

**BY ORDER OF THE
SECRETARY OF THE AIR FORCE**

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Aerospace Medicine

**OCCUPATIONAL AND ENVIRONMENTAL
HEALTH EXPOSURE CONTROLS**

COMPLIANCE WITH THIS PUBLICATION IS MANDATORY

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This Air Force Manual implements AFD 48-1 and establishes procedures for determination of Occupational and Environmental Health (OEH) exposure controls. Commanders require health risk assessment data coupled with exposure control recommendations to optimize operations and eliminate Occupational and Environmental Health threats or mitigate them to acceptable levels. Direction set forth in Air Force Instruction 48-145, *Occupational and Environmental Health Program*, AFMAN 48-153, *Health Risk Assessment*, and AFMAN 48-154, *Occupational and Environmental Health Site Assessment* shall be used in conjunction with this manual to assess health threats and determine control measures for OEH exposures.

This manual does not provide specific guidance for disease control and containment. This information is located in other references including Air Force Instruction (AFI) 48-105, *Surveillance, Prevention, and Control of Diseases and Conditions of Public Health or Military Significance*, AFI 10-2603, *Emergency Health Powers on Air Force Installations* and AFI 10-2604, *Disease Containment Planning Guidance*.

This manual applies to operations performed by Department of the AF civilian and military personnel, the Air National Guard, and the Air Force Reserve Command in both home station (garrison) and deployed settings. Major commands (MAJCOM), direct reporting units (DRU), and field operating agencies (FOA) may not waive any of these requirements, but may supplement this manual when additional or more stringent criteria are required. This manual does not apply to government-owned, contractor-operated (GOCO) operations within the continental United States (CONUS) or United States (US) territories. These operations shall

comply with 29 CFR 1910. GOCO operations located either outside the regulatory jurisdiction of the CONUS or in US territories not covered by the Occupational Safety and Health Act of 1970 shall comply with this standard in response to Air Force Federal Acquisition Regulation Supplement (AFFARS) 52.223-9001. Conflicts in guidance between this manual and other AF or Federal directives will be reported through the MAJCOM Surgeon or DRU to AFMSA/SG3PB, 1400 Key Blvd, Rosslyn, VA 22209. Refer to Air Force Instruction (AFI) 91-301, *Air Force Occupational Safety, Fire Prevention and Health (AFOSH) Program*, for instructions on processing supplements and variances.

Ensure that all records created as a result of processes prescribed in this publication are maintained in accordance with Air Force Manual (AFMAN) 33-363, *Management of Records*, and disposed of in accordance with Air Force Records Information Management System (AFRIMS) Records Disposition Schedule (RDS) located at <https://www.my.af.mil/gcss-af61a/afrims/afrims/>.

Refer recommended changes and questions about this publication to the Office of Primary Responsibility (OPR) using the AF IMT 847, *Recommendation for Change of Publication*; route AF IMT 847s from the field through the appropriate functional's chain of command.

The use of the name or mark of any specific manufacturer, commercial product, commodity, or service in this publication does not imply endorsement by the Air Force.

SUMMARY OF CHANGES

This is the initial publication of AFMAN 48-155, *Occupational and Environmental Health Exposure Controls*.

Chapter 1

Occupational and Environmental Health Exposure Control

1.1. Overview.

1.1.1. Effectively anticipating, identifying and assessing Occupational and Environmental Health (OEH) threats enables the identification and implementation of controls necessary to eliminate or mitigate threats from hazardous OEH exposures. When determining OEH threat control options, it is imperative to follow the OEH health risk assessment guidelines outlined in AFMANs 48-153, *Health Risk Assessment* and 48-154, *Occupational and Environmental Health Site Assessment*. Figure 1.1 outlines the Health Risk Assessment (HRA) and Health Risk Management (HRM) relationship. This manual focuses on the control portion of HRA/HRM (highlighted in Figure 1.1).

1.1.2. A health threat, as defined in AFMAN 48-153, is a potential or actual condition that can cause short or long-term injury, illness, or death to personnel. Routine and special assessments are conducted in accordance with AFI 48-145, *Air Force Occupational and Environmental Health Program*, to identify and assess OEH threats.

1.1.3. A health risk is the combination of an identified health threat and the vulnerability of exposure route completion to the population at risk. Health risks associated with chemical, biological, radiological, nuclear and physical threat exposure(s) may be long-term (chronic) or short-term (acute) and may be reversible or irreversible. Identifying the extent to which individual factors contribute to an OEH threat exposure is critical in the determination of exposure controls. The primary factors that can affect the intensity of an OEH exposure are:

1.1.3.1. Threat source (e.g. hazardous material used in an industrial process, emissions from an open burn pit, etc.)

1.1.3.2. Route of exposure (inhalation, ingestion, absorption, contact, whole body exposure)

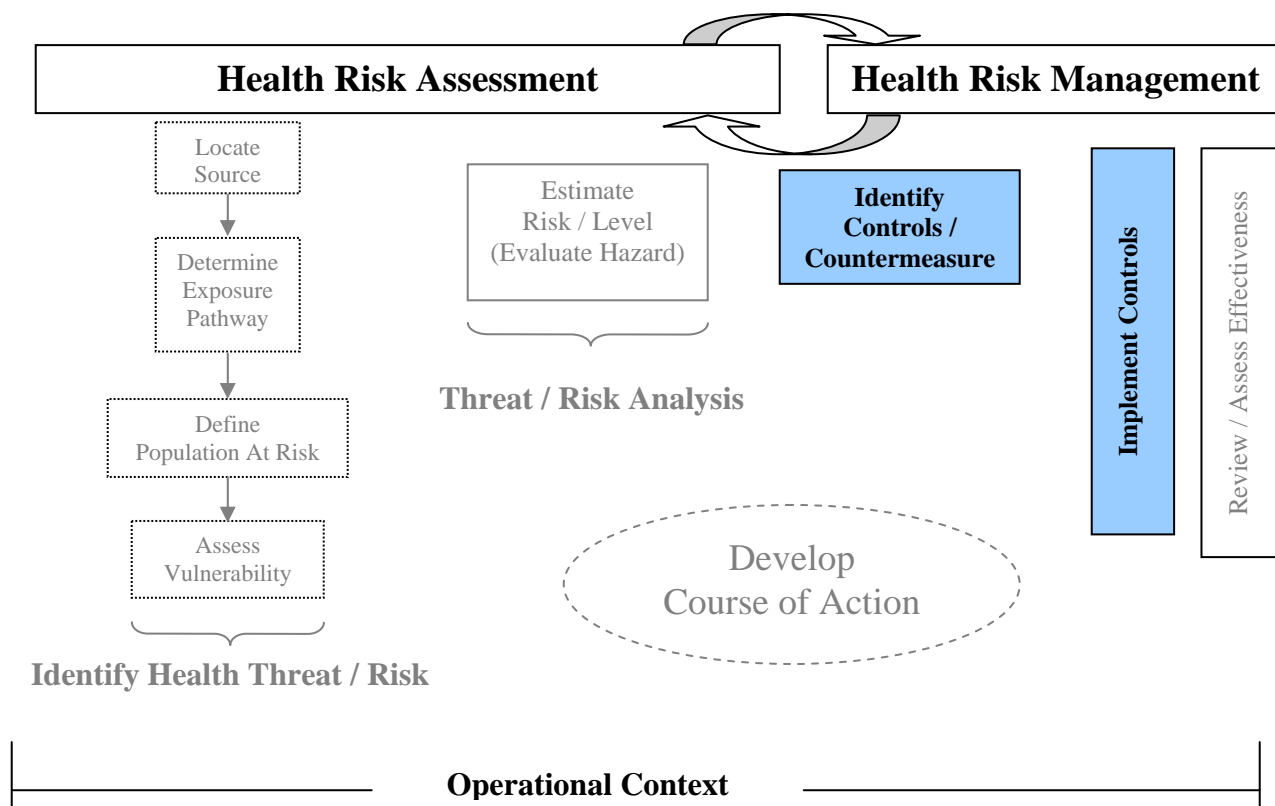
1.1.3.3. Work patterns/practices

1.1.3.4. Concentration

1.1.3.5. Frequency and duration of exposure

1.2. Standards and Exposure Limits.

1.2.1. Occupational and Environmental Exposure Limits (OEEL) are established to protect personnel from OEH threat exposure(s). They apply to occupational and environmental exposures for individuals and/or similar exposure groups (SEG) in a particular Area of Concern (AOC). Bioenvironmental Engineering (BE) can use OEELs to evaluate the effectiveness of established controls and make recommendations to the affected commander on the acceptability of risk from OEH hazard exposures.

Figure 1.1 Health Risk Assessment and Management Relationship

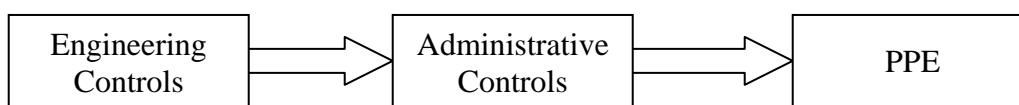
1.2.2. BE determines the OEEL using Air Force standards (AFIs, AFOSH standards, etc.) or the most appropriate exposure limit adopted from established, recognized standards including but not limited to the latest edition of *Industrial Ventilation A Manual of Recommended Practice* and *Threshold Limit Values (TLVs)® and Biological Exposure Indices (BEIs)®*, published respectively by the American Conference of Government Industrial Hygienists (ACGIH); 29 CFR 1910, *Occupational Safety and Health Standards; Emergency Response Planning Guidelines (ERPG) & Workplace Environmental Exposure Levels (WEEL) Handbook*, published by the American Industrial Hygiene Association; 40 CFR 141, *National Primary Drinking Water Regulations*; Technical Guide 230 (TG-230), *Chemical Exposure Guidelines for Deployed Military Personnel*, published by the US Army Center for Health Promotion and Preventive Medicine (USACHPPM), as well as technical reports or guidance documents provided by the USAF School of Aerospace Medicine (USAFSAM). In the absence of recognized standards, BE should contact USAFSAM/OE for guidance on exposure limits for potential OEH threats. However, the determination of an unacceptable level of exposure to a potential OEH threat and, subsequently, the need for controls will require local BE staff to work with the affected unit commander to effectively apply Operational Risk Management (ORM) principles outlined in AFD 90-9, *Operational Risk Management* and AFI 90-901, *Operational Risk Management*, as well as professional judgment.

Chapter 2

Occupational and Environmental Health Threat Controls

2.1 Controls. OEH controls are any one or a combination of engineering, administrative or personal protective equipment control(s) implemented to eliminate or minimize an OEH threat. OEH threat control options should be considered according to the following priority: 1) engineering, 2) administrative, 3) personal protective equipment (PPE) as shown in Figure 2.1. The implementation of engineering controls should always be considered first. If engineering controls are not feasible or are not completely effective in controlling the OEH threat exposure, administrative controls and/or personal protective equipment (PPE) will be used. The mission or unique situations may dictate the need for adjustments to this priority in order to adequately control the health hazard and/or protect health.

Figure 2.1 Priority of OEH Threat Control Selection



2.1.1. Engineering Controls.

2.1.1.1. These controls (e.g. local exhaust ventilation, noise barriers, etc.) are used to isolate, enclose, reduce, attenuate or remove health threats from a SEG. Engineering controls focus on the various sources of threats and should be incorporated during initial design process. However, design changes to existing systems, elimination of processes and/or substitution of less hazardous materials may be required to ensure personnel are provided a workplace free of recognized health threats.

2.1.1.2. In some situations, engineering controls such as ventilation systems may be required to control fire or explosive hazards. These hazards may present additional risks other than the occupational or environmental health hazards, and the fire department and safety office should be consulted when these risks may be present.

2.1.2. Administrative Controls.

2.1.2.1. Administrative controls are any procedures or particular set of actions undertaken in order to significantly limit OEH threat exposure. These controls include measures to reduce exposure frequency/duration for a SEG and development of procedures directed at controlling exposures to a health threat (e.g. wetting down a surface to reduce the release of particulate matter). Administrative controls can also include instituting restrictions or directives necessary to prevent health threat exposures (e.g. directing base housing occupants to boil water due to water contamination).

2.1.2.2. When changing work practices or locations are not feasible or effective solutions to reducing threats, rotating work schedules and/or exposure time limitations can be established to maintain exposures below established OEELs. However, personnel rotation shall not be used to control exposures for human carcinogens or when prohibited by a specific federal, state or Air Force standard.

2.1.3. Personal Protective Equipment (PPE).

2.1.3.1. PPE creates a physical barrier between personnel and the OEH threat (e.g. respiratory protection, hearing protection, and protective clothing). It prevents the OEH threat from completing its exposure route. Identification of the threat, potential routes of exposure, and the effectiveness of a specific protective material in providing a barrier to the threat are the key factors in the PPE selection process.

2.1.3.2. The amount of protection provided by PPE is specific to the protective equipment and threat. For example, protective equipment materials, i.e., rubber gloves, that protect well against some hazardous substances may protect poorly, or not at all, against others. In order to provide effective protection from identified threats, ensure the protective capabilities of the PPE, in relation to the specific health threat, are considered in the selection process.

2.2. Control Determination.

2.2.1. BE will determine and recommend which controls (engineering, administrative, and/or PPE) are appropriate to reduce hazardous exposures to acceptable levels. Commanders will decide whether or not to implement recommended controls based on mission requirements. The following paragraphs and tables illustrate examples of control determination. Note the examples are very similar to those used in AFMAN 48-154, *Occupational and Environmental Health Site Assessment*. These examples were chosen deliberately to help connect this document with companion documents.

2.2.2. Husky AFB (Figure 2.2) represents a typical home station setting. It illustrates Areas of Concern such as base housing, the community center, etc. Examples of potential health threat sources are identified in ***bold italics***. SEGs, threats, potential exposure pathways and possible control options are listed in Table 2.1.

2.2.3. Camp Falcon (Figure 2.3) represents a deployed station setting. Examples of potential health threats sources are identified in ***bold italics***. SEGs, threats, potential exposure pathways and control options are listed in Table 2.2.

Figure 2.2 Husky AFB Site Assessment Model

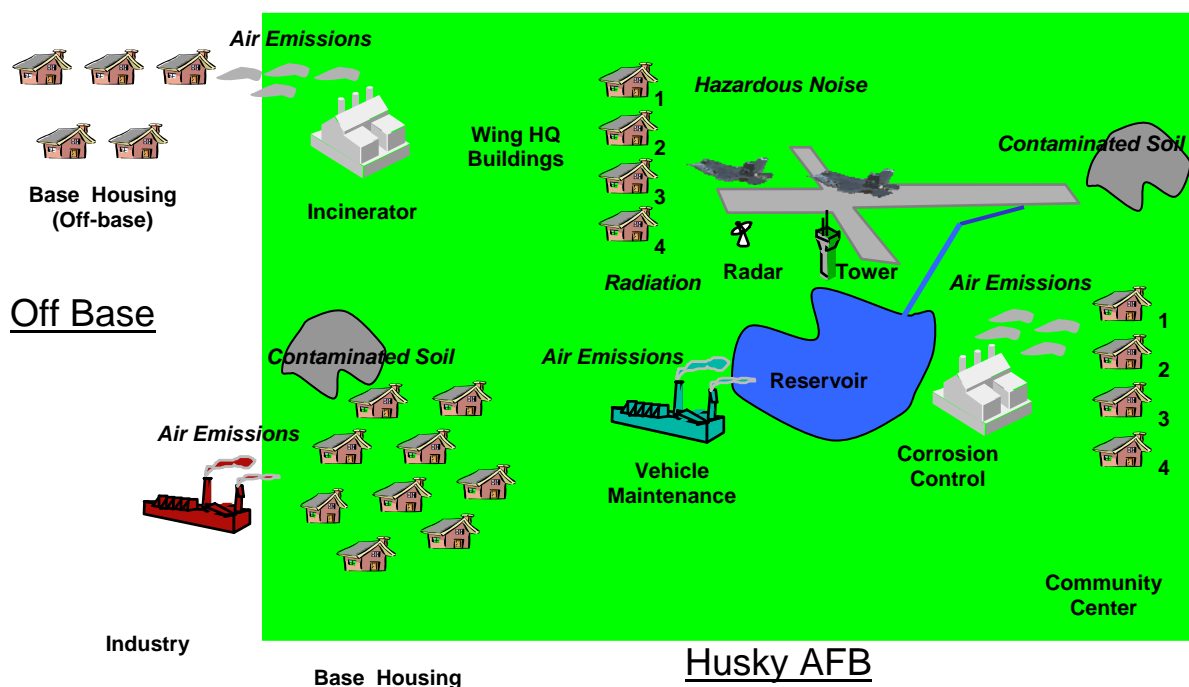
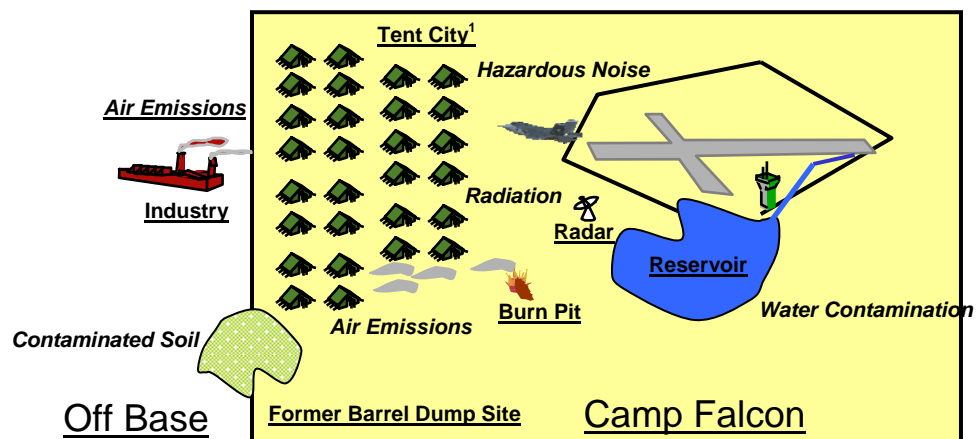


Table 2.1 Husky AFB Site Assessment and Control Determination Data

SEG	Threat (Source)	Pathway	Control
Incinerator Workers	Toxic Industrial Material(s) Combustion By-products (Incinerator)	Air (Inhalation)	Engineering (Air Cleaning Device at Source, Local Exhaust and General Ventilation) Administrative (Rotating Shifts, Waste Segregation coupled with Burn Efficiency Optimization) PPE (Respiratory Protection)
Base Housing Occupants (Off)	Combustion By-products (Incinerator)	Air (Inhalation)	Engineering (Air Cleaning Device at Source) Administrative (Waste Segregation coupled with Burn Efficiency Optimization)
Base Populace	Toxic Industrial Material (Terrorist Event at Local Industry)	Air (Inhalation)	Administrative (Evacuation/ Shelter in Place) PPE (Respiratory Protection & Protective Clothing)

Table 2.1 Husky AFB Site Assessment and Control Determination Data (cont'd)

SEG	Threat (Source)	Pathway	Control
Wing HQ Personnel	Noise (Aircraft)	Air (Whole Body, Ear)	Engineering (Shielding/Barrier)
Wing HQ Personnel	Non-ionizing Radiation (Radar)	Air (Whole Body)	Administrative (Increase Distance of Radar from Personnel, Reposition Radar)
Corrosion Control Workers	Toxic Industrial Materials (Sanding)	Air(Inhalation/Contact)	Engineering (Orbital Sander in Combination with Exhaust Ventilation) Administrative (Routine Workplace Clean-up with HEPA Vacuum) PPE (Respiratory Protection/Protective Clothing)
Base Populace	Toxic Industrial Materials or Microorganism (Contaminated Water)	Public Water System (Ingestion)	Engineering (Water Treatment) Administrative (Boil Water, Bottled Water, System Flush/Loop Isolation)

Figure 2.3 Camp Falcon Site Assessment Model

¹ Location of Tent City and proximity to potential health threats should be considered during OEH Site Assessment and prior to base bed-down

Table 2.2 Camp Falcon Site Assessment and Control Determination Data

SEG	Threat (Source)	Pathway	Control
Occupants of Tent City	Toxic Industrial Material (Local Industry)	Air (Inhalation)	Engineering (Air Cleaning Device at Source) Administrative (Relocate Tent City) ¹
Occupants of Tent City/ Burn Pit Personnel	Toxic Industrial Material (Burn Pit)	Air (Inhalation)	Engineering (Construct Incinerator with Air Cleaning Device) Administrative (Relocate Burn Pit, Segregate Wastes with Toxic Combusted By-products, Coordinate Burn Pit Operations with Weather Accounting for Wind Direction, Temperature Inversion, etc.) PPE (Respiratory Protection for Burn Pit Personnel)
Occupants of Tent City	Noise (Aircraft)	Air (Ear, Whole Body)	Engineering (Shielding/Barrier) Administrative (Relocate Tent City) PPE (Hearing Protection)
Occupants of Tent City	Non-ionizing Radiation (Radar)	Air (Whole Body)	Administrative (Increase Distance of Radar from Personnel, Reposition Radar)
Occupants of Tent City	Toxic Industrial Material (Barrel Dump)	Contaminated Soil (Contact)	Engineering (Remediate Soil, Construct Barrier to Contain Site) Administrative (Restrict Access to Site) PPE (Protective Clothing)
Population at Camp Falcon	Particulate Matter	Air (Inhalation)	Engineering (Barriers/Shielding) Administrative (Move Personnel Indoors) PPE (Respiratory Protection)
Population at Camp Falcon	Unknown Agent (Contaminated Water)	Potable Water Source (Ingestion)	Engineering (Water Treatment) Administrative (Bottled Water, Boil Water)

2.2.4. The basic method for determining OEH controls is the same regardless of the situation or the type of OEH threat. The primary difference in the control determination process relates to the amount of time available to make a decision regarding which control(s) to implement. An extended period of time, e.g., several weeks, may be available to determine an optimum control for a health threat related to an industrial process. Whereas, controls for immediate threats such as those posed by incidents involving the release of hazardous materials or drinking water contamination may require a nearly immediate decision in order to protect human health. Attachment 2 provides examples that illustrate the control determination process for two distinct situations.

2.2.5. The critical step in determining which control to implement is identifying the potential effectiveness of a control relative to a particular OEH threat. USACHPPM TG 230 states that a control's effectiveness can be assessed by applying the following three parameters: 1) the control must be able to mitigate the OEH threat exposure to an acceptable level, 2) the responsible organization must be able to reasonably implement the control option, and 3) the control must be practical when considering cost and time associated with implementation.

2.2.6. The control determination process is dynamic. Once a control(s) has been selected, its effectiveness must be routinely evaluated. Processes and the respective OEH threats associated with them may change. The frequency of evaluating a control should be based on several factors to include but not limited to: risk to personnel if performance of control degrades or fails, reliability and historical performance of control and operators, and toxicity of material. Additionally, new control options may become available that provide better protection (e.g. improved ventilation system, noise source isolation, etc.). BE must continue to aggressively pursue improved control options in order to optimize force health protection for personnel. Utilization of Risk Assessment Codes and forums such as the Environmental, Safety and Occupational Health Council provide opportunities for BE to identify the advantages of new control options to installation leadership.

2.2.7. Information Collection, Records, and Forms

2.2.7.1. Information Collections. No information collections are created by this publication.

2.2.7.2. Records. The program records created as a result of the processes prescribed in this publication are maintained in accordance with AFMAN 33-363 and disposed of in accordance with the AFRIMS RDS located at <https://www.my.af.mil/gcss-af61a/afirms/afirms/>.

2.2.7.3. Forms (Adopted and Prescribed).

2.2.7.3.1. Adopted Forms. AF Form 673, *Air Force Publication/Form Action Request* and AF Form 847, *Recommend-ation for Change of Publication*.

2.2.7.3.2. Prescribed Forms. No prescribed forms are implemented by this publication.

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Surgeon General

Attachment 1**GLOSSARY OF REFERENCES AND SUPPORTING INFORMATION*****References:***

Air Force Federal Acquisition Regulation Supplement (AFFARS) 52.223-9001

AFI 10-2603, *Emergency Health Powers on Air Force Installations*, 7 Dec 2005

AFI 10-2604, *Disease Containment Planning Guidance*, 6 Apr 2007

AFI 48-105, *Surveillance, Prevention, and Control of Diseases and Conditions of Public Health or Military Significance*, 1 Mar 2005

AFI 48-145, *Occupational & Environmental Health Program*, 5 Mar 2008

AFI 90-901, *Operational Risk Management*, 1 April 2000

AFI 91-301, *Air Force Occupational and Environmental, Safety, Fire Prevention and Health (AFOSH) Program*, 1 Jun 1996

AFMAN 33-363, *Management of Records*, 1 Mar 2008

AFMAN 48-153, *Health Risk Assessment*, 28 Mar 2007

AFMAN 48-154, *Occupational and Environmental Health Site Assessment*, 28 Mar 2007

AFPD, 48-1, *Aerospace Medicine Program*, 3 Oct 2005

AFPD 90-9, *Operational Risk Management*, 1 April 2000

AFRIMS RDS, <https://www.my.af.mil/gcss-af61a/afirms/afirms/>

ACGIH, *Threshold Limit Values® (TLVs) for Chemical Substances and Physical Agents and Biological Indices (most current edition)*

ACGIH, *Industrial Ventilation. A Manual of Recommended Practice (most current edition)*

AIHA, *Emergency Response Planning Guide (ERPG) & Workplace Environmental Exposure Levels (WEEL) Handbook (most current edition)*

USACHPPM, Technical Guide 230 (TG-230), *Chemical Exposure Guidelines for Deployed Military Personnel*

29 CFR 1910, *Occupational Safety and Health Standards*

40 CFR 141, *National Primary Drinking Water Regulations*

Abbreviations and Acronyms:

ACGIH - American Conference of Governmental Industrial Hygienists

AFI - Air Force Instruction

AFMSA - Air Force Medical Support Agency

AFOSH - Air Force Occupational Safety and Health

AOC - Area of Concern

BE - Bioenvironmental Engineering
CFR - Code of Federal Regulations
CONUS - Continental United States
DRU - Direct Reporting Unit
ERPG - Emergency Response Planning Guidelines
FOA - Field Operating Agency
GOCO - Government Owned, Contractor Operated
HRA - Health Risk Assessment
HRM - Health Risk Management
MAJCOM - Major Command
OEEL - Occupational & Environmental Exposure Limit
OEH - Occupational & Environmental Health
ORM - Operational Risk Management
OSHA - Occupational Safety and Health Administration
PH - Public Health
PPE - Personal Protective Equipment
SEG - Similar Exposure Group
TG - Technical Guide
TLV ® - Threshold Limit Value
USACHPPM - US Army Center for Health Promotion and Preventive Medicine
USAFSAM - US Air Force School of Aerospace Medicine
WEEL - Workplace Environmental Exposure Levels

Terms

Action Level - An exposure level that dictates active air monitoring, medical monitoring, and employee training. The Action Level for airborne exposures is typically one-half the Occupational & Environmental Exposure Limit for time-weighted average (TWA) exposures, except where 29 CFR 1910 Subpart Z designates a different concentration or where the statistical variability of sample results indicates that a lower fraction of the OEL should be used as the Action Level.

Carcinogens - Hazardous materials that stimulate the formation of cancer. It is AF policy to reduce exposure to confirmed human carcinogens as low as practicable. For the purpose of Hazard Communication compliance, confirmed and suspected human carcinogens are treated as carcinogens. A mixture is considered to be a carcinogen if it contains a carcinogenic component with a concentration of 0.1 percent or greater.

Exposure - The concentration, frequency, and duration to which personnel are subject to a hazardous material.

Exposure Route - The pathway (inhalation, ingestion, contact, absorption, whole body exposure) by which hazardous material comes into contact with personnel.

Occupational & Environmental Exposure Limit (OEEL) - The OEEL is the most appropriate limit adopted from established recognized standards including, but not limited to, those in AFIs and AFOSH Standards, the latest edition of the *TLV® Booklet* published annually by the American Conference of Government Industrial Hygienists, 29 CFR 1910.1000 Tables Z-1, Z-2, and Z-3 and 40 CFR 141. OEELs are limits of exposure established to protect personnel from hazardous OEH threat exposures. OEELs apply to OEH threat exposures for individuals and/or similarly exposed groups of individuals.

Process - Any item of work or situation that may pose a risk, and may require evaluation and control; the lowest level of work that may require evaluation to assess exposure and associated controls. Not all processes are associated with a physical location, e.g., working near the flight line may constitute a process. The terms Activity and Process are synonymous.

Similar Exposure Group (SEG) - A group of individuals for whom representative exposure for any member of the group is predictive of exposures of all members of the group. The term "SEG" is formally defined in the AIHA publication, "A Strategy for Assessing and Managing Occupational Exposures."

Time Weighted Average (TWA) - An average exposure over a defined time period; also referred to as time weighted average concentration.

Workplace - An environment where potential OEH exposures may occur. A workplace may be administrative, industrial, or all encompassing, e.g., any setting where an OEH exposure may occur while deployed.

Attachment 2**Occupational and Environmental Health Threat Control Determination Scenarios****Scenario 1: Corrosion Control Facility Operations**

Corrosion control activities present multiple health threats associated with de-painting (sanding, abrasive blasting, etc.) and painting processes. After BE identifies and evaluates OEH threats in the SEG using the HRA process outlined in AFMAN 48-153, *Health Risk Assessment*, exposure control recommendations are made.

OEH Exposure Assessment:

Based on air sampling, exposure levels are above the OEEL for hexavalent chromium during a sanding operation.

Engineering Control:

Implement local exhaust ventilation in combination with orbital sanding units to reduce exposures.

- If this is effective at maintaining exposures below the OEEL and the action level, then BE must continue to perform routine monitoring to ensure control remains effective.
- If this is not effective or if exposures remain above the action level, then consider implementing administrative controls in addition to the engineering control.

Administrative Control:

Implement new work practices (e.g. utilize a HEPA vacuum to clean the workplace) in order to reduce exposures to acceptable levels.

- If this is effective, then BE must continue to perform routine monitoring to ensure control remains effective and investigate the use of engineering controls in the future.
- If this is not effective, then consider using Personal Protective Equipment (PPE) in addition to the previous controls.

PPE:

Implement respirator usage in addition to coveralls, gloves, etc. to reduce exposures to acceptable levels.

- If this is effective, then BE must continue to perform routine monitoring to ensure control remains effective as well as investigate the possibility of implementing engineering and administrative controls in the future.
- If this is not effective, then an operational risk management decision needs to be made regarding whether or not to continue operations.

Issues to consider:

- What is the mission impact due to ceasing operations?
- Can the ventilation system be modified to meet necessary specifications?
- Can the workload be sent to another base/contract facility that can properly control exposures?
- Is the risk to unprotected personnel acceptable in order meet mission requirements?

Scenario 2: Terrorist Attack Using Tanker Truck

Terrorists commandeer a truck carrying pesticide. The truck is driven up to the main gate of Camp Falcon and an explosive charge releases the pesticide. A plume ensues and begins migrating across Camp Falcon. After the initial first responders arrive on scene, BE is asked to respond. Air sampling indicates that the truck was carrying an organophosphate pesticide. All base personnel are carrying a full complement of individual protective equipment (IPE).

OEH Exposure Assessment:

Personnel are experiencing shortness of breath, headaches and nausea.

What are the control options for this scenario?

Engineering Control:

Engineering controls are not available or applicable for immediate mitigation of the health threat in this situation.

Administrative Control:

Evacuate all personnel in the hazard area upwind or crosswind from the chemical plume.

- If this is effective, then personnel should be monitored for latent effects from exposure.
- If it is not effective, consider a shelter-in-place option and personal protective equipment for those that cannot shelter.

PPE:

Direct personnel to wear IPE. Does this step effectively mitigate the threat in order for mission essential work to continue in contaminated areas?

- If yes, then BE must continue to perform monitoring to ensure control remains effective until the threat is eliminated or dissipates from the AOC.
- If no, then an operational risk management decision needs to be made regarding whether or not to continue operations in contaminated areas.

Issues to consider:

- What is the mission impact due to ceasing operations?
- Can operations be relocated until the threat dissipates in order to meet mission requirements?
- Is the risk to personnel acceptable in order meet mission requirements?
- How quickly/effectively can a shelter-in-place or evacuation plan be executed as the plume migrates?