	4.83E-04	128.2	1	8.35E-06	7.90E+03	10.00%							NA
Oxamyl (Vydate)	2.37E-10	219.3	0	NA	1.32E+09	10.00%							NA
Paraquat	1.00E-09	257.2	0	NA	1.32E+09	10.00%							NA
Phenanthrene	1.24E-04	178.2	1	7.58E-08	8.29E+04	10.00%							NA
Polychlorinated biphenyls (PCBs)	0.00E+00	292	0	NA	1.32E+09	10%	2.00E+00	2.00E+00	2.00E+00	5.30E-04	4.43E-08	8.18E-04	3.63E+02
n-propylbenzene	1.30E-02	120.2	1	1.22E-04	2.07E+03	10%							NA
Pyrene	1.10E-05	202.3	0	NA	1.32E+09	10.00%							NA
Simazine	3.40E-09	201.7	0	NA	1.32E+09	10.00%	1.20E-01		1.20E-01	3.18E-05		4.91E-05	6.06E+03
Strontium	0.00E+00	87.62	0	NA	1.32E+09	1.00%							NA
Sulfate	0.00E+00	98.08	0	NA	1.32E+09	1.00%							NA
2,3,7,8-TCDD (Dioxin)	1.60E-05	322	0	NA	1.32E+09	10.00%	1.50E+05	1.50E+05	1.50E+05	3.98E+01	3.33E-03	6.14E+01	4.85E-03
Terbufos	2.40E-05	288.5	0	NA	1.32E+09	10.00%							NA
Toluene	6.64E-03	92.1	1	1.24E-03	6.49E+02	10.00%							NA
Toxaphene	6.30E-02	413.8	0	NA	1.32E+09	10.00%	1.10E+00	1.12E+00	1.10E+00	2.92E-04	2.49E-08	4.50E-04	6.61E+02
Trifluralin	4.07E-07	335	0	NA	1.32E+09	10.00%	7.70E-03		7.70E-03	2.04E-06		3.15E-06	9.44E+04
1,2,4-trimethylbenzene	5.70E-03	120.19	1	4.03E-05	3.59E+03	10.00%							NA
1,3,5-trimethylbenzene	7.70E-03	120.19	1	2.46E-04	1.46E+03	10.00%							NA
Vanadium	0.00E+00	50.94	0	NA	1.32E+09	1.00%							NA
Xylene	7.34E-03	106.2	1	8.19E-04	7.98E+02	10.00%							NA
Zinc chloride (measured as Zinc)	0.00E+00	136	0	NA	1.32E+09	1.00%							NA
GA	1.50E-07	162.1	0	NA	1.32E+09	8.40%							NA

Table E-1: Estimated Soil Concentrations for Carcinogens

							Endpoint: Cancer						
Chemical	**H** atm-m^3/mole	**MW** (g/mole)	**VOC?***	**DA** (cm^2/s)	**VFs or PEF** (m^3/kg)	**ABS**	**CSF_{oral}** $(mg/kg/day)^{-1}$	**CSF_{inh}** $(mg/kg/day)^{-1}$	**CSF_{dermal}** $(mg/kg/day)^{-1}$	**Ingestion** (kg-kg)/mg	**Inhalation** (kg-kg)/mg	**Dermal** (kg-kg)/mg	**Sc** (mg/kg)
GB	5.34E-07	140.1	0	NA	1.32E+09	6.24%							NA
GD	4.56E-06	182.2	0	NA	1.32E+09	18.72%							NA
HD	2.10E-05	159.08	1	4.97E-06	1.02E+04	16.80%	7.70E+00	3.00E+02	7.70E+00	2.04E-03		5.29E-03	6.68E+01
Lewisite	3.20E-04	207.32	0	NA	1.32E+09	10.00%							NA
VX	3.50E-09	267.4	0	NA	1.32E+09	6.48%							NA

Notes:

H = Henry's Law Constant

MW = molecular weight

Volatile Organic Compound (If 1, then chemical is a volatile)

DA = apparent diffusivity

VFs = volatilization factor

PEL = particulate emission factor

ABS = soil absorption factor

CSF = cancer slop factor

Sc = soil concentration

NA = not applicable/not available

Target Risk	1.E-04	
Body Weight	70	kg
Exposure Duration	1	years
Exposure Frequency	365	days
Averaging time: cancer	25550	days
Soil Ingestion Rate	265	mg/day
Fraction Contaminated	1	fraction
Skin Surface Area	4090	cm^2
Soil-to-Skin AF	1	mg/cm^2
Inhalation Rate	29.2	m^3/day
Particulate Em Factor	1.32E+09	m^3/kg

Table E-2: Estimated Soil Concentrations for Noncarcinogens

							Endpoint: Noncancer						
Chemical	**H** atm-m^3/mole	**MW** (g/mole)	**VOC?***	**DA** (cm^2/s)	**VFs or PEF** (m^3/kg)	**ABS**	**RfD_{oral}** (mg/kg/day)	**RfD_{inh}** (mg/kg/day)	**RfD_{dermal}** (mg/kg/day)	**Ingestion** (kg-kg)/mg	**Inhalation** (kg-kg)/mg	**Dermal** (kg-kg)/mg	**Sc** (mg/kg)
Acenapthene	1.55E-04	154.21	1	4.71E-07	3.32E+04	10%	6.00E-02		6.0E-02	4.4E-03		6.82E-03	6.23E+03
Acenapthylene	1.13E-05	152.2	1	1.28E-07	6.38E+04	10%							NA
Acetone	3.88E-05	58.08	1	1.00E-04	1.30E+04	10%	1.00E+00		8.3E-01	2.7E-04		4.93E-04	9.24E+04
Alachlor	3.20E-08	269.8	0	NA	1.32E+09	10%	1.00E-02		1.0E-02	2.7E-02		4.09E-02	1.04E+03
Aldrin	1.27E-05	364.9	0	NA	1.32E+09	10%	2.86E-05		2.9E-05	9.3E+00		1.43E+01	2.97E+00
Anthracene	6.50E-05	178.23	1	3.20E-08	1.28E+05	10%	1.00E+01		1.0E+01	2.7E-05		4.09E-05	1.04E+06
Aroclor-1016	3.43E-04	257.9	0	NA	1.32E+09	10%	7.14E-05		7.1E-05	3.7E+00		5.73E+00	7.42E+00
Aroclor-1254	2.83E-04	327	0	NA	1.32E+09	10%	5.00E-05		5.0E-05	5.3E+00		8.18E+00	5.19E+00
Arsenic	0.00E+00	75	0	NA	1.32E+09	1%	4.29E-03			6.2E-02			1.13E+03
Benzene	5.55E-03	78.1	1	2.02E-03	5.08E+02	10%	3.00E-03		3.0E-03	8.8E-02		1.36E-01	3.12E+02
Benz(a)anthracene	8.00E-06	228.3	0	NA	1.32E+09	10%	3.00E-02			8.8E-03			7.92E+03
Benzo(a)pyrene	1.13E-06	252.3	0	NA	1.32E+09	10%	3.00E-02			8.8E-03			7.92E+03
Benzo(b)fluoranthene	1.11E-04	252.3	0	NA	1.32E+09	10%	3.00E-02			8.8E-03			7.92E+03
Benzo(k)fluoranthene	8.29E-07	252.3	0	NA	1.32E+09	10%	3.00E-02		3.0E-02	8.8E-03		1.36E-02	3.12E+03
Beryllium	0.00E+00	9	0	NA	1.32E+09	1%	4.43E-01	5.7E-06		6.0E-04	3.88E-03		1.56E+04
Bis(2-ethylhexyl)phthalate	1.02E-07	390.56	0	NA	1.32E+09	1%	2.00E-02		3.8E-02	1.3E-02		1.08E-02	2.92E+03
sec-Butylbenzene	1.90E-02	134.24	1	2.26E-04	1.52E+03	10%	1.00E-02	1.0E-02	1.0E-02	2.7E-02			2.64E+03
Cadmium	0.00E+00	112	0	NA	1.32E+09	1%	5.00E-04	1.0E-04		5.3E-01	2.17E-04		1.32E+02
Carbon disulfide	3.00E-02	76.1	1	1.06E-02	2.21E+02	10%	1.00E-02	2.0E-01	1.0E-02	2.7E-02		4.09E-02	1.04E+03
Chlordane	4.86E-05	409.8	0	NA	1.32E+09	10%	6.00E-04	2.0E-04	6.0E-04	4.4E-01	1.11E-04	6.82E-01	6.23E+01
Chloromethane	2.40E-02	51	1	1.14E-02	2.14E+02	10%	3.57E-02		3.6E-02	7.4E-03		1.15E-02	3.71E+03
Chlorothalonil	2.00E-07	265.9	0	NA	1.32E+09	10%	1.43E-02		1.4E-02	1.9E-02		2.86E-02	1.48E+03
Chromium (total)	0.00E+00	52	0	NA	1.32E+09	1%	2.14E-02	5.1E-03		1.2E-02	4.35E-06		5.66E+03
Chromium III	0.00E+00	52	0	NA	1.32E+09	1%	1.50E+00	5.1E-03		1.8E-04	4.35E-06		3.87E+05
Chromium VI	0.00E+00	52	0	NA	1.32E+09	1%	2.14E-02	2.9E-05		1.2E-02	7.77E-04		5.33E+03
Chrysene	9.46E-05	228.3	0	NA	1.32E+09	10%	3.00E-02		3.0E-02	8.8E-03		1.36E-02	3.12E+03
Cumene	1.20E+00	120.19	1	4.33E-03	3.47E+02	10%	4.00E-01	2.6E-02	4.0E-01	6.6E-04		1.02E-03	4.15E+04
Cyanide (TBMED)	4.22E-04	26.02	1	4.91E-05	3.26E+03	1%	4.29E-01			6.2E-04			1.13E+05
2,4-D (2,4-dichlorophenoxy acetic acid)	1.02E-08	221	0	NA	1.32E+09	10%	1.00E-02		1.0E-02	2.7E-02		4.09E-02	1.04E+03
p,p'-DDT	8.10E-06	354.5	0	NA	1.32E+09	10%	5.00E-04		5.0E-04	5.3E-01		8.18E-01	5.19E+01
Diazinon	1.17E-07	304.4	0	NA	1.32E+09	10%	5.00E-04		5.0E-04	5.3E-01		8.18E-01	5.19E+01
Dibromochloropropane	1.50E-04	236.4	0	NA	1.32E+09	10%	2.00E-03	5.7E-05	2.0E-03	1.3E-01	3.88E-04	2.05E-01	2.07E+02
Dieldrin	5.80E-05	381	0	NA	1.32E+09	10%	5.00E-05		5.0E-05	5.3E+00		8.18E+00	5.19E+00
1,3-Dinitrobenzene	2.33E-06	168.1	0	NA	1.32E+09	10%	4.29E-03		4.3E-03	6.2E-02		9.54E-02	4.45E+02
Dinoseb	5.04E-04	240.2	0	NA	1.32E+09	10%	1.00E-03		1.0E-03	2.7E-01		4.09E-01	1.04E+02
Disulfoton	1.10E-04	274.4	0	NA	1.32E+09	10%	2.86E-04		2.9E-04	9.3E-01		1.43E+00	2.97E+01
Endrin	4.00E-07	381	0	NA	1.32E+09	10%	4.29E-04		4.3E-04	6.2E-01		9.54E-01	4.45E+01

Table E-2: Estimated Soil Concentrations for Noncarcinogens

							Endpoint: Noncancer						
Chemical	**H** atm-m^3/mole	**MW** (g/mole)	**VOC?***	**DA** (cm^2/s)	**VFs or PEF** (m^3/kg)	**ABS**	**RfD_{oral}** (mg/kg/day)	**RfD_{inh}** (mg/kg/day)	**RfD_{dermal}** (mg/kg/day)	**Ingestion** (kg-kg)/mg	**Inhalation** (kg-kg)/mg	**Dermal** (kg-kg)/mg	**Sc** (mg/kg)
Ethyl benzene	7.88E-03	106.2	1	9.06E-04	7.58E+02	10%	1.00E-01	2.9E-01		2.7E-03			2.64E+04
Ethylene dibromide (EDB)	4.47E-04	187.9	1	4.79E-05	3.30E+03	10%	3.57E-06		3.6E-06	7.4E+01		1.15E+02	3.71E-01
Fenamiphos	1.20E-09	303.4	0	NA	1.32E+09	10%	5.00E-04		5.0E-04	5.3E-01		8.18E-01	5.19E+01
Fluoranthene	1.61E-05	202.3	0	NA	1.32E+09	10%	4.00E-01		4.0E-01	6.6E-04		1.02E-03	4.15E+04
Fluorene	7.70E-05	166.2	1	2.10E-07	4.98E+04	10%	4.00E-01		4.0E-01	6.6E-04		1.02E-03	4.15E+04
Fonofos	5.40E-06	246.3	0	NA	1.32E+09	10%	2.14E-03		2.1E-03	1.2E-01		1.91E-01	2.23E+02
Heptachlor	1.48E-03	373.3	0	NA	1.32E+09	10%	5.00E-04		5.0E-04	5.3E-01		8.18E-01	5.19E+01
Heptachlor epoxide	3.20E-05	389.3	0	NA	1.32E+09	10%	1.43E-05		1.4E-05	1.9E+01		2.86E+01	1.48E+00
Hexachlorobenzene	5.00E-02	284.8	0	NA	1.32E+09	10%	3.00E-04		3.0E-04	8.8E-01		1.36E+00	3.12E+01
Isopropylbenzene													
Lead	0.00E+00	207.2	0	NA	1.32E+09	1%							NA
Lead (Tetraethyl)	5.68E-01	323.45	0	NA	1.32E+09	1%	1.00E-07			2.7E+03			2.64E-02
Lindane (TriServ)	3.82E-06	290.85	0	NA	1.32E+09	10%	4.29E-02		4.3E-02	6.2E-03		9.54E-03	4.45E+03
Malathion	1.20E-07	330.4	0	NA	1.32E+09	10%	2.14E-02		2.1E-02	1.2E-02		1.91E-02	2.23E+03
Mercury (inorganic)	7.10E-03	201	0	NA	1.32E+09	1%	1.43E-04	8.6E-05	1.4E-04	1.9E+00	2.59E-04	2.86E-01	3.27E+01
Methyl ethyl ketone	2.70E-05	72.11	1	4.08E-05	3.57E+03	10%	6.00E-01	2.9E-01	6.0E-01	4.4E-04		6.82E-04	6.23E+04
Methylmercury	4.70E-07	215.63	0	NA	1.32E+09	10%	3.00E-04		3.0E-04	8.8E-01		1.36E+00	3.12E+01
Methylparathion	8.40E-08	263.21	0	NA	1.32E+09	10%	3.00E-03		3.0E-03	8.8E-02		1.36E-01	3.12E+02
Molybdenum trioxide	0.00E+00	143.95	0	NA	1.32E+09	10%	5.00E-03			5.3E-02			1.32E+03
Napthalene	4.83E-04	128.2	1	8.35E-06	7.90E+03	10.00%	3.57E-02	8.6E-04	3.6E-02	7.4E-03		1.15E-02	3.71E+03
Oxamyl (Vydate)	2.37E-10	219.3	0	NA	1.32E+09	10.00%	2.86E-02		2.9E-02	9.3E-03		1.43E-02	2.97E+03
Paraquat	1.00E-09	257.2	0	NA	1.32E+09	10.00%	4.29E-03			6.2E-02			1.13E+03
Phenanthrene	1.24E-04	178.2	1	7.58E-08	8.29E+04	10.00%	3.00E-01		3.0E-01	8.8E-04		1.36E-03	3.12E+04
Polychlorinated biphenyls (PCBs)	0.00E+00	292	0	NA	1.32E+09	10%	2.00E-05		2.0E-05	1.3E+01		2.05E+01	2.08E+00
n-Propyl benzene	1.30E-02	120.2	1	1.22E-04	2.07E+03	10%	1.00E-02	1.1E-02	1.0E-02	2.7E-02		4.09E-02	1.04E+03
Pyrene	1.10E-05	202.3	1	NA	1.32E+09	10.00%	3.00E-01		3.0E-01	8.8E-04		1.36E-03	3.12E+04
Simazine	3.40E-09	201.7	0	NA	1.32E+09	10.00%	5.00E-03		5.0E-03	5.3E-02		8.18E-02	5.19E+02
Strontium	0.00E+00	87.62	0	NA	1.32E+09	1.00%	6.00E-01	6.3E-01	6.0E-01	4.4E-04	3.53E-08	6.82E-05	1.37E+05
Sulfate	0.00E+00	98.08	0	NA	1.32E+09	1.00%	2.14E+01		2.1E+01	1.2E-05		1.91E-06	4.90E+06
2,3,7,8-TCDD (Dioxin)	1.60E-05	322	0	NA	1.32E+09	10.00%	2.00E-05		2.0E-05	1.3E+01		2.05E+01	2.08E+00
Terbufos	2.40E-05	288.5	0	NA	1.32E+09	10.00%	2.50E-05		2.5E-05	1.1E+01		1.64E+01	2.60E+00
Toluene	6.64E-03	92.1	1	1.24E-03	6.49E+02	10.00%	2.00E+00	1.1E-01	2.0E+00	1.3E-04		2.05E-04	2.08E+05
Toxaphene	6.30E-02	413.8	0	NA	1.32E+09	10.00%	1.00E-03		1.0E-03	2.7E-01		4.09E-01	1.04E+02
Trifluralin	4.07E-07	335	0	NA	1.32E+09	10.00%	7.14E-03		7.1E-03	3.7E-02		5.73E-02	7.42E+02
1,2,4-trimethylbenzene	5.70E-03	120.19	1	4.03E-05	3.59E+03	10.00%	5.00E-02	3.6E+01	5.0E-02	5.3E-03		8.18E-03	5.19E+03
1,3,5-trimethylbenzene	7.70E-03	120.19	1	2.46E-04	1.46E+03	10.00%	5.00E-02	3.6E+01	5.0E-02	5.3E-03		8.18E-03	5.19E+03
Vanadium	0.00E+00	50.94	0	NA	1.32E+09	1.00%	7.00E-03		7.0E-03	3.8E-02		5.84E-03	1.60E+03
Xylene	7.34E-03	106.2	1	8.19E-04	7.98E+02	10.00%	2.86E+00	4.4E+00	2.9E+00	9.3E-05		1.43E-04	2.97E+05

Table E-2: Estimated Soil Concentrations for Noncarcinogens

							Endpoint: Noncancer						
Chemical	**H** atm-m^3/mole	**MW** (g/mole)	**VOC?***	**DA** (cm^2/s)	**VFs or PEF** (m^3/kg)	**ABS**	**RfD_{oral}** (mg/kg/day)	**RfD_{inh}** (mg/kg/day)	**RfD_{dermal}** (mg/kg/day)	**Ingestion** (kg-kg)/mg	**Inhalation** (kg-kg)/mg	**Dermal** (kg-kg)/mg	**Sc** (mg/kg)
Zinc chloride (measured as Zinc)	0.00E+00	136	0	NA	1.32E+09	1.00%	3.00E-01		3.0E-01	8.8E-04		1.36E-04	6.86E+04
GA	1.50E-07	162.1	0	NA	1.32E+09	8.40%	4.00E-05	9.0E-07	4.0E-05	6.6E+00	2.47E-02	8.59E+00	4.59E+00
GB	5.34E-07	140.1	0	NA	1.32E+09	6.24%	2.00E-05	9.0E-07	2.0E-05	1.3E+01	2.47E-02	1.28E+01	2.69E+00
GD	4.56E-06	182.2	0	NA	1.32E+09	18.72%	4.00E-06	3.0E-07	4.0E-06	6.6E+01	7.40E-02	1.91E+02	2.72E-01
HD	2.10E-05	159.08	1	4.97E-06	1.02E+04	16.80%	7.00E-06	3.0E-05	7.0E-06	3.8E+01		9.82E+01	5.15E-01
Lewisite	3.20E-04	207.32	0	NA	1.32E+09	10.00%	1.00E-04	8.6E-04	1.0E-04	2.7E+00	2.58E-05	4.09E+00	1.04E+01
VX	3.50E-09	267.4	0	NA	1.32E+09	6.48%	6.00E-07	9.0E-08	6.0E-07	4.4E+02	2.47E-01	4.42E+02	7.92E-02

Notes:

H = Henry's Law Constant

MW = molecular weight

Volatile Organic Compound (If 1, then chemical is a volatile)

DA = apparent diffusivity

VFs = volatilization factor

PEL = particulate emission factor

ABS = soil absorption factor

RfD = reference dose

Sc = soil concentration

NA = not applicable/not available

Table E-2 Technical Notes

Target Hazard Index	1	
Body Weight	70	kg
Exposure Duration	1	years
Exposure Frequency	365	days
Averaging time: noncancer	365	days
Soil Ingestion Rate	265	mg/day
Fraction Contaminated	1	fraction
Skin Surface Area	4090	cm2
Soil-to-Skin AF	1	mg/cm2
Inhalation Rate	29.2	m^3/day
Particulate Em Factor	1.32E+09	m3/kg

Table E-3: Soil-MEG Calculations

	Cancer	Noncancer				Acute Consideration		
Chemical	Sc (mg/kg)	Sc (mg/kg)	Csat (mg/kg)	MSG-L (mg/kg)	Soil-MEG Criterion	Soil Intake (mg/kg/d)	RfDacute (mg/kg/d)	Is acute exp a concern?
Acenapthene	NA	6.23E+03	1.25E+02	1.3E+02	Csat	4.73E-04		
Acenapthylene	ND	ND	ND	ND	ND			
Acetone	ND	9.24E+04	1.59E+01	1.59E+01	Csat	6.03E-05		
Alachlor	9.09E+03	1.04E+03	NA	1.0E+03	nc	3.93E-03	1.00E-02	no
Aldrin	4.28E+01	2.97E+00	NA	3.0E+00	nc	1.12E-05	2.86E-05	no
Anthracene	NA	1.04E+06	6.12E+00	6.1E+00	Csat	2.32E-05		
Aroclor-1016	NA	7.42E+00	NA	7.4E+00	nc	2.81E-05		
Aroclor-1254	NA	5.19E+00	NA	5.2E+00	nc	1.97E-05		
Arsenic	1.23E+03	1.13E+03	NA	1.1E+03	nc	4.29E-03		no
Benzene	2.51E+04	3.12E+02	9.00E+02	3.1E+02	nc	1.18E-03	2.14E-02	no
Benz(a)anthracene	2.53E+03	7.92E+03	NA	2.5E+03	c	9.59E-03		
Benzo(a)pyrene	2.53E+02	7.92E+03	NA	2.5E+02	c	9.59E-04		
Benzo(b)fluoranthene	2.53E+03	7.92E+03	NA	2.5E+03	c	9.59E-03		
Benzo(k)fluoranthene	9.96E+03	3.12E+03	NA	3.1E+03	nc	3.77E-02		
Beryllium	2.63E+06	1.56E+04	NA	1.6E+04	nc	5.91E-02	2.57E+00	no
Bis(2-ethylhexyl)phthalate	1.45E+04	2.92E+03	NA	2.9E+03	nc	1.10E-02		
sec-Butylbenzene	NA	2.64E+03	2.25E+02	2.3E+02	Csat	8.52E-04		
Cadmium	3.51E+06	1.32E+02	NA	1.3E+02	nc	5.00E-04	4.29E-03	no
Carbon disulfide	NA	1.04E+03	7.20E+02	7.2E+02	Csat	2.72E-03	1.00E-02	no
Chlordane	2.08E+03	6.23E+01	NA	6.2E+01	nc	2.36E-04	6.43E-03	no
Chloromethane	5.59E+04	3.71E+03	4.05E+03	3.7E+03	nc	1.40E-02	8.57E-01	no
Chlorothalonil	6.61E+04	1.48E+03	NA	1.5E+03	nc	5.62E-03	2.50E-02	no
Chromium (total)	NA	5.66E+03	NA	5.7E+03	nc	2.14E-02	1.43E-01	no
Chromium III	NA	3.87E+05	NA	3.9E+05	nc	1.46E+00		
Chromium VI	5.26E+05	5.33E+03	NA	5.3E+03	nc	2.97E-03		
Chrysene	9.96E+04	3.12E+03	NA	3.1E+03	nc	3.77E-01		
Cumene	NA	4.15E+04	6.43E+02	6.4E+02	Csat	2.44E-03		

Table E-3: Soil-MEG Calculations

	Cancer	Noncancer				Acute Consideration		
Chemical	**Sc (mg/kg)**	**Sc (mg/kg)**	**Csat (mg/kg)**	**MSG-L (mg/kg)**	**Soil-MEG Criterion**	**Soil Intake (mg/kg/d)**	**RfDacute (mg/kg/d)**	**Is acute exp a concern?**
Cyanide (TBMED)	NA	1.13E+05	1.00E+07	1.1E+05	nc	4.29E-01	4.29E-01	no
2,4-D (2,4-dichlorophenoxy acetic ac	NA	1.04E+03	NA	1.0E+03	nc	3.93E-03	1.07E-01	no
p,p'-DDT	2.14E+03	5.19E+01	NA	5.2E+01	nc	1.97E-04	5.00E-04	no
Diazinon	NA	5.19E+01	NA	5.2E+01	nc	1.97E-04	2.14E-03	no
Dibromochloropropane	5.19E+02	2.07E+02	NA	2.1E+02	nc	7.85E-04	2.00E-02	no
Dieldrin	4.54E+01	5.19E+00	NA	5.2E+00	nc	1.97E-05	5.00E-05	no
1,3-Dinitrobenzene	NA	4.45E+02	NA	4.5E+02	nc	1.69E-03	4.29E-03	no
Dinoseb	NA	1.04E+02	NA	1.0E+02	nc	3.93E-04	3.00E-02	no
Disulfoton	NA	2.97E+01	NA	3.0E+01	nc	9.83E-05	1.00E-03	no
Endrin	NA	4.45E+01	NA	4.5E+01	nc	1.69E-04	2.50E-03	no
Ethyl benzene	NA	2.64E+04	2.34E+02	2.3E+02	Csat	8.86E-04		
Ethylene dibromide (EDB)	8.55E+00	3.71E-01	1.79E+03	3.7E-01	nc	1.40E-06	7.14E-04	no
Fenamiphos	NA	5.19E+01	NA	5.2E+01	nc	1.97E-04	9.29E-04	no
Fluoranthene	NA	4.15E+04	NA	4.2E+04	nc	1.57E-02		
Fluorene	NA	4.15E+04	9.03E+01	9.0E+01	Csat	3.42E-04		
Fonofos	NA	2.23E+02	NA	2.2E+02	nc	8.43E-04	2.14E-03	no
Heptachlor	1.62E+02	5.19E+01	NA	5.2E+01	nc	1.97E-04	1.00E-03	no
Heptachlor epoxide	7.99E+01	1.48E+00	NA	1.5E+00	nc	5.06E-06	1.00E-03	no
Hexachlorobenzene	4.54E+02	3.12E+01	NA	3.1E+01	nc	1.18E-04	5.71E-03	no
Lead	NA	NA	NA	See Text				
Lead (Tetraethyl)	NA	2.64E-02	NA	2.6E-02	nc	1.00E-07		
Lindane (TriServ)	5.59E+02	4.45E+03	NA	5.6E+02	c	2.12E-03	4.29E-02	no
Malathion	NA	2.23E+03	NA	2.2E+03	nc	8.43E-03	2.14E-02	no
Mercury (inorganic)	NA	3.27E+01	NA	3.3E+01	nc	4.95E-05	1.00E-02	no
Methyl ethyl ketone	NA	6.23E+04	3.43E+04	3.4E+04	Csat	1.30E-01		
Methylmercury	NA	3.12E+01	NA	3.1E+01	nc	1.18E-04		
Methylparathion	NA	3.12E+02	NA	3.1E+02	nc	1.18E-03	2.86E-02	no
Molybdenum trioxide	NA	1.32E+03	NA	1.3E+03	nc	5.00E-03	5.00E-03	no
Napthalene	NA	3.71E+03	2.25E+02	2.2E+02	Csat	8.51E-04		

Table E-3: Soil-MEG Calculations

	Cancer	Noncancer				Acute Consideration		
Chemical	**Sc (mg/kg)**	**Sc (mg/kg)**	**Csat (mg/kg)**	**MSG-L (mg/kg)**	**Soil-MEG Criterion**	**Soil Intake (mg/kg/d)**	**RfDacute (mg/kg/d)**	**Is acute exp a concern?**
Oxamyl (Vydate)	NA	2.97E+03	NA	3.0E+03	nc	9.83E-03	2.50E-02	no
Paraquat	NA	1.13E+03	NA	1.1E+03	nc	4.29E-03	1.00E-02	no
Phenanthrene	NA	3.12E+04	2.68E+02	2.7E+02	Csat	1.01E-03		
Polychlorinated biphenyls (PCBs)	3.63E+02	2.08E+00	NA	2.1E+00	nc	7.86E-06		
n-propylbenzene	NA	1.04E+03	2.41E+02	2.4E+02	Csat	9.12E-04		
Pyrene	NA	3.12E+04	NA	3.1E+04	nc	1.18E-02		
Simazine	6.06E+03	5.19E+02	NA	5.2E+02	nc	1.97E-03	5.00E-03	no
Strontium	NA	1.37E+05	NA	1.4E+05	nc	5.20E-01		
Sulfate	NA	4.90E+06	NA	1.0E+06	nc	3.79E+00	2.14E+01	no
2,3,7,8-TCDD (Dioxin)	4.85E-03	2.08E+00	NA	4.8E-03	c	1.83E-08	7.14E-08	no
Terbufos	NA	2.60E+00	NA	2.6E+00	nc	9.83E-06	5.00E-04	no
Toluene	NA	2.08E+05	5.21E+02	5.2E+02	Csat	1.97E-03		
Toxaphene	6.61E+02	1.04E+02	NA	1.0E+02	nc	3.93E-04	5.00E-03	no
Trifluralin	9.44E+04	7.42E+02	NA	7.4E+02	nc	2.81E-03	7.14E-03	no
1,2,4-trimethylbenzene	NA	5.19E+03	5.76E+00	5.8E+00	Csat	2.18E-05		
1,3,5-trimethylbenzene	NA	5.19E+03	2.53E+02	2.5E+02	Csat	9.58E-04		
Vanadium	NA	1.60E+03	NA	1.6E+03	nc	6.06E-03		
Xylene	NA	2.97E+05	2.14E+02	2.1E+02	Csat	8.12E-04		
Zinc chloride (measured as Zinc)	NA	6.86E+04	NA	6.9E+04	nc	2.60E-01	5.71E-01	no
GA	NA	4.59E+00	NA	4.6E+00	nc	1.74E-05		
GB	NA	2.69E+00	NA	2.7E+00	nc	1.02E-05		
GD	NA	2.72E-01	NA	2.7E-01	nc	1.03E-06		
HD	6.68E+01	5.15E-01	8.26E+02	5.1E-01	nc	1.95E-06		
Lewisite	NA	1.04E+01	NA	1.0E+01	nc	3.93E-05		
VX	NA	7.92E-02	NA	7.9E-02	nc	3.00E-07		

Table E-3: Soil-MEG Calculations

	Cancer	Noncancer				Acute Consideration		
Chemical	**Sc (mg/kg)**	**Sc (mg/kg)**	**Csat (mg/kg)**	**MSG-L (mg/kg)**	**Soil-MEG Criterion**	**Soil Intake (mg/kg/d)**	**RfDacute (mg/kg/d)**	**Is acute exp a concern?**

Notes:

Sc = soil concentration

NA = not applicable/not available

ND = no toxicity data

Csat = soil saturation concentration

MSG-L = military soil guideline-long-term

Table E-4: Toxicity Information

	Ingestion			Inhalation			Dermal			
Chemical	**RfDoral (mg/kg/day)**	**WOE**	**CSForal (mg/kg/day)-1**	**CSFinh (mg/kg/day)-1**	**RfC (mg/m^3)**	**RfD (mg/kg/day)**	**ACGIH Skin Notation**	**GI ABS %**	**CSFdermal (mg/kg/d)-1**	**RfDdermal (mg/kg/day)**
Acenapthene	6.0E-02						nd	100%		6.00E-02
Acenapthylene		D					nd	100%		
Acetone	1.0E+00	D					nd	100%		8.30E-01
Alachlor	1.0E-02	B2	8.00E-02				nd	100%	8.00E-02	1.00E-02
Aldrin	2.9E-05	B2	1.70E+01	1.72E+01			y	100%	1.70E+01	2.86E-05
Anthracene	1.0E+01	D					nd	100%		1.00E+01
Aroclor-1016	7.1E-05						nd	100%		7.14E-05
Aroclor-1254	5.0E-05						y	100%		5.00E-05
Arsenic	4.3E-03	A	1.50E+00	1.51E+01			n	100%		
Benzene	3.0E-03	A	2.90E-02	2.73E-02			y	100%	2.90E-02	3.00E-03
Benz(a)anthracene	3.0E-02	B2	7.30E-01	3.08E-01			n	100%		
Benzo(a)pyrene	3.0E-02	B2	7.30E+00	3.08E+00			n	100%		
Benzo(b)fluoranthene	3.0E-02	B2	7.30E-01	3.08E-01			n	100%		
Benzo(k)fluoranthene	3.0E-02	B2	7.30E-02	3.08E-02			nd	100%	7.30E-02	3.00E-02
Beryllium	4.4E-01	B1		8.40E+00	2.00E-05	5.71E-06	n	100%		
Bis(2-ethylhexyl)phthalate	2.0E-02	B2	1.40E-02				y	100%	7.37E-02	3.80E-02
Sec-Butylbenzene	1.0E-02	D			3.50E-02	1.00E-02	nd	100%		1.00E-02
Cadmium	5.0E-04	B1		6.30E+00	3.57E-04	1.02E-04	n	100%		
Carbon disulfide	1.0E-02				7.00E-01	2.00E-01	y	100%		1.00E-02
Chlordane	6.0E-04	B2	3.50E-01	3.50E-01	7.00E-04	2.00E-04	y	100%	3.50E-01	6.00E-04
Chloromethane	3.6E-02	C	1.30E-02	6.30E-03			y	100%	1.30E-02	3.57E-02
Chlorothalonil	1.4E-02	B2	1.10E-02				nd	100%	1.10E-02	1.43E-02
Chromium (total)	2.1E-02	D			1.79E-02	5.10E-03	n	100%		
Chromium III	1.5E+00	D			1.79E-02	5.10E-03	n	100%		
Chromium VI (particulate)	2.1E-02	A		4.20E+01	1.00E-04	2.86E-05	n	100%		
Chrysene	3.0E-02	B2	7.30E-03	3.08E-03			y	100%	7.30E-03	3.00E-02
Cumene	4.0E-01	D			9.00E-02	2.57E-02	nd	100%		4.00E-01
Cyanide (TBMED)	4.3E-01	D					n	100%		
2,4-D (2,4-dichlorophenoxy acetic acid)	1.0E-02	D					nd	100%		1.00E-02
p,p'-DDT	5.0E-04	B2	3.40E-01	3.40E-01			nd	100%	3.40E-01	5.00E-04
Diazinon	5.0E-04	E					y	100%		5.00E-04
Dibromochloropropane	2.0E-03	B2	1.40E+00	2.35E-03	2.00E-04	5.71E-05	nd	100%	1.40E+00	2.00E-03
Dieldrin	5.0E-05	B2	1.60E+01	1.61E+01			y	100%	1.60E+01	5.00E-05
1,3-Dinitrobenzene	4.3E-03	D					y	100%		4.29E-03
Dinoseb	1.0E-03	D					nd	100%		1.00E-03

Table E-4: Toxicity Information

	Ingestion			Inhalation			Dermal			
Chemical	**RfDoral (mg/kg/day)**	**WOE**	**CSForal (mg/kg/day)-1**	**CSFinh (mg/kg/day)-1**	**RfC (mg/m^3)**	**RfD (mg/kg/day)**	**ACGIH Skin Notation**	**GI ABS %**	**CSFdermal (mg/kg/d)-1**	**RfDdermal (mg/kg/day)**
Disulfoton	2.9E-04						y	100%		2.86E-04
Endrin	4.3E-04	D					y	100%		4.29E-04
Ethyl benzene	1.0E-01	D			1.00E+00	2.86E-01	n	100%		
Ethylene dibromide (EDB)	3.6E-06	B2	8.50E+01	7.70E-01			y	100%	8.50E+01	3.57E-06
Fenamiphos	5.0E-04						y	100%		5.00E-04
Fluoranthene	4.0E-01	D					nd	100%		4.00E-01
Fluorene	4.0E-01	D					nd	100%		4.00E-01
Fonofos	2.1E-03						y	100%		2.14E-03
Heptachlor	5.0E-04	B2	4.50E+00	4.55E+00			y	100%	4.50E+00	5.00E-04
Heptachlor epoxide	1.4E-05	B2	9.10E+00	9.10E+00			y	100%	9.10E+00	1.43E-05
Hexachlorobenzene	3.0E-04	B2	1.60E+00	1.61E+00			y	100%	1.60E+00	3.00E-04
Lead		B2					n	100%		
Lead (Tetraethyl)	1.0E-07						n	100%		
Lindane (TriServ)	4.3E-02	B2-C	1.30E+00				y	100%	1.30E+00	4.29E-02
Malathion	2.1E-02						y	100%		2.14E-02
Mercury (inorganic)	1.4E-04	D			3.00E-04	8.57E-05	y	100%		1.43E-04
Methyl ethyl ketone	6.0E-01	D			1.00E+00	2.86E-01	nd	100%		6.00E-01
Methylmercury	3.0E-04	C					nd	100%		3.00E-04
Methylparathion	3.0E-03						y	100%		3.00E-03
Molybdenum trioxide	5.0E-03						n	100%		
Napthalene	3.6E-02	C			3.00E-03	8.57E-04	y	100%		3.57E-02
Oxamyl (Vydate)	2.9E-02						nd	100%		2.86E-02
Paraquat	4.3E-03	C					n	100%		
Phenanthrene	3.0E-01	D					nd	100%		3.00E-01
Polychlorinated biphenyls (PCBs)	2.0E-05	B2	2.00E+00	2.00E+00			y	100%	2.00E+00	2.00E-05
n-propylbenzene	1.0E-02	D			3.70E-02	1.06E-02	nd	100%		1.00E-02
Pyrene	3.0E-01	D					nd	100%		3.00E-01
Simazine	5.0E-03	C	1.20E-01				nd	100%	1.20E-01	5.00E-03
Strontium	6.0E-01				2.20E+00	6.29E-01	nd	100%		6.00E-01
Sulfate	2.1E+01						nd	100%		2.14E+01
2,3,7,8-TCDD (Dioxin)	2.0E-05	B2	1.50E+05	1.50E+05			nd	100%	1.50E+05	2.00E-05
Terbufos	2.5E-05						nd	100%		2.50E-05
Toluene	2.0E+00	D			4.00E-01	1.14E-01	y	100%		2.00E+00
Toxaphene	1.0E-03	B2	1.10E+00	1.12E+00			y	100%	1.10E+00	1.00E-03
Trifluralin	7.1E-03	C	7.70E-03				nd	100%	7.70E-03	7.14E-03
1,2,4-trimethylbenzene	5.0E-02				1.25E+02	3.57E+01	nd	100%		5.00E-02
1,3,5-trimethylbenzene	5.0E-02				1.25E+02	3.57E+01	nd	100%		5.00E-02

Table E-4: Toxicity Information

	Ingestion				Inhalation		Dermal			
Chemical	**RfDoral (mg/kg/day)**	**WOE**	**CSForal (mg/kg/day)-1**	**CSFinh (mg/kg/day)-1**	**RfC (mg/m^3)**	**RfD (mg/kg/day)**	**ACGIH Skin Notation**	**GI ABS %**	**CSFdermal (mg/kg/d)-1**	**RfDdermal (mg/kg/day)**
Vanadium	7.0E-03						nd	100%		7.00E-03
Xylene	2.9E+00	D			1.55E+01	4.43E+00	y	100%		2.86E+00
Zinc chloride (measured as Zinc)	3.0E-01	D					nd	100%		3.00E-01
GA	4.0E-05					9.00E-07	nd	100%		4.00E-05
GB	2.0E-05					9.00E-07	nd	100%		2.00E-05
GD	4.0E-06					3.00E-07	nd	100%		4.00E-06
HD	7.0E-06		7.70E+00	3.00E+02		3.00E-05	nd	100%	7.70E+00	7.00E-06
Lewisite	1.0E-04					8.60E-04	nd	100%		1.00E-04
VX	6.0E-07					9.00E-08	nd	100%		6.00E-07

Table E-4: Toxicity Information

	Ingestion			Inhalation		Dermal			
Chemical	**RfDoral (mg/kg/day)**	**WOE**	**CSForal (mg/kg/day)-1**	**CSFinh (mg/kg/day)-1**	**RfC (mg/m^3)**	**RfD (mg/kg/day)**	**ACGIH Skin Notation**	**GI ABS %**	**CSFdermal (mg/kg/d)-1**	**RfDdermal (mg/kg/day)**
Notes:										
RfD = reference dose										
WOE = weight of evidence										
CSF = cancer slope factor										
RfC = reference concentration										
nd = no data										

Table E-5: Physical and Chemical Data for Soil-MEG Chemicals

Chemical	H' unitless	Ref	Da cm2/s	Ref	Dw cm^2/s	Ref	log Kow	Ref	Koc cm^3/g	Ref	Kd cm^3/g	Ref	VP mm Hg	Ref	S mg/L	Ref	DA cm2/s
Acenapthene	6.36E-03	e	4.21E-02	e	7.69E-06	e	3.92	a	4898	e	2.94E+01	e			4.24	e	4.71E-07
Acenapthylene	4.63E-04	h	6.67E-02	n	7.72E-06	n	4.07	c	2.13E+03	c	1.28E+01	b	9.12E-04	c @25C	16.1	c @25C	1.28E-07
Acetone	1.59E-03	p	1.24E-01	p	1.14E-05	p	-0.24	p	5.80E-01	e	3.50E-03	e	2.31E+02	c	1.00E+06	e	9.91E-05
Alachlor	1.31E-06	h	4.55E-02	n	5.27E-06	n	3.53	c	2.28E+00	c	1.37E-02	b	2.20E-05	c	1.40E+02	c	3.27E-07
Aldrin	6.97E-03	a	1.32E-02	a	4.86E-06	a	6.5	c	4.45E+06	a	4.87E+02	L	2.20E-08	L	0.18	a	9.84E-09
Anthracene	2.67E-03	e	3.24E-02	e	7.74E-06	e			23500	e	1.41E+02	e			0.0434	e	3.20E-08
Aroclor-1016	1.41E-02	h	4.69E-02	L	5.43E-06	L	4.38	c	111550	c	2.32E+02	L	0.0004	c	2.63E-01	c @ 25C	1.47E-07
Aroclor-1254	1.16E-02	h	4.00E-02	L	4.64E-06	L	6.3	c	42500	c	9.83E+04	L	0.000077	c	12	c @ 25C	2.45E-10
Arsenic	0.00E+00	h	1.07E-01	L	1.24E-05	L					2.90E+01	L @ pH 6.8	0		0	c	2.76E-09
Benzene	2.28E-01	e	8.80E-02	e	9.80E-06	e	2.13	c	62	e	3.72E-01	e	100	c @ 26.1C	1.75E+03	e	2.02E-03
Benz(a)anthracene	3.28E-04	h	5.10E-02	a	9.00E-06	a	5.7	a	3.98E+05	a	2.60E+03	L			9.40E-03	a	3.56E-10
Benzo(a)pyrene	4.63E-05	h	4.30E-02	a	9.00E-06	a	6.11	a	1020000	a	9.69E+03	L			0.00162	a	1.67E-11
Benzo(b)fluoranthene	4.55E-03	h	2.26E-02	a	5.56E-06	a	6.2	a	1.23E+06	a	8.36E+03	L			1.50E-03	a	6.41E-10
Benzo(k)fluoranthene	3.40E-05	h	2.26E-02	a	5.56E-06	a	6.20	a	1230000	a	8.32E+03	a			0.0008	a	9.10E-12
Bis(2-ethylhexyl)phthalate	4.18E-06	p	3.51E-02	p	3.66E-06	p	7.60	c	15100000	p			9.75E-06	c	0.285	c	
Beryllium	0.00E+00	h	4.39E-01	L	5.08E-05	L					7.90E+02	L @ pH 6.8	0	c	0	c	4.16E-10
sec-Butylbenzene	7.70E-01	e	7.50E-02	e	7.80E-06	e			2200	e	1.30E+01	e			17	e	2.26E-04
Cadmium	0.00E+00	h	8.16E-02	L	9.45E-06	L					7.50E+01	L @ pH 6.8	0	c	0	c	8.14E-10
Carbon disulfide	1.23E+00	e	1.00E-01	e	1.00E-05	e	1.94	c	46	e	2.70E-01	e	359	c @ 25C	1200	e	1.06E-02
Chlordane	1.99E-03	a	1.18E-02	a	4.37E-06	a	5.16	c	120000	a	5.13E+02	L	9.75E-06	c @ 25C	5.60E-02	a	2.42E-09
Chloromethane	9.84E-01	e	1.10E-01	e	6.50E-06	e	0.91	c	3.50E+01	e	2.10E-01	e	4.30E+03	c @ 25C	8.20E+03	e	1.14E-02
Chlorothalonil	8.20E-06	h	4.59E-02	n	5.32E-06	n	2.64	c	1.80E+03	c	1.08E+01	b	1.00E-02	c < @40C	0.6	c @ 25C	4.95E-09
Chromium (total)	0.00E+00	h	1.01E-01	L	4.63E-05	L					1.80E+06	L @ pH 6.8	0.00E+00	c	0	c	1.66E-13
Chromium III	0.00E+00		3.94E-01	d	4.64E-05	d					1.80E+06	Cr(total)	0		0	c	1.67E-13
Chromium VI (particulate)	0.00E+00	h	1.36E-01	L	1.58E-05	L					1.90E+01	L @ pH 6.8	0.00E+00	c	0	c	5.35E-09
Chrysene	3.88E-03	e	2.48E-02	e	6.21E-06	e			398000	e	2.39E+03	e			0.0016	e	2.10E-09
Cumene	4.90E+01	e	1.80E-02	e	7.10E-06	e	3.5	p	220	e	1.30E+00	e	4.50E+00	c	61	e	4.33E-03
Cyanide (TBMED)	1.73E-02	h	5.48E-01	L	2.10E-05	L	1.74	d			9.90E+00	a	6200	d	1000000	d	4.91E-05
2,4-D (2,4-dichlorophenoxy acetic acid)	4.18E-07	h	8.71E-01	d	7.77E-06	d	2.81	c	19.6	c	1.18E-01	b	0.0000825	c	5.40E+02	c @25C	3.18E-07
p,p'-DDT	3.32E-04	a	1.37E-02	a	4.95E-06	a	6.91	c	2630000	a	6.78E+03	L	1.60E-07	c @20 C	0.025	a	3.95E-11

Table E-5: Physical and Chemical Data for Soil-MEG Chemicals

Chemical	H' unitless	Ref	Da cm2/s	Ref	Dw cm^2/s	Ref	log Kow	Ref	Koc cm^3/g	Ref	Kd cm^3/g	Ref	VP mm Hg	Ref	S mg/L	Ref	DA cm2/s
Diazinon	4.80E-06	h	1.71E-02	L	5.24E-06	L	3.81	c	191	c	1.33E+01	L	0.0000901	c	4.00E+01	c @25C	2.85E-09
Dibromochloropropane	6.15E-03	h	1.79E-02	L	8.79E-06	L	2.96	c	9.80E+01	c	9.47E-01	L	5.80E-01	c @ 20C	1230	c @20C	5.49E-06
Dieldrin	6.19E-04	a	1.25E-02	a	4.74E-06	a	5.4	c	21400	a	2.55E+02	L	5.89E-06	c @ 25C	0.195	a	1.69E-09
1,3-Dinitrobenzene	9.55E-05	h	3.18E-02	L	9.15E-06	L	1.49	c	2.45E+01	c	2.06E-01	L	5.13E-06	c	0.0022	c	7.07E-07
Dinoseb	2.07E-02	h	4.92E-02	n	5.69E-06	n	3.69	d	1.24E+02	c	7.44E-01	b	0.00E+00	@25 C	52	c	6.21E-05
Disulfoton	4.51E-03	h	4.50E-02	L	5.21E-06	L	4.02	c	7.40E+02	c	1.80E+01	L	0.000054	c	12	c @20C	5.82E-07
Endrin	1.64E-05	h	1.07E-02	L	5.76E-06	L	5.2	c	3.40E+04	c	1.08E+02	L	0.0000002	c	0.2	c	4.29E-10
Ethyl benzene	3.23E-01	e	7.50E-02	e	7.80E-06	e			2.04E+02	e	1.22E+00	e			169	e	9.06E-04
Ethylene dibromide (EDB)	1.83E-02	h	2.17E-02	L	1.19E-05	L	1.96	c	87	c	3.28E-01	L	11.2	c	4150	c@25C	4.79E-05
Fenamiphos	4.92E-08	h	4.21E-02	n	4.87E-06	n	3.23	c	1497.5109	a	8.99E+00	b	1.00E-06	c @ 25C	700	c @ 25C	3.48E-09
Fluoranthene	6.60E-04	h	3.02E-02	a	6.35E-06	a	5.12	a	107000	a	4.91E+02	L			2.06E-01	a	2.19E-09
Fluorene	3.16E-03	e	6.08E-02	e	7.88E-06	e			7900	e	4.74E+01	e			1.9	e	2.10E-07
Fonofos	2.21E-04	h	4.84E-02	n	5.60E-06	n	3.94	c	870.96359	c	5.23E+00	b	1.88E-04	c @ 25 C	13	c @ 22C	1.11E-07
Heptachlor	6.07E+01	a	1.12E-02	a	5.59E-06	a	5.5	c	1410000	a	9.53E+01	L	0.0004	c @ 25 C	0.18	a	3.30E-04
Heptachlor epoxide	3.90E-04	a	1.32E-02	a	4.23E-06	a	5.4	c	83200	a	7.18E+01	L	1.09E-05	c @ 20C	2.00E-01	a	4.09E-09
Hexachlorobenzene	2.05E+00	h	1.41E-02	L	7.84E-06	L	5.31	c	3.16E+04	c	8.00E+02	L	0.000012312	L	0.035	c	1.87E-06
Lead	0.00E+00	h	5.43E-02	L	6.28E-06	L					9.00E+02	L	0	c	0	L	4.51E-11
Lead (Tetraethyl)	2.33E+01	h	4.03E-02	n	4.67E-06	n			8.62E+03	c	5.17E+01	b	2.00E-01	c	0.29	c @ 25C	8.65E-04
Lindane (TriServ)	5.74E-04	a	1.42E-02	a	7.34E-06	a	3.72	c	1.07E+03	a	6.42E+00	b	9.40E-06	c @ 20C	6.80E+00	a	7.20E-08
Malathion	4.92E-06	h	1.47E-02	L	5.29E-06	L	2.36	c	2.80E+02	c	9.81E-01	L	4.00E-05	c @ 25 C	145	c @ 20 C	3.51E-08
Mercury (inorganic)	4.67E-01	a	3.07E-02	a	6.30E-06	a					1.00E+03	L	0.002	c @ 25 C	0.0562	L	7.42E-07
Methyl ethyl ketone	1.10E-03	e	9.00E-02	e	9.80E-06	e	0.29	c	4.50E+00	e	2.70E-02	e	91	c	270000	e	4.08E-05
Methylmercury	1.93E-05	h	5.28E-02	L	6.11E-06	L					7.00E+03	L					1.32E-11
Methylparathion	3.44E-06	h	1.87E-02	L	6.43E-06	L	2.86	c	9.41E+02	c	2.40E+00	L	1.50376E-06	c @ 20C	55	c @ 20 C	1.80E-08
Molybdenum trioxide	0.00E+00	h	6.92E-02	n	8.01E-06	n					2.00E+01	o-for Mo	20	I	1066	c @ 18C	2.58E-09
Napthalene	1.98E-02	e	5.90E-02	e	7.50E-06	e			1.19E+03	e	7.15E+00	e			3.10E+01	e	8.35E-06
Oxamyl (Vydate)	9.72E-09	h	5.22E-02	n	6.05E-06	n	-0.47	c	1.30E+01	c	7.80E-02	b	0.00023	c @ 25C	2.80E+05	c @ 25C	2.20E-07
Paraquat	4.10E-08	h	4.70E-02	n	5.44E-06	n	-4.22	c	5.08E+05	c	3.05E+03	b					1.16E-11
Phenanthrene	5.08E-03	h	6.00E-02	n	6.95E-06	n	4.57	c	2.09E+04	L	2.09E+02	L			1.28E+00	L	7.58E-08
Polychlorinated biphenyls (PCBs)			4.32E-02	n	5.00E-06	n	5.58	a	3.09E+05	a	1.85E+03	b			7.00E-01	a	1.74E-11
n-propylbenzene	5.40E-01	e	7.50E-02	e	7.80E-06	e	3.57	c	2.80E+03	e	1.70E+01	e	1	c@ 6.3 C	1.40E+01	e	1.22E-04
Pyrene	4.51E-04	e	2.72E-02	e	7.24E-06	e			6.80E+04	e	4.08E+02	e			1.35E-01	e	1.67E-09
Simazine	1.39E-07	h	5.52E-02	n	6.40E-06	n	2.18	c	1.82E+03	c	1.09E+01	b	0.000000022	c @ 25 C	6.20E+00	c @ 20 C	3.79E-09
Strontium																	0.00E+00
Sulfate			1.62E-01	d	1.40E-05	d							0.0000593	c @ 25C	1.00E+06	d	9.05E-07
2,3,7,8-TCDD (Dioxin)	6.56E-04	h	1.27E-02	L	6.81E-06	L	6.64	L	2.69E+06	L	2.69E+04	L	7.4024E-10	L	1.93E-05	L	1.77E-11

Table E-5: Physical and Chemical Data for Soil-MEG Chemicals

Chemical	H' unitless	Ref	Da cm2/s	Ref	Dw cm^2/s	Ref	log Kow	Ref	Koc cm^3/g	Ref	Kd cm^3/g	Ref	VP mm Hg	Ref	S mg/L	Ref	DA cm2/s
Terbufos	9.84E-04	h	4.35E-02	n	5.04E-06	n	3.68	c	2.40E+03	c	1.44E+01	b	0.00032	c @ 25C	1.50E+01	c	1.55E-07
Toluene	2.72E-01	e	8.70E-02	e	8.60E-06	e			1.40E+02	e	8.40E-01	e			5.26E+02	e	1.24E-03
Toxaphene	2.46E-04	a	1.16E-02	a	4.34E-06	a	3.3	c	2.57E+05	a	1.54E+03	b	0.4	c @ 25 C	7.40E-01	a	1.14E-10
Trifluralin	1.67E-05	h	3.94E-02	n	4.56E-06	n	5.07	c	9.64E+04	a	5.78E+02	b	0.0001	c @ 25 C	2.40E+01	c	1.10E-10
1,2,4-trimethylbenzene	2.30E-01	e	7.50E-02	e	7.10E-06	e	3.78	c	3.70E+03	e	2.20E+01	e	2.1	c	2.60E-01	e	4.03E-05
1,3,5-trimethylbenzene	3.20E-01	e	7.50E-02	e	7.10E-06	e	3.42	c	8.20E+02	e	4.90E+00	e	2.48	c	5.00E+01	e	2.46E-04
Vanadium	0.00E+00	h	3.77E-01	d	4.19E-05	d					1.00E+03	a	0	d	0.00E+00	c	2.71E-10
Xylene	3.01E-01	e	7.00E-02	e	7.80E-06	e			1.96E+02	e	1.18E+00	e			1.61E+02	e	8.19E-04
Zinc chloride (measured as Zinc)	0.00E+00	h	1.17E-01	L	1.36E-05	L					6.20E+01	L @ pH 6.8	0	c: 1 mm HG @ 487C	0.00E+00	c	1.42E-09
GA	6.15E-06	k	9.20E-02	k	7.50E-06	k	0.384	k	3.89E+01	k	2.31E-01	k	0.07	k	9.80E+04	k	2.35E-07
GB	2.20E-05	k	1.00E-01	k	8.20E-06	k	0.299	k	3.47E+01	k	2.08E-01	k	2.9	k		k	5.42E-07
GD	1.87E-04	k	8.20E-02	k	6.80E-06	k	1.82	k	2.34E+02	k	1.40E+00	k	0.4	k	2.10E+04	k	5.57E-07
HD	8.60E-04	k	9.90E-02	k	8.40E-06	k	1.37	k	1.32E+02	k	7.98E-01	k	0.11	k	9.20E+02	k	4.97E-06
Lewisite	1.30E-02	k	9.90E-02	k	9.00E-06	k		k		k	NA	k	0.58	k	5.00E+02	k	6.51E-04
VX	1.43E-07	k	0.062	k	0.0000053	k	2.09	k	323.59366	k	1.962	k	0.0007	k	30000	k	1.68413E-08

Table E-5: Physical and Chemical Data for Soil-MEG Chemicals

Chemical	H' unitless	Ref	Da cm2/s	Ref	Dw cm^2/s	Ref	log Kow	Ref	Koc cm^3/g	Ref	Kd cm^3/g	Ref	VP mm Hg	Ref	S mg/L	Ref	DA cm2/s

Notes:
H' = dimensionless Henry's Law Constant
Da = air diffusivity
Dw = water diffusivity
Kow = octanol-water partition coefficient
Koc = soil organic carbon-water partition coefficient
Kd = soil-water partition coefficient
VP = vapor pressure
S = solubility
DA = apparent diffusivity

Table E-6 Soil References

References and Equations Used

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h Calculated using 41 x H

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j U.S. Army Center for Health and Preventive Medicine. Derivation of Health-Based Environmental Screening Levels (HBESLs) for Chemical Warfare Agents. March 1999.

kl U.S. Environmental Protection Agency 1999. Errata to the Human Health Risk Assessment Protocol for Hazardous Combustion Facilities (Peer Review Draft), August 2.

l Backcalculated using H'.

m Calculated using Da = 1.9/(MW)2/3 Dw = 22*10-5/(MW)2/3

n Baes, C.F., R.D. Sharp, A.L. Sjoreen, and R.W. Shor. 1984. Review and Analysis of Parameters and Assessing Transport of Environmentally Released Radionuclides Through Agriculture. Oak Ridge National Laboratory. Oak Ridge, Tennessee.

APPENDIX F
THE ROLE OF SUSCEPTIBILITY IN ESTABLISHING EXPOSURE STANDARDS FOR DEPLOYED TROOPS

A USACHPPM White Paper

The Role of Susceptibility in Establishing Exposure Standards for Deployed Troops

White Paper December 2001

By Coleen Weese, MD, MPH – USACHPPM Program Manager, Occupational and Environmental Medicine

Background. During Operation Desert Shield/Desert Storm, the medical community braced itself for casualties. They were surprisingly few in number. The disease and non-battle-injury rate (DNBI) was the lowest in recorded history, probably due to the unique circumstances such as a prohibition on alcohol use and extremely limited contact with the local population. Somewhat unexpected were the complaints of symptoms in returning troops that remain essentially unresolved ten years later, despite several hundred million dollars in research, and over 60,000 evaluations as part of registries.[1-2] With the aim of circumventing such conundrums, numerous panels and committees made recommendations to the DOD.[3-7] Presuming that symptomatic outcomes were related to measurable or identifiable exposures during the deployment, systematic evaluation was limited by exposure data. Accordingly, all recommendations addressed the need for data collection on deployments.

Exposure Standards. While collecting exposure data may be necessary to classify individuals for epidemiological studies, the data is only immediately useful if it can be compared to a standard to benchmark acceptability/permissibility/degree of risk associated with the concentration. Levels of potential exposure vary with the scenario, and levels considered acceptable may vary with the target population. (Figure 1, scale of exposures) The Occupational Safety and Health Administration (OSHA) and the American Conference of Governmental Industrial Hygienists (ACGIH) have developed concentrations for hundreds of chemicals that are considered acceptable for working populations for eight hours per day, daily, for a working lifetime.[8] These are known as Permissible Exposure Limits (PELs) and Threshold Limit Values (TLVs), respectively. ACGIH values are consensus based and typically selected to prevent acute effects for irritants although some are based on more chronic endpoints. Most of the TLVs were recommended in the 1960's and 1970's. It has been claimed that whenever these limits have been implemented in a particular industry, no worker has been shown to have sustained serious adverse effects on health as a result of exposure to TLV concentrations.[9] While the degree of protection may be variable, the adoption of TLVs greatly reduced the incidence of occupational disease. In the late 1980's there were criticisms that they were not well based in science, that the margins of safety inherent in the various TLVs were inconsistent, that industry had undue influence on the committee, and that objective analysis had not been conducted.[10] In 1990 it was shown that for many of the irritants and systemic toxicants, the TLVs were at or near a concentration 10-50 percent of the population could be expected to experience some adverse health effect.[11] The authors reviewed the basis for the TLV and particularly the incidence of adverse effects and the corresponding exposure data. They concluded that the TLVs were poorly correlated with the incidence of adverse effects, that the TLVs were well correlated with the exposure levels which had been reported at the time that the levels were adopted, and that interpretations of exposure-response relationships were inconsistent between the authors of the individual studies and the TLV committee. Taken together, these observations suggest that the TLVs could not have been based purely on the consideration of health.[12] Responding to this criticism, the TLVs adopted in the early 1990's were more likely to be protective of a greater percentage of the working population. The formaldehyde value went from 2.0 ppm to a ceiling of 0.3 ppm, which was estimated to be protective of 95% of the population. A review of the documentation for this value indicates that it should be protective of as much as 99% of the exposed population. [13] It has been estimated that to achieve the protection of 95% of the working population, the TLVs for irritants might need to be reduced by 10 to 50 fold, factoring inter-individual differences in susceptibility. OSHA standards are designed to prevent similar effects, but also take feasibility and detection limits into consideration, and many are simple adoption of TLVs. However, while some changes to the TLVs come out annually, OSHA cannot update TLVs turned into PELs as the yearly TLV revisions occur. [14.] Both values have increasingly considered carcinogenic risk in recent standards, particularly in the past ten years. Theoretical cancer risks associated with TLVs are centered at from 1 in 10 to 1 in 1000 excess cancers. During the early 1980's, limits were set with the consideration that though they were not completely without risk, the risks were comparable to other occupational hazards such as falls, electrocutions, etc.[15] This risk is estimated to be 1 in 1000. While no absolute acceptable cancer risk

has been identified, acceptable cancer risk for exposures to the general public are typically in the 1 in 10,000 to 1 in 1,000,000 range. Regulatory agencies that have establish exposure limits for carcinogens have set limits with a cancer risk ranging from 4 in 10 to 1 in 10,000.[16]

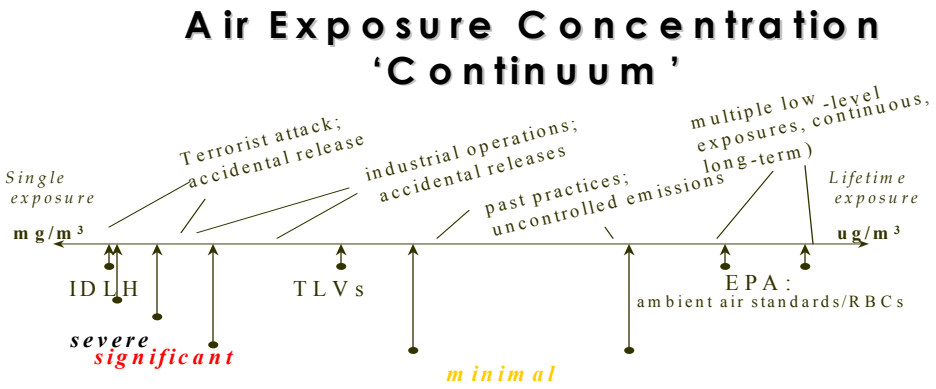

Figure 1. Air Exposure Concentration Continuum

Both sets of values are designed for workers, typically considered a healthy population. This is based on an assumption that workers are screened in some fashion prior to employment, may receive medical surveillance periodically designed to detect disease early, and are healthy enough to show up for work each day (the "healthy worker effect"). [17] In reality, many workers receive no specific pre-employment screening and no specific periodic surveillance, and may have a condition that was not present at the time of hiring or may be working with an undiagnosed condition, particularly as they age. Indeed, any selection advantage that would lead to superior health predictably declines with advancing age. In addition to varying with age, the magnitude of the healthy worker effect varies with race and work-status groups.

These values serve as a basis for decision-making; measured concentrations below the action limit require no action, whereas those above may dictate specific periodic follow-up. Although the advantage of these "occupational" values is that they are readily interpretable and useful in decision-making, they are generally not considered appropriate for deployed populations. The most fundamental shortcoming is that they are derived to be acceptable for eight hour per day exposures and deployed troops could be exposed to ambient concentrations 24 hours per day. Further, exposures during deployments may involve other scenarios such as relatively high exposures sustained for short periods, continuous exposures for varying time periods such as 24 hour to 2 weeks at a transient site, or up to one year for a sustained deployment. To evaluate short-term exposures, ACGIH has derived fifteen minute Short Term Exposure Limits (STELs) for workers. These concentrations are not no-effect levels, but derived so as to protect against irritation, chronic or irreversible tissue damage and narcosis or impairment in the ability to work. A more appealing set of values has been derived for some chemicals, although designed for the general population. In 1995, the National Advisory Committee for Acute Exposure Guideline Levels for Hazardous Substances was established to identify, review and interpret relevant toxicological and other scientific data and to develop these guideline levels for high-priority, acutely toxic chemicals. These values represent threshold exposure limits (exposure levels below which adverse health effects are not likely to occur and their utility is based on the fact that they address three levels of effect: mild and reversible, irreversible and serious, and life threatening.[18] Additionally, the AEGLs specifically address time periods ranging from 10 minutes to eight hours by chemical-specific time extrapolation, a feature that no other set of values provide. The previous name for these values was Community Emergency Exposure Levels (CEELS), but this term was replaced by AEGL to reflect the broader applicability of these values to planning and response and prevention in the community, the workplace, transportation the military and remediation of Superfund sites. For longer-term continuous exposures, the Environmental Protection Agency has derived Reference Concentrations, or

RfCs, that represent airborne concentrations that are considered acceptable for the general population to be exposed to for 24 hours per day for a lifetime.[19] These are used in selecting appropriate clean up levels at Superfund sites, or assessing potential health effects from such exposures. Thus, the AEGLs represent a source of short-term exposure levels with possible application to the deployed military, and RfCs represent continuous exposure levels, which may be useful for long-term deployments.

Issues in Applying Exposure Standards to Deployed Troops.

Unlike the OSHA PELs or the ACGIH TLVs, when the AEGLs or PELS are considered for military application, particularly in deployed settings, an initial concern raised is that they are "too conservative." The source of this concern is twofold: they are derived from data by applying uncertainty factors, and they are designed to protect the general population. Values derived by OSHA and ACGIH identify concentrations "that nearly all workers may be repeatedly exposed day after day without adverse effect " and are derived without the standard application of uncertainty factors. AEGLs and RfCs utilize uncertainty factors that are necessary reductions to account for the lack of data and inherent uncertainty in extrapolations from Lowest Observable Adverse Effect Levels (LOAELs) and No Observable Adverse Effect Levels (NOAELs). [20] The most typical uncertainty factors reduce concentrations by a factor of 10. There are five areas of uncertainty addressed, and each may utilize a factor of 10. They relate to interspecies variability (if animal studies are used), human variability, and adjustment for use of a LOAEL instead of a NOAEL, use of sub-chronic data and an incomplete database. It has been stated that the default value of 10 tends to be protective from the standpoint of the behavior of the average chemical. As the composite UF increases in number, the potential for overprotection increases substantially.[21] Additionally, "sub-threshold doses are considered …to be below the population threshold. However, the degree to which doses are below the population threshold is generally not known." In the definition of a reference dose or concentration (RfC), the Environmental Protection Agency notes that the uncertainty spans perhaps an order of magnitude.[19] This has several interpretations, but the most common is that an RfC of 1 mg/m3 may have a range of 0.3 to 3 mg/m3 (that is, half an order of magnitude above and below.)

Human Variability/Susceptibility.

Of particular interest to this discussion is the inter-human variability uncertainty factor. This factor assumes that there is variability in response from one human to the next and that this variability was not detected in the study, usually due to small sample size. This factor may also assume that subpopulations of humans exist that are more sensitive or susceptible to the toxicity of the chemical than the average population. [21] The term susceptibility is often used to describe individuals who have a predisposition to response to a particular chemical or exposure at levels that do not evoke the response in "most people." Usually, these individuals show susceptibility to specific chemicals, and have little susceptibility to other chemicals. The young, the old, the ill and those with genetic predispositions may display varying susceptibility to varying numbers of agents. Analysis of animal toxicity data for large groups of chemicals indicates that a 10-fold factor would yield an adequate reduction from the median response, but as humans are more heterogeneous than animals, the factor of 10 is not necessarily conservative.[22] Other research evaluating the variability of humans to metabolize substances typically support that the factor of 10 is protective. Thus, the standard default uncertainty factors assume that in the absence of data suggesting another factor, average humans are assumed to be ten-fold more sensitive than experimental animals. In the absence of data suggesting another factor, the most sensitive human will be assumed to be ten-fold more sensitive than the average human. Regarding occupational populations, The National Research Council (NRC) noted in 1994 that because they generally involve healthy adults, and do not include the most vulnerable segments of the general population, they are likely to display less variability in response to hazardous agents than the general population.[23] Likewise, deployed forces do not contain children, the infirm, and individuals with debilitating health conditions. This is interpreted to mean that deployed forces are not only less sensitive and vulnerable to the adverse effects of stressors in the environment, but that the range of variability in response is also likely to be much smaller than it is for the general population. This is the basis of the discussion as to whether or not AEGLs or RfCs are too conservative for deployed troops. Regardless of the validity of that claim, the Congress (in the Strom Thurmond Act, House Report, 1998) requested that "DOD should provide adequate protection of personnel from any low-level exposure to a chemical warfare agent at levels-even if not sufficient to endanger health immediately-are greater than is recognized as maximum safe level of exposure for the general population."

RISK ASSESSMENT MATRIX

SEVERITY	*PROBABILITY*				
	Frequent	Likely	Occasional	Seldom	Unlikely
Catastrophic	E	E	H	H	M
Critical	E	H	H	M	L
Marginal	H	M	M	L	L
Negligible	M	L	L	L	L

E - Extremely High Risk

H - High Risk

M - Moderate Risk

L - Low Risk

Figure 2-4, FM 100-14, Risk Management

Competing Risks and Risk Tolerance.
As the DOD plays the role of identifying health exposure criteria and implementing them, the process is often accompanied by intense external scrutiny, which might tend to encourage DOD to adopt conservative values. On the other hand, the Institute of Medicine (IOM) considered that conservative values might not be appropriate for deployed settings[24] "When a high level of health and safety protection can be achieved without undue burdens or increases in other risks, such margins can be part of an effective risk management program. But when risks or probabilities of casualties must be weighted against immediate military considerations, best estimates of probable impact are more useful." While this is certainly a reasonable perspective, many of the current deployments are stability and support operations and the competing risks or immediate military considerations are minimized. In these settings, unevaluated or uncontrolled risks, or the acceptance of unnecessarily high risk would be less defensible. This is why operational risk management as a consistent tool is effective, in that it allows for at least a pseudo comparison of competing risks, and why a range of toxicity values representing a spectrum of risks is most useful. (Figure 2) The IOM panel acknowledged a need for operational risk management tools with utility to field commanders. They suggest a definition of risk that encompasses probability proposed by Kaplan and Garrick in 1981. For a deployment, the relevant components would be: 1) the likelihood of the presence of a hazard associated with a deployment, 2) the likelihood of releases of agents into the environment, given their presence, 3) the likelihood that troops will suffer exposure (of various magnitudes) given the releases, and 4) the likelihood that health effects will caused among them, given the exposure. The operational risk management framework currently used by commanders for all other threats adds an assessment of the severity of the health effects to characterize risk.[25]

Given that risk tolerance may differ with the scenario, in situations were competing risks are low, it would be desirable to protect troops from all unnecessary health risks to the degree feasible. The IOM identified modifications to the risk assessment paradigms for deployed troops, noting that deployed troops face a number of risks at once, and so the approach typically taken to address a single hazard is insufficient. Conceptually important is whether the threat is evaluated as a threat to individual service personnel while deployed, in cumulative career long and lifelong risk profiles, or as threats to the capabilities of whole military units or to the success of missions. Nonetheless, assuming that in some settings, the preferred goal is to maximally protect troops, we return to the question of whether or not the military requires different uncertainty factors addressing variability than does the general public: Are deployed forces less susceptible to adverse effects from exposures? Some changes in susceptibility that accompany circadian rhythmicity, for example, affect all individuals.[26] Factors affecting susceptibility may interact to increase or decrease the adverse affects of toxic exposures. They may be independent or interdependent. The factors that increase the susceptibility of the aged, for example, are often interdependent and include changes in nutritional status, exercise, medication and the functional reserve of all organs. Such susceptibilities would be most associated with segments of the population, although there is most likely a continuum of responses. Table 1 lists some factors that modify an individual's response to an exposure.

Table 1. Factors that Modify Individual Responses to an Exposure

Modifying Factor	Known or Probable Effect
Age	Susceptibility at age extremes
Gender	Variable
Smoking	Confers additive or synergistic risk
Alcohol Use	Increased susceptibility to hepatotoxins
Exercise at Time of Exposure	Increases exposure via inhalation
Family History	Hereditary conditions with increased susceptibility
Respiratory Disease	Diminished pulmonary reserve, increased reactivity or increased irritation
Atopy	Tendency towards sensitization
Asthma	Increased bronchial reactivity
Cardiovascular disease	Some exposures could precipitate angina
Seizure Disorder	May alter threshold
Dermatological condition	May lead to increased absorption
Renal insufficiency	Increased susceptibility to toxins excreted by the kidneys and renal toxins
Immune deficiency states	Increased susceptibility to toxins affecting the immune system
Infection	Increased susceptibility to bronchial irritation

Sources of Variability: Demographics

Age. The demographics of the active services differ from the general U.S. population.[27-28] Most obviously, the age range differs: the youngest troops are seventeen years of age, and roughly 40% of the population is below 25 years of age. Individuals younger than 25 years make up 35% of the U.S. population. The oldest service members are in the 60-65 year age group; this represents less than one percent of troops. In actuality, less than one percent of troops are above 50 years of age, compared with 28% of the U.S. population. The average age of a service member is between 25-29 years of age. With respect to the age of deployed troops, during the Persian Gulf conflict, 22% of troops were 35 years of age or above, which is similar to the percentage in this age group as a whole. Susceptibility to exposures is most pronounced at the two extreme of the life cycle. The fetus and infant are susceptible for a number of reasons to include the rapid rate of cell division, the large surface area relative to weight, immature detoxification processes, impaired renal excretion, and an immature immune system. Increased susceptibility to methyl mercury, lead, and nitrates, among others, has been demonstrated. The aging process can be identified at all levels of biological organization. Physiological change impairs the maintenance of homeostasis with age, as cardiac, renal, pulmonary and immune function decrease progressively with increasing age.[26] The aged are often able to function under resting conditions, but are less capable of withstanding environmental stress. They are more susceptible to infection, heat, and cold and exhibit a greater predisposition to toxicity of drugs, which would suggest an increased susceptibility to environmental chemicals metabolized in a similar fashion. This susceptibility may be related to impaired host defenses, body surfaces as portals of entry, possible changes in detoxification capabilities, impaired immune function, and impaired physiological functions. For the most part, the age range associated with military service does not contain the most susceptible subgroups of the population based on age.

Sex. Currently, about 15% of service members are female; during the PG conflict, less than 7% of those deployed were female. This sex distribution is markedly different from the U.S population as a whole, where the distribution between males and females is approximately 50/50.[27-28] The IOM recently reported that females and males have differences at the cellular level, which are manifested in differences in reaction to and metabolism of drugs. Male-female differences in response to toxic exposures in the environment have been demonstrated for benzene, lead and cigarette smoke, as well as nerve agents.[26] Females are more susceptible to the effects of exposure to benzene and nerve agents, while men are more susceptible to the effects of cigarette smoking. Thus, the difference in sex distribution may make the military population more or less sensitive, depending on the exposure. The deployed population is supposed to exclude one

susceptible population: pregnant females. The IOM notes that although pregnant women are not deployable, deployed women must have the means to detect pregnancy while deployed and policies for evacuation or movement of pregnant personnel out of the risk area must be developed, clearly understood and strictly enforced.[29] Field duty is restricted after 20 weeks.

Race/Genetic Traits. With respect to racial origin depending on the branch of service in question, 58-74 of service members are white, whereas 71 % of the general population is white. Approximately 15-25% are black, non-Hispanic, in contrast to 11% of the general population, and 8-13% are Hispanic, versus 11 % of the general population. Race is linked to differing susceptibilities to exposures or drugs, likely linked to genetic variation. For example, susceptibility to the antimalarial drug primaquine has been demonstrated due to G6PD deficiency leading to hemolysis of red blood cells. Although there a number of variants, the milder form is found in about 12% of African American males, and the more severe forms more common in those of Mediterranean descent. There have been a number of indications that such individuals are more susceptible when exposed to oxidizing chemicals as well.[26] Although antimalarials are often prescribed for soldiers traveling to malaria endemic regions, not all services screen for deficiency. Thus, in this example, the services may contain unrecognized susceptible populations.
Sickle cell anemia is a genetic disease that causes the red blood cells to sickle or collapse at low oxygen pressures, making it difficult for them to pass thru blood vessels normally, causing pain and tissue damage. Approximately 0.2% of African Americans have sickle cell disease. 8% of African Americans have sickle cell trait, as compared with 0.08% of non-African Americans. Additionally, there is variable prevalence of disease and trait in different ethnic groups, and appearance or ethnic group is not a sensitive indicator of status.[30] Most individuals with sickle cell trait are not aware that they have it as they typically lead normal lives, but problems may occur under unique or stressful conditions producing severe hypoxia such as flying in unpressurized planes. In 1968, four recruits who were trait positive died while training at elevations above 4060 feet.[31] In 1969, the Navy established policy to test all recruits. In the 1970's, operational restrictions were placed on those who were sickle cell trait positive to prohibit their participation in activities that would place them at risk such as aviation, diving, Special Forces and high altitude parachuting. In 1981, the DOD set a cut-point of > 41% HgS for restrictions. In 1985, DOD policy removed all restrictions related to sickle cell trait.[32] In the mid 1990's, three deaths in trait positive recruits under conditions of heat stress. In 1996 the Armed Forces Epidemiology Board recommended increased heat injury prevention measures and continued research.[33] The Army screened only high-risk occupations, although trait positives are not disqualified, and the other three services screen all accessions. Individuals who are trait positive are counseled regarding risks. Recently, five deaths in soldiers under conditions of exertion have led to a change in Army policy to introduce universal screening of recruits. This is another example of a genetically based susceptibility with a rather severe possible endpoint hat is relatively prevalent in the military population. With regards to metabolism of foreign substances such as drugs and chemicals, a phenotype known as "slow acetylators" has been identified. It was noted that there are individuals who acetylate the antituberculous drug isoniazid slowly, leading to prolonged excretion.[26] The blood levels of drug in these patients are higher and they are more prone to toxic reactions. Population studies indicate that 60% of Caucasians and African Americans and 10% of Asians are slow acetylators. Slow acetylation and delays in excretion may be important in the metabolism of chemicals such as arylamines, and may be relevant in the carcinogenesis of bladder carcinogens of this class. Similarly, the cytochrome P450 containing mixed function oxidase system metabolizes many substances. It has been shown that one of these, the aryl hydrocarbon hydroxylase, can be induced to increase activity following exposure to polycyclic aromatic hydrocarbons and insecticides. Increased activity in the instance of PAHs is not beneficial, but results in the formation of carcinogens. Inducible forms of aryl hydrocarbon hydroxylase are found in about 1 in 10 individuals in the U.S. Genetic variability has also been suspected due to hypersensitivity of some members of the population to beryllium. Chronic beryllium disease had occurred in some individuals not occupationally exposed at very low levels. It has been postulated that several alleles affecting sensitivity to beryllium may exist and sensitivity increases as the number of alleles possessed increases. Thus, discrete groups may exist with differing sensitivities, rather than a single continuous dose-response relationship. One allele has been identified in 90% of those with the disease. However, it is also present in 30% of the general population.[34] Therefore, susceptibility is highly linked with getting the disease, but a large portion of the population is at risk. Further, the prevalence of chronic beryllium disease in women is estimated to be six-fold higher than in men. In this particular example, susceptibility is not necessarily restricted to small fractions of the population. Genetic polymorphism was

demonstrated when a soldier demonstrated severe symptoms following pyridostigmine bromide prophylaxis during the Gulf War. He was determined to be homozygous for atypical BuChE. Homozygotes can be present in up to 1% of some population groups. The serum BuChE in homozygotes has much less binding affinity or sensitivity toward PB and other anit-ChE's.[35] Intraspecies variation has also been demonstrated in blood cholinesterase activity, which may affect susceptibility to the toxic effects of nerve agents. Homozygous individuals have plasma ChE activity reduced to less than 25% of normal values, whereas heterozygous individuals have ChE levels about 64% of normal. [36-38] Heterozygotes represent about 3% of the population.[39] Plasma ChE activity may also be depressed in young children and pregnant females as well.

Table 2. Genetic Factors and Susceptibility to Chemicals[a]

Predisposing Factor	Incidence	Chemicals	Environmental interaction?
Glucose-6-phosphate dehydrogenase deficiency	12% in African American males	Oxidizing Chemicals	Likely
Sickle Cell Trait	7-13% in African Americans	CO, aromatic amino compounds	No clear evidence
Methemoglobin reductase deficiency	1% population heterzygotes	Nitrites, aniline	Definite
Aryl hydrocarbon hydroxylase induction	High-induction type Caucasians about 30%	Polycyclic aromatic hydrocarbons	Possible
Slow acetylator phenotype	60% Caucasian and Black populations	Aromatic amine induced cancer	Possible
Immunologic hypersensitivity	Unknown, 2% in some occupational populations	Isocyanates	Definite
Paraoxonase variant	50 % in Caucasians, Asians about 30%, blacks about 10%	Parathion	Possible

a. *From Tarcher, Principles and Practice of Environmental Medicine*[26]

Table 2 provides these and other examples of genetic variants that can affect susceptibility to environmental exposures. Many of these are found in significant fractions of the general population and are not identified by screening prior to military accession. Thus, with respect to these susceptibilities, the military or deployed population cannot be considered less susceptible than the general population. The human genome project has determined that 99.9% of the genome is identical for all persons with variation representing 0.1%. As this 0.1% is explored, it has been proposed that careful phenotyping could identify disease risk associations within the next 5-7 years. As this progresses, previously unrecognized genetic variability may be identified, but the role of environmental factors will also need to be considered. For example, asthma appears to have genetic variations that may determine susceptibility, but environmental factors may precipitate the actual disease. Increasingly, as we learn more about human variability, and its interactions with exposures, stress or hormonal differences, it may be possible to identify susceptible individuals. However, susceptibility is most often not immediately obvious, and may not be detectable without sophisticated testing. Such testing is obviously not currently performed in service members.

General Health in the Deployed Population.
Similar to the healthy worker assumption discussed previously, there is a general assumption that the service members are healthier than the general population, as there are standards of fitness required for military accession and retention. Examination is required on entry to the service to ensure that recruits are free of infectious disease, and conditions or defects which would require "excessive time lost from duty or would likely result in separation from the service for medical unfitness." [40] They also need to be adaptable to the military environment without unnecessary geographical limitations and able to perform duties without aggravation of existing physical defects. Recruits can be disqualified due to the presence of a number of conditions: the most common are hearing loss, vision deficiency, asthma, hypertension, flat feet, musculoskeletal and knee derangements, psoriasis, cardiovascular disease, diabetes and some bone conditions. About three percent of all recruits present with these conditions but receive a waiver. Therefore, although individuals with these conditions may be screened out, many are not, depending on medical judgement. Further, if the recruit does not disclose the presence of a condition not evident on examination, accession would not be blocked. At the time of accession, then, the active duty force would be considered "healthier" than the general population. It is not clear, however, that conditions that make one more sensitive or susceptible to the effects of exposures are the conditions that are identified and disqualify one. Further, many individuals can develop a disease or condition while on active duty, but may not be discharged because of it. The physical conditioning of U.S. forces prior to deployment has generally never been better.[29] Active-duty forces are maintained in excellent physical and dental health. However, the trend in downsizing the standing forces and relying on the National Guard and Reserve Forces changes the fitness and age profile of the deploying force. For example, 17% of forces deployed in support of the Persian Gulf War were reserve component members. Reserve component members tend to be older on average, and may have more general health and fitness issues than the active force. Additionally, an increasing proportion of deployments now include coalition forces and the composition of those forces is quite heterogeneous and often different from U.S. forces Increasing use and dependence upon DOD contractor personnel will require an assessment of the characteristics of these additional personnel such as age, health status, fitness, past medical treatment and records, training proficiency, and possible stress level associated with separation.

Lifestyle Factors and Coexisting Exposures
Susceptibility to environmental exposures can be affected by exposure to other toxic chemicals. Individuals may thus have increased susceptibility on the basis of occupation and lifestyle-related exposures. The best example of this increased susceptibility is the increased risk for lung cancer in smokers exposed to asbestos. The risk of lung cancer is increased by a factor of five for those exposed to asbestos versus those not, and by a factor of ten for those who smoke versus those who do not. However, when an individual is exposed to cigarette smoke and asbestos, the risk rises to 50 times that of unexposed individuals. [41] This phenomenon is known as synergistic interaction. The prevalence of smoking is currently approximately 30% in the military as compared with about 22% in the general population.

Coexistence of Disease.
Many disease processes make an individual more susceptible to the effects of environmental toxicants. Asthma and other pulmonary conditions would increase susceptibility to airborne pollutants; liver disease might increase the susceptibility to toxicants metabolized by the liver. While asthma has a prevalence of 4-6% in the general U.S. population, service applicants are disqualified if they give a history of asthma. The portion of the physical examination that would identify the presence of asthma is auscultation of the lungs, not a particularly sensitive test, and individuals might not reveal their conditions. In the past five years, 6% of applicants were disqualified due to disorders of the lungs and chest, the third most common cause behind weight and cannabis use as a reason for disqualification.[42] However, the Army, Navy and Marines will grant a waiver if the individual has been symptomatic since age 12. One recent small-scale evaluation indicated that up to 4% of individuals might receive waivers for asthma. Asthma has been the top disease or disorder for which waivers have been granted for the past three years. Additionally, individuals may develop asthma while on active duty or fail to disclose a history of asthma. During periodic physicals, soldiers found to have asthma are not necessarily discharged. Referral for a medical evaluation board occurs when asthma persists greater than six months or requires the use of medications to perform all military training duties. Even so, such individuals may be given a temporary profile for one year. During the past four years, about 15% of early discharges are for asthma.[42] Asthma ranks thirty-ninth when

conditions requiring medical encounters in the military are ranked, and 44th in terms of numbers of individuals affected.[43] Therefore, while the military has a lower prevalence of asthma than the general population, as well as other respiratory conditions such as emphysema and chronic bronchitis, it is not a safe assumption that no asthmatics will be deployed, nor that all individuals who may be more sensitive to the effects of air pollution or irritants, for example, will be excluded from deployment. Indeed, asthma was one of the major causes for evacuation out of theatre during the Persian Gulf conflict.

Skin disorders represent a common condition seen in the military. Although individuals may be disqualified if presenting with severe psoriasis or other conditions at accession, skin disease is very common in service members. Skin conditions rank 10th in terms of the reason for medical encounters, and represent 10-20% of outpatient medical encounters. [43] Most skin conditions that are diagnosed during service do not require evaluation for discharge unless they interfere with duties or wearing of the uniform. Skin disease may increase the sensitivity of an individual to exposures, particularly by the dermal route, due to breaks in the skin integrity.

Asthma and skin conditions might be uncovered by observation or history at the time of exam, but not all conditions are apparent in this manner. For example, liver disease would likely interfere with the metabolism of some xenobiotics, but sub-clinical disease might exist and be apparent only if liver function tests are performed. There are a number of tests ordered as part of the physical examination. Some are specific to certain diseases whereas others are not. Tests currently performed as part of the physical are noted in Table 3. While some conditions such as diabetes or high cholesterol (hyperlipidemia) may be detected, liver and renal function are not specifically evaluated, nor are many other specific diseases which might interfere with the metabolism of contaminants which enter the body, or increase one's susceptibility to an adverse outcome from an exposure.

Required Testing as Part of the Physical Examination Process

Test	Target organ or conditions
Cholesterol	Hyperlipidemia
HIV Test	HIV infection
Stool Guiac	Gastrointestinal bleeding
Urine microscopy	Cells, infection
Urine Specific Gravity	Evaluates hydration, fluid regulation
Fasting Blood Sugar	Diabetes
Chest Xray	Lung lesions, etc
Syphilis Test	Syphilis
Pregnancy Test	Females only at accession
Hemoglobin/hematocrit	Anemia
Sickle Cell Test	Only for Special Forces, combat diving
G6PD	G6PD deficiency, only for combat diving

Adequacy of Uncertainty Factors for Various Chemicals.
Although in the classic risk assessment process, an uncertainty factor of ten is the default value, for some chemicals, the intra-species variability is addressed utilizing an uncertainty factor of three versus ten. This is because the effect under concern is considered local, and the substance is direct acting and doesn't require metabolic conversion[44 a] factor of ten has been has been estimated to address 80% of variability in the ability to metabolize foreign substances.[21] when the effect of concern is irritation, intra-species variability is not considered to be large. Ideally, sufficient data would exist to document the appropriate uncertainty factor, rather than utilizing the default value of 10. This would obviously limit conservatism. In the recent AEGL proposals published in the Federal Register (May 2001), of the 18 chemicals, an uncertainty factor of 3 was used in 2/3 of the derivations.[45] Insufficient data was available for some chemicals to use three, or the variability factor of ten was supported by available data in the rest of the

instances, except for a UF of zero used for the carbon monoxide value. This was due to the selection of an exquisitely sensitive population (those with heart disease) in the critical study. For this specific chemical, the value based on that endpoint might be too conservative for a deployed population that should be expected to have a lower prevalence of heart disease. However, given the considerations in the derivation of the other values, it cannot be concluded that such values are "too conservative" for deployed troops on the basis of the interspecies variability uncertainty factor.

The IOM noted that "deployed forces can be expected to vary greatly in age, ethnicity, genetic susceptibilities and prior histories of exposures to toxicants and disease, as well as in possible allergic or stress reactions to exposures or countermeasures." Additionally, the deployed military population is subject to a variety of battle-related risks, including those related to chemical and biological warfare agents, and additional risks of infectious disease, exposure to chemical contaminants in air, water, food, and soil and a variety of physical threats, including those associated with accidents and explosions and with certain forms of ionizing radiation, and with excessive heat, cold and noise. Medical treatments designed to protect forces from risks may pose other health threats.[24] With respect to the deployment to the Persian Gulf, the IOM noted that "Service personnel were exposed to an extraordinary array of environmental conditions. Their complex experiences combined to yield what is a truly varied and sometimes confusing picture of exposure that has proven difficult to understand, much less reconstruct."[29,46] Forces might be exposed to these conditions intermittently, continuously, or simultaneously. Furthermore, the deployed population might have greater opportunity for exposure based on their activity patterns, resulting in greater internal doses received. Weight for weight air or soil concentrations assume certain default parameters for exposed skin, inhalation rate, etc. Dermal exposures can be significant during field exercises and combat situations, and inhalation doses can be greatly affected by the amount of air inhaled, the frequency of respiration and the depth of penetration of the air inhaled into the lungs.[24]

These factors create a complex environment that is difficult to summarize and quantify in risk assessment with a single value. Individual, situational, geographical and cumulative factors may influence susceptibility. Assessing susceptibility to toxic exposures requires a highly individualized approach, difficult to translate to heterogeneous situations and populations. The statement that deployed military populations are less susceptible to exposures than the general population is simplistic and deserves further study.

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KEY POLICY and GUIDANCE DOCUMENTS RELATIVE TO CHEMICAL RISK MANAGEMENT IN DEPLOYMENT SETTINGS:

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Implementing Guidance Documents (Relative to assessment and management of chemical hazards during deployment, as directed by aforementioned DoD and Army Requirements)

- Technical Bulletin-Medical (TB MED) 577, *Sanitary Control and Surveillance of Field Water Supplies*, 7 March 1986 (currently being updated)
- USACHPPM Technical Guide 248, *Guide for Deployed Preventive Medicine Personnel on Health Risk Management*, Aug 2001
- USACHPPM Technical Guide 230, *Chemical Exposure Guidelines for Deployed Military Personne*l, January 2002, Version 1.3 updated May 2003

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