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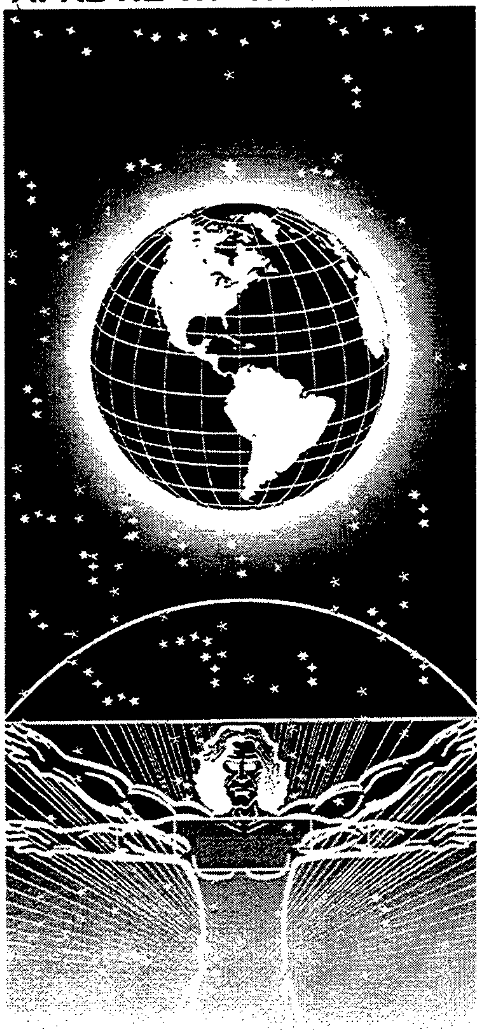

UNITED STATES AIR FORCE RESEARCH LABORATORY

MILITARY-SPECIFIC EXPOSURE FACTORS STUDY

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This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE DIRECTOR

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13. ABSTRACT *(Maximum 200 words)*
The Environmental Protection Agency's (EPA's) recently revised (August 1997) Exposure Factors Handbook (EFH) provides many factors needed in the assessment of human health risk that were derived from general population studies or studies involving relatively small groups that may not be representative of military populations. This short term study assessed the differences between exposure factors presented in the EPA's EFH and those based upon military-specific data. Military factors data sets that were identified, evaluated, and selected for sensitivity analysis using Crystal Ball software included: drinking water consumption, activity-specific inhalation rates, body weights, body surface areas, and on-base residence times of military populations. In comparison of risk for a hypothetical dermal exposure of benzene, the risk was nominally reduced from 3.3E-7 (EFH factors) to 1.0E-7 (military factors). This was due to the shorter military exposure duration. In contrast, the ground water ingestion risk was increased from 7.2E-5 (EFH factors) to 1.2E-4 (military factors). This was due to the increased military drinking water consumption in comparison to the U.S. population. The inhalation route risk was marginally reduced from 7.04E-4 (EFH factors) to 2.8E-4 (military factors) due to the decreased exposure duration. The study also identified additional military-specific data involving food consumption, site-specific housing data, and population mobility that were either not acquired or not analyzed because of the time constraints of the study. Further investigation would be necessary to locate other military studies that could provide dermal contact data, incidental soil ingestion data, and activity pattern data (e.g., time spent outdoors, time spent showering, time spent swimming, time spent gardening).

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PREFACE

This report was prepared by Operational Technologies Corporation, 1370 North Fairfield Road, Dayton, Ohio 45432 under Contract Number F41624-94-D-9003/008. The effort was initiated in April 1998 and completed in June 1998 under the Project Management of Mr. Erik Vermulen. Major Steve Channel of the Operational Toxicology Branch, Human Effectiveness Directorate, Air Force Research Laboratory (AFRL/HEST), served as contract monitor. Maj Lana Harvey, AFRL/HEST, served as the technical representative of the contracting officer.

The authors would like to extend their appreciation for the technical assistance of Mr. Jody Wireman and Captain Brian Sassaman, Human Systems Center, Occupational and Environmental Health Directorate, Occupational Medicine Division, Health Risk Assessment Branch (DET 1 HSC/OEMH). Numerous stakeholders who provided critical information included Colonel Postlewaite from the Assistant Deputy Secretary's Office of the Air Force, Environment, Safety and Occupational Health (SAF/MIQ); Colonel Joyce of Base Bioenvironmental Engineering at Wright-Patterson Air Force Base (WPAFB); Dr. Patton, U.S. Army Research Institute of Environmental Medicine; Dr. Carpenter, Naval Medical Research Institute; Ms. Stoll, Deputy Director of Base Housing at WPAFB; Ms. Robinette, Computerized Anthropometric Research and Design (CARD) Laboratory located within Air Force Research Laboratory, Human Effectiveness Directorate, Human Interface Technology Branch (AFRL/HECP); and Dr. Joe McDaniel, technical monitor for Crew System Ergonomics Information Analysis Center (CSERIAC).

LIST OF SYMBOLS, ABBREVIATIONS AND ACRONYMS

3D	Three Dimensional
74th AMDS/SGPB	74th Aerospace Medical Squadron, Bioenvironmental Engineering Flight
88th CEG/CEH	88th Civil Engineering Group, Housing Division
88th CEG/CERC	88th Civil Engineering Group, Information Systems Branch
ADSCD	Active Duty Service Computation Date
AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
AFCEE/EQ	Air Force Center for Environmental Excellence, Environmental Consultants Division
AFCESA	Air Force Civil Engineering Services Agency
AFIT	Air Force Institute of Technology
AFMC	Air Force Materiel Command
AFMC/DPZM	Air Force Materiel Command, Personnel Division, Executive Military System Management Branch
AFMC/SG	Air Force Materiel Command, Command Surgeon
AFMIC	Armed Forces Medical Intelligence Center
AFMOA	Air Force Medical Operating Agency
AFRL/HECP	Air Force Research Laboratory, Human Effectiveness Directorate, Human Interface Technology Branch
AFRL/HEST	Air Force Research Laboratory, Human Effectiveness Directorate, Operational Toxicology Branch
APG	Aberdeen Proving Grounds
ASC/EMR	Aeronautical Systems Center, Acquisition Environmental Management, Restoration Division
AT	Averaging Time (days) for Carcinogen, 25,500 days
AT_n	Averaging Time for noncarcinogens, (days) (ED x 365 days/year)
ATSDR	Agency for Toxic Substances and Disease Registry
AVG	Average
BEE	Bioenvironmental Engineer
bpm	beats per minute
BUD	Basic Underwater Demolition
BW	Body Weight, kg
CARD	Computerized Anthropometric Research and Design
CBIAC	Chemical Warfare/Chemical and Biological Defense Information Analysis Center
CCS	Command Core System
CG	Center of Gravity
CHPPM	U.S. Army Center for Health Protection and Preventative Medicine
Civ	Civilian
cm	centimeter
cm^2	square centimeters
cm^3	cubic centimeters
C_{media}	Concentration in media, mg/kg (soil), mg/L (water) or mg/cm^3 (air)
CSERIAC	Crew System Ergonomics Information Analysis Center
CSF	Cancer Slope Factor, mg/kg/day
d	day
DASA (ESOH)	Deputy Assistant Secretary of the Army, Environment, Safety and Occupational Health
DoD	Department of Defense
DSN	Defense Systems Network
DTIC	Defense Technical Information Center
ED	Exposure Duration (year)
EF	Exposure Frequency (days/year)
EFH	Exposure Factor Handbook
EIAC	Environmental Information Analysis Center

EPA	United States Environmental Protection Agency
ESOH	Environmental Safety and Occupational Health
ESSRA	Enhanced Site-Specific Risk Assessment
est	establishing
ft	feet
ft^2	square feet
ft^3	cubic feet
H	Height, cm
H_o	Null Hypothesis
HEAR	Health Enrollment Assessment Review
HQ	Hazard Quotient
HQ AFMC	Headquarters, Air Force Materiel Command
HQ AFMC/DPZD	Headquarters, Air Force Materiel Command, Data Automation and Analysis Branch
HQ AFMC/SGBZ	Headquarters, Air Force Materiel Command, Health Promotion/Fitness Branch
HQ AMC	Headquarters, Air Mobility Command
HR	Heart Rate
HRA	Health Risk Appraisal
HSC/OEMH	Human Systems Center, Occupational and Environmental Health Directorate, Occupational Medicine Division, Health Risk Assessment Branch
IR	Intake Rate
IWIMS	Integrated Work Information Management System
Kcal	Kilocalories
Kg	Kilogram
L	Liter
log	logarithm, base 10
m^3	cubic meters
mg	milligram
min	minute
mL	milliliter
mm	millimeter
MMR	Massachusetts Military Reserve
mph	miles per hour
MSEF	Military-Specific Exposure Factor
N/A	Not Applicable
NCEA	National Center for Environmental Assessment
NEHC	Navy Environmental Health Center
NMRI/TD	Naval Medical Research Institute, Toxicology Detachment
O_2	Oxygen
OPHSA	Office for Prevention and Health Services Assessment
ops	operations
P	significance level
PBPK	Physiologically Based Pharmacokinetic
PCS	Permanent Change of Station
PRA	Probabilistic Risk Assessment
RfD	Reference Dose, mg/kg/day
RME	Reasonable Maximum Exposure
RTP	Research Triangle Park
SA	Surface Area
SAF/MIQ	Assistant Deputy Secretary of the Air Force, Environment, Safety and Occupational Health
SD	standard deviation
SEAL	SEa, Air, Land
STINET	Scientific & Technical Information Network
t	student t statistic
TOS	Time On Station

UCL	Upper Confidence Limit
USAF	United States Air Force
USARIEM	United States Army Research Institute of Environmental Medicine
USDA	United States Department of Agriculture
V_e	Minute Volume
VR	Ventilation Rate
WPAFB	Wright-Patterson Air Force Base
wk	week
X	mean
yr	year

MILITARY-SPECIFIC EXPOSURE FACTORS STUDY

EXECUTIVE SUMMARY

Background

The human health risk assessment process has changed significantly since it was first described by the U.S. Environmental Protection Agency (EPA) in the 1987 Superfund Public Health Evaluation Manual. During the past decade the risk assessment process has evolved into an extensive series of sub-processes that rely upon a continuously expanding collection of information, including chemical toxicity and exposure mechanisms. Among the large and growing collection of EPA guidance documents is the Exposure Factors Handbook (EFH) (EPA, 1989a & 1997). The EFH provides many factors needed in human health risk assessment. For example, population specific parameters that need to be considered in evaluating specific exposure pathways include: physical factors (e.g., body weight, skin surface area); activity patterns which define exposure frequency and duration (e.g., time of residence, time spent outdoors, time spent showering or bathing, etc.); and intake factors (e.g., rates of inhalation and ingestion of drinking water, foods and soil). Although the EFH was recently revised (August 1997), many of the exposure factors provided in the EFH are derived from general population studies or studies involving relatively small groups that may not be representative of military populations. Site-specific information and probabilistic risk assessments (PRAs) have been identified and used by the EPA as means to address the limitations of general population exposure parameters at specific locations. Exposure scenarios on military installations can include a variety of populations, sometimes similar to the civil sector but in some circumstances quite different. To assess the differences between exposure factors presented in EPA's EFH and military-specific exposure factors (MSEFs) based upon military-specific data, the short-term study described in the body of this report was performed under contract to the Operational Toxicology Branch, Human Effectiveness Directorate, Air Force Research Laboratory (AFRL/HEST).

Approach

Initially the EPA's revised EFH was reviewed to evaluate the current human exposure factors used in the risk assessment process. Exposure factors described in the EFH include: inhalation rates; skin surface area; soil adherence; incidental ingestion of soil; life expectancy; body weights; activity patterns (e.g., time spent showering/bathing, time spent swimming, time spent indoors and outdoors); drinking water intake rates; consumption of fruits, vegetables, beef, dairy products and grain; breast milk intake rates; consumption of seafood to include both commercially and recreationally caught fish and shellfish; consumption of home produced foods; time spent inside vehicles; occupational tenure; population mobility; and residential volume and air exchange rates (EPA, 1997).

A summary of the supporting data, exposure assessment equations, and default values was prepared; a review of other key EPA reference documents was performed. These documents included guidance on site-specific risk assessments (Opresko, 1996), application of the probabilistic approach (Region VIII, 1995) and the Risk Assessment Guidance for Superfund Parts D and E (EPA, 1998a & b). Contact was also made with as many MSEF stakeholders as possible to identify relevant research involving military subjects. Stakeholders, in this report, refers to military organizations with relevant data holdings or interests in the development of military exposure parameters. A literature search strategy was developed and applied to identify appropriate sets of published data. The applicability of available data sets was evaluated and selected data sets were prioritized for subsequent sensitivity analysis using Crystal Ball® software (Decisioneering, Inc., Denver, CO). MSEF data sets selected included: drinking water rates, activity-specific inhalation rates, body weights, body surface areas, and on-base residence times of military populations.

Additional military-specific data sets identified can provide data distributions for residency time or exposure duration (e.g., military family housing and current time-on-station data), housing data (e.g., type of construction, number of occupants, size/volume, etc.), and food consumption rates (via Army garrison-level studies). However, the short-term nature of this report did not allow sufficient time to develop data distributions from these data sources.

Results

The extensive U.S. Air Force and U.S. Army anthropometric data that are available includes body weight and height information. The 1988 U.S. Army data were as recent as the body weight data cited in the EFH (EPA, 1997). Surface areas used in the dermal route of exposure are estimated from regression equations defined in the EFH as a function of body weight and height. The only military study cited in the EFH was a 1983 U.S. Army water planning study. It provided upper bound drinking water rates for different climatic conditions. More recent U.S. Army drinking water studies indicated consumption rates at about half of these upper bound limit (Szlyk *et al.*, 1988; Roberts *et al.*, 1989).

The military population was found to be more active than the general population as confirmed by the 1985 Anderson *et al.* report that compared the activity patterns of 56 subpopulation groups. Daily activity patterns consisted of slow, moderate and heavy activity levels. This EPA report provided an inhalation rate distribution for each of the activity levels and an inhalation route distribution was derived for the representative military member (Anderson *et al.*, 1985). An Army study of 42 physical activities included heart rate and minute volume data that were used to generate a regression equation to estimate the inhalation rate from heart rate input data (Patton *et al.*, 1995).

An average residential volume from 2,140 housing units at Wright-Patterson Air Force Base (WPAFB) was calculated (266 ± 67 m^3 versus the EFH value of 369 ± 258 m^3 for the general U.S. population). With respect to population mobility, interviews revealed that the housing residents at WPAFB averaged 2.5 years in a residence with a required minimum of 1 year and a maximum of 10 years. In contrast, the EFH recommends a mean of 9 years and a 95th percentile of 30 years. Distribution data for time on station were also calculated.

Health risk distributions were estimated using Monte Carlo analysis. Data sets for some of the exposure parameters were based upon studies which did not directly measure the parameter in question. For example, drinking water intake was based on Army water use planning guidance which presented upper bound intake rates. Respiratory rates were calculated based on activity levels and the duration of exposure for military personnel was based on housing information. However, data sets with direct measurements of these parameters were either unavailable or could not be located. Sensitivity analysis with Crystal Ball® software was used to compare health risks of hypothetical exposures to benzene calculated with EFH and military-specific factors. The dermal pathway, risk was nominally decreased from 3.3E-7 using EFH factors to 1.0E-7 using MSEFs. This was due to the reduced military exposure duration. In contrast, the groundwater ingestion risk was increased from 7.2E-5 (EFH factors) to 1.2E-4 (military factors) because of increased military drinking water consumption in comparison to the U.S. population. The inhalation route risk was minimally decreased from 7.0E-4 (EFH factors) to 5.0E-4 (military factors) due to the shorter exposure duration.

Conclusions and Recommendations

Military-specific studies involving U.S. Army, Air Force, and Navy personnel were identified, providing military-specific data for body weight, surface area, inhalation rate, water intake rate, and residence time exposure factors. The body of available data was found to be sufficiently robust to support the development of probability density functions for many of these exposure factors. It was also evident that further investigation could provide additional military-specific data involving food consumption (i.e., garrison-level studies performed by United States Army Research Institute of Environmental Medicine (USARIEM)), site-specific housing data (e.g., location, number, and volume of military family housing units from installation-level housing offices), and population mobility data (e.g., time-on-station data from service-wide demographics databases). Additional investigation may also identify other military studies that could provide dermal contact data, incidental soil ingestion data, and activity pattern data (e.g., time spent outdoors, time spent showering, time spent swimming, time spent gardening). Gaining access to these data requires extended effort. A longer duration study will be necessary to identify, acquire, translate, and document data distributions for these exposure factors.

Reports from this study indicate that most military-specific exposure factor data are not centrally located. To support Enhanced Site-Specific Risk Assessment (ESSRA) activities at hazardous waste sites, as well as deployment risk assessments, a central data depository of MSEFs should be considered. Initial efforts started by the Air Force to create a handbook on methods to address uncertainty and variability should be expanded to address means to collect site specific information. This would describe the steps to follow to prepare probability distribution functions for military specific behavior and uptake rates. It would expand on the "how to" guidance for performing probabilistic risk assessments and build on the generic probability density functions currently referenced in the handbook.

MILITARY-SPECIFIC EXPOSURE FACTORS STUDY

INTRODUCTION

To guide the risk assessor through the exposure assessment step in the risk assessment process, the U.S. Environmental Protection Agency (EPA) published its initial exposure factors handbook (EFH) in 1989 and followed up with a revised/expanded EFH in August, 1997. The updated EFH provides data needed in the assessment of human health risk that were not available nearly a decade ago. Examples of population specific parameters that need to be considered in quantifying exposure estimates include: physical factors (e.g., body weight, skin surface area); activity patterns which define exposure frequency and duration (e.g., time of residence, time spent outdoors, time spent showering or bathing, etc.); and intake factors (e.g., rates of inhalation, ingestion of drinking water, foods and soil). The bulk of the data presented represent the general U.S. population (EPA, 1997).

In the absence of site-specific data on any given exposure parameter, EPA recommends default values that represent averages or upper bound levels. Where parameter distributions are available, the 50th percentile value is used as the central tendency and values above the 90th or 95th percentile are used as the reasonable maximum exposure (RME). Supplemental guidance recommends using the 90th or 95th percentile for the default contact rate, exposure frequency and exposure duration variables (EPA, 1991). The Guidelines for Exposure Assessment specifically refer to EPA's EFH as the primary source for the default values to use for exposure parameters (EPA, 1992a); however, EPA Regional Offices have the authority to specify default values different from those listed in the Superfund Guidelines for use within their region (Opresko, 1996).

Exposure of military personnel may differ from that of the general population. This report summarizes efforts to determine if unique data sets were available to develop military-specific exposure factors for use in risk assessment current and future exposure scenarios at Department of Defense (DoD) facilities. Potential sources of military-specific exposure factors were located by conducting a preliminary literature survey and canvassing military stakeholders to identify unpublished data sets.

Concurrent Technical Direction

Although the focus of this effort was on the application of probabilistic risk assessment (PRA) in environmental risk assessments at military sites, probabilistic analysis can also be utilized in Agency for Toxic Substances and Disease Registry (ATSDR) public health assessments as well as in risk calculations for military operations. The application of the probabilistic approach to risk assessments, the use of more site-specific data in risk calculations and the development of military-specific exposure factors to more accurately assess exposures to chemical substances are encompassed in a new program within the Air Force called Enhanced Site-Specific Risk Assessment (ESSRA). This recent initiative was spearheaded by the Human Systems Center, Occupational and Environmental Health Directorate, Occupational Medicine Division, Health Risk Assessment Branch (DET 1 HSC/OEMH) at Brooks Air Force Base (AFB) in San Antonio, Texas. An ESSRA stakeholder from the Air Force Center for Environmental Excellence (AFCEE) recently briefed the National Research Council on ESSRA and the development of "how to" guidance for the Navy's future use (Postlewaite, personal communication, 1998). Recent discussions with ESSRA stakeholders in the Army indicate that they, like their Air Force and Navy counterparts, are very interested in moving forward with the application of better science to their risk assessment process. ESSRA represents the next major step in improving the risk assessment process. It will enable risk assessors to identify risk factors that are more representative of site-specific conditions and it will provide risk managers with better information for their risk-based decision making process. For example, ESSRA holds the promise of reopening old records of decision, reassessing risk, and providing some relief from long-term maintenance and monitoring requirements that the Air Force and other military services have been committed to perform. It may also become a key element in the related development of more realistic assessments of indigenous risk for both short-term and long-term troop deployments in potentially contaminated theaters around the world (Postlewaite, personal communication, 1998).

Military Relevance

Many of the exposure factors that are included in EPA's EFH were derived from studies that involved very few military data sets. Appendix A presents the exposure factors and identifies the military data sets that were cited in the revised EFH. A review of this summary data shows that the 1983 U.S. Army water requirements study used to develop drinking water ingestion rates was the only military-specific data set referenced in the EFH (EPA, 1997). The military population is defined as active duty members within residential, occupational, and combat training scenarios; it does not include dependents, civilians working on base, or retirees. Although some military subpopulations may be nearly indistinguishable from the general U.S. population for which most of the exposure factors were derived, there are characteristics associated with military life that are unique. For example, there are numerous Air Force installations that are dedicated to a single mission, such as flying fighters, bombers, or transports. The military populations associated with these missions are more mobile than the general U.S. population because of the frequent rotation of aircrews and their families. In many cases they live in relatively isolated places, forming a community that is largely self-sufficient. Similarly, all military branches have facilities that are used primarily for training recruits, conducting simulated combat training exercises, or testing/proving military weapons and munitions. Across all of these types of installations, the military populations are younger, in better physical condition, and are generally more mobile than the U.S. population as a whole. It is likely that this subpopulation is lighter, has lower inhalation rates (at rest), drinks more water, has more frequent contact with soil (e.g., crawling across terrain), and resides for shorter periods of time (on average) in any one location than the general U.S. population. Therefore, it is possible that the exposure factors for this subpopulation are significantly different from those presented in EPA's Exposure Factors Handbook.

Characteristics of the military population may not extend to the military's civilian employees. Civilian exposure parameters are likely more similar to those of the general U.S. population. It should be noted that civilian employees rarely are authorized residence on military installations for extended periods, so their exposure is occupational as opposed to residential. Additional exposure scenarios outside active duty personnel can occur at many installations, depending on activities at particular sites. Figure 1 depicts these exposure scenarios and whether each scenario is likely or merely feasible. When the scenario is similar to a civil sector scenario, there is no justification for using exposure factors different than those accepted for the general public. On many military installations, the numbers of military and civilian employees can be similar. However, the number of military dependents is will often be two or more times the number of active duty members. Normally, access by the general public is limited but sizable numbers can be present on installations for special events and recreational activities. Recognizing that all these exposure scenarios can occur at a military installation, the focus of this report was to identify and, if possible, characterize those exposures which may not currently be effectively described by general exposure factors.

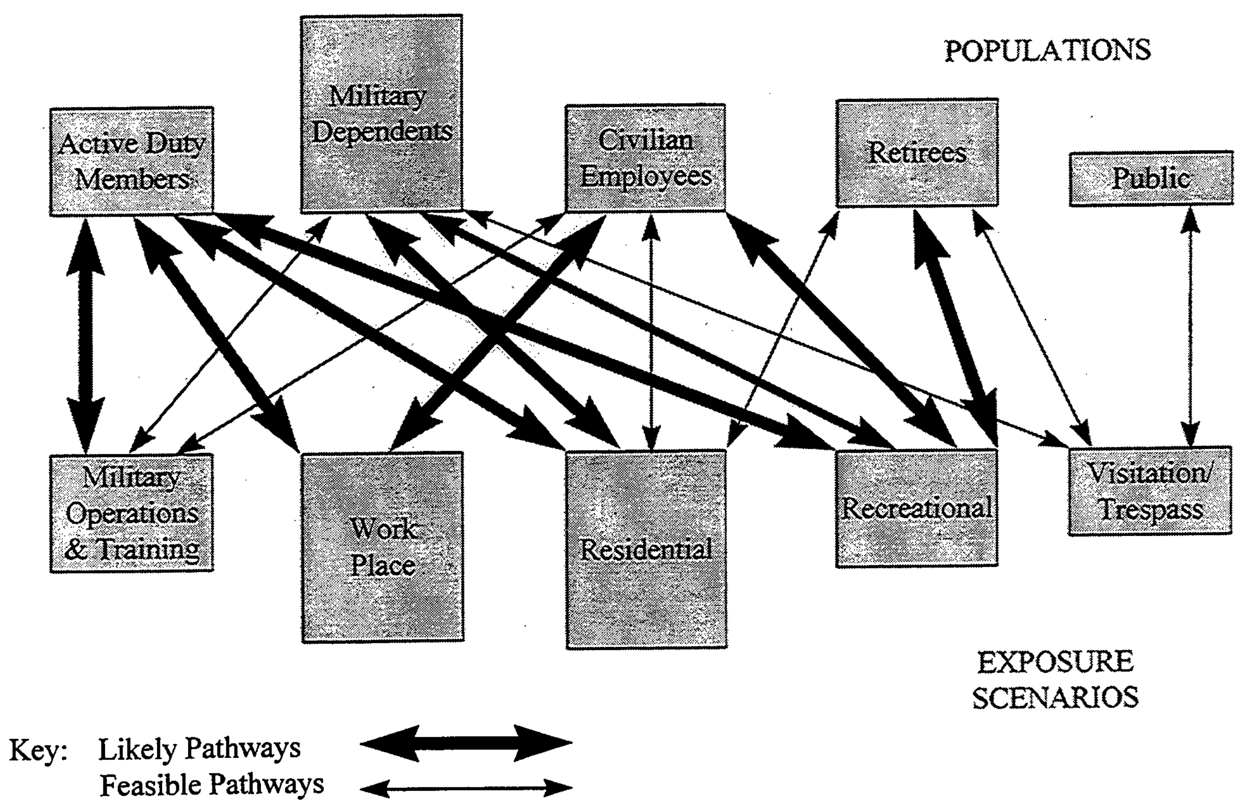

Figure 1. Potential Exposure Circumstances for Military Installations

METHOD

Literature Search Strategy

Because of the preliminary nature of this effort, a literature search strategy was developed to focus the effort on pertinent exposure factors used in the development of remediation goals. The initial search strategy was constructed in July 1997 to identify readily accessible sources of military exposure factors data. Resources used included both Medline and Toxline from the National Library of Medicine, the Defense Technical Information Center (DTIC) Scientific and Technical Information Network (STINET) (unclassified and unlimited technical report database) and multiple search engines on the Internet. The keyword template for this search was the EFH, then in draft form (EPA, 1997). Types of keywords used included:

- General Factors: Search terms corresponded to the general exposure factors such as average lifetime and veteran life span, anthropometrics (body weight and skin surface area), inhalation rate and volume, water intake (drinking water, tapwater and total liquid consumption), water usage, incidental soil ingestion, and pica (i.e., non-incidental or excessive ingestion of soil, generally in children).
- Activity Factors: Key activity terms included demographic descriptors such as time usage, occupational mobility, and job tenure. Characteristics of military housing (residence and room volume, foundation types and home air transport rates) and consumer products use (household solvents and cleaners, paints and cosmetics) were also queried.
- Food Ingestion Factors: Consumption statistics of specific food types (grains, fruits, vegetables, garden and home produce, fish and shellfish, meats, dairy products and breast milk) were also sought through literature and Internet searches.
- Additional Internet Queries: Outside of the specific factors searched in the literature databases and on the Internet, additional web sites were sought. Sites containing military and federal statistics including the Census Bureau and sites maintained by military human and health research laboratories were investigated.

A more definitive literature search was conducted from April to June 1998. The search strategy employed for this effort was based on understanding: 1.) the ways in which military populations differ from the general population in respect to exposure parameters used to establish remediation goals, and 2.) the appropriate and accepted methods of handling these differences.

A search for peer reviewed guidance documents was initiated. Guidance from the EPA and its regions, National Research Council, ATSDR, American Industrial Health Council, Health Canada, Presidential/Congressional Commission on Risk Assessment and Risk Management, U.S. Army Corps of Engineers, and others were sought. Guidance topics included exposure factors, exposure assessment, probabilistic methods, and Monte Carlo analysis. Agency web sites and the EPA Online Library System were instrumental in identifying several of these documents.

Reference searches are an iterative process. Once primary resources were found, their bibliographies were scanned for additional articles and documents that could be useful. Other secondary references were found by searching on authors' names and relevant topic areas. The authors chosen for this secondary search were researchers who had published frequently for organizations identified by stakeholders. "Stakeholders" typically refers to organizations that have an interest in the remediation efforts of a contaminated site, such as landholders or trustees of natural resources. In this report, "stakeholders" refers to military organizations that may either have relevant data holdings or an interest in the development of military-specific data that may be used in environmental risk assessments.

Several DoD research centers including the Crew System Ergonomics Information Analysis Center (CSERIAC), the Environmental Information Analysis Center (EIAC), and Chemical Warfare/Chemical and Biological Defense Information Analysis Center (CBIAC), as well as the consultative support staff at Air Force Center for Environmental Excellence PRO-ACT, were contacted. CSERIAC has 50 international anthropometric databases including 21 military-specific data sets contained within the Computerized Anthropometric Research and Design (CARD) Lab. EIAC is focused on environmental information and includes centers of expertise such as the Environmental Modeling Simulation and Research Center and the Hazardous Waste Research Center. The CBIAC, although focused on chemical and biological warfare, was contacted regarding any information on skin surface area, inhalation rates and activity rates of military members. AFCEE was contacted to access military housing information including the construction features of military housing units and numbers of the military population using this housing. In addition, the Humans Systems Center staff was contacted for any pertinent military-specific physiological data.

Interaction with Stakeholders

A preliminary assessment of existing data for military-specific situations was conducted in November 1997 and this information was combined with leads from stakeholders that were defined during the initial phase of this effort. This input was used to narrow the focus to relevant data applicable to military-specific exposure scenarios. The network of stakeholders was defined by interfacing with the Army, Navy, and Air Force headquarters and their occupational and environmental support organizations. Within the Air Force, Assistant Deputy Secretary of the Air Force, Environment, Safety and Occupational Health (SAF/MIQ) staff, Headquarters Air Force Materiel Command (HQ AFMC) staff, Air Force Research Laboratory, Human Effectiveness Directorate, Operational Toxicology Branch (AFRL/HEST) toxicologists, and anthropometric consultants (AFRL/HECP), as well as AFCEE Environmental Consultants Division (AFCEE/EQ) risk assessors, were consulted via phone or personal interview for inputs on military-specific scenarios and exposure factors. Staff at the base housing office and computer programmers for the housing database at Wright-Patterson Air Force Base (WPAFB), Ohio were interviewed for available information on military housing. Staff at the Air Force Materiel Command (AFMC) Personnel Directorate were contacted and residence time information was requested for active-duty personnel assigned to Air Force bases in the continental U.S. Within the Army, researchers at the Natick Research, Development and Engineering Center, the U.S. Army Institute of Environmental Medicine, and the U.S. Army Center for Preventive Medicine and Health Promotion, Aberdeen, MD were contacted. Personnel from the Naval Environmental Health Center (NEHC), the Naval Medical Research Institute, and the U.S. Navy's Environmental Research Laboratory, Fort Dietrick, MD were also interviewed.

Conversations with stakeholders and the subsequent chain of contacts led to the identification of military research institutions and offices which had performed or currently perform work relevant to one or more of the exposure factors. Once these offices were identified, Internet, Medline/Toxline, and DTIC STINET searches were used to find existing publications from these institutions. Additionally, organization web sites were sometimes useful for generating contact persons and phone numbers. Stakeholders were asked to identify any data sets they thought may exist, but were not available in public domain literature.

Collect Data

Initially, the revised EFH was reviewed and the exposure factors summarized as shown in Appendix A. Each of the exposure factors was evaluated with regard to their data sources and recommended values, confidence in these values, and any pertinent military information cited in the EFH (EPA, 1997). Relevant exposure scenarios were selected (see Exposure Scenario Section below) and a preliminary sensitivity analysis was conducted using the EPA intake equations and varying each of these parameters to gain insight into which exposure factor was most sensitive. The higher the sensitivity, the higher the priority given to that particular exposure factor for the search for any pertinent military-specific data. Through this process, Air Force, Army, and Navy anthropometric data were obtained that provided body weight and body size/surface area distributions. We identified an Air Force breast milk study but it only presented data on the duration of breastfeeding and reported that there was a reduced number of military active duty women who breastfeed in comparison with the U.S. population. Also identified was the means to determine the residence time for military personnel assigned to base housing at WPAFB and the time on station for Air Force personnel. One of the significant constraints to this approach involved the time delay in collecting unpublished data in a format useful for further analysis.

Characterize Data Distributions

Whenever raw data were available, statistical analysis was performed using Crystal Ball® (Decisioneering, Inc., Denver, CO) to determine the best fitting distribution. In many cases, the data were already statistically analyzed. In these cases, we did not reanalyze the data set but reported the stated descriptive statistics.

Data Applicability and Quality Analysis

Each data set was evaluated for its applicability as a military-specific exposure factor. The major applicability criteria were the particular data set's utility for military risk assessment use and its suitability in a risk assessment. A review of the data sets was made using the quality criteria specified in the EPA EFH (1997). The selected exposure factors and identified military-specific data sets were characterized with the following criteria and the results summarized in Appendix B.

- Level of Peer Review - peer reviewed literature and final government reports
- Accessibility - user could access study in its entirety
- Reproducibility - sufficient information in study to allow reproduction or assessment and evaluation of methodology
- Focus on Exposure Factor of Interest - either directly studied or addressed related significant factors
- Data Pertinent to U.S. - data outside U.S. may be included if behavioral patterns were similar
- Primary Data - secondary data were used if original analysis was conducted (e.g., United States Department of Agriculture (USDA) Nationwide Food Consumption Survey)
- Current Information - studies reflect current exposure conditions
- Adequacy of Data Collection Period - chronic preferred over acute studies
- Validity of Approach - direct measurement preferred over indirect
- Representativeness of Population - focus on military and note any limitation in study
- Minimized or Defined Bias in Study - either under- or over-estimate of the parameter is stated or apparent from study design
- Minimized or Defined Uncertainty in Study - evaluate all above factors, identified uncertainties and quality assurance/quality control measures in study preferred

Exposure Scenario and Pathways

Environmental risk assessments typically assess the hypothetical risk from exposure (either direct or indirect) to four media: soil, sediment, water, and air. Site-specific risks may also be estimated from contaminant exposure through locally produced foods and fish. Bio-uptake models can then be used to estimate potential contribution of contaminants to those food types from soil, water, and sediment. At many installations, military personnel, dependents, and civilians may be exposed in occupational, residential, or recreational scenarios. Site-specific activities and practices control exposure pathways.

Exposure pathways typically evaluated include, but are not limited to, the following routes: incidental ingestion of soil, inhalation of volatiles and/or resuspended contaminants in outdoor or indoor air, ingestion of drinking water (either from a groundwater or surface water source), dermal contact with soil, dermal contact with water, and inhalation of volatiles during showering or other household use of groundwater. Potential carcinogenic risk estimates are calculated using this standard algorithm (EPA, 1989b):

$$Risk = \frac{C_{media} * IR * EF * ED * CSF}{BW * AT}$$

where:

C_{media}	=	Concentration in media (mg/kg), (mg/L), or (mg/cm^3)
IR	=	Intake Rate [i.e., ingestion or inhalation rate (mg/day) or (L/day)]
EF	=	Exposure Frequency (days/yr)
ED	=	Exposure Duration (yr)
BW	=	Body Weight (kg)
AT	=	Averaging Time (days), 70 yr x 365 d/yr = 25550 days
CSF	=	Cancer Slope Factor (mg/kg/day)$^{-1}$

Potential noncarcinogenic risks are estimated similarly by calculating a hazard quotient (HQ). The HQ is a ratio between the estimated intake and a reference dose (RfD) (EPA, 1989b).

$$HQ = \frac{C_{media} * IR * EF * ED}{BW * ATn * RfD}$$

where:

HQ	=	Hazard Quotient (unitless)
AT_n	=	Averaging Time for noncarcinogens (days) = ED x 365 days/yr
RfD	=	Reference Dose (mg/kg/day)

The IR refers to inhalation rate or ingestion rates of water, soil, or foods. In cases of dermal contact, the IR is replaced by the body surface area exposed (SA in m^2) times either an adherence factor or absorption factor or both.

Based on these exposure pathways and the standard risk algorithms, a comparison of risk estimates using Monte Carlo simulations of general population data verses military population data was conducted. The results were then compared to determine if sufficient differences between populations exist to warrant the development of a military-specific exposure factor handbook. The distributions used for the general population were taken from EPA's EFH (EPA, 1997). Military-specific data were obtained for drinking water rates, activity-specific inhalation rates, body weights, body surface areas and residency time or exposure duration. Data on military-specific activity frequency and foods ingestion rates were not available. Hence, the simulations were run on the following exposure pathways:

- ingestion of water,
- incidental ingestion of soil,
- inhalation of volatiles, and
- dermal contact with soil.

Unit concentrations of 1 mg/kg benzene for soil, 1 mg/L benzene for water and 1 mg/m^3 benzene for air were used as point estimates for media concentrations in all simulations. The oral and inhalation cancer slope factors for benzene were also used as point estimates.

RESULTS AND DISCUSSION

Literature Search Findings

Inhalation Rate

Patton *et al.* (1995) conducted a metabolic study of military physical tasks in the traditional battle dress uniform and the chemical defense ensemble. This study included the minute ventilation rate, oxygen uptake rate, and heart rate for 42 physical activities unique to combat or combat training situations. Appendix C provides a summary of the physical activities, the minute ventilation rate (VR), and heart rate (HR) in beats per minute (bpm) for both men and women. Patton *et al.* performed regression analyses on HR and VR which resulted in a coefficient of linear regression (R) of 0.934 for men and 0.877 for women. Based on these correlations, the linear regression on the log VR, in terms of the HR, for military men is as follows:

$$LogVR = 0.481 + 0.00876HR$$

where:
VR = ventilation rate (L/min)
HR = heart rate (bpm)

The linear regression for military women is:

$$LogVR = 0.491 + 0.0076HR$$

(note: To convert L/minute to m^3/day: multiply VR by 1.44)

These regressions are comparable to the individual regression equations presented in Shamoo *et al.* (1991). It may be appropriate to use heart rate monitors during military-specific activities and these derived regression equations to estimate the inhalation rates. Such an approach could be applied to combat exercises, combat training or any military-specific activity that can occur at the military installation or garrison or during field situations such as deployments or training exercises. Review of the assessed activities, as listed in Appendix C, suggests that digging foxholes in more tightly bound soils as compared to sandy soils will yield much higher heart rate and corresponding inhalation rate (See Activity M-13 in Table C-1, Appendix C).

The EFH (EPA, 1997) noted that the inhalation rate can be estimated from the activity pattern of the population and provided a distribution for the inhalation rate as a function of slow, moderate, and heavy activity levels. Appendix D of this report summarizes the military-specific inhalation rate studies. The military activity pattern was taken from a 1985 EPA report (Anderson *et al.*, 1985). As shown in Table D-2, using this activity pattern the military male and female would have an inhalation rate of 24.8 m^3/d and 14.5 m^3/d, respectively, as compared to the EFH recommended values of 15.2 m^3/d and 11.3 m^3/d for the general population male and female, respectively.

The 1991 Shamoo *et al.* paper cited in the EFH linearly correlated the individual heart rate to the log of the inhalation rate (EPA, 1997). Mello *et al.* (1986) reported the heart rate over five days for simulated combat exercises. Using an average regression equation from the Shamoo *et al.* (1991) paper, this would yield a 5 day inhalation rate of 21.9 m^3/day.

Aerobic capacity studies have been done by both the U.S. Army and U.S. Air Force. There are extensive military data using the heart rate to estimate the aerobic capacity. A preliminary literature review did not locate a paper that correlated the aerobic capacity to the inhalation rate although both have been estimated by heart rate measurements. Future research would be needed to determine if military aerobic capacity data could be used to estimate military inhalation rate. Currently, the military collects data on basal heart rate, height, and weight as part of physical fitness assessments. The Air Force's Human Systems Center (Major (Dr.) Mike Snedecor) provided insight to the current algorithm used to express fitness from submaximal workload determination of heart rate. Data exist over the last several years on Air Force populations.

Body Weight

Table 1 provides a summary of the military anthropometric studies identified in the literature search. Appendix E provides a summary of each of these military studies. All military anthropometric data sets were compared to the U.S. general population body weight reported in the EFH, Table 7-4 (men) and Table 7-5 (women) (EPA, 1997). These tables report the body weights from ages 18 to 74, and ages 18 to 24, 25 to 34, 35 to 44, 45 to 54, 55 to 64, and 64 to 74. To compare the U.S. general population to the military, the body weight values of the U.S. population in ages 18 to 54 were compared to the military anthropometric studies. All of the military data sets would be representative samples of the age-adjusted U.S. population as determined by the student t-test at $P = 0.01$ (see Appendix E for the analysis).

The EFH body weight distributions reported in Table 7-4 and Table 7-5 were based on the 1987 National Center for Health Statistics study (EPA, 1997) and would be in the same time frame of the U.S. Army 1988 anthropometric study (Gordon *et al.*, 1989). In 1996, this study was assessed for its validity with the demographic changes that have occurred in the Army since 1988. Gordon (1996) concluded that the 1988 study was valid for anthropometric sizing and design in 1996. The Air Force anthropometric studies were conducted in the mid 1960's. The Navy study cited is based on a draft Naval Medical Research Institute technical report. The body weights cited in this report were from multiple sources and typically extracted from active-duty members' medical records.

This effort did not include height and weight data from the military's physical fitness assessments. Because of entrance policy impacts, the tails of the military distributions are expected to be significantly different than the general population. Please consult the original data sources if information on the ends of the distributions are needed.

TABLE 1. SUMMARY OF MILITARY ANTHROPOMETRIC STUDIES FOR BODY WEIGHT

Study	Number of Male Subjects	Mean Male Body Weight, Kg	Number of Female Subjects	Mean Female Body Weight, Kg
USAF, 1996[a]	30	79.4	33	58.8
USAF Men, 1965[b]	1,236	75.9	N/A	N/A
USAF Male Flyers, 1967[b]	2,420	78.7	N/A	N/A
USAF Women, 1968[b]	N/A	N/A	1,905	57.7
USAF Female Flyer, 1968[b]	N/A	N/A	455	59.5
Army, 1988[c]	1,774	78.8	2,208	62.1
Navy[d]	2,794	80.3	355	62.1
EFH, age (18-54)[e]	3,490	78.2	3,843	64.6

[a] Brunsman and Files, 1996
[b] Kennedy, 1986
[c] Gordon *et al.*, 1989
[d] Carpenter *et al.*, 1998
[e] EPA, 1997

Surface Area

For dermal factors, the EFH noted that the total body surface area for both men and women can be estimated using height and weight distribution data. Appendix 6a of the EFH provides several formulas to correlate the total skin surface area (SA, m^2) with body height (H, cm) and body weight (Kg). The EPA determined the Gehan and George equation to be the best choice for estimation (EPA, 1997). As an example, a Naval study's male mean height was 178.0 cm and the male mean body weight was 80.7 Kg (Carpenter *et al.*, 1998). Using the Gehan and George equation, the surface area was estimated as follows:

$$SA = 0.0239H^{0.417}\,BW^{0.517} = 0.0239(178)^{0.417}\,(80.69)^{0.517} = 2.00\ m^2$$

The EFH reported a total body surface area for men of 1.94 m^2 and that the correlation between height and weight influenced the total surface area final distribution by less than one percent

(EPA, 1997). Table 2 provides a summary of the whole body surface area calculated for a variety of military anthropometric data sets based on the Gehan and George equation. Military anthropometric studies are discussed in the body weight section.

The Air Force Research Laboratory, Human Effectiveness Directorate, Human Interface Technology Branch (AFRL/HECP) CARD facility at WPAFB has a three dimensional (3D) anthropometric system which can scan the human body surface in a few seconds. The new scanning technology has many advantages over the old system of measurement, which used tape measures, anthropometers (a type of measuring ruler), and other similar instruments. Some key advantages include:

- It reduces the guesswork about the body surface, which makes data much easier to use in computer aided design and rapid prototyping.
- It provides the first viable method for capturing humans in their clothing, with equipment and real workspaces, and in realistic postures.
- Being a non-contact system, it reduces measuring differences between measurers, making data sets collected by different groups more comparable.

TABLE 2. WHOLE BODY SURFACE AREAS OF MILITARY ANTHROPOMETRIC DATA SETS

Population	**Mean Body Weight (± SD), Kg**	**Mean Height (± SD), cm**	**Whole Body Surface Area, m^2**
U.S. Population, men	78.1 ± 13.5 (EFH, 1997, Table 7-4, ages 18-74)	Not presented in EFH	1.94 (EFH, 1997, Table 6-4)
U.S. Population, women	65.4 ± 14.6 (EFH, 1997, Table 7-5, ages 18-74)	Not presented in EFH	1.69 (EFH, 1997, Table 6-4)
Navy, men[a]	80.3 ± 11.8	178.2 ± 7.1	2.00
Navy, women[a]	62.0 ± 8.6	165.0 ± 6.7	1.70
USAF, men[b]	75.9 ± 10.6	175.8 ± 6.7	1.93
USAF, male flyer[b]	78.7 ± 9.7	177.3 ± 6.2	1.98
USAF, women[b]	57.7 ± 7.5	162.1 ± 6.0	1.62
USAF, female flyer[b]	59.5 ± 4.9	168.5 ± 3.8	1.68
Army, men[c]	78.8 ± 11	175.9 ± 6.7	1.97
Army, women[c]	62.1 ± 8.3	163.1 ± 6.4	1.69

[a] Carpenter *et al.*, 1998
[b] Kennedy, 1986
[c] Gordon *et al.*, 1989

The Air Force is participating in a survey called the Civilian American and European Surface Anthropometry Resource. This is a joint venture between governments and industry, sponsored by the Society of Automotive Engineers. Data sets are available via the Internet (http://cfhnetra.al.wpafb.af.mil/cardlab/cgi-in/nomozilla.cgi/internat_data.html). To date, 53 Air Force personnel and over 270 civilians have been whole body scanned (Robinette, personal communication, 1998). The Army also has a 3D anthropometric data acquisition and analysis system at the Natick Research Development and Engineering Center, Natick, MA. They are collecting the body surface area from whole-body images in conjunction with the Defense Logistics Agency and industry partners to better define clothing issue and design (http://www-scom.army.mil/services/biomech/3danthro.htm). Software algorithms are available to more accurately calculate the whole body and segmental surface areas such as hands, face, feet, arms, and legs. These 3D data sets should be used to more accurately estimate the surface area of the body and segments for both the military and civilian populations (these data sets were not available for analysis during this short-term study). The current EFH relies on regression equations that provide whole body and segmental (e.g., head, trunk, upper extremities, arms, upper arms, forearms, forearms, hands, lower extremities, legs, thighs, lower legs, and feet) surface areas based on body weight and height inputs (EPA, 1997).

Soil Adherence to Skin

Soil adherence to skin is discussed in Chapter 6.3 of the EFH (EPA, 1997). Soil adherence is a required parameter to calculate the dermal dose when the exposure scenario includes dermal contact with a chemical in soil. The EFH listed two Kissel *et al.* papers(1996a, 1996b) as key soil adherence studies. These papers reported a range of hand loadings that varied from 1E-3 to 1E+2 mg/cm^2, depending on the activity. Default range values of 0.2 to 1.0 mg/cm^2 were produced with activities providing relatively vigorous soil contact such as rugby and farming. Loadings of less than 0.2 mg/cm^2 were found in activities with less opportunity for direct soil contact on the hands and other body parts such as soccer or professional grounds maintenance. Because soil adherence levels are activity dependent, quantification of dermal exposure to soil will remain inadequate until more data are generated that address the type of activity, frequency, duration including interval before bathing, and clothing worn. The relevant studies listed in the EFH did not exceed 1.5 mg/cm^2 for the soil adherence factor (EPA, 1997). Our literature search did not reveal any military-specific soil adherence studies. Many military outdoor activities could be compared to soccer or professional grounds keeper duties, with a listed soil adherence factor of 0.2 mg/cm^2. Kids playing in mud had geometric mean soil adherence levels as high as 54 mg/cm^2 (Kissel, 1996b). It is possible that military members conducting combat training and exercises that include crawling would have soil adherence levels higher than the typical adult and could approach the levels of kids playing in mud. Additional research is needed to characterize the soil adherence factor for direct contact with soil during combat training exercises.

Drinking Water Intake Rate

The EFH cited the 1983 Water Consumption Planning Factors Study developed by the U.S. Army Quartermaster School, Fort Lee, VA. The results of this paper were suggested to serve as a bounding estimate for individuals. The EFH noted that the U.S. Army study did not represent the general population. It instead represents the water requirements for troops in the field during training and deployment. There is a distinction between water intake for deployed troops and military serving at U.S. installations. There were no military-specific data sets found in the literature search or provided by the stakeholders to suggest military water consumption rates for military members serving at U.S. installations differ from the U.S. civilian population.

Primarily, maximum water intake of physically active individuals such as deployed military members can vary from 5.7 L/day in temperate climates, to 7.6 L/day for cold climates and to 11.4 L/day in hot climates. This 1983 Army study assumed an activity pattern of 15% light work, 65% medium work and 20% heavy work (EPA, 1997). Later Army studies of combat exercises over a five day period indicated moderate activity levels and only heavy work loads during marches (Mello *et al.*, 1986). Appendix C lists the physical tasks studied by the Army (Patton *et al.*, 1995). They are characterized by activity levels of light, moderate and heavy based on energy expenditures (i.e., less than 325 watts = light, 325-500 watts = moderate, and greater than 500 watts = heavy).

The United States Army Research Institute of Environmental Medicine (USARIEM) has conducted water consumption studies during combat training exercises in winter conditions. Light infantry units were tested over a ten day exercise (-13°C to 7°C with a mean of -3°C) (Roberts *et al.*, 1989). One unit was encouraged to consume 4 L water/day while the other unit was monitored for water consumption. The two units ate Rations, Cold Weather, which would imply that their food intake would not be a potential route of exposure. The average energy level expended was estimated to be 4,700 Kcal versus an average of 2,534 Kcal consumed per day. The "encouraged to drink" unit averaged 3.68 L water/day versus the "control" unit, which averaged 3.36 L/day. The study concluded that combat or combat training exercise personnel had insufficient time and means to melt snow or ice to sufficiently hydrate themselves. Other units not in the test had higher urine specific gravity results than the test units suggesting that these untested units did not consume as much water as the tested units. There is a bias in the study as the tested personnel were briefed on the importance of water consumption and were observed daily by research personnel during the exercise. The actual consumption rate of the tested personnel (3.7 L/day) was far lower than the 7.6 L water/day planning rate for cold climate presented in the EFH (EPA, 1997).

Szlyk *et al.*, 1988 conducted water consumption tests in the laboratory for simulated desert walking with 33 unacclimatized men. They were tested for six hours (40°C dry bulb, 26°C wet bulb, 4.02 km $hour^{-1}$ wind speed) for *ad libitum* water consumption. The observed mean consumption rate was 2.6 L over 6 hours. These test subjects walked on a treadmill at 4.82 km/hour, 5% grade for 30 minutes every hour. Assuming an 8 hour sleeping period, this would equal a 7 L/day water consumption rate. Military members who are required to maintain hydration via forced drinking perform better than those who drank *ad libitum*. The U.S. military forces in the Persian Gulf War were required to consume water at a certain rate. It may be more appropriate to use the prevailing forced water consumption rate (if it is enforced) in a risk assessment involving military personnel in a desert deployment scenario than the 11.4 L/day value cited in the EFH (EPA, 1997).

Breastfeeding

The incidence and duration of breastfeeding in active duty military women were assessed by Sandercock (1993). She examined the duration of breastfeeding in 20 active duty women who delivered at a Midwestern military medical center. In contrast to the 55% breastfeeding rate observed in civilian employed mothers, 45% of the active-duty mothers were breastfeeding upon discharge from the hospital. Most of the active-duty mothers (88%) discontinued breastfeeding within two weeks and none were breastfeeding at six months. The EFH presents a different volume of breast milk for mothers who breastfeed up to six months (742 ml/day) as compared to mothers who breastfeed at a 688 ml/day rate for 12 months duration (EPA, 1997). Should breastfeeding be a significant uptake pathway, site-specific data from the installation's medical center should be obtained.

Input from Stakeholders

Considerable effort was applied to identifying and contacting military stakeholders who may have insight into data sets which are not available in public domain literature. The following paragraphs and the tables presented in Appendix F provide a summary of the stakeholder network.

Body Weight Data

The Navy Medical Research Institute, Toxicology Detachment (NMRI/TD) at WPAFB shared with us a draft technical report with pertinent data sets. These data sets included height, weight, age, and percent body fat information obtained from Navy personnel that included about 150 BUD (Basic Underwater Demolition) and SEAL (Sea, Air, Land) divers, about the same number of aviators, and more than 2000 general fleet staff. Statistical analysis of these data sets was complete, including their distribution types. The data were provided on a floppy disk, along with a copy of a draft report that included a listing of the raw data (Carpenter *et al.*, 1998). This data set is summarized in Appendix E.

Residential Volume

To gain insight into military housing data sets, the deputy director for base housing at WPAFB, OH (Ms. Elizabeth Stoll) was contacted. She provided a list of 2,147 currently occupied and available housing units with their gross and net square feet area. WPAFB has housing units that are typical of those found in the Air Force. Information on 102 senior field grade and general office housing units was not collected as these were not typical Air Force housing units. Neither the base housing office nor the Air Force maintain records on the historical number of housing units available at an Air Force installation by year; only current year data are available. These housing data from WPAFB, which would be representative of base housing units at most Air

Force installations, were analyzed. The analysis yielded a minimum of 169 m^3 volume to a maximum of 456 m^3 volume with a mean of 266 m^3 and a standard deviation of 67 m^3. In contrast, the EFH reported from two studies that the arithmetic mean of both studies for the residential volume in the United States was 369 m^3 with standard deviations of 258 and 209 m^3. (EPA, 1997). If a detailed risk assessment requiring the housing volume is done for a military installation, it is suggested that a more representative site-specific military housing residential volume be used. If the housing office at that installation can not provide the square footage of each housing unit to calculate the residential volume (assume height of 8 feet x square footage / 35.315 ft^3/m^3), the housing volume could be estimated using the WPAFB data described above.

Table 1-2 of Air Force Instruction 32-6002 (1994) provides the statutory space limits that are authorized for base housing, which is listed by rank and number of bedrooms. The maximum net area ranges from 88 m^2 (Junior Enlisted and Company-Grade Officer, two bedrooms) to 195 m^2 (General Officer). A colonel is authorized 158 m^2. So only a general officer or colonel would be authorized base housing that would exceed the average value reported in the EFH for residential volume (369 m^3/8 ft x 3.28 ft/m = 151 m^2). At a typical base, there over 80% junior enlisted and company grade officers compared to higher enlisted grade, field grade, and general officers (81.6% as of 30 September 1995). These values could be used as a range of default values for base housing if there were no site-specific base housing information readily available. The net area averaged 109 m^2 for WPAFB. The EFH default residential volume values are significantly higher than the military housing residential volume values represented by the WPAFB data.

In follow-up interviews with WPAFB civil engineering computer programmers, (Jean Moore and David Johnston), they noted that the computer support services center at Gunter AFB has fee for services to do computer programming and analysis of the Air Force housing data. Each Air Force installation must submit housing data to the computer support staff at Gunter AFB. Neither the base-level services offices nor the support center at Gunter AFB were able to provide the requested information during the period of performance.

Following our interviews with the civil engineering computer support staff, we forwarded an official request for the following additional WPAFB housing data: 1.) the dates of occupancy for Air Force members currently assigned to base housing units; 2.) the type of unit that each member occupies (e.g., single family, duplex, etc.) and its location (e.g., Page Manor, Woodland Hills, Green Acres/Pine Estates, "Brick Quarters", or mobile home park); 3.) the age of each of the units that are occupied (i.e., the month and date when construction was completed); 4.) the floor plan, number of bedrooms, and living space (net square footage) of each occupied unit; 5.) the number of adults and children in the military family along with their ages and gender; and 6.) the Active Duty Service Computation Date (ADSCD) for the military members. The ADSCD will be used to estimate the age of the military member if this data is not otherwise available. These data were not received in time to be included in this effort.

Population Mobility

Colonel John Joyce, 74th AMDS/SGPB, WPAFB, informed us that he was currently accessing selected Air Force demographic data through the Personnel Directorate at HQ AFMC. Part of the information contained in this massive data system provides population distribution data at Air Force installations, and is connectable to other military data systems that may contribute to our data collection efforts. The point of contact at HQ AFMC for access to this data system is MSgt Melvin Buckman, AFMC/DPZM.

MSgt Buckman provided an analysis of the time on station for all active-duty personnel assigned to continental United States Air Force bases. In the past, military members received orders to rotate from an assignment at two to four year intervals. With the declining DoD budget, less money is available for permanent change of station (PCS) assignments. This time on station value could be an upper bound estimate for military populations and it would be more appropriate than the population mobility value used in the EFH, as a military member can occupy more than one residence during a single assignment to a specific duty station. The time on station data do not differentiate individuals serviced by the personnel center but assigned to a nearby satellite installation. Care must be used in applying the data. The EFH cited Israeli and Nelson (1992) who used the average current residence time (time since moving into current residence) for population mobility. Israeli and Nelson estimated the average total household residence time as 4.6 years. However, the EFH recommended population mobility value was 9 years with 33 years as the 90th percentile based on 1993 U.S. Bureau of the Census data (EPA, 1997).

Military assignment duration is impacted by mission area and national level budget policies. Examples of two base level assignment histories are included in Appendix G along with Air Force wide data for officers and enlisted personnel. These data were provided by Buckman and Tolle (personal communication, 1998). These residence times are estimated from military records of "Date Assigned on Station" and are ordered from time since arrival. These data do not account for multiple residences at a single station, nor do they address the possibility of multiple assignments on one installation. Years on station data (Figures G-1 and G-2) smooth out the annual variations seen in the days on station curves (Figures G-3 and G-4). Base-to-base variations (Figures G-5 and G-6) evolve from mission demands. Air Force dependent information can be found in Figures G-7 and G-8. These data do not differentiate between service members living on or off base.

For base housing residency at WPAFB, the housing office stated that the most likely stay for base housing at WPAFB was 2.5 years with a minimum of 1 year (occupants must sign an agreement to stay at least a year) and a maximum of 10 years (Stoll, personal communication, 1998). Other Air Force base housing offices will most likely have a different residency distribution for their military housing as some have a maximum occupancy period. Unlike WPAFB, many bases do not have multiple opportunities for the military member to change assignments and remain at the same PCS location; therefore, the installation mission should be expected to significantly impact occupancy periods. The government was not able to provide detailed housing data during the period of performance; however the data provided on WPAFB residence areas are included in Figure G-9.

Food Consumption Studies

Lt Col Dianne Cortner, an Air Force Dietitian and nutrition specialist at Kessler AFB, MS, discussed a "healthy heart" study she participated in that will be published in August, 1998, in the Journal of Applied and Preventive Psychology. This study involved two groups of about 400 basic trainees at Lackland AFB. One group ate the "healthy heart" (low fat, low cholesterol) diet and the other (control) group ate the normal meals served in the dining halls. One result of the study noted that the body mass index of the subjects eating the "healthy heart" menu reached their ideal value by the end of the sixth week. The total study length was 18 weeks. She presently has a 50-page draft that she could forward via email.

Colonel Esther Myers, Andrews AFB, MD, the Air Force Representative on the DoD Nutrition Committee, told us about a food consumption study that was performed by Colonel Warber while he was at the USARIEM. She believed that this study replicated the USDA study that was used by the EPA in their exposure factors handbook.

Dr. H. Lieberman, Director of USARIEM, informed us that Col Warber's study was not fully written at this time. Although the study involved about 1,000 soldiers, the research did not quantify the food that they consumed. Col Warber's study is one of a series of studies that has been performed at USARIEM over the past few years. From this work it is hard to say that the diets of soldiers, sailors, marines, or other military personnel differ from the diets of their civilian counterparts. It is also important to note that most of these studies have involved small groups of subjects that are not representative of military populations (e.g., a group of 150 Army Rangers). It would also be very difficult to compare the data from these studies to the National Health and Nutrition Examination Survey data developed by USDA. However, USARIEM has conducted several garrison level food consumption studies that may be helpful. Each of these studies involved about 100 subjects and were conducted at several different garrisons.

No nutrition or dietary studies were located which fully address the installation level military scenario. Several self reported questionnaires and other studies as discussed above present insight into parts of the food consumption exposure factors. However, regional dietary exposure distributions can be obtained from the 1994-1996 USDA Continuing Survey of Food Intakes by Individuals. These data would be useful for site-specific risk assessments at bases located where local dietary habits are applicable to the military population due to access to game, fish, or gardening. This USDA survey database is the most current source accepted by the EPA for acute dietary exposure assessments. It contains 435,165 individual records of food consumption. It will be supplemented with additional survey data for children in 1999. Data on subpopulations based upon age, gender, season, region, race, origin, breast feeding status, pregnancy/lactation status, and income are included. Data are also provided on 7,532 foods, comprised of 3,008 ingredients (USDA, 1998 as cited by Baugher, personal communication, 1998). Therefore, if an analyst has site-specific information on residual concentrations found in a locally produced ingredient, the residual value can be carried over to estimate concentrations in other foods utilizing that ingredient.

Data Applicability and Quality Assessment

Each of the data sets reviewed in the literature survey and received from the stakeholders were evaluated using the EFH quality assessment criteria and the results are listed in Appendix B. Table 3 is a summary of the data applicability and quality assessment process for the exposure factors with military-specific data sets.

TABLE 3. SUMMARY OF DATA APPLICABILITY AND QUALITY ASSESSMENT FOR MILITARY-SPECIFIC DATA SETS

Data Set Description	Applicable Exposure Factors	Quality Ranking	Comments
1985 EPA Report[a]	Inhalation Factor	High	Appendix D of this report incorporates 56 subpopulations by activity level including military; Need to use distribution of ventilation rate for each activity level to yield an inhalation rate with a distribution
USAF CG Study (1996)[b]	Body weight, whole body and segmental surface areas	High	Aviator body weights fit within EFH population; Need additional analysis of whole body scans to yield segmental surface areas
USAF 1986 Anthropometric Collation[c]	Body weight, stature, surface area	High	Can use EPA EFH regression equations to estimate surface areas from body weight and height
U.S. Army 1988 Anthropometric Survey[d]	Body weight, stature, surface area	High	Can use EFH regression equations to estimate surface areas
NMRI/TD Naval Subpopulation Study (1998)[e]	Body weight, stature, surface area	Low	Can use EFH regression equations to estimate surface areas; However, report is still a draft and data were extracted from medical records

[a] Anderson *et al.*, 1985
[b] Brunsman and Files, 1996
[c] Kennedy, 1986
[d] Gordon *et al.*, 1989
[e] Carpenter *et al.*, 1998

Comparison of Risk Estimates using EPA versus Military-Specific Exposure Factors

A comparison of probabilistic analyses run on risk calculations was conducted using exposure parameters on which suitable data for comparison between the general public and a military population were found. The objectives of running these simulations were: 1.) to determine the exposure parameters which contribute the greatest amount of uncertainty to calculated risk values, 2.) to compare the probabilistic risk results calculated with EPA's data versus military-specific data, and 3.) to determine if using military-specific data reduce the uncertainty in developing remediation goals.

As described in the preceding sections, some military-specific data were found on body weight, height, respiratory rates, water ingestion rates, and exposure duration. With this limited set of distributions, Monte Carlo simulations were run, using Crystal Ball®, on the risk calculations for the following exposure routes: inhalation of indoor air, ingestion of drinking water, and dermal contact with soil. These exposure routes are commonly used to establish risk-based cleanup criteria for soil and water. Incidental ingestion of soil, dermal contact with water and ingestion of food stuffs are pathways which are also commonly used in the development of cleanup levels; however military-specific data on ingestion rates of soil and various food types could not be located during this study. It appears highly possible that these data do not exist. Also military-specific data on activities such as showering time and swimming frequency were not available. Sensitivity analyses were also run on the risk calculations. Sensitivity refers to the amount of variability in a forecast that is caused by both the uncertainty of a parameter assumption and the model sensitivity. Model sensitivity refers to the overall effect that a change in a parameter produces in a forecast. This effect is solely determined by the formulas in the model.

Latin Hypercube analyses were also run on selected pathways to compare results with those obtained using Monte Carlo. Differences in the forecasts statistics were not significant. Therefore only Monte Carlo results were used to determine the impact of using military exposure factor distributions versus EPA distributions.

The exposure factors analyzed were limited to those that may be customized to military scenarios. Point estimates were used in the risk calculations for factors which cannot be assigned values that are truly "military-specific". For example, soil adherence rates, toxicity values, life span, and dermal absorption rates are factors which impact risk calculations but would be considered equivalent for both military and other "general population" exposure scenarios, such as residential, commercial or recreational. Unit values of 1 mg/kg, 1 mg/m^3, and 1 mg/L were used as media concentrations for soil, air, and water, respectively. In real world situations, there generally is considerable variability in the exposure point concentrations, because media concentrations are often measured over a large area and complex environmental processes like partitioning between media and biodegradation contribute to variability in measured contaminant concentrations. In addition, point estimates for cancer slope factors (CSFs) and RfDs were used because changes to the accepted toxicity criteria published in the Integrated Risk Information System and Health Effects Assessment Summary Tables are beyond the scope of this project and do not apply as parameters which vary from a military or public residential scenario. It should be noted that toxicity criteria development incorporates assumptions of intake rates and, assuming the point estimates are valid, may or may not be appropriate; toxicity criteria appropriateness should be confirmed during a site-specific assessment. The exposure parameter distributions and point estimates used in this analysis are listed in Table 4. A detailed list of all parameter distributions, including percentiles used in cumulative distributions, is provided in Appendix H.

Probabilistic Effect on Dermal Contact with Soil Risks

Using the height and body weight data, distributions for total body surface area were calculated utilizing the equation developed by Gehan and George in 1970 (EPA, 1997):

$$SA = 0.0239 * BW^{0.517} * H^{0.417}$$

where:

SA = Total body surface area

BW = Body Weight

H = Height

TABLE 4. EXPOSURE PARAMETER DATA USED IN PROBABILISTIC RISK COMPARISON

Parameters	EPA's EFH Distribution	Reference	Military-Specific Distribution	Reference
Body Weight	Lognormal, X = 78.5 Kg, SD = 13.5 Kg	EPA, 1997	Cumulative, See Appendix H for percentiles	Gordon *et al.*, 1989
Skin Surface Area	Cumulative, See Appendix H for percentiles	EPA, 1997	Cumulative, See Appendix H for percentiles	Gordon *et al.*, 1989; EPA, 1997
Exposure Duration	Lognormal, X = 78.9 yr, SD = 12.7 yr	EPA, 1997	Triangular, 1, 2.5, 10 yr	Stoll, personal communication, 1998
Inhalation Rates	Cumulative, See Appendix H for percentiles	Respiration rates per activity level taken from EPA, 1995.	Cumulative, See Appendix H for percentiles	EPA, 1995
Water Ingestion Rates	Normal, X = 1.5 L/d, SD = 0.3 L/d	EPA, 1997	Triangular, Minimum = 1.80 L/d, Maximum = 11.4 L/d, Likeliest = 2.8 L/d	EPA, 1997
Exposure Frequency	Point estimate 350 d/yr	EPA, 1989b	Point estimate 350 d/yr	EPA, 1989b
Skin Absorption Factor	1.0	EPA, 1989b	1.0	EPA, 1989b
Soil Adherence Factor	1.48 mg/cm^2	EPA, 1992b	1.48 mg/cm^2	EPA, 1992b
Averaging Time for Carcinogens	70 yr	EPA, 1989b	70 yr	EPA, 1989b

A number of researchers have developed equations for predicting surface area from body weight and height. Because the Gehan and George formula is based on the largest number of direct measurements, their method is recommended by EPA (1997). Body weight and total body surface area are strongly correlated and should not be treated as independent variables in calculating a dermal exposure using Monte Carlo simulations. Phillips *et al.* (1993) reported a Pearson's correlation coefficient of 0.98. Combining values from the upper end of a surface area distribution with a mid or lower end value from a body weight distribution may lead to biased results. Consequently the distributions must be correlated. Crystal Ball® and other forecasting software, such as @Risk® (Palisade Corporation, Newfield, NY), allow the user to correlate distributions.

For soil contact scenarios, dermal exposure was expected to occur at the hands, legs, arms, neck, and head with approximately 26% and 30% of the total surface area exposed for adults and children, respectively. Less conservative scenarios have limited exposure to the arms, hands and feet. For example, if an individual was wearing a long sleeve shirt, pants, and shoes, one would expect the exposed skin surface to be limited to the head and hands (i.e., approximately 10% or 2000 cm^2). However, the case has been made from studies using personal patch monitors placed beneath clothing of pesticide workers that significant dermal exposure may occur on skin surface covered by clothing. Therefore, EPA recommends applying the upper end of the range, 25% of total body surface area, which yields default values from 5000 to 5800 cm^2 (0.25 times the 50^{th} to 95^{th} percentiles, respectively) (EPA, 1992b). Hence in this project, 25% of the total body surface areas calculated from the Army's body weight and height data was used for this comparison. The correlation between body weight and the surface area of extremities is not expected to be as high as the correlation between body weight and total skin surface area. Since a correlation based on actual skin measurements of extremities was not currently available, a correlation of 0.95 was derived between BW and 25% of the estimated total body surface area.

Figure 2 presents the measured contribution to variance of risk using EPA and military data for dermal contact with soil. Both scenarios indicate that exposure duration contributes the greatest amount of variability to the forecasted risk (greater than 98%). Skin surface area is calculated from weight and height. As discussed in the previous section, body weight distributions for both military populations and the general population did not vary greatly. Therefore, skin surface area distributions between the two populations did not vary greatly (see Appendix H). In addition, the high correlation between body weight and skin surface area was incorporated into the simulations, further reducing the contribution to variance in the forecasts.

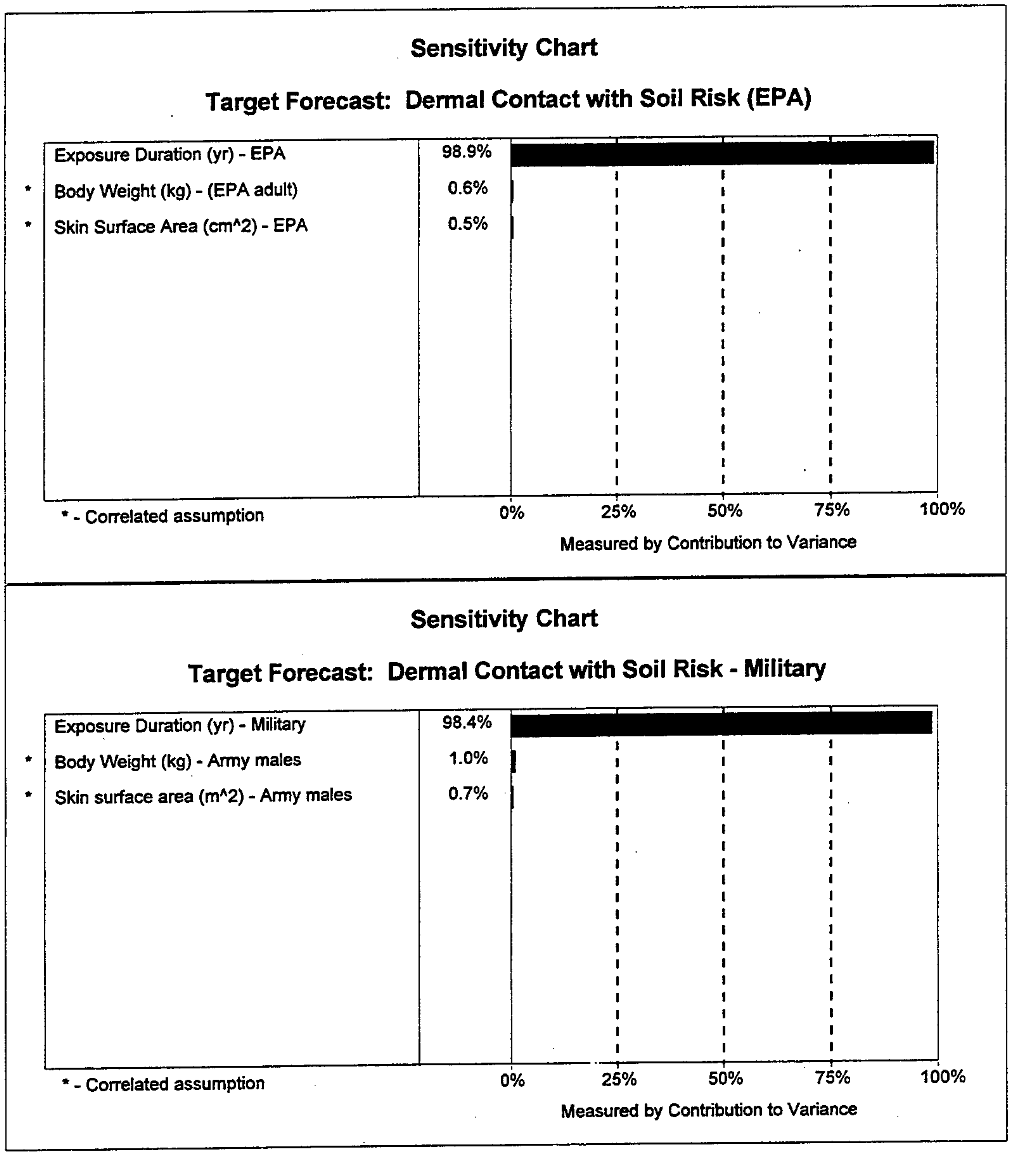

Figure 2. Comparison of Sensitivity Analyses for Dermal Contact with Soil Risk, Using Parameters from EPA's EFH vs. Military-Specific Parameters

Figure 3 presents the risk forecasts for dermal contact with soil containing 1 mg/kg benzene using both sets of data. Risks were within the same order of magnitude (i.e., 3.3×10^{-7} using EPA EFH values and 1.0×10^{-7} using military distributions for Army males). However, the resulting distribution of risk for the general population (i.e., EPA data) is more skewed, due to greater variability in the exposure duration distribution for the general public.

Unfortunately, military-specific data on soil adherence were not available for comparison purposes. Therefore a point estimate was used (see Table 4) (EPA, 1992b). Soil adherence and chemical specific permeability contribute much uncertainty to this pathway. However, these parameters are not specific to either the general population or the military, and are therefore not appropriate to address in a handbook of MSEFs.

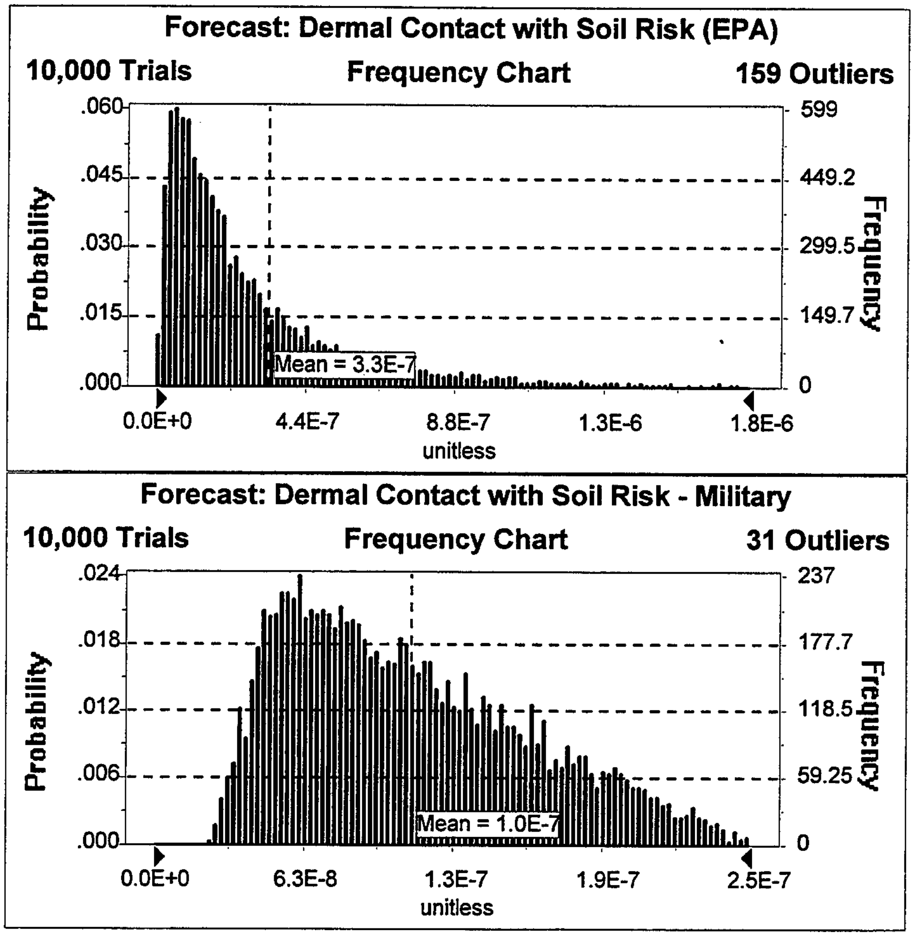

Figure 3. Comparison of Risk Forecasts for Dermal Contact with Soil, Using Parameters from EPA vs. Military-Specific Parameters

Probabilistic Effect on Water Ingestion Risks

A comparison of the two sensitivity analyses is presented in Figure 4. Using parameter distributions from EPA's EFH for exposure duration, water ingestion rate, and body weight, exposure duration contributes the greatest amount variability (94.7%) to the end risk forecast. Alternatively, the contribution to variance from exposure duration drops to 56.9% and the contribution from the water ingestion rate increases to 39.1% for the military scenario.

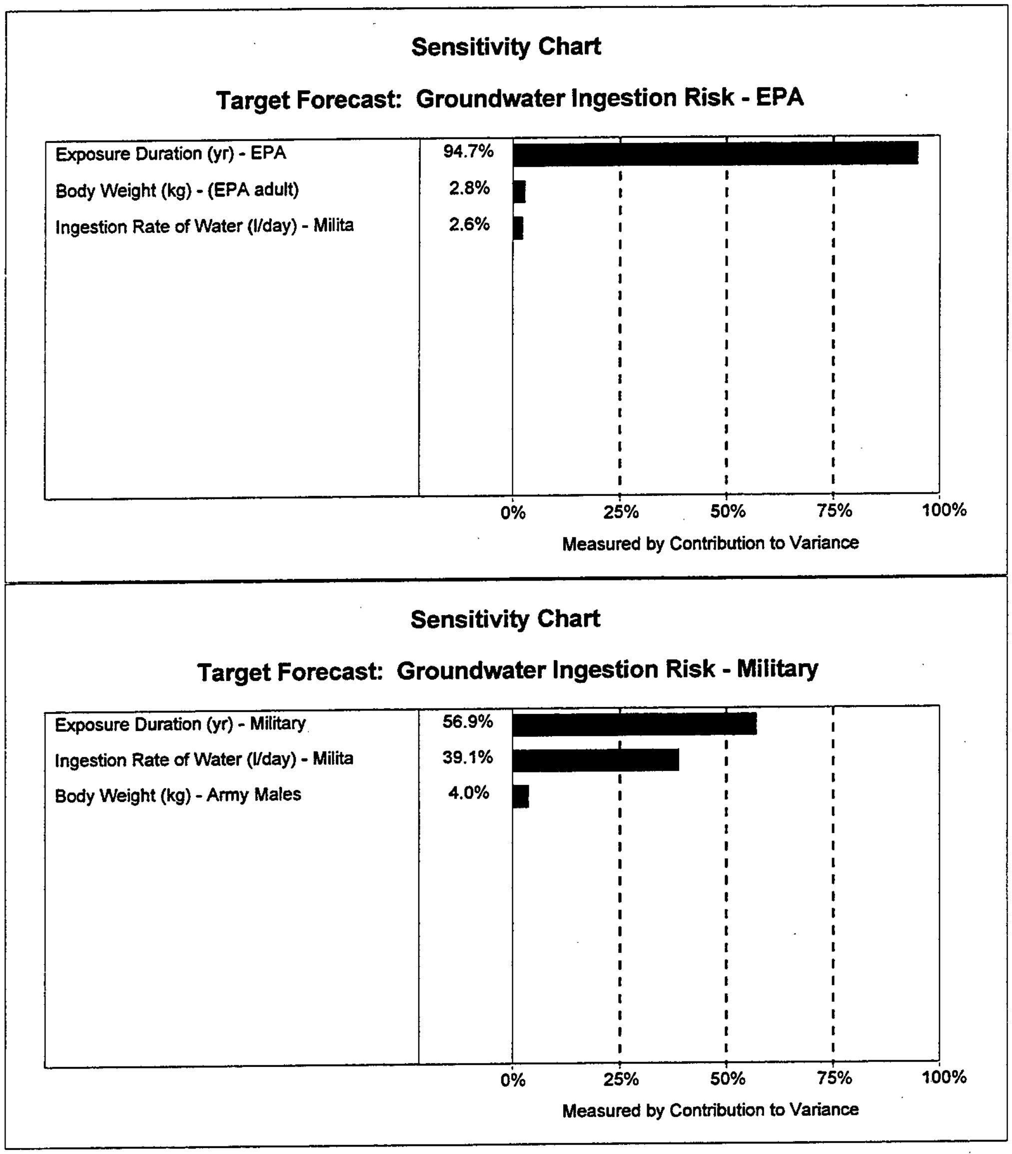

Figure 4. Comparison of Sensitivity Analyses for Water Ingestion, Using Parameters from EPA's EFH vs. Military-Specific Parameters

The forecasted risk range (see Figure 5) for drinking water containing 1 mg/L benzene using military-specific data (mean = 1.2×10^{-4}) was higher than that using data from EPA's EFH (mean = 7.2×10^{-5}). The increased risk for the military scenario is attributed to the much higher water consumption rate per the EFH citation of the U.S. Army 1983 water planning study. It should be noted that the study reported only upper bound consumption rates for cold, temperate, and hot climates. Because the purpose of the water consumption study was to develop safety factors for establishing potable water demands in deployment scenarios, lower bound values were not reported. As a result, an accurate distribution could not be derived for this parameter without evaluating the raw data, which were not available. A triangular distribution ranging from 1 to 11 L/day was used. These data are not be recommended for environmental risk assessments for site remediation purposes but may be applicable for field exercises or deployments. The U.S. Army 1983 water intake study was revised in July 1988 and in May 1994. However, the revised documentation did not include the data needed to develop a water intake distribution (U.S. Army Quartermaster School, 1994).

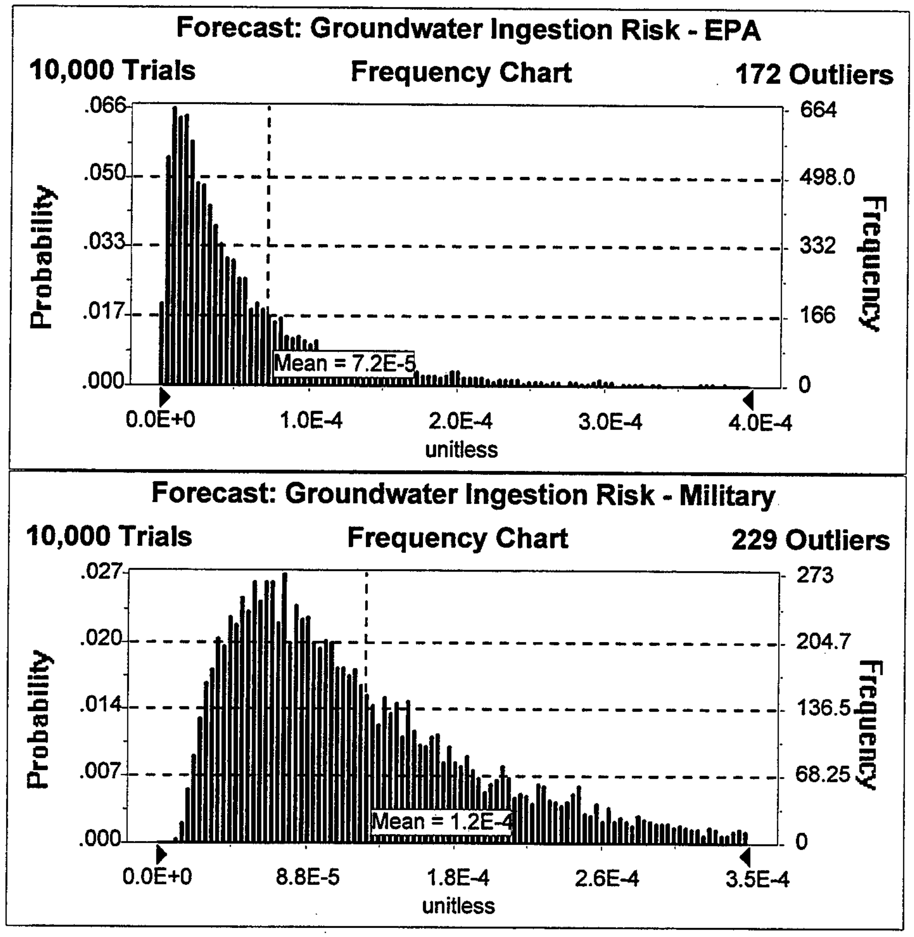

Figure 5. Comparison of Risk Forecasts for Water Ingestion, Using Parameters from EPA vs. Military-Specific Parameters

Probabilistic Effect on Inhalation Risk

The sensitivity analyses for both EPA and military scenarios were similar (see Figure 6). Again, exposure duration contributed the majority of variability in risk, 87.6% and 85.1% for EPA and military, respectively. Because a higher inhalation rate was identified for military men, this parameter contributes more variability to risks than the inhalation rate for men of the general population. Tables 5 and 6 present the percentiles used to develop inhalation rate distributions. The inhalation data used for military males were calculated based on activity patterns reported for military personnel (Anderson *et al.*, 1985) (see Appendix D). Based on the time spent at each activity level, percentiles of inhalation rates were calculated to develop a cumulative distribution.

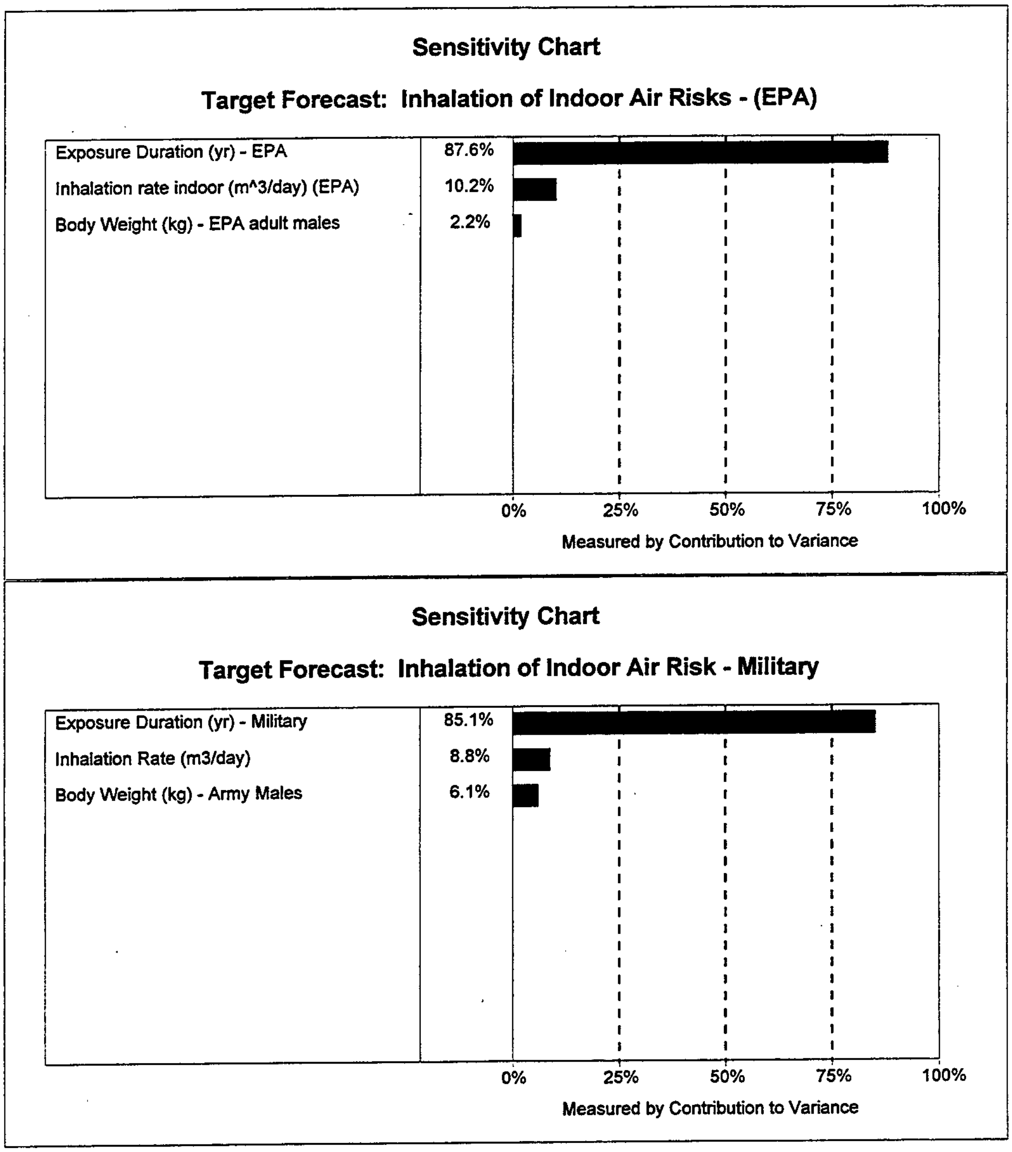

Figure 6. Comparison of Sensitivity Analyses for Inhalation Risks, Using Parameters from EPA's EFH vs. Military-Specific Parameters

TABLE 5. PERCENTILES OF INHALATION RATES FOR MILITARY MALES (EPA, 1997)

Activity Level	hr/wk	Inhalation Rate (L/min)	Inhalation Rate (m^3/day)	Cumulative Percentile
Rest	0	12.2	17.6	0.00
Low	145	13.8	19.9	0.86
Moderate	22	40.9	58.9	0.99
High	1	80	115.2	1.00

TABLE 6. PERCENTILES OF INHALATION RATES FOR MALES (EPA, 1997)

Inhalation Rate (m^3/day)	Cumulative Percentiles
5.40	0.01
8.40	0.03
9.39	0.05
15.11	0.50
26.25	0.95
30.62	0.98
64.95	0.99

The ranges of risk reported for this pathway were similar, as shown in Figure 7. Both the military data and the EPA data resulted in a mean risk level in the 10^{-4} range.

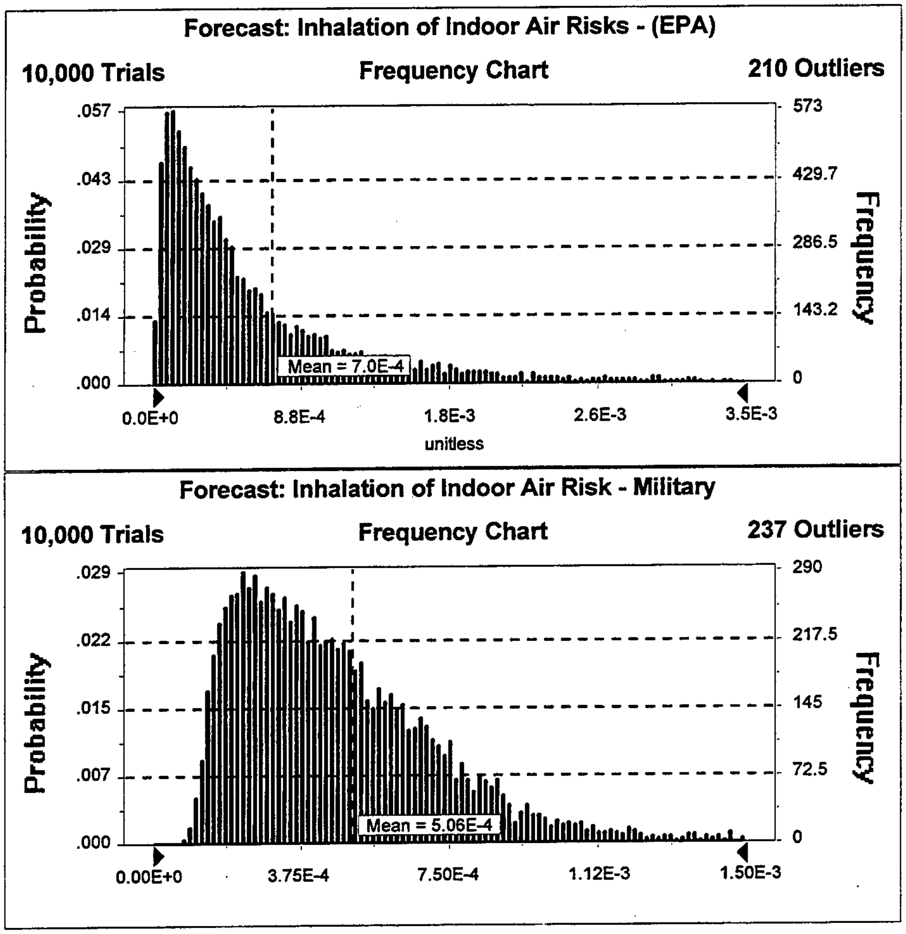

Figure 7. Comparison of Risk Forecasts for Inhalation Pathway, Using Parameters from EPA vs. Military-Specific Parameters

A statistical summary of the forecast risks from each of the pathways evaluated is presented in Table 7. There was little difference in risk results using data from the EPA EFH versus military data. In terms of reducing uncertainty, the factor most in need of military-specific data is exposure duration. Exposure frequency is also a factor that should be evaluated. Military data on exposure frequency were not available during this brief study. Much of the activity data reported by EPA are self-reported and may not provide robust results.

TABLE 7. SUMMARY OF PROBABILISTIC RISK COMPARISONS

	Dermal Contact with Soil Risks		Water Ingestion Risks		Inhalation Risks	
	EPA	**Military**	**EPA**	**Military**	**EPA**	**Military**
Trials	1.0E+04	1.0E+04	1.0E+04	1.0E+04	1.0E+04	1.0E+04
Mean	3.3E-07	1.0E-07	7.2E-05	1.2E-04	7.0E-04	5.0E-04
Median	1.9E-07	1.0E-07	3.9E-05	1.0E-04	4.1E-04	4.0E-04
Standard Deviation	4.4E-07	5.0E-08	1.2E-04	8.3E-05	9.3E-04	3.6E-04
Variance	2.0E-13	2.5E-15	1.6E-08	6.9E-09	8.6E-07	1.2E-07
Skewness	5.3E+00	5.9E-01	1.6E+01	1.5E+00	4.3E+00	3.0E+00
Kurtosis	5.1E+01	2.6E+00	6.0E+02	5.9E+00	3.8E+01	2.0E+01
Coefficient of Variability	1.4E+00	4.5E-01	1.7E+00	6.8E-01	1.3E+00	7.0E-01
Range Minimum	2.3E-09	2.5E-08	3.9E-07	1.0E-05	4.5E-06	8.3E-05
Range Maximum	7.7E-06	2.9E-07	6.1E-03	6.3E-04	1.9E-02	4.9E-03
Range Width	7.7E-06	2.6E-07	6.1E-03	6.2E-04	1.9E-02	4.8E-03
Mean Standard Error	4.4E-09	5.0E-10	1.2E-06	8.3E-07	9.3E-06	3.6E-06

Other Exposure Pathways

The soil ingestion pathway was not compared because no military-specific data on geophagia were found in our searches and inquiries. Soil intake studies on children are probably more reliable than those on adults. There appears to be a general consensus that among adults in western society who do not routinely contact the soil by occupation or hobby, intake of soil is very low, on the order of a few milligrams to a few tens of milligrams per day (Simon, 1998). Although available studies on military activities were not located during this effort, one may assume that some military personnel spend more time exercising and training outdoors. Therefore assuming a 100 mg/day incidental soil ingestion rate, as recommended by EPA (1997) for adults, may be more reasonable for a military-specific scenario than a scenario for the general public. Further documentation of soil ingestion rates in military training scenarios is indicated.

CONCLUSIONS AND RECOMMENDATIONS

MSEF Data

Military-specific studies involving U.S. Army, Air Force, and Navy personnel were identified that provided military-specific data for body weight, body surface area, inhalation rates, daily water intake, and residence time. The available data were found to be sufficient to support the development of probability density functions for many of these exposure factors. It was also evident that further investigation could provide additional military-specific data involving food consumption (i.e., garrison-level studies performed by USARIEM), site-specific housing data (e.g., location, number, and volume of military family housing units from installation-level housing offices), and population mobility data (e.g., time-on-station data from service-wide demographics databases). Additional investigation may also identify other military studies that could provide dermal contact data, incidental soil ingestion data, and activity pattern data (e.g., time spent outdoors, time spent showering, time spent swimming, time spent gardening). Gaining access to these data requires extended effort. Military studies are not necessarily published and once government-owned databases are stored, they may become virtually impossible to access. A longer duration study will be necessary to identify, acquire, analyze, and document distributions.

Risk Assessment Results using EPA Factors versus MSEFs

Assuming a typical site exposure scenario and unit risk exposure concentrations, the sensitivity of risk projections due to exposure factor distributions for military populations was compared to the sensitivity using EPA EFH distributions (1997). Mean body weight distributions for military populations and the general population did not vary greatly. Therefore, skin surface area distributions between the two populations were also very similar. Risks for dermal exposure were within the same order of magnitude (3.3×10^{-7} using EPA EFH values and 1.0×10^{-7} using military distributions for Army males). However, the resulting distribution of risk from the EPA data was more skewed, due to greater variability in the exposure duration distribution for the general public.

The forecasted risk range for drinking water containing 1 mg/L benzene using military-specific data (mean = 1.3×10^{-4}) was higher than the risk range using data from EPA's Exposure Factor Handbook (mean = 7×10^{-5}). The increased risk for the military scenario can be attributed to the much higher water consumption rate than the EPA EFH rate. It should be noted, however, that the drinking water study used to develop military water consumption data only reported maximum values for extreme climatic conditions. An analysis of the entire database may yield a distribution more similar to that of the general population; unfortunately, the database was not available.

The ranges of risk reported for the inhalation pathway were comparable as both the military-specific and EPA EFH exposure factor distributions resulted in a mean risk level of 10^{-4}. Little difference in risk results for the dermal and inhalation routes was noted when military-specific data were used in lieu of the EPA EFH data. Risk assessments using MSEFs such as the drinking water rate and exposure duration are likely to differ significantly from the risk based upon EPA EFH factors. Supporting data were not found for any additional MSEFs during this short-term study. A summary of the MSEFs obtained during this study is presented in the following table.

TABLE 8. SUMMARY OF MSEFs

Military-Specific Exposure Factor	Data Source	Estimated Impact
Time on Station	Assignment Data	Exposure Duration
Body Weight, Height & Surface Area	Anthropometric Studies	Dose Levels
Inhalation Rates	Anthropometric Studies	Intake Rates
Drinking Water Ingestion	Operational Studies	Maximum Rate Data
Breastfeeding Duration	Clinical Studies	Exposure Duration
Housing Volume	Installation Housing Data	Concentrations
Residence Times	Installation Housing Data	Duration

Additional Research Needs

Several areas were identified where military activities are suspected to vary from their civilian equivalents, but no empirical data could be located. Some of these are expected to have measurable impact on risk assessments.

Drinking water rate was the only the military-specific population study cited in the EPA EFH. It serves as an upper bound of 11.4 L water/day for hot climates based on a 1983 U.S. Army water planning guide (EPA, 1997). The U.S. Army updated this water planning guide in 1994 but the revised documentation did not contain any water intake distribution data (U.S. Army Quartermaster School, 1994). A specific "hot environment" study by the Army indicated a voluntary drinking water upper bound value of about 7 L/day (Szlyk *et al.*, 1988). The EFH's cold climate upper bound was 7.6 L/day whereas the Army studies revealed a voluntary consumption rate of 3.7 L/day (Roberts *et al.*, 1989). Policy in the Persian Gulf War was to require military members to drink water at a specific rate and not rely on the voluntary consumption rate. Using the current forced drinking water rate in lieu of the U.S. Army upper bound data proposed by the EFH or conducting specific drinking water consumption rate studies to better define this exposure factor is recommended. Actual *ad libitum* water consumption data were not located other than as noted. Water consumption by activity category and thermal burden should be collected.

To better estimate the inhalation rate, the use of heart rate monitors during specific activities and the use of regression equations specific to men and women to calculate ventilation rates are recommended to reduce uncertainty of the inhalation pathway. The regression equations were derived from Patton *et al.* (1995), which presented heart rate and minute volume information for 42 military-specific physical activities. The activity patterns recommended by Anderson *et al.* (1985), as cited in the EFH (EPA, 1997), are flawed because they attribute zero hours per week to rest. Information on inhalation rates is adequate, but data on activity patterns are needed.

Both the U.S. Air Force and U.S. Army have 3D whole body scanning capability. The U.S. Air Force has developed software to estimate the whole body surface area and segmental skin surface area of the face, hands, arms, legs, and feet. These surface area estimations would be more accurate than the regression equation surface area estimations used in the EFH (EPA, 1997). Resources were not available during this project to access the software and database.

Housing occupancy and demographics data are available for each military installation. Base housing data are currently being converted from a COBOL database to an Oracle-based system. The bioenvironmental engineer (BEE) offices at all AFMC installations, some Air Combat Command and Air Education and Training Command as well as overseas bases have a computerized system called Command Core System (CCS). CCS has Oracle-based databases that describe the occupational demographics for military personnel. It is recommend that the CCS be linked with this housing data to allow the BEE to estimate the population mobility of personnel assigned to base housing.

Time on station (TOS) data for all Air Force active-duty personnel from AFMC/DP were acquired. It would be more useful for a specific risk assessment to determine the TOS for a specific installation as TOS is expected to vary between commands. Then the TOS distribution could be used as a bounding estimate for the exposure duration for that specific hazardous waste site.

It has been demonstrated that certain exposure pathways involve little or moderate uncertainty. Of the parameters evaluated, exposure duration contributes the greatest variability to risk. The dermal pathway, however, involves a number of factors which are highly variable, some of which are chemical or media specific. A critical research area is the development of realistic soil adherence factors useful for military personnel that conduct combat exercises or are involved in actual combat. Military personnel are more likely to have a higher surface area of contact and more frequent contact with soil in these situations than the typical occupational soil exposure described in the EFH (EPA, 1997). A summary list of additional research efforts needed to support the development of MSEFs is presented in Table 9.

TABLE 9. RECOMMENDED RESEARCH AREAS

Research Area	Anticipated Impact	Rationale
Occupational Activity Patterns	High	Task frequency controls uptake. Currently only task strength demands are available. Occupational Measurements Center has task descriptions.
Recreational Activity Patterns	High	Military sports participation is generally high. This factor impacts soil ingestion, inhalation uptake, on-base hunting and fishing food consumption (many military bases allow civilians to hunt on-base).
Residential Activity Patterns	High	Patterns are expected to vary by installation mission. Nationwide distributions will be misleading.
Gardening Activities	Moderate	Military families garden in designated plots; however some gardening next to housing/buildings is known to exist. Gardening impacts ingestion rates.
Soil Adherence	High	Soil adherence by activity type for military operations and recreation is needed for dermal uptake. Adherence is an important operational factor.
Soil Ingestion	Moderate	No data on military operational ingestion rates could be located.
Body Weight Distributions	Low	Military policy excludes the very small and very large body sizes. Available distributions need to be obtained and assessed.
Skin Surface Areas	Low	Available technology enables collection of skin surface by body appendage. Raw data exist.
Nutrition / Dietary Uptake by Activity	Low to Moderate	Current studies address only part of the installation level consumption by source and activity type. Residential patterns are expected to reflect U.S. norms; operational patterns are expected to be much different.
Respiration Rates	Moderate	Correlation of respiratory rates and volumes to submaximal workload can provide inhalation intake rates.
Health Enrollment Assessment Review (HEAR) Data	Moderate	Self reported information on health status and behavioral factors may be useful for benchmarking and frequency assessments.

Case for Developing Military-Specific Exposure Factors

This project focused on military-specific exposure factors that could be used in risk assessments for hazardous waste sites and could be used by Air Force Public Health Officers and other risk assessors. Military land-use scenarios may not always differ much from the scenarios of the site's surrounding population. More significant differences are seen in occupational or deployment scenarios. The outbreak of unexplained illnesses of troops following their return home from the Persian Gulf War has resulted in keen interest in precluding this scenario from future deployments. The approach used to evaluate site-specific environmental risks may be applicable to operational risk assessments. In response, all military services have developed a risk assessment capability for deployment of their personnel.

Reports from this study indicate that most military-specific exposure factor data are not centrally located. To support site-specific risk assessments, a central data depository of MSEFs should be considered. The Occupational and Environmental Health Directorate, Human Systems Center (DET 1, HSC/OEM) sponsored development of a handbook, "Methods to Quantify Uncertainty in Human Health Risk Assessment" with the objectives of presenting the current state of science and advanced tools for performing analyses of uncertainty and variability in a tiered approach to risk analysis (Aurelius and Sassaman, 1998). This handbook emphasizes the current regional regulatory policies and effectively describes the principal mathematical methods. References are provided for common distribution information resources but not military specific information on receptor behavior and uptake data. The revised handbook would build on the lessons learned from this initial effort to guide the risk assessor through the steps involved in acquiring site-specific data such as residence time distributions from demographics databases and military family housing data through installation-level sources. It would describe the steps for preparing probability distribution functions from these site-specific data. It would also provide "how to" guidance for performing probabilistic risk assessments and avoiding the errors that usually result from extrapolations of the factors common to dose response and exposure assessment computations. This approach would facilitate site specific assessments meeting EPA, ATSDR or operationally related needs. Figure 8 outlines this process template.

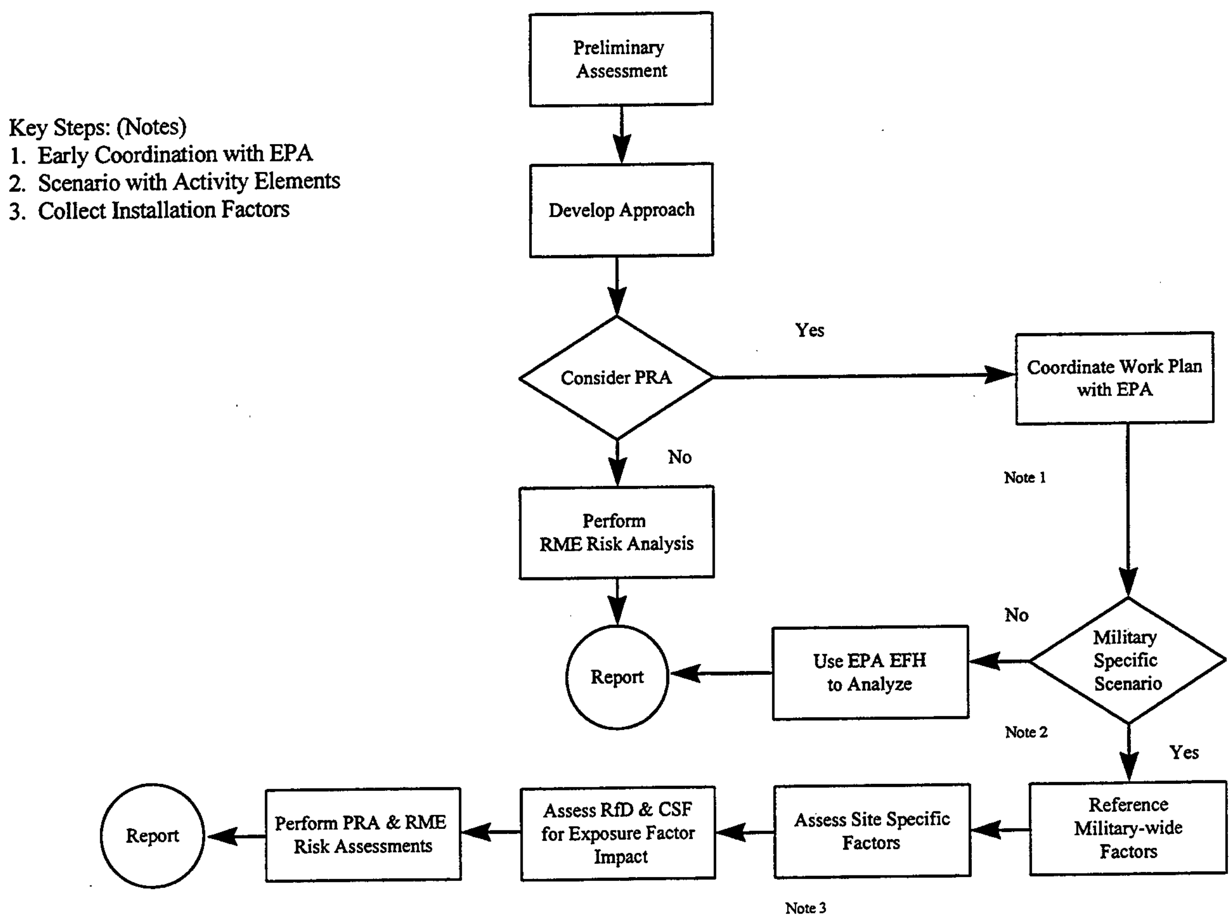

Figure 8. Process Template for Assigning Site-Specific Exposure Factors

Toward the end of this short-term study, discussions with stakeholders and other interested persons suggested there are at least two major improvements in risk assessments that could be achieved through follow-on work. The first improvement would result from the development of a MSEF handbook using data from studies involving military subjects who adequately represent military populations. The second, and perhaps more substantial improvement would result from the development of a textbook for conducting site-specific risk assessments at military installations.

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APPENDIX A. SUMMARY OF EPA EXPOSURE FACTOR HANDBOOK'S DATA SETS

TABLE A-1. SUMMARY OF EXPOSURE FACTORS CITED IN EPA EXPOSURE FACTOR HANDBOOK (EPA, 1997)

Exposure Factor	Recommended Values	Confidence	Comments
Inhalation Rate	child<1 yr - 4.5 m^3/d AVG child (1-12 yr) - 8.7 m^3/d adult female - 11.3 m^3/d adult male - 15.2 m^3/d	High High High High	These rates do not represent moderate or heavy activity individuals. For outside workers use 1.3 m^3/hr AVG, 3.3 m^3/hr upper percentile. Outside workers/athletes are a "high risk" subgroup for air pollutants.
Surface Area (SA)	**Water contact,** during bathing/swimming, use total body SA, see Tables 6-2 to 6-4 for adult and Tables 6-6 to 6-8 for child, percentiles are included **Soil contact,** use whole body part area, see Tables 6-2 to 6-4 for adult and Tables 6-6 to 6-8 for child, percentiles are included **Bathing & Swimming,** water contact -adult 20k cm^2 -50th percentile, 23k cm^2 95th percentile **Outdoor activities,** Soil Contact - adult, 5k cm^2, 5.8k cm^2 - 95th percentile	High	Table 6-10: statistical results for total adult SA show for the EPA data a skewness of 0.27 and kurtosis of 3.08, which suggests a fairly symmetrical distribution (-0.5< skewness <0.5). A normal distribution has a kurtosis of 3.0.
Soil Adherence	Use Table 6-17, depends on activity and body part (AVG only)	Low	A child playing in mud could represent worst case combat training/exercises mean soil adherence (mg/cm^2) for body parts (hands, arms, legs and feet). Small study size (n=6) is a problem.
Soil Ingestion Rate	Child 100 mg/d AVG and 400 mg/d upper percentile Adult 50 mg/d AVG Pica child - 10 g/d	Low	In the past, EPA suggested 50 mg/d for industrial and 100 mg/d for residential/agricultural scenario. No distribution was discussed.
Life Expectancy	75 yr	High	Life expectancy broken out by sex and race (Table 8-1). There are more males than females in military.
Body Weight	71.8 kg	High	Table 7-4 & 7-5 give percentiles by sex with age distribution. Military closer to 18-54 distribution. Log normal BW follows normal distribution for each sex.
Showering/ Bathing	**Showering Time** 10 min/d AVG, 35 min/d 95th percentile **Bathing Time** 20 min/event, 45 min/event 90th percentile 1 event/d	Medium High	
Swimming	1 event/month, 60 min/event (median), 180 min/event 90th percentile	High	

Exposure Factor	Recommended Values	Confidence	Comments
Time Indoors	Child (3-11) 19 hr/d weekday 17 hr/d weekends Adult (>12) : 21 hr/d Residential 16.4 hr/d	Medium Medium High	
Time Outdoors	Child (3-11) 5 hr/d weekday 7 hr/d weekend Adult (>12) 1.5 hr/d Residential 2 hr/d	Medium Medium High	
Drinking Water Intake Rate	21 ml/kg-day or 1.4 L/d AVG 34 ml/kg-day or 2.3 L/d (90th percentile) Percentile & Distribution given	Medium	See Table 3-30 for summary. Key study was based on 1978 data collection. 1983 U.S. Army study notes 6-11 L/d intake for temperate to hot climate activities; value can be used as bounding estimate. Table 3-11 shows log normal distribution.
Total Fruit Intake Rate	3.4 g/kg-d (AVG), 12.4 kg-d (95th percentile)	Medium Low	See Table 9-11 for percentiles.
Total Vegetable Intake Rate	4.3 g/kg-d (AVG), 10 g/kg-d (95th percentile)	Medium Low	See Table 9-12 for percentiles.
Total Meat Intake Rate	2.1 g/kg-d (AVG), 5.1 g/kg-d (95th percentile)	Medium Low	Percentiles included.
Total Diary Intake Rate	8.0 g/kg-d (AVG), 29.7 g/kg-d (95th percentile)	Medium Low	Percentiles included.
Grain Intake Rate	4.1 g/kg-d per capita (AVG), 10.8 g/kg-day per capita (95th percentile)	High Low in long-term upper percentiles	Percentiles included.
Breast Milk Intake Rate	742 ml/d (AVG), 1,033 ml/d upper percentile for 1-6 months 688 ml/d AVG, 980 ml/L upper percentile for 12 months.	Medium Medium	Upper percentile defined as middle range of mean ± 2 SD.
Fish Intake Rate	**General Population** 20.1 g/d total fish, 13.5 g/d marine AVG, 6.6 g/d freshwater or estuarine AVG, 63 g/d total fish 95th percentile **Recreational Marine Anglers** 2-7 g/d, recreational freshwater 8g/d and 25 g/d (95th percentile) **Native American Subsistence Population** 70 g/d AVG, 170 g/d 95th percentile	Medium Low	

Exposure Factor	Recommended Values	Confidence	Comments
Home Produced Food Intake	**Total Fruits** 2.7 g/kg-d AVG, 11.1 g/kg-d 95th percentile **Total Vegetables** 2.1 g/kg-d AVG, 7.5 g/kg-d 95th percentile **Total Meat** 2.2 g/kg-d AVG, 6.8 g/kg-d 95th percentile **Total Dairy Products** 14 g/kg-d AVG, 44 g/kg-d 95th percentile	Low for long-term distributions	Use Equation. 13.2 to transfer data from consumer to general population.
Time Spent Inside Vehicle	Adult 1 hr 20 min/d	Medium	
Occupational Tenure	6.6 years	High	See Table 15-158 for age & sex effects. If age is known, use Table 15-158 to recalculate occupational tenure.
Population Mobility	9 years AVG, 30 yr 95th percentile	Medium	See Table 15-163 & 164 for different types of residences.
Residence Volume	369 m^3 AVG, 217 m^3 conservative (mean of 25th percentile)	Medium	Assumes 8 ft ceiling & 369 m^3. Reflects 1,628 ft^2 space. Used mean of 2 distributions
Residential Air Exchange	0.45 median, 0.18 conservative (10th percentile)	Medium	See Table 17-9. 1.26 Air Changes per Hour is 90th percentile.

APPENDIX B. DATA SET QUALITY ASSESSMENT

TABLE B-1. INHALATION RATE FROM DEVELOPMENT OF STATISTICAL DISTRIBUTIONS FOR RANGES OF STANDARD FACTORS USED IN EXPOSURE ASSESSMENTS (ANDERSON *et al.*, 1985)

Consideration	Comments	Confidence Level
Level of Peer Review	EPA report with peer review	High
Accessibility	DTIC report	High
Reproducibility	Results can be reproduced - Used standard methods	High
Focus on Factor of Interest	The study looked at ventilation rate for various subpopulations including military	High
Data Pertinent to U.S.	Data were restricted to U.S. personnel	High
Primary Data	Studies analyzed secondary data	Low
Adequacy of Data Collection Period	Not addressed in report	Low
Validity of Approach	Distribution for ventilation rate not given	Low
Study Sizes	Sample size is greater than 20, n >100 for both men and female in ventilation rate study	High
Representative of Population	Not discussed in report	Low
Variability in the Population	Not discussed in report	Low
Lack of Bias in Study Design	Cited 11 references for ventilation rates	Not Discussed
Response Rates	Not specifically noted in report	N/A
Measurement Error	Not discussed in report	High
Number of Studies	Cited 11 studies for estimating ventilation rate	High
Agreement among Researchers	Comparable results	High
Overall	11/16 high out of total	High

TABLE B-2. BODY WEIGHT AND SURFACE AREA USAF CG STUDY (BRUNSMAN AND FILES, 1996)

Consideration	Comments	Confidence Level
Level of Peer Review	Government Technical Report	Low
Accessibility	DTIC report	High
Reproducibility	Results can be reproduced - Used standard methods	High
Focus on Factor of Interest	The study looked at whole body scan of subpopulations representing military. It can be used to generate body weight and specific surface areas	High
Data Pertinent to U.S.	Data restricted to U.S. personnel	High
Primary Data	Study generated primary data	High
Adequacy of Data Collection Period	Not addressed in report	Low
Validity of Approach	No distribution for surface area given	Low
Study Sizes	Sample size is greater than 20, n >100 for both men and women in study	High
Representative of Population	Subjects were to represent military aviation	High
Variability in the Population	Not discussed in report	Low
Lack of Bias in Study Design	Not discussed	Not Discussed
Response Rates	Not specifically noted in report	N/A
Measurement Error	Direct laser scanning should reduce anthropometric measurement error	High
Number of Studies	1, although Army also has 3D scanning ability	Low
Agreement among Researchers	Need comparison of Army and USAF data	Low
Overall	9/15 high out of total but need actual surface areas calculated	Low

TABLE B-3. BODY WEIGHT AND SURFACE AREA USAF ANTHROPOMETRIC COLLATION REPORT (KENNEDY, 1986)

Consideration	Comments	Confidence Level
Level of Peer Review	USAF Technical Report but publication of work has been done	High
Accessibility	DTIC report	High
Reproducibility	Results can be reproduced - Used standard methods	High
Focus on Factor of Interest	The study looked at various anthropometric measurements including body weight and height	High
Data Pertinent to U.S.	Data restricted to U.S. military personnel	High
Primary Data	Studies included only active duty USAF personnel	High
Adequacy of Data Collection Period	Data from 1950-1968 and may not represent current USAF population	Low
Validity of Approach	Standard anthropometric techniques used	High
Study Sizes	Sample size is greater than 20, n >100 for both men and female in ventilation rate study	High
Representative of Population	Careful screening of subjects to assure representation of USAF population	High
Variability in the Population	Statistically addressed in report	High
Lack of Bias in Study Design	Careful screening of subjects to minimize bias	High
Response Rates	Not specifically noted in report	N/A
Measurement Error	Primary measurements by skilled anthropometry staff	High
Number of Studies	Cited 4 studies	High
Agreement among Researchers	Comparable results	High
Overall	15/16 high out of total	High

TABLE B-4. BODY WEIGHT AND SURFACE AREA U.S. ARMY 1988 ANTHROPOMETRIC SURVEY (GORDON *et al.*, 1989)

Consideration	Comments	Confidence Level
Level of Peer Review	Final technical report without peer review	Low
Accessibility	DTIC report	High
Reproducibility	Results can be reproduced - Used standard methods	High
Focus on Factor of Interest	The study looked at specific exposure factors for military subpopulations (body weight, stature)	High
Data Pertinent to U.S.	Data restricted to military personnel	High
Primary Data	Studies analyzed primary data	High
Adequacy of Data Collection Period	Measurements were taken over a period of 1 year (1988)	High
Validity of Approach	Used standard anthropometric methods	High
Study Sizes	Sample size is greater than 20, n >1000 for both men and female	High
Representative of Population	Screened subjects to match Army demographics	High
Variability in the Population	Variability was well-characterized	High
Lack of Bias in Study Design	No bias noted in the study design	High
Response Rates	Not specifically noted in report	N/A
Measurement Error	Used direct reading weight scales	High
Number of Studies	One	Low
Agreement among Researchers	In comparison to surface areas values within EFH, good agreement	High
Overall	13/16 high out of total	High

TABLE B-5. BODY WEIGHT AND SURFACE AREA NAVAL SUBPOPULATION STUDY (CARPENTER *et al.*, 1998)

Consideration	Comments	Confidence Level
Level of Peer Review	Draft technical report without peer review	Low
Accessibility	Draft report	Low
Reproducibility	Results can be reproduced - screening medical records	High
Focus on Factor of Interest	The study looked at specific exposure factors for military subpopulations	High
Data Pertinent to U.S.	Data restricted to military personnel	High
Primary Data	Studies analyzed multiple source generated data	Low
Adequacy of Data Collection Period	The report did not reflect over which time period the measurements were taken	Low
Validity of Approach	Extract data from multiple sources	Low
Study Sizes	Sample size is greater than 20, number of males was greater than 1000 and females were 317	High
Representative of Population	Specific Naval subpopulations selected	High
Variability in the Population	Variability was well-characterized	High
Lack of Bias in Study Design	No bias noted in the study design	High
Response Rates	Not specifically noted in report but comment was made regarding to extensive coordination was required	Low
Measurement Error	Uncertainty exists because study relies on various sources to conduct measurements	Low
Number of Studies	One	Low
Agreement among Researchers	In comparison to body weight and surface areas values within EFH, good agreement	High
Overall	8/16 high out of total used	Low

TABLE B-6. ASSIGNMENT HISTORY DATA (BUCKMAN AND TOLLE, PERSONAL COMMUNICATION, 1998)

Consideration	**Comments**	**Confidence Level**
Level of Peer Review	Raw data from AF personnel system	Low
Accessibility	Requires approval to acquire output	Low
Reproducibility	Data by individual, continuously updated	High
Focus on Factor of Interest	Contains assignment data, not focused on residence	Low
Data Pertinent to U.S.	Addresses entire continental USAF population	High
Primary Data	Source is primary data	High
Adequacy of Data Collection Period	Contains data relevant to current assignment	High
Validity of Approach	Data relates to time on station	High
Study Sizes	Contains all continental U.S. enlisted and officer personnel	High
Representative of Population	Contains total population on date of run	High
Variability in the Population	N/A	Low
Lack of Bias in Study Design	May contain some satellite base assignment data	High
Response Rates	N/A	N/A
Measurement Error	May contain minor errors in assignment history	Low
Number of Studies	N/A	N/A
Agreement among Researchers	N/A	N/A
Overall	Data represent an analysis of entire current continental U.S. population	High

TABLE B-7. HOUSING AREA DATA - WPAFB, OH (STOLL, PERSONAL COMMUNICATION, 1998)

Consideration	Comments	Confidence Level
Level of Peer Review	Represents individual base inventory data	Low
Accessibility	Requires approval for access to output file	Low
Reproducibility	Represents entire base inventory	High
Focus on Factor of Interest	Space used as one criteria in housing assignments	High
Data Pertinent to U.S.	Only applicable to those units on WPAFB	Low
Primary Data	Data exist on each housing unit	High
Adequacy of Data Collection Period	Addresses housing units from several construction cycles over many decades	High
Validity of Approach	Useful for this metric only	High
Study Sizes	Addresses units only at WPAFB	High
Representative of Population	N/A	High
Variability in the Population	N/A	Low
Lack of Bias in Study Design	May not be representative of units built in the 1990s as these are older designs	High
Response Rates	N/A	N/A
Measurement Error	N/A	Low
Number of Studies	N/A	N/A
Agreement among Researchers	N/A	N/A
Overall	Limited data exist at each installation. All data are to be stored in a repository at Gunter AFB	High

APPENDIX C. SUMMARY OF PHYSICAL ACTIVITIES STUDY - VENTILATION RATE VS. HEART RATE

TABLE C-1. VENTILATION RATE AND HEART RATE FOR MILITARY PHYSICAL ACTIVITIES (PATTON *et al.*, 1995)

Activity	Men V_e, L/Min	Men HR bpm	Women V_e, L/Min	Women HR bpm
L-1 Maintain an M-16 Rifle, Assemble/Disassemble 3-5 times, 10 min	26.7±1.5	107±4	20.0±1.1	108±7
L-2 Sentry, Prolonged Standing in combat gear, 15 min	13.7±0.4	87±3	11.6±1.0	86±4
L-3 Missile Loader, Lift 105 mm projectile, 25 Kg projectile carried 15 m and lifted 1.32 m (height of 2 1/2 ton truck) one time/2 min, 15 min	15.3±0.7	88±3	14.3±0.7	103±2
L-4 Relocate/establish operations (est. ops.), Lift 22.7 Kg box 1.32 m, one time/min, 15 min	18.1±0.5	95±3	15.1±0.8	100±3
L-5 - Same as L-3 except one time/min, 15 min	18.3±0.8	97±4	19.7±0.8	115±2
L-6 Rig a supply load for airdrop, Lift 36 Kg ammo box 0.9 m and carry 6.1 m, one time/min, 15 min	24.4±0.7	104±4	Not Tested	Not Tested
L-7 Relocate/est. ops., Lift/lower 25 Kg box 1.32 m one time/4 min for 15 min (lift every 2 min/lower every 2 min	16.1±0.7	87±2	13.4±0.6	87±5
L-8 Relocate /est. ops., Lower/lift 25 Kg box to/from ground level to 1.32 m, one time/min (lift every 30 s/lower every 30 s)	20.4±0.9	100±4	20.0±0.8	120±4
L-9 Quartermaster, Lift 18 Kg rations 0.9 m and carry 6.1 m, 1 time/min, 15 min	20.5±0.7	98±4	18.1±0.6	108±3
L-10 Relocate/est. ops., Lift 22.7 Kg box 1.32 m, two times/min for 15 min	20.9±0.5	106±3	20.8±0.7	120±4
L-11 Load crates of explosives, Lift 27.3 Kg carry 4 m and load onto 2 1/2 ton truck (1.32m) one time/min, 15 min	23.0±0.5	98±1	22.7±0.9	113±5
L-12 Perform emergency destruction ops, Lift 6.8 Kg, carry 15 m and hold at fullest upward reach for 1 min, repeat every 2 min for 15 min	19.3±0.6	89±3	16.0±0.5	94±5
L-13 Load artillery pieces for firing, Lift 45 Kg projectile to 1.7 m and carry 5 m, 2x/min, 15 min	22.7±1.0	104±3	Not Tested	Not Tested
M-1 Wearing combat equipment without rucksack, march on level hard surface at 1.11 m/s for 15 min	26.2±0.7	95±2	23.7±0.9	103±3
M-2 Wearing combat equipment with 20 Kg rucksack, march on level hard surface at 1.11 m/s for 15 min	27.0±0.7	101±1	27.1±1.2	101±1
M-3 Lift, carry and move patients, given 2 person litter team, move patient of 68 Kg on level ground 500 m in 20 min.	28.8±1.8	103±6	27.8±1.3	111±5
M-4 Load artillery pieces for firing, Lift 45 Kg projectiles to 1.7 m and carry 5 m, 4x/min for 10 min	37.1±1.5	130±5	Not Tested	Not Tested
M-5 Load artillery pieces for firing, Lift 45 Kg projectiles to 1.7 m and carry 5 m, 3x/min for 10 min	31.3±2.1	115±5	Not Tested	Not Tested
M-6 Move by foot wearing combat equipment without rucksack on level ground at 1.48 m/s for 15 min	30.3±1.0	107±2	28.1±1.1	119±2

Activity	Men V_e, L/Min	Men HR bpm	Women V_e, L/Min	Women HR bpm
M-7 Move by foot wearing combat equipment with a 30 Kg rucksack on level ground at 1.11 m/s for 15 min	31.0±0.7	110±3	30.6±1.3	130±5
M-8 Move by foot wearing combat equipment (7 Kg), carrying M-16 (3 Kg) and 30 Kg rucksack on level ground at 1.11 m/s for 15 min	32.0±0.7	116±5	33.6±2.4	143±7
M-9 Lift 105 mm projectiles (25 Kg) and carry 15 m to height of 1.32 m, 2x/min for 15 min	27.5±1.1	104±3	28.4±0.9	124±5
M-10 Unload and stack paper stock, Lift 18.2 Kg box and carry 9 m to include stairs of 2.5 m height, 1x/min, for 15 min	29.0±0.9	109±3	26.2±0.8	114±4
M-11 Relocate/est. ops., Lift 22.7 Kg box to 1.32 m, 4x/min for 15 min	29.6±1.6	119±4	29.3±0.7	146±4
M-12 Relocate/est. ops., Lift 22.7 Kg box to/from 1.32 m, 6x/min for 10 min (lift in 10 s/lower in 10 s)	33.9±1.2	119±4	32.1±1.5	127±4
M-13 Dig individual defensive position, Using entrenching tool, dig foxhole 0.45 m deep, approx. 0.6 m by 1.8 m in sandy soil in 30 min	36.6±2.7	122±5	28.2±1.8	128±5
H-1 Employ hand grenades, Engage a 5 m radius target, 40 m from a covered position, 3x/min for 10 min	42.1±3.5	124±4	27.0±1.5	109±7
H-2 Move by foot, Wearing combat equipment with 20 Kg rucksack, march on level ground at 1.48 m/s (3.3 mph) for 15 min	37.8±1.0	117±2	37.5±1.9	131±5
H-3 Move under direct fire, Wearing combat equipment, carrying a weapon, conduct crawl and rush maneuvers over wooded terrain, complete 136.5 m course in 90 s, 5 times	61.3±2.8	162±6	52.1±3.3	174±2
H-4 Move by foot, Wearing combat equipment with 20 Kg rucksack, march in loose sand at 0.98 m/s for 15 min	37.1±1.6	119±4	38.4±1.3	144±3
H-5 Carry TOW equipment, Carry 24.5 Kg unit wearing combat equipment up a 10% grade at 0.89 m/s for 15 min	41.3±1.6	126±4	44.1±2.4	148±4
H-6 Move by foot, Wearing combat equipment with 30 Kg rucksack, on level hard surface at 1.48 m/s for 15 min	42.6±1.5	126±5	48.0±2.7	151±5
H-7 Move by foot, Wearing combat equipment (7 Kg), carrying weapon (3 Kg) with 30 Kg rucksack on level hard surface at 1.48 m/s for 15 min	54.7±3.1	142±3	57.9±4.1	160±8
H-8 Move by foot, Wearing combat equipment, with 20 Kg rucksack, march in sand at 1.31 m/s for 15 min	57.2±1.8	149±5	62.2±2.2	173±4
H-9 Carry M5 smoke pots, Lift two 13.6 Kg smoke pots and carry 30 m and lower, 4 times/min for 10 min[a]	104.8±7.6	167±3	71.3±4.9	170±5
H-10 Lift 105 mm projectiles, 25 Kg and carry 15 m to height of 1.32 m, 4 times/min for 15 min[a]	46.4±2.5	135±5	40.2±1.7	157±4
H-11 Lift, carry and move patients, Using a 4 person litter team, move patient (81.8 Kg over level terrain a distance of 1000 m in 30 min[a]	54.2±2.9	142±6	51.5±2.2	160±5

Activity	Men V_e, L/Min	Men HR bpm	Women V_e, L/Min	Women HR bpm
H-12 Lift, carry and move patients, Given a 2 person litter team, move patient (68.2 Kg) 100 m every 90 s for 10 min	47.3±2.2	137±6	Not Tested	Not Tested
H-13 Carry TOW Equipment, Wearing combat equipment, carry 24.5 Kg unit up 20% grade at 0.89 m/s for 15 min	86.8±4.6	173±3	Not Tested	Not Tested
H-14 Move by foot, Wearing combat equipment without rucksack, move on hard level surface at 2.24 m/s (5 mph) for 10 min	66.6±5.6	150±4	62.5±3.5	162±4
H-15 Lift, carry, and move patients, Given a 2 person litter team, carry a 68.2 Kg patient, 27.5 m, lift to 1.32 M, return 27.5 m to retrieve next patient, complete 10 cycles in 10 min	56.2±3.4	146±8	61.2±1.8	169±4
H-16 Move over, through and around obstacles, Wearing combat equipment, traverse a 150 m obstacle course in 2 min. at constant rate; complete 5 cycles in 10 min	64.7±2.7	153±3	54.5±2.0	160±4

[a] Modified for women, H-9, 3 times/min, H-10, 3 times/min; H-11 63.6 kg

APPENDIX D. SUMMARY OF INHALATION RATE DATA SETS

Anderson *et al.* noted that there were insufficient data to derive a distribution for ventilation rate but provided a minimum, maximum, and mean ventilation rate at three activity levels (Anderson *et al.*, 1985, Table 4-5). This report incorporated activity patterns for 56 subpopulations, including military, to permit time-weighted average calculation of the ventilation rate. The activity pattern for each subpopulation was presented for a week and included a typical work day representing Monday through Friday and the weekend with leisure activities on Saturday and Sunday. Each hour of the 24 hour day was represented by an activity level ranging from 1 (light) to 3 (heavy) activity. For a military female or male, the estimated inhalation rate is presented in Table D-1 and compared to the recommended values reported in the EFH Table 5-23 (EPA, 1997). The Anderson *et al.* (1985) study did not report any resting activities such as sleep, yet the report cited a lower ventilation rate for resting as compared to the low activity ventilation rate.

TABLE D-1. ESTIMATED MILITARY INHALATION RATE BASED ON EPA ACTIVITY PATTERN

Activity Level	Hours in Week (Anderson *et al.*, 1985, Appendix D)	Mean Ventilation Rate (L/min) (Anderson *et al.*, 1985)
Female:		
Resting	0	5.7
1 Low	145	8.1
2 Moderate	22	26.5
3 High	1	47.9
		mean = 10.9 L/min = 15.0 m^3/day vs. 11.3 m^3/day reported in Table 5-23 of EFH (EPA, 1997)
Male:		
Resting	0	12.2
1 Low	145	13.8
2 Moderate	22	40.9
3 High	1	80
		mean = 17.7 L/min = 25.5 m^3/day vs. 15.2 m^3/day reported in Table 5-23 of EFH (EPA, 1997)

Table D-2 presents a summary of the calculated ventilation rates for various occupational groups with subgroups. Two inhalation rates are given, one using the three activity levels reported in the Anderson *et al.* (1985) and the other assuming eight hours of sleep at the resting ventilation rate. Diaries of 20 volunteer subjects for an activity patterns study of outdoor workers indicated that sleep occupied about 33% of the subjects' time (Shamoo *et al.*, 1991). The activity levels of the military were comparable to craftsmen and indoor operatives and laborers. Outdoor operatives and laborers were reported with higher activity levels. This activity pattern does not address more rigorous military training required for basic recruits or military personnel engaged in combat training or combat exercises that are conducted primarily outdoors.

TABLE D-2. COMPARISON OF SELECTED OCCUPATIONAL GROUPS VERSUS MILITARY VENTILATION RATES (ANDERSON *et al.*, 1985)

Occupational Group	Subgroup	Low Level Efforts hr/wk	Medium Level Efforts hr/wk	High Level Efforts hr/wk	Male Inhalation Rate m^3/d	Sleep Adjusted Male Inhalation Rate m^3/d	Female Inhalation Rate m^3/d	Sleep Adjusted Female Inhalation Rate m^3/d
Managers & Profession-al	< 30 min. commute, Single family housing	164	4	0	20.8	20.0	12.3	11.3
Sales	Outdoors	150	18	0	24.0	23.3	14.5	13.5
Clerical	Indoor	164	4	0	20.8	20.0	12.3	11.3
Craftsmen	Indoor	143	25	0	25.7	24.9	15.6	14.6
Operative & Laborers	Indoor	145	23	0	25.2	24.4	15.2	14.2
Operative & Laborers	Outdoor	136	22	10	30.7	29.8	18.5	17.5
Military	**N/A**	**145**	**22**	**1**	**25.5**	**24.8**	**15.0**	**14.5**
Retired	Full Mobility	154	14	0	23.1	22.3	13.9	12.9

The EFH (EPA, 1997), cited Linn *et al.* (1992) as a key inhalation study. Linn *et al.*. used a regression equation relating inhalation rate or ventilation rate to the HR based on Shamoo *et al.* (1991) research which linearly correlated the HR of individual outdoor workers to the log of the VR. Mello *et al.* (1986) assessed the physical activity intensity during infantry combat-simulated operations and using field measurements of HR; he reported on the first day in the field HR an average of 101 bpm with a low of 89 bpm on the fifth test day. If the 15 male individual regression equations of the Shamoo study were combined, an average regression equation of Log VR = 0.368 + 0.00914 HR would be obtained. The daily average of 101 bpm would yield a 28.2 m^3/day inhalation rate and 89 bpm would yield a 21.9 m^3/day inhalation rate. The most demanding task was a forced 10 kilometers march which resulted in a mean HR of 128 bpm for 140 minutes (corresponds to an estimated 49.7 m^3/day inhalation rate during the march). This study concluded that high activity level was minimal during simulated combat or combat training and that combat or combat training can be adequately supported by an aerobic capacity of 50 ml oxygen (O_2) per Kg body weight per minute.

Vogel *et al.* (1986) completed an analysis of aerobic capacity of a large United States population (U.S. Army recruits representing the civilian sector of 19 years olds and soldiers in various assignments and physical training programs). New recruits averaged 51 and 37 ml O_2 per Kg body weight per minute for males and females, respectively. This aerobic capacity increased 5% following the initial basic training and decreased about 10% annually or 0.5 ml per Kg body weight per minute. A selected group of highly trained Army individuals in combat arms yielded an average aerobic capacity of 53.0 ml O_2 per Kg body weight per minute. This study compared the effects of occupational training as well as physical training programs on aerobic capacity. Many occupational groups did not have significant improvement in the aerobic capacity beyond the initial basic training and, except for infantry trades, no further improvement in the aerobic capacity was observed. Continued physical training reduced the annual decline of aerobic capacity by half. Physical intensity of occupations plays a role in the eventual level of aerobic fitness in large populations. However, there is more aerobic conditioning from recreational activity than from daily job activities. Conditioning can be provided by short bursts of high-intensity activity that can occur in recreational or sport activities but seldom occur in occupations. This implies that the availability of sports facilities and encouraged use by the military is more beneficial in maintaining aerobic conditioning than the typical occupational taskings assigned to the military. The current Air Force aerobic physical fitness test is based on the use of the heart rate response to estimate the body's maximal capacity to use oxygen (Hartung *et al.*, 1993). A preliminary literature review could not identify a paper that correlated the aerobic capacity to inhalation rate although both can be estimated from HR. Further research would be needed to confirm if aerobic capacity could be related to inhalation rate.

APPENDIX E. SUMMARY OF MILITARY ANTHROPOMETRIC STUDIES

Air Force Anthropometric Studies

The most recent Air Force anthropometric study by Brunsman and Files (1996) was a whole body surface scan of 53 subjects. Although the report did not specify whether the subjects were military, they were selected based on representation of the aviation population as the purpose of the study was to determine the center of gravity (CG) of the male and female aviators for the Air Force and Navy Joint Primary Aviation Trainer System (Robinette, personal communication, 1998). This study presented whole body scans of 25 males and 29 female subjects (one subject was rejected). These scans included seventy-six anatomical landmarks placed on each subject. Traditional measurements taken with anthropometers, scales and tape measures included body weight and stature. Table E-1 presents the summary statistics for the body weight for this USAF center of gravity study, which indicated that both male and female subjects for this study were representative of the EFH population sets (EPA, 1997).

TABLE E-1. COMPARISON OF USAF CG BODY WEIGHT DISTRIBUTIONS (BRUNSMAN AND FILES, 1996) TO EFH TABLES 7-4/7-5 (EPA, 1997)

Air Force Center of Gravity Study	Mean Age yr	Age Range yr	Mean BW Kg	SD	EFH Data Set	Mean BW Kg	t[a]	H_o: USAF CG mean = EFH mean
Men, n=30	28.6	20-43	79.4	12.8	Male (18-44) n=2,800, SD=13.3	77.6	0.05	Accept at P=0.01
Women, n=33	26.8	20-38	58.8	7.66	Female (18-44) n=3080, SD=14.0	63.7	-0.14	Accept at P=0.01

[a] The EFH Tables 7-4 and 7-5 present summary statistics for the general population body weight for each sex broken down by age distributions (i.e., 18-74, 18-24, 25-34,35-44, 45-54, 55-64, and 65-74 years old) (EPA, 1997). The test statistic to compare two means with unequal standard deviations is as follows (Spiegel, 1961):

$$t = \frac{X_1 - X_2}{\sigma\sqrt{\frac{1}{N_1} + \frac{1}{N_2}}} \quad \text{and} \quad \sigma = \frac{N_1 SD_1^2 + N_2 SD_2^2}{N_1 + N_2 - 2}$$

where the test hypothesis is that the means are the same (H_0: $X_1 = X_2$) and the alternative hypothesis is that the means are not the same. If the calculated $t > t_{n>1000,\,0.995} = 2.57$, or $t < -2.57$, the hypothesis that the means are the same at P=0.01 significance level must be rejected.

The Air Force summarized its earlier more extensive anthropometric surveys in an Aerospace Medical Research Laboratory technical report (Kennedy, 1986). Their key studies were from males in 1965 and 1967 and females in 1968. Table E-2 provides the summary statistics of these collated data for body weight. These studies were conducted on active duty personnel.

TABLE E-2. AIR FORCE ANTHROPOMETRIC BODY WEIGHT DATA (KENNEDY, 1986)

Air Force Study	Mean Age yr	Age Range[a] yr	Mean BW Kg	SD	EFH Data Set	Mean BW Kg	t[b]	Ho: USAF Subpopulation mean = EFH mean
USAF Men (1965), n=1236	29.81	18.3-49.4	75.87	10.59	Male (18-44) n=2,800, SD=13.3	77.6	0.33	accept at P=0.01
USAF Male Flyers (1967), n=2420	30.03	22.1-45.7	78.74	9.72	Male (18-44) n=2,800, SD=13.3	77.6	0.30	accept at P=0.01
USAF Women (1968), n=1905	23.43	18.1-46.5	57.73	7.52	Female (18-44) n=3080, SD=14.0	63.7	-1.43	accept at P=0.01
USAF Female Flyers (1968), n=455	23.35	17.8-43.6	59.51	4.85	Female (18-44) n=3080, SD=14.0	63.7	-0.48	accept at P=0.01

[a] 1st percentile to 99th percentile range

[b] $t_{n>200,\ 0.995}$ = 2.53 at P = 0.01 level

1988 Anthropometric Survey of U.S. Army Personnel

The 1988 Anthropometric Survey was conducted on 25,000 screened subjects at 11 Army bases. At that time, only 44% of the male soldiers were under 24 and 66% were white. A quarter of the Army men were black. Black women comprised over 40% of the Army's women in 1988 and a majority of Army women were 25 years old and over. Only 10.88% of the Army personnel were women. A working database of 1,774 men and 2,208 women were selected representing the various racial/ethic and age groups found in the Army in June 1988 (Gordon *et al.*, 1989). Table E-3 presents a comparison the men and women body weight means to the EFH (EPA, 1997). Based on a students' t test at P=0.01, both sets of body weight distributions for the Army men and women could be represented by the male and female EFH data sets in the age range from 18 to 54 years old. The 1988 Anthropometric survey listed the 1st, 2nd, 5th, 10th, 25th, 50th, 75th, 90th, 95th, 98th, and 99th percentiles for both the male and female body weight distributions and stature (Gordon *et al.*, 1989).

TABLE E-3. COMPARISON OF ARMY MALE AND FEMALE BODY WEIGHT DISTRIBUTIONS (Gordon *et al.*, 1989) TO EFH TABLE 7-4/7-5 (EPA, 1997)

Army Subpopulation	Mean Age yr	Age Range yr	Mean BW Kg	SD	EFH Data Set	Mean BW Kg	t^a	H_o: Army Subpopulation mean = EFH mean
Male, n=1,774	27.2	17-51	78.75	11.0	Male (18-54) n=3490, SD=13.3	78.2	0.12	Accept at P=0.01
Female, n=2,208	26	18-50	62.08	8.33	Female (18-54) n=3843, SD=14.2	64.6	-0.62	Accept at P=0.01

[a] $t_{n>200, 0.995} = 2.53$ at P = 0.01 level

Naval Medical Research Institute Naval Subpopulation Study

NMRI/TD has prepared a draft technical report on statistical descriptions of physiological variables for seven Naval populations (Carpenter *et al.*, 1998). The research effort assumed that strenuous physical fitness standards and occupational requirements as well as active wellness and physical fitness programs could be expected to extend a more robust response to a chemical exposure. Data were extracted from available medical records to test this hypothesis. The collected data represented seven subpopulations (i.e., divers, SEAL trainees or BUD divers, SEALs, male aviators, female aviators, male fleet, and female fleet). It was assumed that the BUDs/SEALs would be a trimmer, more athletic community. Aviators would have to pass a stringent flight physical annually whereas the fleet sailors were used as a benchmark for comparison and approximate the general population. The data elements were age, body weight and body height. These data were extracted from Navy research and data holding facilities such as the Naval Health Research Center, San Diego, CA; Naval Aviation Medical Institute, Pensacola, FL; the Naval Hospital, San Diego, CA (fleet data); and the Naval Medical Institute, Bethesda, MD (diver data). The body fat data were collected to be used in physiologically based pharmacokinetic (PBPK) modeling. Body fat, body weight, and body height were found to be normal or lognormal using the Wilk-Shapiro test (n<2,000) or the skewness-kurtosis chi-square test of normality (n>2,000). If the data were not found to be normal, the data were log transformed and the normality test was reapplied. The mean, median, standard deviation, minimum, and maximum were found on body fat, weight, and height for each subpopulation. Pearson product moment correlation suggested for males a relationship between age, body weight, body fat, and body height. For females, body weight, body fat, and body height were correlated. Appendices of the Carpenter *et al.* report include the statistical analysis and the original data in a manner suitable for further analysis.

Table E-4 presents the Body Weight Summary Statistics for the NMRI/TD study. All seven Naval subpopulations can be represented by the body weights found in the EFH (EPA, 1997). The Carpenter *et al.* (1998) draft technical report proposed that the Male and Female Fleet members would reflect the general civilian population. However, the female fleet members were leaner (mean of 62.1 kg) than the general civilian population females (mean of 64.6 kg for ages 18 to 54) and the male fleet members were heavier (mean of 80.6 kg) than the general civilian population males (78.2 kg for ages 18 to 54).

TABLE E-4. COMPARISON OF NAVAL SUBPOPULATIONS BODY WEIGHT MEANS (CARPENTER *et al.*, 1998) TO EFH TABLE 7-4/7-5 (EPA, 1997)

Naval Subpopulation	Mean Age yr	Age Range yr	Mean BW Kg	SD	EFH Data Set	Mean BW Kg	t[a]	Ho: Naval Subpopulation mean = EFH mean
BUD or SEAL Trainees, n = 39	22	19-28	76	6	Male (18-24) n=988, SD=12.7	73.8	0.09	Accept at P=0.01
SEALs, n=48	26	18-36	78.9	7.9	Male (18-34) n=1733, SD=13.2	74.5	0.18	Accept at P=0.01
Male Aviators, n=150	32	21-51	81.2	9.1	Male (18-54) n=3,490, SD=13.3	78.2	0.21	Accept at P=0.01
Female Aviators, n=38	28	21-45	61.5	7.9	Female (18-44) n=3080, SD=14	63.7	-0.07	Accept at P=0.01
Male Fleet, n=2411	30	18-56	80.6	12.2	Male (18-54) n=3490, SD=13.3	78.2	0.55	Accept at P=0.01
Female Fleet, n=317	28	18-50	62.1	8.6	Female(18-54) n=3843, SD=14.2	64.6	-0.22	Accept at P=0.01
Divers, n=145	25	18-37	77.3	8.14	Male (18-34) n=2052, SD=13.2	76.3	0.07	Accept at P=0.01

[a] $t_{n>200,\ 0.995} = 2.53$ at P = 0.01 level

All student t test analyses of the body weight sample sets indicated that the military (Air Force, Army, and Navy) subpopulations could be represented by the EPA EFH body weight distributions for the 18 to 54 year old age groups. However, if actual military body weight distributions are not used in a risk assessment, the EPA EFH body weight distributions must be adjusted for the appropriate age distribution of the military population.

APPENDIX F. STAKEHOLDERS AND OTHER CONTACTS

Table F-1 provides a list of the MSEF stakeholders and other interested persons who were visited or contacted by telephone during this study. A summary of the meeting and telephone conversations with the MSEF stakeholders and other interested persons is provided in Table F-2.

TABLE F-1. MSEF STAKEHOLDERS AND OTHER INTERESTED PERSONS

NAME	GRADE	TITLE	LOCATION	TELEPHONE
Barbara Larcom	Lt Col	Environmental Health Officer	MMR (Otis AFB)	DSN 557-5824
Wade Weisman	Major	Research Toxicologist	AFRL/HEST, WPAFB	DSN 785-3174
Jeff Fisher	Dr.	Research Toxicologist	AFRL/HEST, WPAFB	DSN 785-3108
Jim McDougal	Dr.	Research Toxicologist	AFRL/HEST, WPAFB	DSN 785-3182
Dennis Druck	Mr.	Program Manager	CHPPM, APG	DSN 584-5207
Darol Dodd	Dr.	Research Toxicologist	AFRL/HEST	DSN 785-5150
Veronique Hauschild	Ms.	Risk Assessor	CHPPM, APG	DSN 584-5213
Colleen Lovett	Ms.	Risk Assessor	AFMC/SG	DSN 787-2618
Bruce Russo	Major	AFIT Student	Fort Dietrick, MD	(310) 682-4306
Andrea Lunsford	Ms.	Department Director	NEHC	DSN 864-5554
Steve Ice	Dr.	Epidemiologist	Brooks AFB, TX	DSN 240-3471
Roger Gibson	Lt Col	Epidemiologist	Brooks AFB, TX	DSN 240-3471
Bill Brown	Civ	Environmental Engineer	ASC/EMR, WPAFB	DSN 785-7716
Kevin Grayson	Lt Col	Epidemiologist	Travis AFB, CA	DSN 350-6535
Mary Francis Tracey	Ms.	Staff Researcher	CBIAC	(410) 612-6417
Craig Postlewaite	Col	Staff Officer	SAF/MIQ, Pentagon	DSN 227-1016
Bob Carpenter	Dr.	Research Toxicologist	NMRI/TD, WPAFB	DSN 785-6058
Drew Rak	Civ	Toxicologist	AFCEE, Brooks AFB	DSN 240-5230
Jody Wireman	Civ	Consultant	HSC/OEMH, Brooks AFB	DSN 240-6123
Dennie Van Hook	Col	Staff Officer	HQ AMC	DSN 576-6136
John Joyce	Col	Bioenvironmental Engineer	74th AMDS/SGPB, WPAFB	DSN 785-6815
Dianne Cortner	Lt Col	Dietitian	Kessler AFB, MS	DSN 597-6964
Melvin Buckman	MSgt	Data Analyst	AFMC/DPZM	DSN 787-2104
Paula Block	Col	Dietitian	HQ AFMC/SGBZ, WPAFB	DSN 787-6210
Danielle Frank	Capt	Dietitian	USAF Hospital, WPAFB	DSN 787-8815
Donald Noah	Major	Epidemiologist	AFMIC	DSN 343-7269
Elizabeth Stoll	Civ	Deputy Housing Manager	88th CEG/CEH, WPAFB	DSN 787-8423
Joel Williams	Major	Research Toxicologist	AFMIC	DSN 343-3877
Jean Moore	Civ	Analyst	88th CEG/CERC, WPAFB	DSN 787-6550
Annie Jarabek	Ms.	Research Toxicologist	EPA, RTP	(919) 541-4847
Esther Myers	Col	Staff Officer	Andrews AFB, MD	DSN 858-3901
R. Brawley	Captain	Staff Officer	NEHC	DSN 864-5588
H. Lieberman	Dr.	Director	Director of USARIEM	DSN 256-4856
Steve Walker	Col	Staff Officer	DASA (ESOH), Pentagon	DSN 227-0440
J.F. Patton	Dr.	Research Analyst	USARIEM, Natick, MA	DSN 256-4800
Kathy Robinette	Ms.	Anthropologist	AFRL/HECP, WPAFB	DSN 785-8810
Joe McDaniel	Dr.	Human Factors Engineer	CSERIAC, WPAFB	DSN 785-2558
Mike Snedecor	Major	Physician	OPHSA	DSN 240-6518
Mr. Jim Allen	Civ	Data Systems Spec.	Gunter AFB, AL	DSN 596-2409
Claire Gordon	Dr.	Biological Anthropologist	USARIEM, Natick, MA	DSN 256-5429
Matt McAtee	Civ	Risk Assessor	CHPPM, APG	DSN 584-8552
Debra Urzi	Ms.	Human Factors Analyst	CSERIAC, WPAFB, OH	DSN 785-3700
Pam Jernigan	Ms.	Analyst	PRO-ACT, Brooks AFB, TX	DSN 240-4215
Jeff Tolle	TSgt	Data Analyst	AFMC/DPZM	DSN 787-3792

TABLE F-2. SUMMARY OF DISCUSSIONS WITH STAKEHOLDERS AND OTHER INTERESTED PERSONS

NAME & GRADE	ORGANIZATION	TELEPHONE NUMBER	EXPERTISE	EXPRESSED INTEREST	COMMENTS
Jeff Fisher, Dr.	AFRL/HEST, WPAFB, OH	DSN: 785-5150	Toxicologist	Future Land Use Scenarios	Exposure duration may be the single most important factor in risk assessment calculations.
Dennis Druck, Mr.	CHPPM, APG, MD	DSN: 584-5207	Military deployments	Soldier Specific Assumptions	A Tri-Service working group is needed to focus on the entire human health risk assessment area, particularly soldier specific exposure factors.
Veronique Hauschild, Ms.	CHPPM, APG, MD	DSN: 584-5213	Risk Assessments	Military standard exposure factors	Exposure frequency and exposure duration are likely to be very different between the U. S. populations cited in the revised EFH and most military populations
Bruce Russo, Major	AFIT Student, Ft. Dietrick, MD	(301) 682-4306	Deployment risk assessment	MSEFs	Probabilistic risk assessments provide more/better data for risk management decision makers.
Andrea Lunsford, Ms.	NEHC, Natick, MA	DSN: 864-5554	Risk Assessment	Exposure scenarios	Apply the deployment risk assessment computer model developed at CHPPM to hazardous waste site risk assessments.
Roger Gibson, Lt Col	Air Force Epidemiology Lab, Brooks AFB, TX	DSN: 240-3471	Epidemiologist	Human exposure pathways	Link human exposure information at OPHSA, AFMOA, Epidemiology Lab, Tri-care, with MSEF work to support ESSRA.
Bill Brown, Mr.	ASC/EMR, WPAFB, OH	DSN: 785-7716, ext. 345	Environmental Engineer	Computer-based risk assessment tools	Tie MSEFs to IRPIMS data to assess human health risks at Air Force facilities.
Craig Postlewaite, Col	SAF/MIQ, Pentagon, Washington D.C.	DSN: 227-1016	Environment, Safety, Occupational Health	Site-specific risk assessments	Develop exposure factors that are representative of military populations. Provide data distributions to support probabilistic risk assessments at military installations.
Bob Carpenter, Dr.	NMRI/TD, WPAFB, OH	DSN: 785-6058, ext. 212	Research Toxicologist	PBPK Models	Development of MSEF would support current research into human toxin tolerance as a function of physical fitness levels. I have age, gender, height, weight, and percent body fat data for seven groups of Navy personnel to help develop MSEF.
Drew Rak, Mr.	AFCEE, Brooks AFB, TX	DSN: 240-5230	Toxicologist	MSEFs, particularly activity patterns	I have encountered instances where MSEFs were needed to perform a site-specific risk assessment. I hope that your MSEF efforts will provide data on outdoor activities, such as the gardening habits of Air Force personnel.

NAME & GRADE	ORGANIZA-TION	TELEPHONE NUMBER	EXPERTISE	EXPRESSED INTEREST	COMMENTS
Jody Wireman, Mr.	HSC/OEMH, Brooks AFB, TX	DSN: 240-6123	Risk Assessment Consultant	Military-specific data to provide exposure factor distributions	We need to tap available military-specific data to develop MSEF data distributions to support probabilistic risk assessments at military facilities.
Dennie Van Hook, Col	HQ AMC, Scott AFB. IL	DSN: 576-6136	Health risk factors	Military-specific factors affecting health risk profiles	The military services have been collecting health risk appraisal (HRA) data for years. The command wide HRA database at HQ AMC and the DoD mandated HEAR data system for Tri-Service Medical Care contain a lot of self-reported data, including height, weight, age, gender, blood pressure, etc..
John Joyce, Col	74th AMDS/SGPB, WPAFB, OH	DSN 785-6815, ext. 210	Bioenvironmental Engineer	Occupational Health Risk Assessments	The Air Force Demographic Information Management System can be accessed through the military personnel office at HQ AFMC/DPZD. This system contains a variety of personnel data, including time-on-station data that can be used to develop residence time distributions for military personnel and their families at Air Force installations.
Dianne Cortner, Lt Col	Base Hospital, Kessler AFB, MS	DSN: 597-6964	Dietitian	Military personnel risk factors	I participated in a "healthy heart" study involving two groups, each containing about 400 basic trainees at Lackland AFB, TX. This study, to be published in August 1998 in the Journal of Applied and Preventive Psychology, may contain some of the food consumption data needed to support the development of MSEFs.
Melvin Buckman, MSgt	HQ AFMC/DPZD, WPAFB, OH	DSN: 787-2104	Data Systems Analyst	Developing residence time distributions from Air Force demographics data	I can structure a query to provide the date (month and year) of arrival for Air Force personnel at their present duty locations. The query can include the number of dependents for each service member, plus age and gender information for the whole military family across all major commands in the continental U.S.
Paula Block, Col	HQ AFMC/SGBZ, WPAFB, OH	DSN: 787-6210	Dietitian	Health risk appraisal counseling	Although I have not participated in any nutritional or other food consumption studies, Colonel Esther Myers at Andrews AFB, MD has considerable expertise in this area. She should be able to help you identify any military studies that include this type of data.

NAME & GRADE	ORGANIZA-TION	TELEPHONE NUMBER	EXPERTISE	EXPRESSED INTEREST	COMMENTS
Elizabeth Stoll, Ms.	88th CEG/CEH, WPAFB, OH	DSN: 787-8423	Base Housing Management	Accessing central housing data files to support development of MSEFs	The occupancy time in military family housing units at WPAFB varies from less than one year to more than 10 years, with an average residence time of about 2.5 years. A more complete download of housing data can be obtained by contacting Ms. Jean Moore at 88th CEG/CERC.
Joel Williams, Major	AFMIC, Ft Dietrick, MD	DSN: 343-3877	Toxicologist	Developing hazard identification data for deployed forces	AFMIC does not perform or sponsor any studies, and they do not conduct any research. However, they do rely heavily on available data to project potential health effects for deployed forces in foreign theaters of operation.
Jean Moore, Ms.	88th CEG/CERC, WPAFB, OH	DSN: 787-6550	Data Systems Analyst	Accessing the Air Force's IWIMS database at Gunter AFB, AL to support MSEF	IWIMS presently stores military family housing data for all Air Force bases on some 30 servers located at Gunter AFB, AL. This COBOL data system has a large number of flat files containing a variety of housing data, including the date military members were assigned, the number, age, and gender of their children.
Annie Jarabek, Ms.	NCEA, EPA, RTP, NC	(919) 541-4847	Toxicologist	Correct use of RfDs and reference concentrations in exposure assessment equations.	The methodology used to develop the RfD or the reference concentration must be considered when one uses EPA's exposure assessment equations to calculate human health risk.
Esther Myers, Col	Andrews AFB, MD	DSN: 858-3901	Nutritionist	Support MSEF development using advanced degree candidates	USARIEM has conducted a number of food studies, including a study that like the national food consumption study performed by USDA. They may have a few technical reports that contain data suitable for developing MSEFs.
H. Lieberman, Dr.	Director of USARIEM, Natick, MA	DSN: 256-4856	Toxicologist	Using studies performed by USARIEM to support development of MSEFs	USARIEM has conducted several garrison level food consumption studies that may be helpful. Each of these studies involved about 100 subjects, and they were conducted at several different garrisons. The technical reports can be forwarded via email.

NAME & GRADE	ORGANIZA-TION	TELEPHONE NUMBER	EXPERTISE	EXPRESSED INTEREST	COMMENTS
Steve Walker, Col	DASA (ESOH) Pentagon, Washington D.C.	DSN: 227-0440	Health & Safety	Application of MSEF to overall ESOH activities	There may be some direct applications for MSEFs to the Army's overall ESOH program. Please forward via email a summary copy of the MSEF task for consideration at this level.
Jim Allen, Mr.	Gunter AFB, AL	DSN: 596-2409	Data Systems Specialist	Downloading data from Air Force military family housing files	Some of the data needed for MSEF (e.g., age of the military member and his/her spouse) is not normally entered. It is permissible to enter all 9s in this field and this is what most records contain, particularly for the age of the spouse.
Gary Lee, Mr.	AFCESA, Tyndall AFB, FL	DSN: 523-6202	Housing Specialist	Air Force military family housing summary data	The computer systems people at Gunter AFB, AL generate a number of roll-ups (summary reports) that go up to Air Staff on a regular basis. Some of these roll-ups may contain housing data that can be used to support MSEFs.
Jeff Tolle, TSgt	HQ AFMC/DPZD	DSN: 787-3792	Data Systems Specialist	Providing TOS data for Air Force members	A query of the Air Force demographics data at the Air Force Personnel Center has provided dates assigned to current installations for both officer and enlisted personnel. These two data files were forwarded electronically to AFRL/HEST.
Claire Gordon, Dr.	USARIEM, Natick, MA	DSN: 256-5429	Anthropometrist	Providing current Army anthropometric data	Dr. Gordon reviewed the 1988 anthropometric data and compared it to data she collected in 1996. She concluded that the 1988 data was still representative of the current Army population; consequently, no new, 1996, anthropometric data has been developed.
Matt McAtee, Mr.	CHPPM, APG, MD	DSN: 584-8552	Risk Assessor	Site-specific risk assessments that include site-specific exposure factors	MSEFs would benefit human health risk assessments at military installations. All too frequently the use of default exposure factors results in an overestimate of risk.

APPENDIX G. ASSIGNMENT AND HOUSING DATA

USAF assignment data, effective May 1998, for all continental U.S. personnel were obtained from HQ AFMC (Buckman and Tolle, personal communication, 1998). The raw data contained information on "date arrived station", military grade, number of dependents (military information includes only legal dependents and not adult offspring), and base of assignment. The raw data were obtained late in the survey effort and a decision was made to analyze only representative data. Data from two locations, Wright-Patterson AFB in Ohio and Cannon AFB in New Mexico, were selected to analyze for site specific variation. The entire data set was used for assessing time on station for officer and enlisted personnel. The raw data were transferred to a Microsoft® Access database. Query results were then analyzed using Crystal Ball® (version 4.0) software and statistical summaries were obtained.

Due to the large size of the population, this analysis is considered robust. It is recognized there may be some variance in the raw data. No consideration is included for multiple assignments to a single installation, for dependents staying at an installation while the sponsor is elsewhere or for assuming the sponsor is on station while in actuality he/she is on temporary assignment elsewhere. Variances such as these need to be recognized but are not believed to impact the robustness of the data.

These distributions are considered representative of military personnel. However, these USAF data were compiled in May of 1998 and are strictly correct for that month only. Assignment practices do change over time. Real-time assignment data from a particular installation are available from the military personnel system to facilitate site specific risk assessments.

The military's manpower model has been developed to encourage a large number of military members to leave the service after one tour. The specifics of this model are not presented here but its implications can be seen in the relatively short time-on-station and the large number of military members with no dependents. Analysts may wish to assess the impact of total military versus career military populations on their risk assessments.

Information was also available from WPAFB (Stoll, personal communication, 1998) on the size distribution of military family housing. Excluded from the raw data were historical homes constructed in the 1930s, as they were not representative of housing units built in the period 1940 through the 1980s, as seen on most military installations.

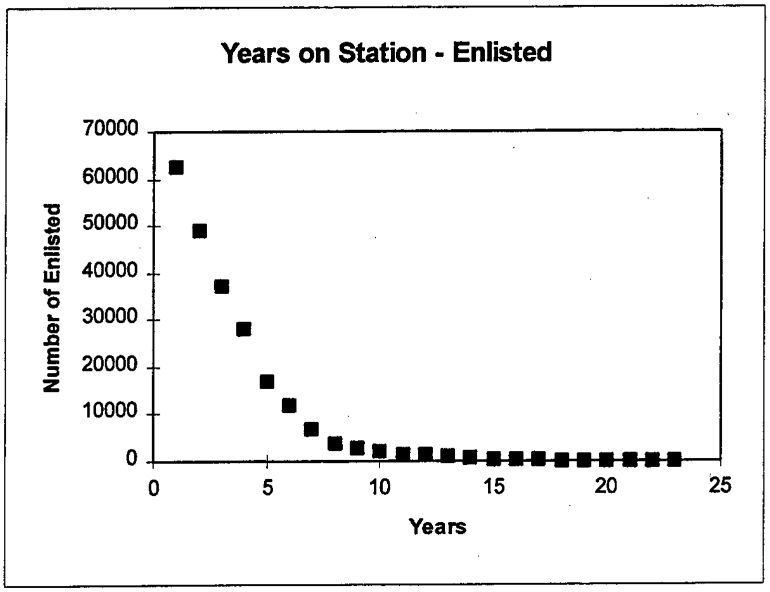

Figure G-1. USAF Enlisted Years on Station (Buckman and Tolle, personal communication, 1998)*

(*Mean - 5.7 yr, SD: 7.7, 95th percentile - 22.2 yr, 97.5th percentile - 22.8 yr)

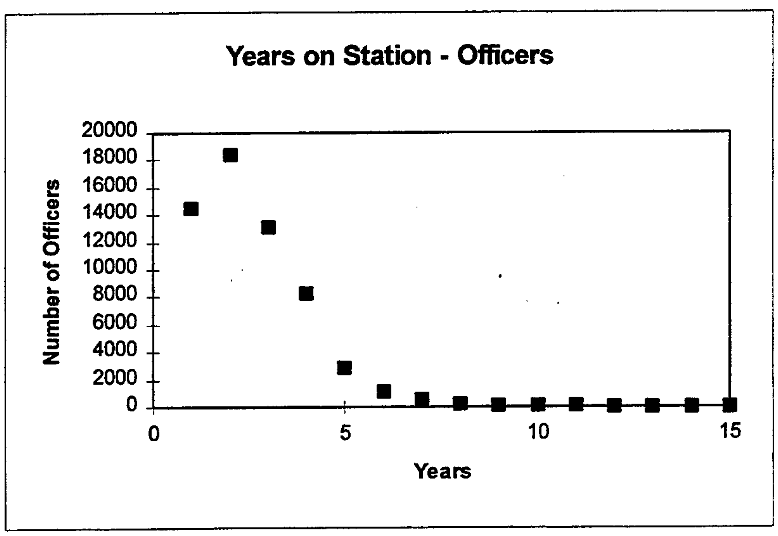

Figure G-2. USAF Officer Years on Station (Buckman and Tolle, personal communication, 1998)*

(*Mean - 2.6 yr, SD: - 1.5, 95th percentile - 5.0 yr, 97.5th percentile - 6.0 yr)

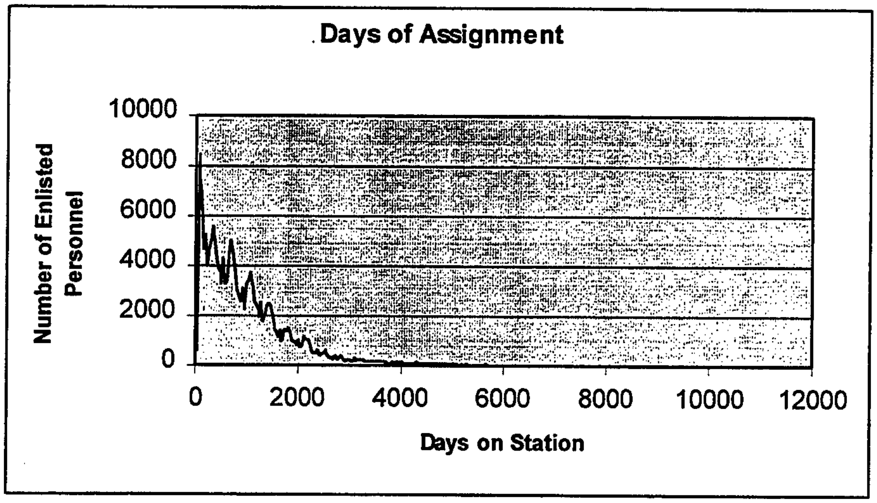

Figure G-3. Days on Station - USAF Enlisted (Buckman and Tolle, personal communication, 1998)

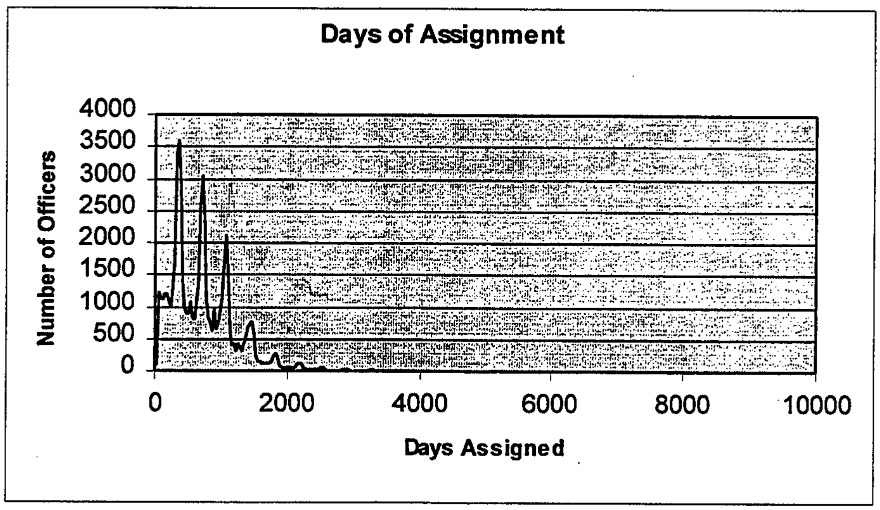

Figure G-4. Days on Station - USAF Officers (Buckman and Tolle, personal communication, 1998)

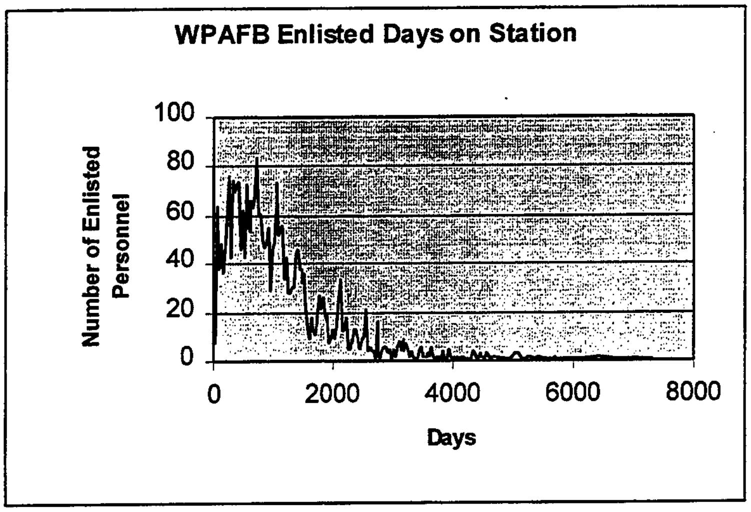

Figure G-5. Days on Station - WPAFB (Buckman and Tolle, personal communication, 1998)*

(*Mean - 3.7 yr, SD: - 4.9, 95th percentile - 14.9 yr, 97.5th percentile - 17.1 yr)

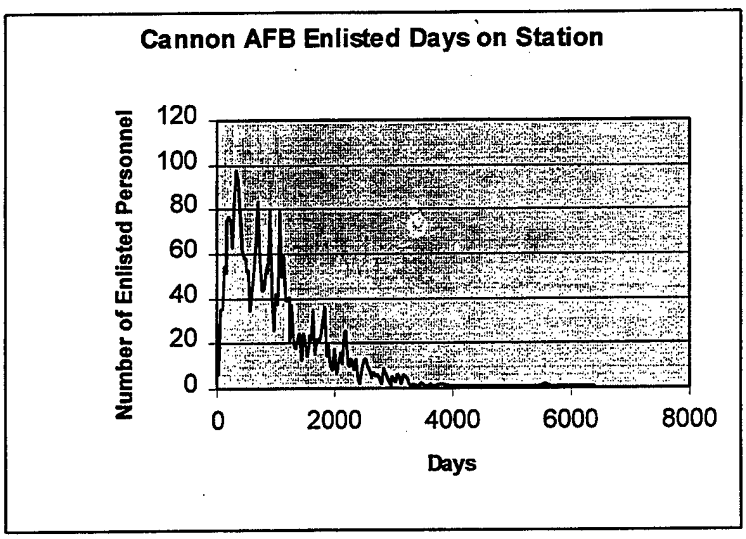

Figure G-6. Days on Station - Cannon AFB (Buckman and Tolle, personal communication, 1998)*

(*Mean - 3.1 yr, SD: - 4.1, 95th percentile - 12.7 yr, 97.5th percentile - 14.7 yr)

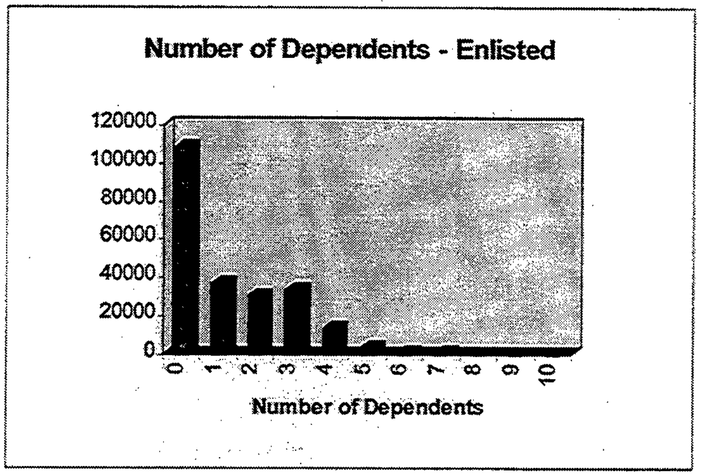

Figure G-7. Number of Dependents - USAF Enlisted Personnel (Buckman and Tolle, personal communication, 1998)*

(*Mean - 2.5 people, SD: - 3.4, 95th percentile - 9.7 people, 97.5th percentile - 9.9 people)

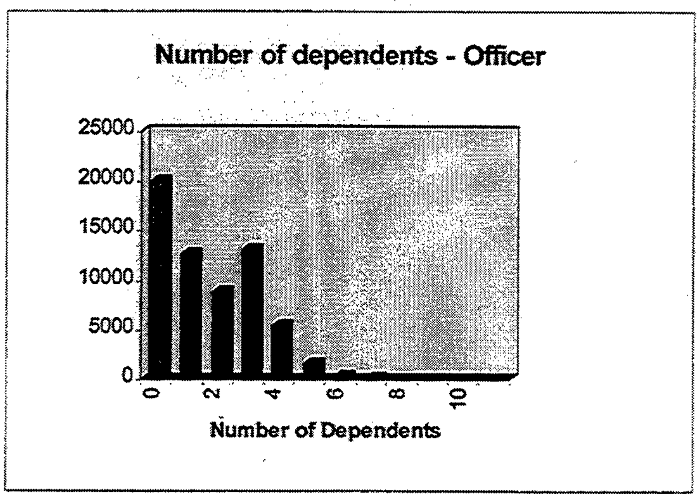

Figure G-8. Number of Dependents - USAF Officer Personnel (Buckman and Tolle, personal communication, 1998)*

(*Mean - 2.7 people, SD: - 3.7, 95th percentile - 10.6 people, 97.5th percentile - 10.9 people)

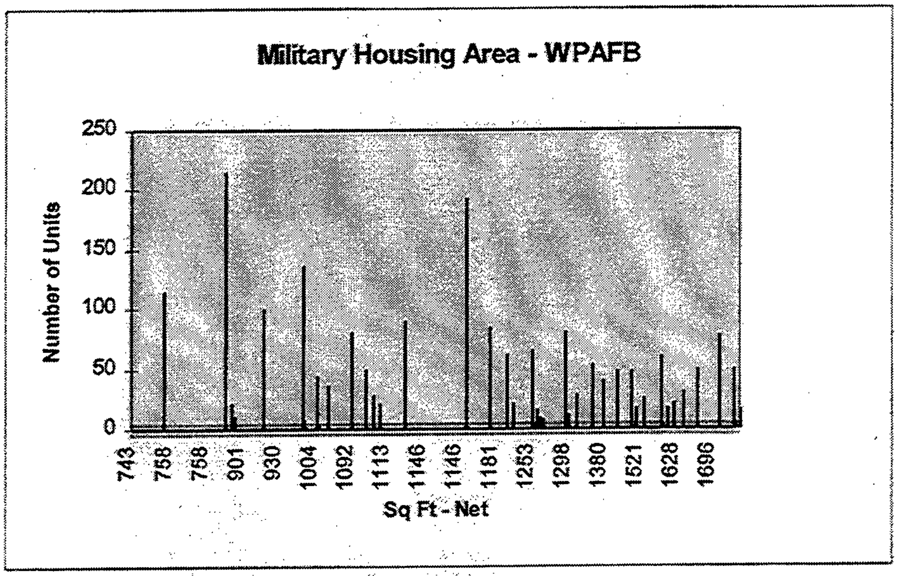

Figure G-9. Floor Space for Military Family Housing - WPAFB
(Stoll, personal communication, 1998)

APPENDIX H. SENSITIVITY ANALYSIS

Assumptions Used for Exposure Factors Handbook

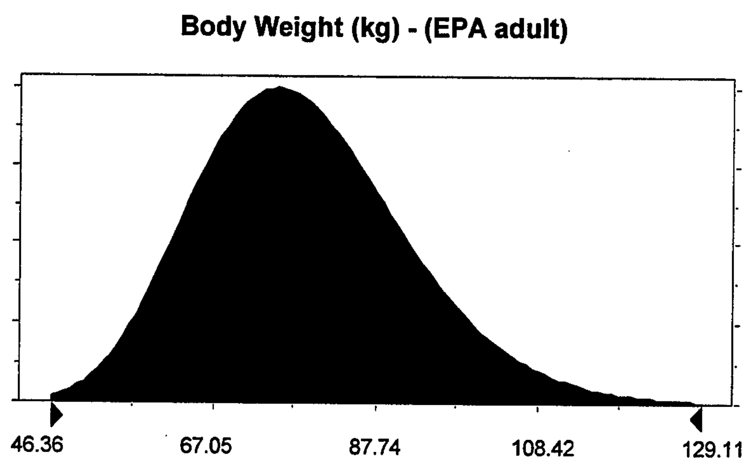

Figure H-1. Assumption: Body Weight (Kg) - Adult (EPA, 1997)

Where: Lognormal distribution with parameters
Mean 78.50
SD 13.50

Selected range is from 0.00 to +Infinity
Mean value in simulation was 78.47

Correlated with: Skin Surface Area (cm^2) - EPA 0.95

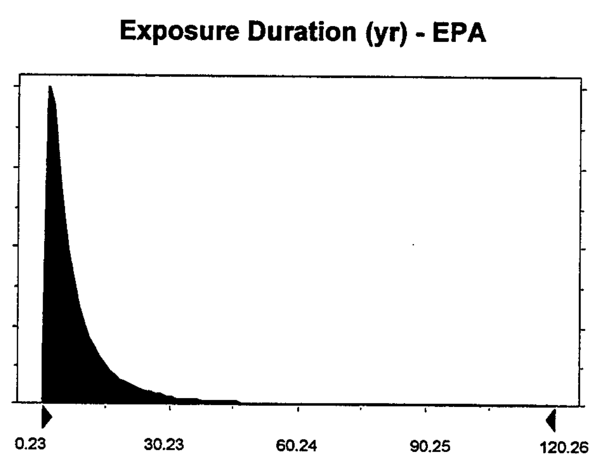

Figure H-2. Assumption: Exposure Duration (yr) (EPA, 1997)

Where: Lognormal distribution with parameters:

Mean	9.00
SD	12.70

Selected range is from 0.00 to +Infinity
Mean value in simulation was 8.88

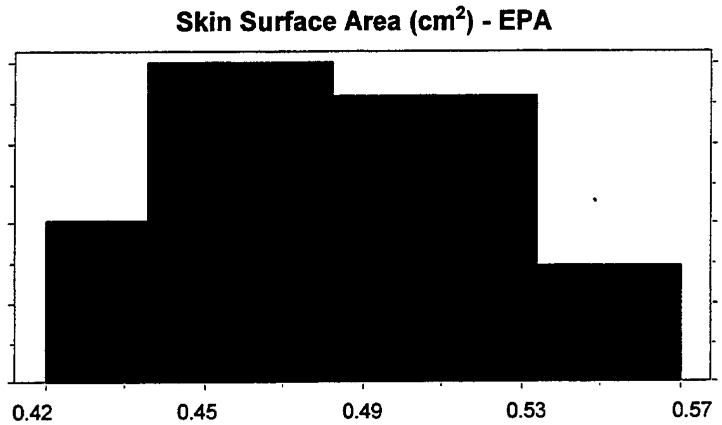

Figure H-3. Assumption: Skin Surface Area (cm^2) (EPA, 1997)

Where: Custom distribution with parameters:

				Relative Probability
Continuous range	0.42	to	0.44	0.10
Continuous range	0.44	to	0.54	0.35
Continuous range	0.49	to	0.54	0.35
Continuous range	0.54	to	0.57	0.10
Total Relative Probability				0.90

Mean value in simulation was 0.49

Correlated with: Body Weight (Kg) - (EPA adult) 0.95

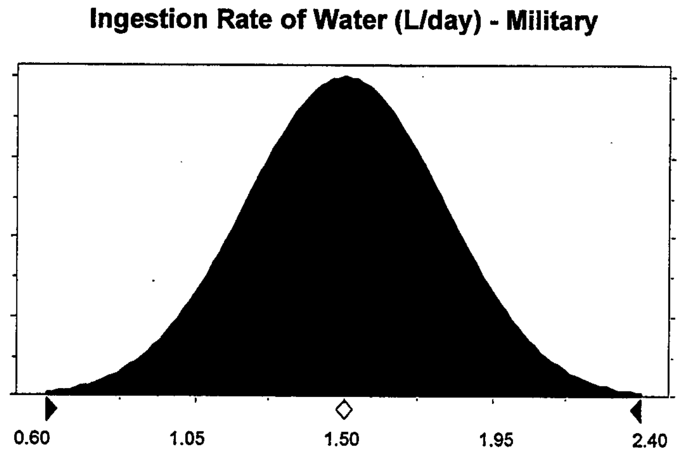

Figure H-4. Assumption: Ingestion Rate of Water (L/day) (EPA, 1997)

Where: Normal distribution with parameters:

Mean 1.50
SD 0.30

Selected range is from -Infinity to +Infinity
Mean value in simulation was 1.50

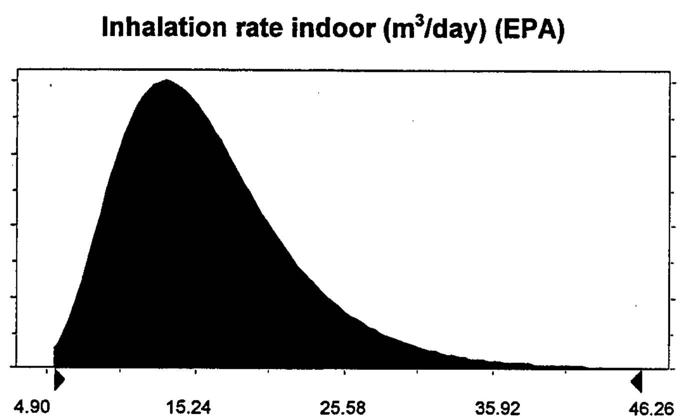

Figure H-5. Assumption: Inhalation Rate Indoor (m^3/day) (EPA, 1997)

Where: Lognormal distribution with parameters:

Mean 16.15
SD 6.26

Selected range is from 5.40 to 64.95
Mean value in simulation was 16.08

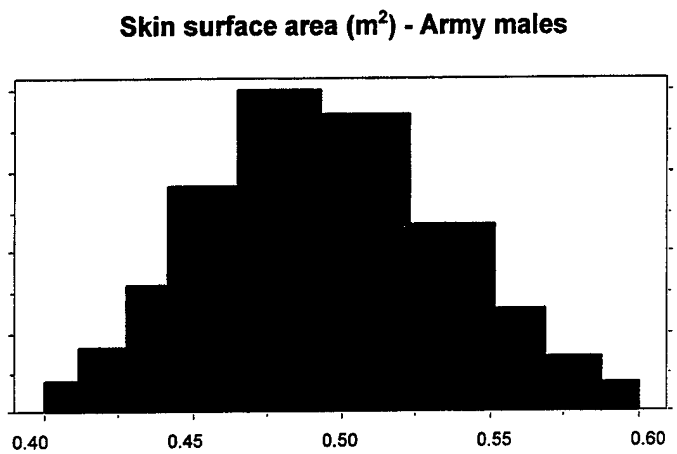

Figure H-6. Assumption: Skin Surface Area (m^2) - Army males
(Data: Gordon *et al.*, 1989; Equation: EPA, 1997)

Where: Custom distribution with parameters:

				Relative Probability
Continuous range	0.40	to	0.41	0.01
Continuous range	0.41	to	0.42	0.03
Continuous range	0.42	to	0.44	0.05
Continuous range	0.44	to	0.46	0.15
Continuous range	0.46	to	0.49	0.25
Continuous range	0.49	to	0.52	0.25
Continuous range	0.52	to	0.55	0.15
Continuous range	0.55	to	0.57	0.05
Continuous range	0.57	to	0.59	0.03
Continuous range	0.59	to	0.60	0.01
Total Relative Probability				0.98

Mean value in simulation was 0.49

Correlated with: Body Weight (Kg) - Army males (C8) 0.95

Body Weight (kg) - Army males

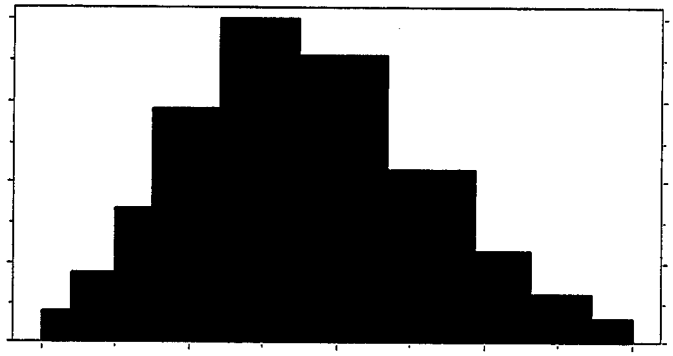

Figure H-7. Assumption: Body Weight (Kg) - Army males (Gordon *et al.*, 1989)

Where: Custom distribution with parameters:

				Relative Probability
Continuous range	55.46	to	58.14	0.01
Continuous range	58.14	to	61.96	0.03
Continuous range	61.96	to	65.29	0.05
Continuous range	65.29	to	71.02	0.15
Continuous range	71.02	to	77.99	0.25
Continuous range	77.99	to	85.81	0.25
Continuous range	85.81	to	93.52	0.15
Continuous range	93.52	to	98.31	0.05
Continuous range	98.31	to	103.72	0.03
Continuous range	103.72	to	107.24	0.01
Total Relative Probability				0.98

Mean value in simulation was 78.84

Correlated with: Skin surface area (m^2) - Army males (C11) 0.95

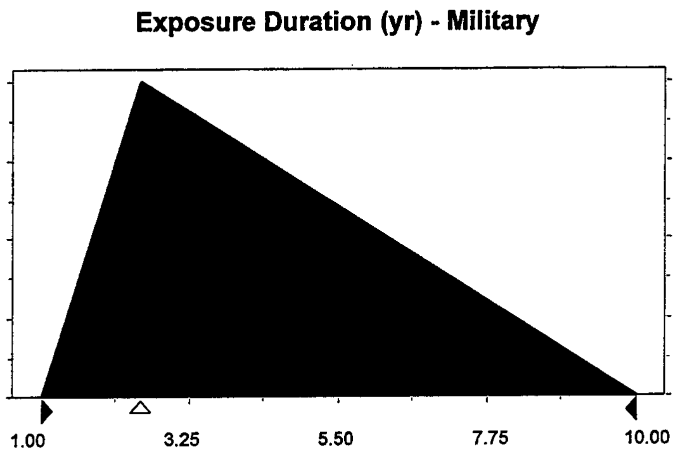

Figure H-8. Assumption: Exposure Duration (yr) - Military (Stoll, personal communication, 1998)

Where: Triangular distribution with parameters:

Minimum	1.00
Likeliest	2.50
Maximum	10.00

Selected range is from 1.00 to 10.00
Mean value in simulation was 4.47

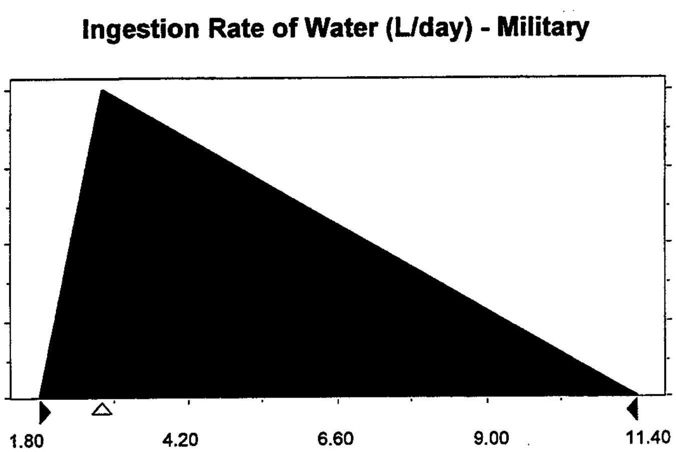

Figure H-9. Assumption: Ingestion Rate of Water (L/day) - Military (EPA, 1997)

Where: Triangular distribution with parameters:

Minimum	1.80
Likeliest	2.80
Maximum	11.40

Selected range is from 1.80 to 11.40
Mean value in simulation was 5.30

Inhalation Rate (m^3/day) - Military

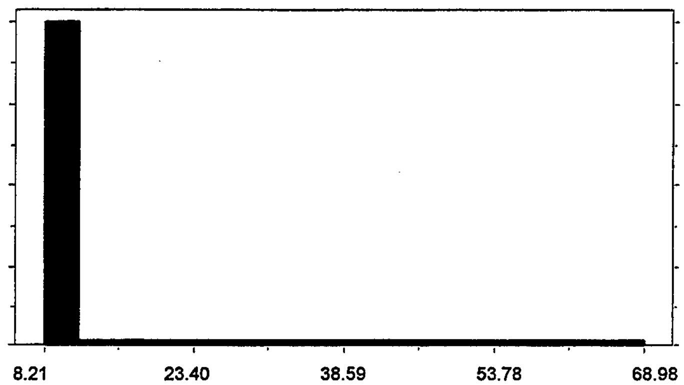

Figure H-10. Assumption: Inhalation Rate (m^3/day) - Military (EPA, 1997)

Where: Custom distribution with parameters:

				Relative Probability
Continuous range	8.21	to	11.66	0.86
Continuous range	11.66	to	38.16	0.13
Continuous range	38.16	to	68.98	0.00
Total Relative Probability				1.00

Mean value in simulation was 12.12